
PERSPECTIVE REPORT ON

Electronics in India

Copyright © Electronics Commission (IPAG), 1975

Price Rs. 60

*Published by the Director, Information, Planning & Analysis Group, Electronics Commission, Government of India, New Delhi-110016,
and printed by him at the Recorder Press, New Delhi-110049, India.*

Reprinted by Indian National Scientific Documentation Centre, New Delhi-12, 1977

Preface

The Government of India constituted a Committee under the chairmanship of Dr. Homi J. Bhabha in 1963, to make an overall assessment of the requirements of electronic components and equipment in the country, to survey the existing and potential sources of supply and to recommend measures for the planned development of electronics so that the country could become self-sufficient in this field in the shortest possible time. The Report of the Bhabha Committee was submitted to Government in early 1966. The Report contained the following major recommendations:

- (i) Components form the crux of the electronics industry, and should be manufactured in the country as quickly as possible;
- (ii) in the field of general purpose components, manufacture in quantity is desirable both to secure the economies of scale of manufacture, as also to ensure that research and development facilities could be set up in the manufacturing units to keep them abreast of advances in technology which are extremely rapid in this very dynamic industry;
- (iii) equipment (as opposed to components), lends itself to manufacture on a smaller scale and the manufacture of equipment could, therefore, be organised in this manner;
- (iv) for immediate requirements, equipment will have to be mostly imported or assembled from imported components;
- (v) equipment required after about five years and later should be qualitatively identified and developed in the country with a view to production and issue to users at the appropriate time;
- (vi) in certain fields, foreign collaboration should be sought for immediate development; but, from the beginning, Indian scientists and engineers should engage themselves in further developing and elaborating the technologies acquired under licence or otherwise from abroad;
- (vii) in the field of components, etc., from the beginning, there should be standardisation with a view to manufacturing in quantity certain "preferred" types of components;
- (viii) about Rs. 1,000 crores worth of equipment would be required in the ten year period, from 1966 to 1975; ultimately, the value of annual production would be of the order of Rs. 300 crores; for establishing an industry of this size, a total of, approximately, Rs. 170 crores of investment would be needed over the ten year period.

Government accepted all the recommendations made by the Bhabha Committee. For advising Government in the implementation of the recommendations of the Bhabha Committee, an Electronics Committee was appointed under the chairmanship of Dr. V. A. Sarabhai in June 1966. This Committee was charged with the following responsibility:

"To take account of the most urgent needs for the rapid develop-

ment of electronics, keep track of the research being done in design and development and give guidance and direction, where necessary, identify sectors where indigenous production could be built up, and promote the speedy building up of such capacity”.

In March 1970, a National Conference on Electronics was organised by the Government at Tata Institute of Fundamental Research in Bombay. It was attended by engineers, technologists, administrators and those in the management from Government, public and private sector industry, laboratories, research and development establishments, etc. A wide variety of subjects were discussed at this conference. Views expressed in the conference indicated that though the electronics industry had progressed satisfactorily in several areas in the previous three to four years, there were other areas in which progress was much less than what was needed or had been envisaged in the Bhabha Committee Report. In the field of consumer electronics (largely for entertainment), and in certain other areas, production was higher than that envisaged by the Bhabha Committee. However, in the field of defence and telecommunication equipment, there appeared to be need for achieving a much greater amount of self-sufficiency and self-reliance.

Recognising the importance of developing an integrated and self-reliant electronics industry in the country, and the need for rapid progress in this regard, Government constituted a separate Department of Electronics with effect from June 26, 1970. In February 1971, the Government constituted the Electronics Commission.

In the resolution setting up the Electronics Commission, it is stated: “Government attaches the highest importance to the development of an integrated and self-reliant electronics industry in the country, as rapidly as possible. Electronics occupies a key position in modern science and technology. It has a vital role to play in the fields of atomic energy, communications, defence, education, entertainment and space technology. It is assuming increasing importance in the monitoring and control of production processes in the engineering, chemical and metallurgical industries. Because of its dynamic character, its pervasive nature and its significant impact on science, industry and society, electronics is today in the vanguard of technological progress. Technological progress and obsolescence are both very rapid in this field. An intensive promotional effort relating to both production, and research and development is, therefore, essential to ensure a rapid growth of self-confidence and of indigenous capabilities”.

The Electronics Commission has been charged with full responsibility to review the entire field of electronics with regard to research, development and industrial operations, with full authority to formulate policy in this field and to direct implementation, on sound technical and economic principles, of all measures both promotional and regulatory that are necessary for the country to attain self-reliance in the shortest possible time and in the best possible manner.

The Bhabha Committee Report was the first detailed analysis in the Indian context, of a sophisticated and fast changing areas of science, technology and industry. The Report had looked into questions relating to materials, components, equipment and systems; it had also covered problems relating to investment, production, employment and know-how. At the time

the Electronics Commission was set up in February 1971, this was the only detailed analysis available to plan for the growth of the electronics industry. It was, however, recognised by the Electronics Commission that the Bhabha Committee Report was prepared during the years 1963-65. The rate of change in the field of electronics was so significant that major areas, where revolutionary developments had taken place by 1971, such as solid state electronics and computers, had been dealt with in a rather tentative and preliminary way in the Bhabha Committee Report. At the National Conference on Electronics held in 1970, it had also been brought out that many of the numbers given in the Bhabha Committee Report needed reconsideration from the view point of being accepted as realistic figures for production and purchase, based on approved financial provisions. It was, therefore, recognised that whilst the Bhabha Committee Report could be accepted as an initial document for starting on the work assigned to the Electronics Commission, there would have to be significant re-analyses from the view point of planning for the electronics industry during the 1970s and 1980s.

Recognising the importance of accurate and timely information, for macro- and micro-level planning, and for critical, in-depth techno-economic analyses, the Electronics Commission decided to set up an Information, Planning and Analysis Group (IPAG), with the mandate to provide information required by the Electronics Commission for its decision making, as well as to disseminate information to laboratories, industries, entrepreneurs and all concerned with the growth of the electronics industry. Over the past four years, under instructions from the Electronics Commission, IPAG has set up a large number of expert technical panels to examine, in depth, various specified fields of electronics. These panels were composed of experts from Government, industry, academic institutions, research and development laboratories, etc. They were asked to assess the current status of the particular field in terms of investment, licensed and installed capacity, production, technology, cost of production, exports, etc., and to provide forecasts concerning all of these matters over the Fifth Plan period (1974-79) and in perspective into the Sixth Plan period (1979-84). Staff members of IPAG have also carried out in-depth analyses of specific aspects. A regular monthly journal, "Electronics—Information & Planning" has been under publication since October 1973 in which the IPAG Analysis Reports and the reports of the various Expert Panels in summary form are published.

Apart from the above, a consolidated report on Telecommunication and Electronics Industry was prepared during 1972-73 and submitted to the Planning Commission. This report was prepared by a Task Force set up by the Planning Commission, at the instance of the Steering Group on Engineering Industries which was self concerned with the broad area of formulating policies and programmes relating to the development of engineering industries during the Fifth Plan period. The Task Force on Telecommunication and Electronics Industry worked through eight Working Groups in the following areas:

- (a) Consumer electronics
- (b) Mass communication
- (c) Telecommunications
- (d) Aerospace electronics & communication
- (e) Radar and defence systems
- (f) Computers, controls and industrial electronics

(g) Instruments and instrumentation

(h) Components and materials.

IPAG provided the analytical and secretarial support for these Working Groups, and was responsible for the final preparation of the Task Force Report. This Report formed the basis for discussions between the Department of Electronics, Planning Commission and Ministry of Finance concerning the Fifth Five Year Plan for Telecommunication and Electronics. On account of restraints on resources, the final plan allocations were different from the figures recommended by the Task Force.

The Estimates Committee of Parliament which examined the Department of Electronics during 1973-74 had strongly recommended that a consolidated document should be brought out concerning the current status of this field in the country and plans covering the Fifth and Sixth Plan periods. The Informal Consultative Committee of Parliament for the Department of Electronics had also emphasised the need for this. IPAG was entrusted with this task and has produced a document by integrating the reports submitted by various technical panels, the analysis reports prepared by various IPAG staff members and the Report of the Task Force on Telecommunication and Electronics Industry submitted to the Planning Commission. After integrating all of this material, the relevant parts were submitted for comments to concerned Ministries and Departments in the Government of India and to a wide spectrum of knowledgeable persons in the electronics community of the country. After taking into account all the comments received, IPAG has finally produced this document entitled "Perspective Report on Electronics in India".

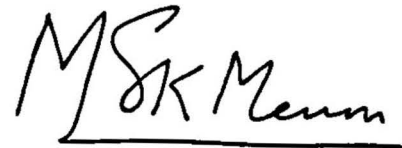
It is essential to point out certain basic features inherent in any such document. The figures given in this report are the best available at present, but they must be regarded as only indicative figures and subject to changes. In this connection, one has only to recall that, in the case of the Bhabha Committee Report, it was felt at the National Conference on Electronics held in 1970 that the numbers indicated in many areas were those one would have liked to hope for, but which could not be implemented in the absence of financial provisions for purchase by the end user or for investment to produce these. We have also to bear in mind the fact that we are at present in a highly complex and unstable economic situation involving inflationary pressures within the country and highly competitive demands on the economy from many priority sectors; with inflationary and recessionary tendencies abroad with a continually increasing pricing for energy and many raw-materials, industrial products and know-how; with fluctuations caused by situations outside the control of individual countries or governments, such as natural calamities, effects of hostilities at various locations in the world, etc. All these factors tend to ultimately affect national priorities, investments available, buying power of individual consumers as well as that of the Government as a whole for public purposes, etc. Electronics is an area which couples intimately with defence, atomic energy and space programmes, telecommunications, mass communications and the large consumer areas of entertainment. It is therefore, very sensitive to changes of priorities in these various sectors.

In spite of all this, it is still felt that it is important to have a consolidated document in which effort that has gone into the extensive collection of information and vast amount of analytical work done over the past four

years, could be brought together at one place. This is the essential purpose of this Report.

It must also be emphasised that this is not a document which lays down government policies over the entire field of electronics. The Fifth Five Year Plan for Telecommunication and Electronics accepted by the Planning Commission and Ministry of Finance, figures as a basic element in this Report. But Government policies relate not only to the Plan in its bare essentials, but also to other aspects such as availability of foreign exchange, policies towards large houses or foreign collaboration, export policies, etc. It is obvious that Government policies and decisions relating to a fast changing industry like electronics, cannot be decided for the entire field in one go. These decisions are taken with respect to individual elements of this vast field, in consultation with all other Government bodies concerned with the different facets of that one element, but in taking these decisions Government is no doubt guided by the totality of the picture of the field of electronics and its applications as covered in this Report. And that is the value of such a report apart from its intrinsic merits.

The Electronics Commission is grateful to Dr. N. Seshagiri, Director, IPAG and his colleagues who have put in considerable effort to produce this Report; as also to the officers of the Department of Electronics and the many technical experts and others connected with the electronics industry who have given of their time and energy in participating in various panels, committees and meetings to arrive at optimal national solutions in this area.



M. G. K. MENON

Contents

	Page No.
I Introduction	1
1 Report of the Electronics Committee—A summary	3
2 Review of events since Electronics Committee Report	14
3 Proceedings of National Conference on Electronics	20
—A summary	20
4 Formation of Electronics Commission and Department of Electronics	39
5 National Seminar on R&D Policy—A summary	42
6 Technology Development Council	60
7 National Advisory Committee on Electronics	62
8 National Radar Council	63
9 Report of the Estimates Committee of Parliament	64
—A summary	
II Ten Year Profile	71
1 Introduction	71
2 Search for invariants	71
3 Natural, feasible and limit growth trends	76
4 The ten year profile	79
III Mass Communication	105
1 Introduction	105
A. Ground segment	105
2 Current status	105
3 Technological trends	107
4 Demand profile	108
5 Proposed guidelines	111
6 Investment	118
B. Space segment	119
7 Current status	119
8 Technological trends and alternatives	122
9 Demand profile—INSAT system	125
10 Technological alternatives and indigenous capabilities— Guidelines for production	127
IV Consumer Electronics	139
1 Introduction	139
2 Current status	140
3 Demand profile	144
4 Analysis of gaps	146
5 Proposed guidelines	147
6 Investment profile	150

	Page No.
V Communication, Radar and Navigation Systems	151
1 Introduction	151
2 Telecommunication	153
3 International communication	183
4 Radio communication	187
5 Telemetry and telecontrol	193
6 Radar and navigational aids	196
VI Computers	208
1 Introduction	208
2 Current status of production and use of computers in India	209
3 Technology trends and alternatives	212
4 Ten year demand profile for computers	218
5 Analysis of gaps	225
6 Guidelines for technology development and indigenous production	229
7 Investment and production profile	251
VII Control Components and Systems	254
1 Introduction	254
2 Instrument servo components	255
3 Process control instrumentation	266
VIII Industrial Electronics	305
1 Introduction	305
2 Industrial drive control	306
3 Numerical control	323
4 Induction and dielectric heating	327
5 Mining electronics	330
6 Environmental pollution monitoring	334
7 Agri-electronics	341
IX Medical Electronics	348
1 Introduction	348
2 Current status	352
3 Demand profile	360
4 Analysis of gaps	363
5 Technological trends	365
6 Guidelines for production	367
7 Investment and production profile	368
8 Test and maintenance	369
9 Manpower	377
10 Postscript comment	378
X Instruments	379
1 Introduction	379
2 Current status	385
3 Demand profile	397
4 Analysis of gaps	399
5 Guidelines for production and technology development	404
6 Investment and production profiles	408

	Page No.
XI Electron Tubes	412
1 Introduction	412
2 Current status	413
3 Demand forecast	415
4 Analysis of the demand	417
5 Technology trends	418
6 Guidelines for production	418
7 Guidelines for research and development	424
XII Semiconductor Devices	427
1 Introduction	427
2 Current status	428
3 Technology profile and the available alternatives	436
4 Demand profile	460
5 Analysis of gaps	461
6 Proposed guidelines	468
XIII Passive Components	475
1 Introduction	475
A. General passive components	475
2 Current status	475
3 Demand forecast	485
4 Analysis of gaps	488
5 Guidelines for production and R&D	489
6 Investment	505
B. Microwave passive components	505
7 Classification of microwave passive components	505
8 Demand profile	507
9 Current status	509
10 Analysis of gaps and guidelines for development and production	510
XIV Mechanical and Electrical Components	515
1 Introduction	515
2 Electromechanical components	515
3 Printed circuit boards	544
4 DC micromotors	551
5 Batteries	553
6 Guidelines for production and R&D	554
XV Materials	559
1 Introduction	559
2 Current status	561
3 Demand forecast	567
4 Analysis of gaps	568
5 Production and investment	570
6 Proposed guidelines	571
XVI Standardisation, Testing and Evaluation	617
1 Introduction	617

	Page No.
2 Standardisation	618
3 Testing and evaluation	622
4 Reliability	629
5 Implementation structure	631
6 Testing and production equipment manufacture	632
XVII Defence Electronics	633
1 Introduction	633
2 Requirements of defence electronics	633
3 The approach towards indigenisation of defence electronics	634
4 Conclusion	640
XVIII Exports and Export Facilities	641
1 Introduction	641
2 Santacruz Electronics Export Processing Zone	645
3 Electronics Trade and Technology Development Corporation	646
XIX Manpower	655
1 Introduction	655
2 The experience of developed countries	656
3 Indian public sector experience	659
4 Employment potential of the Indian electronics industry during the Fifth and Sixth Five Year Plans	659
5 Breakup of requirement of production workers	661
6 Present status of availability of trained manpower	662
7 Anticipated gap in the demand and availability of trained manpower	662
8 Future training programme	663
9 Reversing the brain drain	665
Bibliography	667
Appendix	675
Index	691

Introduction

The electronics industry in India is growing fast at an average annual rate of twenty per cent. The industry owes the vitality to many intrinsic merits:

- o It is a labour intensive industry which provides more employment per unit investment, particularly for skilled workers and engineers.
- o For a given foreign exchange investment, the complementary rupee investment is very high in the long run.
- o Capital formation ability of the industry is the highest among all sectors.
- o Technological competence for self-sufficiency and self-reliance can be achieved within a short time span.
- o The industry is by and large location independent and can be sustained even in backward districts of every State of the country.
- o The size of the industry can be anywhere from a few workers to a few thousand workers, thereby allowing technocrat entrepreneurs with limited resources to enter the field and grow.
- o The public sector and the private sector can complement in parts and supplement in parts in a natural and homogenous way, thereby strengthening the mixed economic framework of the country.
- o The industry has a very high export potential in view of its labour intensiveness.
- o It is one of the most vital industries assisting the defence preparedness of the country. It is also a sector in which it would be strategically disadvantageous to depend on imports.
- o It is the basic industry which has helped the continuous increase of productivity of process industries as well as facilitate large scale production.
- o The growth of any economy implies a commensurate growth in its communication facilities. The industry is at the core of this activity.

Sustaining and improving the growth on a self-reliant base with due regard to its relevance to the socio-economic conditions in the country, call for a conscious continual planning of the industry. Electronics is an industry with perpetual conflicts of interest between the private sector and the public sector, between the small scale sector and the large scale sector or Indian companies and foreign companies, between import and local manufacture of equipment and components, or import of know-how and indigenous development, just to

mention a few. In an industry beset with so many conflicts, collection of information often gets tricky, techno-economic analysis gets highly involved and macro planning of the industry gets highly complicated. The problem of implementation of policies and plans so formulated in the background of conflicting interests becomes a very arduous task. If we desire to grow the industry along the lines which are synchronous with the larger national interest, implementation would indeed require a cautious approach—cautious to see that we do not give ourselves in the hands of foreign economic interest just to buy a disproportionately little time, that we do not import know-how when indigenous know-how is just at the threshold of delivering goods or stifle production and reduce international competition and export by not acquiring know-how needed and readily available from abroad, that we do not stifle the industry by over-control nor encourage malpractices by check on foreign exchange, to mention a few. The Electronics Commission and the Department of Electronics were set up to safeguard these larger national interests and to improve the growth of the electronics industry in a planned manner. Conscious planning implies, conscious collection, collation, organisation and analysis of information. The Electronics Commission, therefore, set up an Information, Planning and Analysis Group (IPAG) with a staff predominantly of electronics engineers combining research and industry background along with a complement of specialists in mechanical engineering, chemical engineering, management science, information science and techno-economics.

IPAG coordinated the proceedings of a number of panels composed of well known specialists in the field and carried out large number of information and analysis projects. The Electronics Commission constituted a number of other committees, principally, the Technology Development Council (TDC), National Advisory Committee on Electronics (NACE), Defence Electronics Committee and the National Radar Council for evolving policy guidelines on a continuing basis. In addition, the Estimates Committee of Parliament made a detailed analysis on the structure, functions and responsibilities of the Department of Electronics and submitted a valuable report to the Lok Sabha. The Planning Commission also set up a Task Force on Electronics and Telecommunication under the chairmanship of the Chairman, Electronics Commission and coordinated by the IPAG for the preparation of the Fifth Five Year Plan for the industry. After the preliminary profile of investment for the electronics industry during the Fifth Five Year Plan was discussed with the Planning Commission in January 1974 and received the assent of the Government, it was taken as the most appropriate time to consolidate all the findings from 1965 to 1975 in a single report. The present volume is the result of this effort.

A summary of the report of the Electronics Committee (Bhabha Committee Report) and a review of some of the notable events subsequent to the submission of the Bhabha Committee Report are presented in the rest of this chapter. The electronics profile for the ten-year period 1974-84 is given in Chapter 2 following the presentation of the techno-economic basis necessary for the intensified growth of electronics in the country. Current status, technological trends, demand profile and investment required during the Fifth Five Year Plan period, etc., in various areas, namely, 1. Mass communication, 2. Consumer electronics, 3. Communication, radar and navigational systems, 4. Computers, 5. Control systems, 6. Industrial electronics, 7. Medical electronics, 8. Instruments, 9. Electron tubes, 10. Semiconductor devices,

11. Passive components, 12. Electrical and mechanical components, and 13. Materials are given in Chapters 3 to 15. The norms for standardisation and the facilities to be set up for testing and evaluation are discussed in Chapter 16. A profile of the defence electronics is given in Chapter 17. The general facilities like custom manufacture of capital equipment and import & export, etc., are discussed in Chapter 18. The manpower required for the electronics industry during the Fifth Plan period is discussed in Chapter 19.

1.1 Report of the Electronics Committee— A Summary

The Electronics Committee was appointed by the Government of India by a resolution, dated August 12, 1963, under the Chairmanship of Dr. H. J. Bhabha with the following terms of reference:

- (a) to assess the total requirements of the country in respect of various items of electronic components and equipment;
- (b) to survey the existing and potential sources of supply and to recommend how best these sources can be tapped and capacity expanded; and
- (c) to recommend measures for the planned development of electronics, so that the country as a whole may become self-sufficient in this field in the shortest possible time and in the most economical manner.

Each ministry and organisation of the Government of India, which is a substantial user of electronic equipment or whose responsibility it is to assess the public demand for electronic equipment, was invited to nominate a representative on the Committee. The Committee had on it throughout its work, representatives of the Ministries of Defence, Information and Broadcasting, Railways, Transport and Communications, the Department of Atomic Energy, the Department of Economic and Defence Coordination and the Council of Scientific and Industrial Research.

1.1.1. General Review

The value of electronic equipment required over the ten-year period 1965-75 has been assessed by the Committee at Rs. 1,650 crores at 1965 prices. The value of the electronic equipment produced by the electronics industry in India in 1965 is about Rs. 26 crores per annum. The estimated need during the ten years 1965-75 of various categories of electronic equipment and the extent to which this need can be met by the industry is given in Table 1.1.

It is obvious that on the one hand some equipment needed most urgently will have to be imported, while on the other, the present industry will have to be expanded many fold. The equipment to be imported during the next few years cannot be estimated with any confidence, as this depends not only on the urgency of the need, but on the availability of foreign exchange or special aid arrangements for importing it. The Committee has tentatively estimated that roughly Rs. 50 crores worth of equipment may have to be imported immediately for defence purposes, leaving the rest to be produced in the country. On this basis, it can be seen that if the annual output of the electronics industry is increased every year by Rs. 30 crores over a ten-year period starting from the second year, the industry will have a capacity to produce approximately Rs. 300 crores worth of electronic equipment per annum at the end of the ten-year period and the

I

total amount of equipment produced during this ten-year period will be approximately Rs. 1,600 crores. As an alternative, it is possible to think of the present industry expanding its production geometrically at the rate of 38 per cent per annum in value over a ten-year period. In this case the total value of equipment produced in the ten-year period is again about Rs. 1,600 crores but the annual output at the end of ten-year period much higher, being about Rs. 480 crores per annum. Although the total investment in the industry at the end of ten years would be much greater for geometric than for linear growth, this may, to some extent, be easier to achieve, as the industry will generate some of its own capital during the intervening period. It is quite likely that the real pattern of growth will lie somewhere in between the two. It may be easier, by determined planning, to increase the capacity of the industry by more than 30 per cent a year at the beginning, which would require only the addition of new production capacity to the value of roughly Rs. 50 crores in the first three years. On the other hand, when the industry grows to a considerable size, it may well be difficult to increase its capacity even by 20 per cent per annum, for this would require an increase of the order of Rs. 50 crores in the last year of the ten-year period.

Table 1.1. Estimated demand during 1965-75 and available supply.
(In Rs. crores)

Sr. No.	Item	Requirements over ten years (1965-75)	Extent of available supply from existing (1965) industry
1.	Radio receivers and other consumer products	450	170
2.	Low power radio communication equipment	310	37
3.	Microwave systems and associated equipment including radar and radio navigational aids	290	17
4.	High power radio trans- mitters, industrial heating equipment, railway signalling and process control installations and other major industrial equipment	250	3
5.	Electronic equipment for line communication systems	150	34
6.	Computing, data processing and nuclear, medical and industrial equipment	165	4
7.	Test instruments	35	—
	Total	1,650	265

It is estimated that the total capital investment in the industry at the end of ten years will be approximately Rs. 170 crores, which is expected to give finished equipment of all types valued at Rs. 300 crores per annum, starting from primary materials. There are many imponderables in making an estimate for ten years, as appetite grows with what it feeds upon. Hence even in sectors which are developed rapidly at the beginning, the total investment at the end of ten years may not be less than anticipated, as the demand for such equipment may well have grown beyond present estimates in the meantime.

The annual production of Rs. 300 crores envisaged would represent less than one per cent of the estimated gross national product in 1975. At present electronics production accounts for a mere 0.15 per cent of the gross national product. As against this, electronic equipment in Japan, where electronics is used almost exclusively for non-defence purposes, is 3.5 per cent of the gross national product. In the United States of America and France this figure is higher.

The total investment of Rs. 170 crores envisaged in the electronics industry during the ten-year period 1965-75, is an extremely modest sum considered in the context of the proposed size of the Fourth Five Year Plan, not to mention the Fifth Five Year Plan. It would represent an investment in ten years which would be less than one per cent of the proposed outlay in the Fourth Five Year Plan alone. The Committee has no hesitation in recommending, therefore, that in view of the vital importance of electronics in modern life, industry, and defence, this investment should be made and given a high priority.

It is expected that the average wage bill for producing electronic equipment of sale value of Rs. 10,000 would be of the order of Rs. 3,800 of which the wage bill for those engaged in direct production, engineering supervision, design and development in the plant, would be about Rs. 2,800, the wage bill for auxiliary staff in stores, purchase, security etc., being roughly Rs. 1,000. The corresponding ratio of the persons employed in these two categories would be roughly 3:1. Thus, the wage bill for skilled workers and engineering personnel for equipment production would amount to nearly 30 per cent of the sale value of the product, while the total wage bill, including supporting staff, would come to about 38 per cent. The figures for the proportion of wage to sale value of finished product in the United States range from 35 to 50 per cent, and the figures given above for India are reasonably in accord. However, the lower productivity of labour in India compared with that in the United States implies that the number of persons employed in India for the same amount of production will be larger. On the basis of experience, one may assume that the annual wage per person averaged over all categories would be approximately Rs. 3,500 per annum. The sale value of the product for a person employed on the manufacture of equipment in electronics industry, including all supporting and auxiliary staff, would be approximately Rs. 9,000 while the sale value of the product for a person employed in direct production would be approximately Rs. 12,000. It follows that the total wage bill in 1975 for producing Rs. 300 crores worth of electronic equipment will come to Rs. 115 crores and the total number of persons employed will be 3,30,000 of which 2,50,000 will be skilled workers, technical staff and engineers.

The labour for producing components is not included in the estimate

I

made in the preceding paragraph. The production of Rs. 300 crores worth of equipment will require the production roughly of Rs. 84 crores worth of components. If the manufacture of components is undertaken in each unit on a scale adequate for cheap and economic production, it is estimated that the sale value of the product per person employed in the components industry would be roughly double that for equipment in the preceding paragraph.

For research and development activities in laboratories and research institutions outside the plants, an additional force of some 15,000 scientists and engineers will be required, with approximately 30,000 supporting technical staff.

It thus follows that the total number of persons who will be employed directly or indirectly in an electronics industry of the size envisaged for 1975 will be about 4,00,000 of which over 3,00,000 will be engineers, scientists and skilled workers. The electronics industry has therefore a very high potential for the employment of skilled workers, engineers and scientists and will provide important avenues for the gainful employment of university graduates appropriately trained and qualified in the subject, as also for skilled artisans. One further point needs to be noted in this connection. An investment of some Rs. 170 crores is expected to provide employment in the industry for some 4,00,000 scientists, engineers, skilled workers and supporting staff, from which it follows that the investment per man is approximately Rs. 4,000 to Rs. 5,000.

It is clear that the pace of development of the industry will be set by the rate at which skilled scientific and technical manpower can be marshalled, rather than by availability of finance. This, more than any other, is an industry in which technical persons must be in key positions at all levels of the industry, from policy making and management of plants down to the individual production operations. The Committee is convinced that the necessary scientific and technical personnel required by the industry for its development at the pace suggested can be found in India without great difficulty. A policy decision by Government to develop the industry on the scale recommended will itself lead to large numbers of young men and women going in for electronics in universities and technical institutions, and will thus provide the steady supply of trained manpower required.

Intense and continuous research and development is essential, if the electronics industry is to face world competition and grow. In certain areas covering both equipment and components, development cycles are of the order of three years, while in certain others involving large and complex systems, development cycles upto seven years are envisaged. Specific steps have been recommended for building up the necessary expertise in the latest design trends. In spite of the general technical backwardness of the country, special technical knowledge is available in the country and efforts should be made to marshal the available expertise, organise it and give it a purpose and direction.

For research and development to be fruitful, adequate test facilities are essential. Presently such facilities are woefully lacking and it is necessary to augment them considerably to enable the country to produce components and equipment to professional standards.

Self-sufficiency in electronics industry depends to a large extent on the indigenous availability of primary materials. An assessment has been made of the needs, applications and specifications of primary materials re-

I

quired for the industry. It should be possible to establish sources of production for most of the primary materials required within two to three years.

Components form the backbone of electronics, and the production of these in adequate quantities and of the necessary quality should be given the highest priority. The economy of large scale production is the most important consideration in the manufacture of components, which means that it is in the public interest to produce components cheaply by concentrating the production of each type in a couple of large plants.

There is an urgent need for large quantities of radio communication equipment and microwave systems. To meet these urgent requirements, and to avoid continued drain on foreign exchange of imports, production facilities for these should be set up immediately and manufacture under licence commenced. This recommendation has been made by the Committee only as an interim measure in order to 'buy time'. It is essential that action should be taken simultaneously to design, develop and produce the next generation of equipment indigenously. It should not be necessary to resort to any foreign consultancy after the first three or four years, and many of the plants even in the first year are capable of being set up without reliance on imported know-how on the basis of the knowledge and expertise which already exist in the country. To achieve this, persons with adequate technical knowledge must be put in charge of plants at the managerial level.

The very backwardness of the country in electronics and the smallness in size of the present electronics industry could be turned into an asset, if early stages in the development of the industry in other countries are bypassed and the industry planned on the basis of the latest ideas and techniques. In no circumstances should India follow step by step the development of the electronics industry in the more advanced countries, entailing, as this would inevitably, the production of obsolete components and equipment and the use of obsolete and obsolescent techniques and production processes.

1.1.2. Proposals for Future Expansion

It should be noted that under the present licensing policy, units involving a capital investment of less than Rs. 25 lakhs no longer need to be licensed. While this is entirely desirable and the trend in the direction of dispensing with licensing should be raised to higher levels, it is necessary, in order to have a comprehensive picture of what is being produced in the country, every unit producing equipment, components or primary materials, specifically for the electronics industry, should be made to furnish annual returns to some central organisation. This information should be made freely available to the public, so that deficiencies or gaps in production can be made up either through government action or through private initiative.

1.1.2.1. Equipment

The total value of the electronic equipment required in the country over the ten years 1966-75 is likely to be about Rs. 1650 crores. The aim should be to develop a balanced electronics industry to cater to this need to the maximum extent possible. A small proportion of equipment not manufactured at present, the need for which during the first two or three years is considered essential, will have to be imported. But after some three years there should be no need for significant imports. The types of equipment to be imported for meeting the minimum immediate needs should be carefully

I

selected bearing in mind the types to be manufactured in the country under licence and be such as will fit in with future developments.

Also in selecting the items of equipment to be manufactured under licence, the choice should be for types that will help not only bridge the technological gap to the maximum extent but also provide a sound base for indigenous development of equipment for use in the seventies. In entering into foreign collaboration agreements care should be taken to ensure:

- (i) that such collaboration results in the establishment of a definite base for indigenous development and production, and obviates further collaboration;
- (ii) that for the period for which royalty is paid, the foreign collaborator imports the results of his latest development efforts;
- (iii) that there is no restriction on the sources from which components and primary materials are purchased; and
- (iv) that where intermediary products have to be purchased from the foreign collaborator, they are charged on the basis of cost plus handling expenses only.

When the electronics industry was first established in the country, foreign collaborators were made responsible for all aspects of manufacture, including the planning of the factory, the selection of plant and equipment for it, choice and procurement of components, organisation of production, etc. With the experience gained during the last ten years, it should no longer be necessary to require any assistance in planning, construction and operation of electronics factories and where foreign collaboration is required for the manufacture of some equipment, this should be restricted to the obtaining of a licence for producing that equipment in the country.

In the absence of indigenous design and development group to adapt the equipment to standardised components available in the country, multiplicity of different components from various countries are imported resulting in unnecessarily large amounts being tied up in the maintenance of spares. This clearly shows that foreign collaboration agreements when they are necessary at all, should be restricted to equipment which is compatible in interest. It is likewise desirable to confine one's collaboration agreements generally to one country, or at most to countries having compatible equipment and components.

To meet the large and urgent requirements of certain categories of equipment like radio communication equipment and microwave systems, adequate production capacity should be established immediately with foreign technical assistance.

With regard to industrial equipment, the requirement for which is expected to grow only as the other industries develop further, the investment in the first five years need be only about a quarter of what is projected by the end of the ten-year period.

Test instruments are absolutely essential for the growth of sophisticated electronics industry. There is no production of such instruments in India at present and a total investment of about Rs. 2 crores during the next two years should be able to produce all the test instruments required during the next ten years. Moreover the number of types of instruments to be produced is very large, and the Committee recommends that their production be farmed out to parties in the private or public sectors willing to take up production of various types.

1.1.2.2. Radio Receivers and Other Consumer Products

The present (1965) annual capacity of producing radio receivers and other consumer products is worth Rs. 17 crores, which means that it will be possible without expansion to produce Rs. 170 crores worth of these items in the ten-year period. The shortfall of Rs. 280 crores worth of equipment in ten years has, therefore, to be met by expansion. It is assumed that the expansion of this sector is linear over ten years, resulting in an additional annual production capacity of Rs. 62 crores worth of equipment per annum in this sector at the end of ten-year period. On the other hand, if the industry in this sector is expanded geometrically, its annual production capacity being increased by 20 per cent per annum, it will be able to produce all equipment during the ten-year period and it will have a total capacity to produce Rs. 107 crores worth of equipment per annum at the end of ten-year period. It is therefore necessary for Government to create the conditions which will enable this industry to expand at this rate by generating its own capital from savings, and having created the conditions, see that the industry does what is required of it. It should be noted, however, that the expansion in this sector is not merely to be quantitative but also qualitative and the industry must move to newer and better types to keep in the forefront of the world market. Moreover, the industry will have to make a determined effort to reduce cost, and Government will equally have to create the conditions necessary for making this cost reduction possible.

UNESCO and the International Radio Consultative Committee (CCIR) have made certain studies of the essential minimum of broadcast receiver facilities to be made available in the developing countries. According to these, there is a requirement of 420 million radio receivers of which 333 million would be the requirement of Asian countries, excluding Japan. India and Japan are the only two countries in the region technically capable of meeting this demand. As the technological base for domestic radio receiver production already exists in India today, the aim should be to capture a part of this market. Even if a modest 3 per cent of this market is captured by India in the next ten years, about 10 million receivers will be required for export. A set, to meet the specifications of CCIR is likely to cost Rs. 100. Therefore the aim should be to reach an export target of Rs. 100 crores for domestic radio receivers during this period. Unless urgent action is taken to establish production capacity, the country will lose a great opportunity to enter the export market and earn valuable foreign exchange.

1.1.2.3. Components

So long as equipment is made with imported components, its production cannot be increased naturally to meet the demand, as these would involve an increasing drain on foreign exchange. Thus, the dependence on imported components, inhibits the growth of the industry and prevents legitimate consumer demands from being satisfied, for which the public would willingly pay. For this reason and also for self sufficiency and security of the country, this Committee attaches the greatest importance to the establishment of a complete components industry as soon as possible. By giving the topmost priority, every component of vital importance can be produced within three years. The design and characteristics of equipment depend crucially on the characteristics and quality of the components available, and advanced electronic equipment cannot be made without components of high quality conforming to stringent

specifications. Self-sufficiency in the production of equipment can, therefore, only be achieved on the basis of a component industry producing the type of components required. As already mentioned, capacity to manufacture components, which are obsolete or obsolescent, should not be established and considerable effort will be required to keep pace with new developments such as tunnel diodes, field effect transistors, high frequency silicon transistors and other solid state devices. This necessarily means that the component industry must have a strong scientific base and adequate numbers of research and development personnel, who will follow developments abroad, so that they can be initiated here without dependence on foreign collaboration. Some additional capacity for producing components for replacement may be installed if, and only if, the foreign exchange expenditure on the import of these components over the period of the life of equipment is likely to exceed the foreign exchange expenditure on setting up the facilities and on the production of the components. It is clear that unless this condition is fulfilled the setting up of production facilities for components, which are either obsolete or obsolescent in the rest of the world, will either entail infructuous investment or a tendency to lengthen the life of obsolescent equipment. For example, many types of electron tubes are in the process of obsolescence, being replaced either by better varieties of tubes or by transistors, and in such cases their manufacture should only be undertaken after a strict application of the criterion given. Moreover, sufficiently powerful design and development groups would permit even existing equipment, in which such components are used, to be modified to use newer components whose manufacture is worth undertaking, making it possible to reduce the import of obsolescent components or to obviate undertaking their manufacture.

1.1.2.4. Primary Materials

Practically all the materials are imported today, thus making the electronics industry completely dependent on foreign supply. Both for economic and strategic reasons, it is essential that their production should be established in the country on a priority basis. The Committee estimates that to reach an annual production worth Rs. 20 crores of these materials at the end of the ten-year period will require an investment of approximately Rs. 12 crores.

1.1.2.5. Pattern of Investment

The true pattern of investment and growth of the industry will lie broadly between the linear and geometric patterns of growth. The radio receiver and other consumer products sector would have to be expanded at only 20 per cent per annum to meet the total estimated requirement in the next ten years. It is clear, however, that in most of the other sectors, as for example, microwave equipment, it would be preferable to invest substantial sums in setting up new plants during the next two to three years, so that at least a portion of the urgent needs of equipment in these sectors can be met by indigenous production, making a substantial saving in foreign exchange over the ten-year period. Though equipment, components and primary materials are interdependent on each other, the technologies involved in their production are quite different. The production of each of these has, therefore, to be planned separately in the manner most appropriate for it. There is no ad-

vantage to be gained by combining the production of components with the production of equipment in one plant, but on the contrary there are some disadvantages. Economies of scale are very important in the production of components, and it is, therefore, desirable to concentrate on the production of a particular type of component in at most a couple of plants, which would then supply the entire industry with these components. On the other hand, economies of scale are not so important in the manufacture of equipment, especially for professional use, and provided high standards are maintained, specialised professional equipment can be produced economically in relatively small units, the components for it being produced, as already mentioned, by components industry. In the case of large units producing sophisticated electronic equipment, subcontracting of sub-assemblies to other smaller units should be an important feature of the industry.

Further, the Committee considers it of the greatest importance to stress that the electronics industry has to be considered as a whole and developed in an integrated and interlocked manner. In the national interest, it is essential that all equipment, whether for civilian or military use, should be produced in the most economical manner possible. This requires that the production of equipment should be organised according to technologies and economies of production, as is done in the highly industrialised countries. If the separation of civil and military production is not required by security considerations even in the technically advanced countries, it clearly cannot be justified in India. It also follows from technological considerations that production in the public sector cannot be separated from production in the private sector, and for the optimum development of the industry it is necessary to plan it on an integrated basis taking the two sectors together.

1.1.2.6. Research, Design and Development

With the exception of a few areas in which groups have been built up capable of designing and developing components and equipment without foreign collaboration, most of the existing electronics industry in the country is abjectly dependent on foreign collaboration. In order to develop a self-reliant and a largely self-sufficient industry capable of meeting Indian needs and of competing in the world market, the establishment of powerful design and development groups is an absolute necessity.

The first and most urgent need is to establish in every plant producing electronic equipment, scientific and technical design and development groups with sufficient competence to redesign equipment either being manufactured under licence or whose design is readily available in the literature, in order to adapt it to Indian conditions and to use the components available in India. These groups should also bring prototypes developed in the country to the production stage. In all such work a considerable saving in development time can be effected by studying imported equipment and making such modifications as may be necessary to adapt it to Indian requirements.

During the period of a development cycle, which is about three to five years, a plant should be in a position to produce new equipment of indigenous design. In order, however, that the equipment so produced five years from now should be of the type which the user wants, it is necessary that the user should be able to specify three to five years in advance the qualitative requirements and general characteristics of the equipment required. There should be constant liaison and exchange of ideas between the users and the

I

designers of the equipment, and a proper appreciation of each other's difficulties.

In the manufacture of components, there are two distinct stages. First, the development of the necessary materials with the characteristics needed and their assembly into a component having the necessary performance and characteristics. The second stage involves the technology of producing this component economically in large numbers. The first stage requires development groups with the necessary knowledge of materials and techniques. It should be possible to establish groups which can develop practically any component within a period of one to two years, though very specialised components may take longer to develop. The second stage, however, requires knowledge of production techniques, and unless there are people with experience in modern production techniques using automated or semi-automated machinery, it may be necessary initially to import some of the specialised equipment and obtain the necessary expertise under licence. Again, design and development groups for production technology should be immediately built around this equipment, so that when any other component is developed indigenously, its production can be organised without recourse once more to foreign assistance. This will also mean eventually development of groups capable of designing specialised machinery for the mass production of components, and once familiarity has been established with typical examples of such machinery used in the production of valves, transistors, resistors, capacitors etc., development of such production machinery should not present any real difficulty.

In connection with the import of production machinery it has been observed that when a collaboration arrangement with a foreign concern exists in respect of the manufacture of a particular component, the Indian manufacturer does not generally find it difficult to obtain the foreign exchange required for the import of all equipment needed, whereas if a component has been developed and tested indigenously and some specialised piece of equipment is required for its large scale manufacture, the foreign exchange required for the purpose is generally much more difficult to obtain. This acts as a disincentive for indigenous development of design and manufacturing know-how. It is clear that a more discriminating licencing policy is necessary, which gives preference to production on the basis of indigenous know-how rather than the reverse.

It is quite necessary, if the country is to keep pace with such relatively imminent developments, that strong development groups should be established both in Government organisations, like Atomic Energy, the Council of Scientific and Industrial Research, Defence Research Laboratories and in large undertakings in the electronics industry. In developing systems which are well known, it is possible to split the job between a number of separate development groups. It is not necessary that these groups working on various aspects of a large system be located in one institution. It is, however, essential that one person or group should be made responsible for directing their efforts towards a unified system design.

It is essential that India should also participate in long range research, and for this purpose strong support should be given by the Government to such research, not directed towards immediate application, in Government supported laboratories as well as in the universities, and, indeed, in any laboratory privately or publicly owned, where there is an outstanding research

I

worker or group. It must be understood that only research workers, who have proved their capabilities, and promising young men must be supported for such long range research, which should not be confused with much of the directionless and so called pure research, which is done in India today. In particular, advanced study and research in solid state should be strongly supported. It must be emphasised that long range research can and must only be built round outstanding individuals in order to yield any worthwhile results.

1.1.3. Problems of the Present Electronics Industry

The Committee received evidence from representatives of the industry both in the public and private sectors. A summary of the points made by the representatives is listed below:

- (i) The basic weakness of the electronics industry arises from the fact that it has grown in a haphazard manner to meet the needs of electronics equipment. No view of the industry as a whole has been taken and consequently it is at present merely a collection of a number of disconnected units with little correlation between them. The major part of the industry has developed under foreign collaboration arrangements, and this is the source of its greatest weakness.
- (ii) Though foreign exchange expenditure on the import of components in the country is being reduced progressively, the drain on foreign exchange continues to remain appreciable. This is due to the fact that the value of the primary materials imported for indigenous manufacture of components is considerable.
- (iii) Manufacturers of components prefer to get special primary materials such as pure germanium, silicon, ceramic rods and epoxy resins from outside agencies rather than undertake their production themselves, because many of these are required in small quantities usually considered uneconomical for commercial production.
- (iv) Where indigenous primary materials are available their cost is invariably many times the imported cost (e.g. bakelites, polystyrene, ceramic rods, tinned copper wire etc.).
- (v) Sub-components, mainly metal parts, require special skills not directly connected with electronics industry and their manufacture could be undertaken by other specialised industries, like the metal working industry.
- (vi) In the manufacture of electronic components, economies of scale have a vital bearing on costs. This has not been sufficiently appreciated.
- (vii) Manufacturers of components cater mainly to the requirements of the entertainment industry and do not generally produce the high quality components indispensable for professional equipment such as those required for atomic energy, communications, defence, industry and research.
- (viii) Manufacturers of components of the entertainment industry have not organised development work. Only organisations with sufficient resources will be able to undertake this task and Government's policy should be such as to encourage them to do so.
- (ix) Foreign capital participation in manufacture of components is generally on terms that are not favourable. The collaborator gene-

rally supplies plant and machinery at inflated prices and this is set off against his share of the capital. For example, one plant established on these lines declared dividends only after 6 years.

- (x) Manufacturers of components prefer to get versatile manufacturing equipment because of uncertain fluctuations in pattern of demand. This necessitates a compromise in the efficiency of production.
- (xi) Manufacturers of equipment have a tendency to modify the specifications of their requirement of components to suit the design changes introduced by their foreign collaborators from time to time.
- (xii) Unutilised licensed capacity in the component industry is an important factor in discouraging new entrepreneurs from entering the field.
- (xiii) Production engineering and supporting industries will be necessary to develop and fabricate the machinery required for manufacture of components.
- (xiv) In the field of radio receivers more than a year elapses between the time the foreign collaborators bring out new models abroad and their associates commence manufacture of similar design in India. This delay places manufacturers in a position of disadvantage in the export market. Cost is another factor.
- (xv) A small number of radio receivers is being exported, but as the international price levies are low, these sets are being sold below cost.
- (xvi) Labour productivity in the radio receiver industry is comparable to standards in some other countries, as for example, the United Kingdom.
- (xvii) Presently there is a serious dearth in the country of up-to-date tool room capacity, particularly for press tools.
- (xviii) Pooling of processing facilities such as etching of aluminium foil for electrolytic capacitors, can make for reduction in capital investment, foreign exchange expenditure and idle capacity.
- (xix) Supplies of power and water are erratic and seriously affect the even flow of production, particularly in the components industry.
- (xx) Facilities for duplicating tools are inadequate.
- (xxi) Licensing procedures for import and manufacture involve delays ranging from 18 to 24 months.
- (xxii) The importance of an indigenous electronics industry was not recognised by the major users of professional electronic equipment in the country. Government also failed to recognise the essential and strategic importance of the industry and did not give it a sufficiently high priority in planning.

Most of these difficulties are genuine though in varying degrees. These are, however, merely different facets of the basic weakness of the present electronics industry in the country which must be studied and understood if the disease is to be cured.

1.2 Review of Events Since Electronics Committee Report

There has been a steady growth of the electronics industry in India since Bhabha Committee submitted its recommendations in 1966. The Bhabha Committee reviewed the status of the electronics industry and the prevailing technology to estimate the requirements of electronic equipment for the

I

decade 1966-75 and made a number of recommendations. Government accepted all the recommendations made by the Bhabha Committee. For advising Government in the implementation of the recommendations of the Bhabha Committee, an Electronics Committee was appointed under chairmanship of Dr. Vikram A. Sarabhai in June 1966. This Committee had initiated a number of programmes for rapidly expanding and diversifying the engineering and know-how bases of the industry through research and development and taken various steps to set up the production capacity required to meet the assessed demand.

During the past five years, the industry has grown at an average annual rate of twenty per cent. From 1964-65 to 1972-73, there was a seven-fold increase in total production. The public sector has played a multi-faceted role in this growth. The Indian Telephone Industries and Bharat Electronics Limited have become major producers and exporters of professional equipment. The drive for self-reliance in this highly sophisticated field resulted in the establishment of the Electronics Corporation of India Limited in 1967 based entirely on indigenous know-how. Hindustan Aeronautics Limited, at Hyderabad, Hindustan Teleprinters Limited at Madras and Instrumentation Limited at Kota have also significantly contributed to the overall growth of this industry.

The main thrust behind the country's self-reliance and near self-sufficiency in consumer electronics has been provided by the organised private sector and the small scale sector. The private sector is also responsible for substantial export of electronic items. This sector has not only pioneered the production of less challenging items like radios, TV receivers, electronic desk calculators and measuring instruments, but has also ventured into harder options like radio frequency cables, microwave components, digital instruments, control equipment, record players, audiotapes, and stereo systems.

The local TV industry has grown substantially in the past five years. There are eighty manufacturers licensed to make B&W TV receivers. About thirty different brands of TV receivers are available in the market. In 1973-74, TV production was 75,000 sets. A few units have also been licensed to manufacture other TV equipment. The growth of radio industry has been tremendous. At present, the product-mix in radio receivers ranges from a one band medium wave radio to a sophisticated thirteen band stereo tuner. Medium wave sets costing less than Rs. 70 are also available. There has been a remarkable progress in the case of stereo record players, tape recorders, cassette recorders, PA systems etc.

At present there are over three hundred manufacturers engaged in production of a wide variety of test and measuring instruments, process control instruments, analytical instruments and medical instruments. The production of commercial grade test and measuring instruments is fairly well established in the country. A few component manufacturers have also developed automated test equipment for captive use. In the area of medical electronic instruments, the local industry has shown good progress. A wide variety of instruments like ECG, EMG, EEG, defibrillators, external and internal pace makers, foetus monitors, and diathermy equipment, to mention a few, are marketed. About 50 per cent of the total volume of medical instruments production is comprised of X-ray equipment. In the case of process control instruments, approximately 70 manu-

facturers are making various types of thermocouples, temperature controllers, recorders, flow meters, control valves, pressure gauges, etc.

A review of the progress made in the entertainment industry reveals that initial momentum has not been maintained after 1970-71. In 1970-71, production of entertainment equipment was worth Rs. 80 crores and it dropped to Rs. 65 crores in 1972-73. One reason behind this drop is lack of promotional efforts. Also, electronic goods manufactured locally could not compete in the international market. Moreover, there has been erosion of the buying power during the past few years.

The requirement of defence electronics was estimated by Bhabha Committee to be Rs. 750 crores, out of the total requirement of Rs. 1650 crores for the decade 1966-75. Upon review, it was found that Rs. 750 crores outlay for defence electronics was on the high side. The discrepancy in anticipating defence requirement has been due to the fact that a few anticipated programmes could not be implemented. These include production of sophisticated weapon systems, assumption of increased use of UHF equipment by 1967-68, and replacement of existing communication equipment by new generation of equipment.

The bulk production of defence electronic equipment is in the public sector units—BEL, HAL, and ITI. BEL has become an important producer of high and low-power transmitters, various types of trans-receivers, radars and some sophisticated components. HAL is producing air-to-air communication and radar equipment. ITI and HTL are also making communication equipment. The shortfall in area of defence equipment is mainly in the field of high power systems and avionics. The design of the next generation of such equipment depends upon the availability of the next generation of sophisticated components. A sound base for development and production of professional grade components has not been established so far. One reason for this is the long gestation period required. Also, since demand for such components is small, the total production to investment ratio is low. Apart from this aspect, it can be stated that as far as defence electronics is concerned, the right kind of activities have been initiated and considerable progress has been made in recent years.

The growth rate in the field of computers was rather low. This low growth rate is linked to non-availability of professional grade components and precision tooling required for the production of peripherals. Absence of a semiconductor production base for making sophisticated IC devices on a large scale has been the real bottle-neck in the production of computer CPU. In the past five years, ECIL has made appreciable progress in developing computers. After successfully marketing TDC-12, ECIL has gone ahead with the development and manufacturing of TDC-16, TDC-312 and TDC-316.

Like computers, there has been a slow growth in industrial electronics and process control instrumentation. The technology in these areas is fast changing and indigenous efforts have not been organised adequately.

Now that the demand for industrial and process control instruments is increasing in other fields like textile, steel and pharmaceutical industries, this area is expected to gain momentum in the coming years.

In the field of components, the production has been almost in step with that of equipment. The production of components has risen from mere Rs. 6.5 crores in 1965-66 to Rs. 55 crores in 1973-74. However, as compared to consumer grade components, the production of professional grade components is

I

to consumer grade components, the production of professional grade components is lagging behind. While, it has become possible to meet not only the domestic demand of consumer grade components but also to export them, the country still depends on imports for quite a few professional grade components; one of the reasons underlying the lack of progress in the area of professional grade components being the large type diversity of their requirement which results in an insufficient demand for each type. In so far as the different categories of components are concerned, almost all of them are now being produced indigenously. In the area of electron tubes, the production includes that of receiving and transmitting tubes, magnetrons, X-ray tubes, TV picture tubes and nixie tubes. In the area of semiconductor devices most of the production today is of germanium and silicon discrete devices. As regards ICs, BEL has, only recently, started the production of TTL ICs with indigenous know-how, and is soon starting the production of CMOS ICs with foreign collaboration. Most of the other firms who have been producing silicon planar transistors have also been licensed to produce ICs. The setting up of a semiconductor complex in the public sector, devoted to the manufacture of MOS LSI, bipolar LSI, LEDS and packages has also been contemplated. In the area of hybrid microcircuits, BEL is fairly well equipped to undertake the production of some of the circuits. In the area of passive components, there are about 40 firms, both in organized and small scale sectors, producing resistors of almost all types and about 70 firms producing various types of capacitors. The connector industry in the country is coming up. There are about a dozen firms, nearly all of them in the private sector, producing various types of connectors. Amphetronix Ltd., Poona which is the major connector producing firm and has Amphenol, USA back up, produces coaxial, rack and panel and printed circuit connectors. HAL, Hyderabad produces a few types of rectangular multipin connectors with glass filled phenolic insulation. Relays are being produced in a fairly wide range in the country by over 10 firms. ITI, Bangalore makes telephone type relays for their telecommunication equipment, O.E.N. Ltd., Cochin and many others make a variety of general purpose electro-magnetic relays. About three firms are already licensed to produce reed relays. Switches which include the rotary wafer, push button, toggle, snap action, stepping and key board type are being produced in the country by over 25 manufacturers. As regards other passive components, that include crystals, transducers, magnetic components and printed circuit boards, many of them are being produced in the country though there are certain items like magnetic tapes, TV deflection components and multilayer printed circuit boards whose production is either not established or in the process of being established.

In so far as the materials are concerned, the electronic component industry still depends on their imports to the tune of over 50 per cent. Most of the metals and alloys are still being imported, though with the starting of the proposed Special Alloys Plant at Hyderabad, many of them will become indigenously available. Among the ultra pure metals and semimetals, the Special Materials Plant at Nuclear Fuel Complex, Hyderabad has recently established the production of most of the materials. As regards semiconductors, while germanium is being imported as germanium dioxide, silicon is imported in the polycrystalline form. In respect of glasses, many of the sealing glasses and the glass shells for TV picture tubes are being imported. Among ceramics, while several of them are being imported as component

I

parts, the production of many of them that include both electrical and magnetic ceramics, is being established in the country. Regarding chemicals and plastics, the production of some of the electronic grade solvents and a few types of plastics has been started in the country.

1.2.1. Progress in Technology Development

In 1966-67, the time when Bhabha Committee submitted its recommendations, R&D outlay was of the order of Rs. 4 crores. The Bhabha Committee envisaged that by 1975, annual outlay for R&D should be about Rs. 85 crores. Such a huge outlay might appear high, but it is indicative of the extensive effort required in a fast changing field like electronics. Although R&D outlay has not been according to expectations, considerable progress has been made in this direction. The R&D activities in various sectors of electronics are summarized below:

In the area of consumer electronics, R&D efforts have not matched the needs and special requirements of the market. At present, such efforts are confined mainly to a few national laboratories and manufacturers in the organized sector. Hardly 0.3 per cent of the total sales of private sector organizations has been spent on R&D, and that also in developing Hi-Fi equipment and radio receivers. On the other hand, national laboratories have shown a steady growth. For example, CEERI has developed technical know-how in TV test instruments and antennas, TV camera, monitor and distribution transformer, community antenna, stereo tape recorder, record reproduction heads, ceramic pick-ups for disc and reproduction, a wide variety of microphones, to mention a few. The Electronics Systems Division of ISRO has developed a solid state TV, and Research Department of AIR has also developed a solid state TV and a wide variety of test instruments.

Since R&D base in consumer electronics is not very strong, rural and international markets could not be exploited.

In the field of mass communication, most of the R&D work is going on in BEL and AIR. BEL has developed several types of transmitting tubes, high power valves for broadcasting and communication equipment. ITI has been engaged in development of microwave link equipment. Indigenous efforts have resulted in the development of MW transmitters upto kW, TV transmitters and several types of accessories. At present, development efforts are underway for items like control consoles, antenna turning units, portable tape recorders, disc playback consoles, TV relay receivers, etc.

The field of computers and control is still in infancy in India. Thus, R&D activities in this field are rather limited. TIFR, ISI, and Jadavpur University are among the first ones to initiate development of indigenous computers. The design and development of TIFRAC was ready before the setting up of Bhabha Committee. In recent years, TIFR and some other organizations have been engaged in development of peripheral hardware, on-line data processor (OLDAP), visual display consoles, etc. At present, ECIL is working on third generation computers. IIT, Kanpur is actively participating in developing computer hardware.

A suitable and competent nucleus exists in the country for undertaking R&D activities in process control instruments and systems. Most of the development activities are confined to CSIR laboratories, BARC, Instrumentation Limited, ECIL and Fertilizer Corporation of India.

In the field of instruments, a lot of progress has been made in the past decade. Extensive efforts have resulted in development of a large number

of items from multimeters to complex medical instruments. Existing R&D activities are in several laboratories under CSIR, Department of Atomic Energy, Indian Space Research Organization, Ministry of Defence, various IITs and some other educational institutions. Although development efforts have been commendable, non-availability of a wide variety of materials and components has hampered development of some sophisticated instruments. Furthermore, instruments industry in India has been quite reluctant to adopt new generation of instruments and this has slowed down R&D activity in this field.

In the field of communications, a major part of R&D activities is carried out by institutions attached to the user departments and inhouse R&D units of various manufacturers. Telecommunication Research Centre, Overseas Communication Service Research Department, various laboratories under the Ministry of Defence, R&D departments of BEL, ITI and HAL, account for most of the work being done. Significant contributions of TRC are for microwave links, telephone and telegraph equipment, automatic telex exchanges, data modems etc. ITI has developed a wide variety of telephone equipment, intercom systems, equipment for strewger and cross bar switching systems, line equipment, and narrow-band solid state systems of railways and defence. OCS has also developed telephone and telegraph equipment. In the case of radar and HF/VHF equipment, BEL, HAL, and LRDE have significantly contributed. Other national laboratories like Space Application Centre, Solid State Physics Laboratory, Himalayan Radio Propagation Unit, National Physical Laboratory, Tata Institute of Fundamental Research, Bhabha Atomic Research Centre have been actively engaged in development of C-band, X-band, J-band, S-band systems, transmitters, transreceivers, LOS systems upto 960 channels, radio relay stations, and VHF/UHF receivers, to mention a few.

The growth of electronic components and materials industry demands a far greater effort and expenditure on R&D than any other sector of the electronics industry. In recent years, R&D efforts in this field have not made any substantial impact. This has happened because resources were spread too thin and there was not much coordination among various organizations.

In case of electron tubes, main R&D centres are BEL, CEERI, NPL, TIFR, ECIL, BARC, and IISc. A wide variety of receiving, transmitting, microwave and display tubes has been developed. Strong R&D groups have been formed at BEL and other places to undertake development work on TWT, TV pick-up tubes, gas lasers, high power klystrons, photo tubes, and power tubes.

As far as semiconductor devices are concerned, R&D work at the industry level is confined to BEL and ECIL in the public sector, and Semiconductors Limited and Continental Devices (India) Limited in the private sector. A few types of capital equipment have also been developed in addition to diodes, transistors, varactor diodes, and a few types of ICs. National laboratories like SPL, CEERI, TIFR, and NPL have been engaged in development of semiconductor devices. NPL has been concentrating on thin film technology. In addition to developing semiconductor devices and circuits, some packaging materials have also been developed. Apart from these professional institutions, a few academic institutions like IITs and IISc are doing meaningful research in this direction.

In the case of passive components, main centres engaged in R&D

work are ECIL, CECRI, NPL, BEL and BARC. They are engaged in developing passive components for consumer industry and professional equipment. A vast variety of resistors, capacitors, ferrites and ceramic based components has been developed with the result that a major portion of component requirements is met through indigenous sources.

In the field of electronic materials, the performance has not been encouraging. R&D efforts are mainly confined to national laboratories, and some educational institutions. Development work to a limited extent is also undergoing in manufacturing organizations. In case of metals and alloys, DMRL, BARC and NML are main centres engaged in R&D activity. BARC is also undertaking work on ultra pure materials. Major development activities in area of glasses, ceramics and other insulators are at CGCRI, NPL, NCL, RRL, IISc, SPL, CEERI and NML. In addition, some R&D groups in various production units are putting efforts in the development of high grade solvents, cleaning agents, acids and other process chemicals. Despite all these efforts, the country still depends on import of certain electronic grade materials.

From the foregoing, it can be seen that in the field of consumer electronics, the growth was more rapid than that predicted by the Bhabha Committee. However, the professional electronics had a retarded growth. In order to identify and eliminate the factors contributing to this retarded growth of the professional electronics sector in particular, and to discuss and focus attention on the problems facing the electronics industry in general, the Electronics Committee at the request of the Committee on Science and Technology organized a National Conference in 1970, a summary of which is given below.

1.3 Proceedings of National Conference on Electronics — A Summary

The National Conference on Electronics was held at Bombay from 24th to 28th March, 1970. The conference discussed the various aspects of the electronics industry namely, developments since the publication of the Bhabha Committee report, industrial and import licensing policies and procedures, foreign financial participation and technical collaboration, indigenous research, design and development, role of small scale industry, development of computer technology, microelectronics, television industry, etc. The discussions represented a wide spectrum of view points.

In the following sections a summary of the observations made during the various sessions and the major steps suggested for achieving a rapid growth of the electronics industry is given.

1.3.1. Developments in the Electronics Industry Since the Publication of the Bhabha Committee Report

A review of the developments in the electronics industry leads to the following observations:

- (i) While the electronics industry in entertainment field has developed substantially, progress in other fields is quite small. In defence electronics, the progress is even less than in the area of communication electronics.
- (ii) In both defence electronics and communications there is still much dependence on foreign know-how and imports.
- (iii) There is no stated policy on materials, components and equipment, on aspects such as volume, sophistication, time schedules of the national demand for each category. There is no general R&D policy regarding the categories and their mutual rela-

tionship, on the basis of which direction and allocation of tasks to various organizations can be prescribed.

- (iv) Research, development and production activities in the country are unco-ordinated and widely dispersed under various agencies.
- (v) There has been a lack of primary data regarding facilities for research, the number and quality of research personnel at the various research institutions in the country and manpower requirements for the next decade or so.
- (vi) There is no planning on appropriate R&D programmes and locating them in various existing organizations. It is necessary to outline a continuing forward thinking policy to forecast requirements when trends change in the decade or so, from those forecast in the Bhabha Committee report.

Progress today is closely connected with intelligent application of electronics in an ever increasing measure to various sectors of our national activities. In doing so, the goal should be self-reliance. Modernisation and increased tempo of research and development are necessary to prevent obsolescence. In addition to a close watch on the inputs and outputs of the various industrial enterprises, a continuous effort to up-date the findings of the Bhabha Committee and to check sectional imbalances in the progress is very necessary.

The implementation of the recommendations of the Bhabha Committee while covering a broad range of activities, basically involves two major tasks: (a) developing a policy and initiating programmes for rapidly expanding, and diversifying the engineering and know-how base of the industry through research and development, and (b) taking steps to set up the production capacity required to meet the assessed demand. It is to be noted in this connection that promotion of an industry in a ministerial Government requires committing substantial executive resources to securing effective interministerial action. So, it would appear best to replace Electronics Committee by a policy making and implementing body, set up under an act of Parliament, or as a consequence of such an act.

A problem which has seriously restricted the effectiveness of the Electronics Committee is the fact that the executive control over the crucial functions of industrial and import licensing has not been exercised solely by the Department of Defence Supplies. The Department has had to work through the cumbersome procedures of the Directorate General of Technical Development and the Licensing Committee on the one hand and the Chief Controller of Imports on the other. This has resulted in licence scrutiny at several offices, thereby fragmenting and diluting decision making. Another aspect which needs immediate attention is the ability to take quick decisions with minimum delays and less paper work. Quick decisions in this field are necessary because of the rapid developments in technology. Delay in making decisions on the part of the Government will only result in the purchase of obsolete technology or manufacture of obsolete products. The new policy making and implementing body must, therefore, have its own import and industrial licensing section. An important step to be taken for developing the industry is to explore new markets. This can be of the form of (i) export markets or (ii) throwing open for manufacture by the private sector, some items now reserved for the public sector, viz., microwave equipment and components, walkie-talkie sets and communication equipment.

I

Electronics can be one of the areas in which India can make some impact in the export market. This, in fact, results from the advantage of low-cost labour as well as engineering which applies in this country at this stage. In cases, where certain basic parts are obtained from abroad, the added value of finishing the electronic item can actually result in benefits for the country.

It is natural that Government departments with major interests in electronics, should concentrate their R&D and prototype engineering activity on specific pieces of hardware. However, it is important to ensure at the same time, that the development of advanced techniques, whether of manufacturing, operation, use or applications, is not neglected. This can be achieved in two ways: (a) by setting up, in expensive areas, such as computer, and in areas where we do not have any competence at all, such as systems engineering, technique-oriented laboratories, (b) by providing financial and organisational resources to support the growth of technique-oriented work in CSIR laboratories, IIT's, universities and research organizations. The feasibility of the projects should be evaluated through panels. It is most important for the funding authority to have the funds and the management systems expertise, to carry forward such support, in promising cases, to the stage of pilot plant production (whether existing or newly set up by it) and further to full-scale commercialisation. Some inter-sectoral re-allocation of financial resources would have to take place between entertainment electronics and professional electronics. Whether it should be done through a compulsory research cess on all production and then its allocation by Electronics Committee to approved projects in various units while the Government also will be sharing a fair burden, is a matter that would need closer examination of related technical and financial parameters.

Today there is a serious shortage in the country of electronic engineers, solid-state physicists, metallurgists and chemists around whom energetic research, development and production engineering groups can be built, especially at the project level. The creation of well-planned technique-oriented research and development programme will be an incentive for such personnel who are at present abroad, to return home both to existing laboratories and to new ones which the country cannot escape setting up. If these were done, India would not only obtain their leadership capabilities but also their up-to-date skills.

1.3.2. Industrial and Import Licensing Policies and Procedures

On the basis of the recommendations of the Administrative Reforms Commission, the Industrial Licensing Policy Inquiry Committee and the Planning Commission, the Government has accepted certain changes in the Industrial Licensing Policy, the policy with regard to assistance from public financial institutions and the policies relating to growth of the public sector. The Government has decided that there should be a list of core sector industries in the country. Detailed industry plans would be prepared for these industries and essential inputs made available on a priority basis. A list of core industries has been drawn up and substantial portion of the electronics industry has been included in this list. Selected electronic components, test and control equipment, wireless and microwave equipment have been included in the core sector. This would ensure that for the more important and sophisticated electronic items, liberal licensing would be permitted and

I

foreign exchange and other essential inputs could be made available on a priority basis.

Another important decision is to do away with the licensing altogether for all new undertakings or for substantial expansion of existing units which do not require an investment of more than Rs. 1 crore by way of fixed assets in land, buildings and machinery, subject to some stipulations. The stipulations are:

- (i) that such undertakings should not belong to any of the larger industrial houses as classified by the Industrial Licensing Policy Inquiry Committee;
- (ii) that they do not require more than Rs. 10 lakhs or more than 10 per cent of their investment, whichever is less, by way of foreign exchange for import of machinery and equipment;
- (iii) that they do not require foreign exchange except marginally for import of raw materials, components, etc;
- (iv) that they are not included in the category of dominant undertakings as defined in the Monopolies Act;
- (v) that they do not belong to a foreign company or are not a branch or a subsidiary of a foreign company; and
- (vi) that they are not for items included in the banned list or those reserved for small scale sector.

These conditions have been further clarified to mean that foreign exchange commitment for import of raw material/components should not exceed 3 years' requirements from the date the plant goes into production and should not in any case in any one year exceed 3 per cent of the value of the production or Rs. 3 lakhs, whichever is less.

The Government has also accepted a new concept of the middle sector in which will be included industries which require investment of more than Rs. 1 crore but not exceeding Rs. 5 crores. For such industries, there will be very liberal treatment in the matter of issue of licences. However, issue of such liberal licences will also be governed by the same conditions which are applicable to the delicensed industries.

It should be possible for the industry to expand at a much faster rate in view of the fact that no industrial licence would be required if the total investment in fixed assets, land, buildings, plant and machinery does not exceed Rs. 1 crore.

The current import licensing policy and procedures suffer from several drawbacks. Some of these are mentioned below:

- (i) The materials imported by the manufacturers of electronics equipment are of a specialised and sophisticated nature, yet their monetary value is small compared to that of other industries. The present procedure covers all industries irrespective of the cost of the items being imported. There has, therefore, been considerable delay in dealing with import licence applications of small value for the electronics industry.
- (ii) Even though the total value of import licence for import of raw materials is small, it is split up into three sources, viz., free foreign exchange, rupee payment source and USAID.
- (iii) Import licences are issued to actual users at six monthly periods and hence entrepreneurs are not able to plan production in a meaningful manner. Also because of the procedural delays

I

involved, quite often it is not possible to import the goods within the validity period of the licences.

- (iv) The need for 'technical certification' of the identity of the imported items leads to frequent disagreements with the customs authorities on the nature of the items involved. This results in customs duty on raw materials and components being levied on a non-uniform basis and also leads to delay in clearance of imports.

These drawbacks are genuine and action has been taken to devise procedures which would overcome the difficulties that have been experienced by the manufacturers. It may be stated that it is neither feasible nor desirable to evolve entirely separate procedures for each industry. No separate procedures can, therefore, be evolved for import of machinery and materials required for the electronics industry. However, in order to avoid hardship to the small scale manufacturers, who get small value licences for the import of raw materials and components, it has been recommended that no splitting of the licence should be done provided the total value of the licence does not exceed Rs. 10,000 in each case. As regards the technical certification of the identity of the item, it may be stated that suitable instructions are issued from time to time, so that entrepreneurs are not put to any unnecessary hardship.

Multiplication of ministerial control, supervision or assistance must be avoided in future. There should be one body who should be concerned, if rapid development is desired. It has been the general experience of foreign collaborators that the Government of India takes a long time to process applications for industrial licences and very often such delays ultimately result in their losing interest in the Indian projects. Many reputed manufacturers have set up feeder plants in Hong-Kong, Taiwan and other countries where they are not confronted with time-consuming formalities. With low labour rates prevailing in India and plenty of manpower, we would attract many foreign manufacturers to set up feeder plants in India provided procedural delays are eliminated and licences are issued within a reasonable time.

Although considerable progress has been made during the past 20 years, our country is still far behind the developed countries in the field of electronics. While advanced countries have already switched over to integrated circuits and multilayer printed circuit boards, we are still in the process of switching over from valves to transistors. If we have to catch up with the advanced countries it is essential that we resort to "leap-frog" technology, i.e., by-pass the interim phase of development and adopt the latest technology from advanced countries like USA and Japan. To accomplish this, the Government must adopt a liberal policy to allow fresh collaborations involving the latest technology. Considering these factors it is clear that we should have a fresh look on what should be set up which will ensure quick production, development in design and assist in promotion of basic research in this field. The following are some of the suggestions made in respect of the industrial and import licensing policies and procedures:

- (i) A Directorate of Electronics Production having, executive powers should be formed immediately with proper terms of reference which shall include the processing of licence applications of all types and examination and evaluation of foreign collaboration proposals, etc. This will facilitate the issuing of licences for the

-
- industry without going into the lengthy process of obtaining licences as at present.
- (ii) Every factory whether in the public, private, or proposed joint sector and of large, medium or small size should be licensed and registered with the Directorate.
 - (iii) The Directorate should have the responsibility to process all the import licences to step up the procedures. It may be necessary to have a Director of Export Marketing.
 - (iv) The Directorate should also have a Director whose responsibility should be to study and advise on the financial requirements of the factories, for expanding their production or for new schemes.
 - (v) In the field of export-oriented technical know-how, the licensing should be liberal. It should enable the entrepreneur not only to set up the base for making the items in the country quickly but also export the same to meet the tight target dates.
 - (vi) The panel of experts to review licence applications for the electronics industry should be broad-based to include at least one or more users of the component or the equipment. At present the user is not at all in the picture and by the time he is brought in, it is too late to make any necessary modifications.
 - (vii) Delicensing should not be undertaken without considering its adverse impact on the small scale sector.
 - (viii) In the electronics field a decentralised pattern of industrial structure should be promoted, so as to avoid vertical development and curb monopolistic tendencies.
 - (ix) Items which can be technically and economically produced in the small scale sector should be reserved for it. However, both the small scale and the large scale sectors have their own role to play. Therefore, any attempt to reserve any items exclusively for small scale sector should keep in view the effect of such reservation on the larger national interest.

In the field of components it has been the policy to license economic quantities and the units which are manufacturing a certain item in un-economic quantities are given preference in licensing substantial additional capacity to bring down their prices. The licences issued also contained a condition requiring the units to set up adequate research and development facilities so that they do not have to depend upon import of foreign technology in future and are also able to develop more sophisticated types of components in their own laboratories. The objective is that the entire field of components is covered and the requirements are met not only quantitatively but also qualitatively.

It was also noted that the recommendation of the Bhabha Committee against distinction between public and private sectors for the production of electronics equipment, whether meant for civilian use or for military use, is contrary to the Industrial Policy Resolution. Hence the production of defence equipment has to be established only in the public sector and not in the private sector (unless suitable amendments are made to the IPR).

1.3.3. Foreign Financial Participation and Technical Collaboration in Electronics

It would be impossible for any country, even for a developed one, to grow and expand in this field in isolation. As new technologies are being

continuously evolved, there is rapid obsolescence of technology. A certain amount of interdependence has, therefore, to be accepted if we want to keep abreast of the latest developments in this field. While the guidelines framed by the Bhabha Committee in regard to foreign financial and technical participation should by and large govern the policies, there should be no hesitation in making a departure from these whenever it is necessary to do so for the rapid building up of a sound electronics industry in the country.

In planning a strategy in any meaningful sense, it is necessary to define the overall objectives to be achieved by the strategy. Some of the important objectives before the nation are (i) to increase the rate of growth of the national economy so that the country could emerge into the stage of a developed nation in the shortest possible time, and (ii) to spread the benefits of increased productivity to the largest section of the population.

It would be desirable to acquire the latest technology and to build the super-structure on that foundation so that the expansion could be achieved with a minimum of imports and could lead to a large proportion of exports. Also the emphasis would have to be placed on the employment opportunities generated by the new industries. The industries to be emphasised would, therefore, have to be so chosen that (i) there are large returns for a given investment, and (ii) the investment required per worker is not excessive.

It is generally recognised that left to itself, import of technology tends to have an adverse effect on the balance of payments position of a country. This import of technology is also habit-forming especially in protected markets, since profitability is assured without taking risks so far as the individual industrial units are concerned. But with this habit, the problem of the balance of payments can become chronic and the prospects of a self-generating economy become poor. A vital question, therefore, is how to make the most of the import of technology that the country may be able to afford, and how to make the imported and the indigenous technology complementary and coupled to each other. The answer to this question should be the keystone of any strategy that the planners of a country evolve.

In order to reap the full fruits of foreign collaboration, it is necessary that the arguments normally advanced in favour of the import of technology are made actually operative in each situation. For instance, if the imported know-how is to be a stepping-stone to a still higher level of technology, the plans put forward by the sponsors of this import must include (i) projections of future markets, technology developments and the proposed means to tap markets without any further import of know-how, and (ii) efficiency and cost reduction benefits, and export potential in terms of minimum percentage of the output.

Foreign collaboration is normally covered under the distinct patterns: (i) technical collaboration for production with equity participation by foreign entrepreneurs and (ii) technical collaboration without equity participation. The disadvantages, in the case of foreign collaboration without equity participation, are:

- (i) Since there is no financial participation by the foreign principals, there is, therefore, no motivating factor on their part towards the profitability of the venture.
- (ii) Experience so far has shown that personnel who were deputed to effect the transfer of the know-how in India were not fully

- competent to advise on the transfer.
- (iii) Since no equipment manufacturer would normally fabricate in his own factory all the assemblies, sub-assemblies and components required to manufacture a product, the collaboration agreement does not normally cover the know-how of manufacture of 40 to 50 per cent of these assemblies, sub-assemblies and components. As a result, the Indian entrepreneur has either to buy these from sub-contractors abroad with consequent heavy drainage of FE for all times or he has to go into indigenisation of these items without any assistance from the foreign collaborator.
 - (iv) In most cases of foreign collaborations, the design know-how passed on to indigenous entrepreneurs normally pertains to equipment already marketed and hence tends to be obsolete/obsolescent in nature and, therefore, by the time these equipment are produced in India, there would be a limited export market for them.
 - (v) It has been observed in a number of cases that the project schemes prepared under such collaboration are over-pitched as far as requirements of plants and machinery are concerned, both in terms of quantities and in terms of suitability of the machines.

The following are some of the suggestions made with respect to future technical and financial collaborations:

- (i) Foreign technical collaboration by R&D establishments be sought over the next 10 years or so in specialised fields so that we could design, develop and productionise sophisticated and contemporary equipment indigenously.
- (ii) The time-element should decide upon the choice between indigenous know-how and collaborated know-how. The level of know-how in question is also an important criteria.
- (iii) There should be no collaboration for turn-key projects or for systems design, management, procurement, execution, installation, testing, commissioning, operation and maintenance.
- (iv) The technical services clause should be kept as an optional item to be changed only to the extent used.
- (v) The collaboration agreement should be flexible enough to permit adaptation to Indian conditions.

1.3.4. Research and Development in the Field of Electronics

The Bhabha Committee in laying emphasis on design and development within the industry had observed, "the first and most urgent need is to establish in every plant producing equipment, scientific and technical design and development groups with sufficient competence to redesign equipment either being manufactured under licence or whose design is available in the literature in order to adopt it to Indian conditions. These groups should also bring prototypes developed in the country to the production stage".

It should be noted, however, that even when the status of R&D is very advanced in this country, import of technology will have to be continued, for it is not possible to develop every item to a high degree of sophistication with the limited R&D facilities and personnel available. Even advanced nations find it cheaper both in money value, deployable human resources and time, to import technology from another country where it has been

highly developed, in spite of the fact that there are strong groups working on the problems at home.

Import of technology may be allowed to gain time but it should be restricted to organisations having strong R&D groups in the respective fields so that import of successive refinements can be dispensed with. Purchase of software technology for system design, systems engineering, management, etc., should be discouraged. At the same time facilities should be created at all levels to see that with proper assistance from software groups, the indigenous hardware designs are made available within four years. When technology is imported, it should be assimilated and further developed by the industry with the help of both their development staff and those in other laboratories.

To achieve best utilisation of foreign know-how, the following suggestions have been made:

- (i) A suitable authoritative body should be evolved which will decide and demarcate the areas for R&D activity and foreign know-how. This body should include members from the industry, research and development organisations, licensing authority and representatives from the user organisations.
- (ii) Reports should be made on the state of the technology already imported. It should be made available, if necessary, after payment of royalty to those concerned.
- (iii) While establishing an industry with foreign know-how, it should be made mandatory that an R&D programme is set up simultaneously to understand the technology of the know-how and further develop the products to avoid extension of know-how agreements indefinitely in the same area.
- (iv) Priority should be given (to R&D grants) for those technologies contributing to larger economic benefit to the nation.
- (v) Usefully employing engineers of Indian origin from abroad can bring in technology cheaply.
- (vi) Import of foreign products for studying is imperative in order to make R&D more effective.
- (vii) The Government should encourage R&D efforts by liberally granting import licences for components and test equipment.

One of the biggest problems to be overcome in indigenous development and production will be the development of high quality components and materials of a large variety to meet stringent specifications. Unless a concerted effort is made to mobilise all agencies in the country to develop these, indigenous development and production effort will be seriously hampered.

Another problem that is of importance is the long time gap between development and production of an item. The process of transfer of technology from laboratory development to a factory is very complex, and the best way may be for the originator of the idea himself to follow his brain-child into development, testing and final production. The research organisations must be closely associated with the industry right from the start, so that these laboratories benefit from the licensed know-how, and will be in a better position to modify or improve the existing production line later on. This close association is possible only if the research organisations are allowed to establish field units in industries. These field units may consist

I

of a few scientists of the research organisation working in the factory, making use of the services and facilities available there. Their main production will be to translate the laboratory development into production processes, if the need arises, as well as to get familiar with the production problems and limitations so that a feed-back to laboratory is possible. On the other hand, their role should be to anticipate future improvements and advances in this technology so that these can be developed in the laboratories and passed on to the industry.

In order to achieve a compression of the R&D to production time gap, it is necessary that,

- (i) there should be an adequate work force on each of the projects taken up;
- (ii) there should be careful forward planning of facilities and resources;
- (iii) there should be adequate feed-back between industry and the R&D team so that in production, initial design problems can be overcome;
- (iv) modern management tools and techniques should be utilised for effective management of the projects; and
- (v) where an item developed by the R&D establishment is required in quantities below the level to attract any production agency, the item should be produced on a pilot plant scale in the R&D establishment itself.

The educational institutions can take up pure research and could train the post-graduate students on the right lines so that the students coming out fit in better with the needs of the R&D organisations. However, certain types of basic problems required to support the developmental activities may be tackled by these institutions.

(i) The obsolescence setting in the development-production cycle can be retarded, if we start at a higher take-off point.

(ii) The component base must be strengthened in the country by feeder industries duly encouraged on a small scale basis so that heavy capital investment is not called for in a single industry.

(iii) Intensive programmes of training in India and training abroad on specific problem-oriented issues should be encouraged on a sustained basis.

(iv) Whenever the R&D effort has grown up to a satisfactory level, consolidation of manpower should be implemented with adequate incentive schemes and financial grants.

(v) Recruitment programmes should be completely reoriented to attract top talents in each field towards R&D and production efforts.

(vi) In order to reduce the inter-organisational mobility of personnel, adequate career planning opportunities and incentives should be provided within the organisations so that the drift of personnel is minimised, as their migration would be highly detrimental to planned growth.

Expenditure on development in India must be product-oriented. Products must be identified, users committed and entrepreneurs found. In-house developments in industries have much larger chances of success, i.e., of the product reaching the users. It would be advisable to merge development establishments with industries and provide unified control whereby goals could be better set and achievement oriented development rendered possible, thus minimising the problems of transfer of technology.

1.3.5. Role of Small Scale Units in the Development of Electronics

According to the present classification, an industry where the cost of plant and machinery is not more than Rs. 7.5 lakhs (Rs. 10 lakhs for ancillary units) is a small scale industry. Investment for an enterprise of this nature can be organised by a small group of entrepreneurs. As people in this country are still not used to investment in shares of large companies where the administration and control is impersonal, the small scale sector taps a large investment potential of the public.

Small scale industries allow better management-labour relations and a versatility of production. Such industries can be weaved away from congested towns and can be spread throughout the country subject only to the transport economics of raw material and finished goods to the market. The small scale units also show lower capital investment per labourer and higher production per unit of investment as compared to the medium and large units. No doubt, there are drawbacks, such as higher cost of consultancy services, difficulties in tapping raw material supply sources because of the small quantities required, higher cost of machine maintenance and testing of goods and problems in marketing the goods. However, from the national point of view, it is obvious that wherever small scale industries are economic, it is in the country's interest to encourage this sector, so that the return on investment can be large and labour can be employed in plenty.

A decentralised small scale electronics industry will give opportunity to all parts of the country to profit by the potential for employment in this industry, whereas concentrating efforts in only some areas around big towns may deny opportunities to many of the young scientists and others living in areas far from these townships. But, an important requirement of a decentralised small scale electronics industry is test facilities. In view of this, the Bhabha Committee had suggested:

"The development of electronic components and equipment requires appropriate and well equipped test facilities. It may not be possible for all small units to provide each test facilities for themselves. It is, therefore, desirable for test facilities established in large units to be made available to smaller units which do not have them against payment of appropriate charge. The establishment of test facilities in each area of the country in which the electronics industry is established, is an urgent necessity and the committee considers that such centralised test facilities should be available as early as possible in the industrial centres such as Bangalore, Bombay, Calcutta and Delhi".

CIL provides this facility for testing and evaluation to defence specifications. Also in accordance with the recommendations of the Bhabha Committee, facilities for environmental and durability testing have been set up at BARC and NPL, and are available to the manufacturers. LRDE also provides testing facilities to manufacturers for the components being developed in collaboration with them. Progressively, such facilities would need to be established at more centres, either by Central and State Governments or by the industry itself.

Two other facilities required for developing a strong small scale industry in electronics are consultancy and R&D. In this connection it has been suggested that a centralised unit in the State, to be helped by the Small Scale Industries Development Organisation and the Development Commissioners' Organisation, should be the focal point for receiving inquiries and arranging the necessary consultancy services. Also public sector factories

I

producing electronic equipment and the research laboratories should give similar service to all small scale entrepreneurs in electronics. As regards R&D support, some method should be devised by which equipment needed for research and which are available in the research laboratories and public sector laboratories are made available on suitable terms for such research by small units and individuals.

With a view to seeking optimum utilisation of the research talents, it is suggested that every year the national laboratories invite suggestions from entrepreneurs and from representative associations of this sector before drawing up their development programmes. The technical entrepreneurs may be given research grant for developing new instruments as is given to universities. There is a need for setting up an R&D organisation for small scale industries. Such an R&D organisation should be set up with regional test centres at all principal cities in the country.

As regards reservation of certain areas for small scale, the Bhabha Committee had observed:

“Economies of scale are not so important in the manufacture of equipment especially for professional use provided high standards are maintained. Specialised professional equipment can be produced economically even in relatively small units. In case of large units, producing sophisticated electronic equipment, sub-contracting of sub-assemblies to other smaller units should be an important feature of the industry”.

The Committee had also identified a number of sub-assemblies which can be passed on to the ancillary industry system. Not only public sector projects, but factories in the private sector can usefully follow this recommendation. The public sector projects will have to take the lead in this matter.

Manufacture of components has been recognised as an important area in the electronics industry that should not be brought under the small scale sector. It has been observed that in view of the large numbers of these required in equipment manufacture, and the need to make these at competitive prices in the export market, components manufacture should be in the large scale sector.

Some of the other suggestions made are as follows:

- (i) For any meaningful policy to be implemented effectively, it is necessary to have an accurate base of information regarding small scale industry. It is also necessary to have a clear picture of the responsibility of the various Central and State Government agencies.
 - (ii) Organisation of service co-operatives for the small scale units would be extremely valuable.
 - (iii) Better link-up between educational institutions and small scale sector should be achieved, say, by consultation help from the institutions, use of test instruments at the institutions etc.
 - (iv) Provision should be made for appropriate tax relief for expenses on design and development incurred by a small scale industry.
 - (v) In the case of radio industry, on the technical side the Government organisations should develop a fairly wide variety of circuits and models of radios, on the lines of UNESCO and CCIR studies, and give them to the small scale sector manufacturers free of cost and arrange the certification of products made by them, so that uniformity in design and performance can be maintained and quality ensured.
-

1.3.6. Special Materials Required for the Electronics Industry

From an assessment of the primary materials requirement for the electronics industry (in terms of quality and quantity) and the R&D efforts in this area in the country, the indications are that self-sufficiency in production of many of the special materials (either from totally indigenous resources or from relatively inexpensive imported crudes) is definitely attainable at an early date provided a determined effort is made to pool the technical capabilities already established in the private and public sectors. It is mainly a question of establishing a good liaison between the user industries and the development organisations so that materials specifications are unambiguously spelt out, and the quality of the products, in the course of their development, is thoroughly evaluated for the end applications, upto the point of acceptability.

With its stimulant action on a chain growth of allied industries, such as metals and ceramics, chemicals and plastics, it offers the means for accelerated industrial advancement. In the overall strategy for this growth, materials research and development form a very important first stage, though this has to be coupled with matching programmes on the fabrication of devices and systems. Development of new materials and technologies in device fabrication highlights the rapid advances that are taking place in this fast-moving field. The weakest link in the electronics industry is the growth of single crystals, free from imperfections as far as possible. New methods of doping such as ion-implantation are coming to the fore. There seems to be a prospect, some day, of the emergence of epitaxially grown semi-conducting diamond and of high temperature semi-conductors such as silicon carbide, zinc sulphide and cadmium sulphide, to name a few. Development of new superconductors and garnets is opening up new and fascinating avenues. The areas of relevance, both fundamental and applied, call for strong reinforcement in R&D, if India is to come level with the advanced countries. Gains there have been, but many gaps are yet to be bridged. It is an area where the geologists, chemists, metallurgists, physicists and electronic engineers can join hands with the industry in an era of challenging opportunities.

The following suggestions have been made for developing a strong R&D and production base in the area of special primary materials, required for the electronics industry.

(i) In terms of proportional cost, the primary materials required for the electronics industry form only a small component of the finished equipment cost. However, considering the rapid growth of the industry as a whole, specific requirements of individual items or groups of items of similar nature are bound to grow to substantial volumes in the coming years, to justify the establishment of units for their production. Apart from the familiar arguments of self-sufficiency and foreign exchange savings, the indigenous base for the production of such special materials should really be viewed from the stand point of generating self-reliance for the growth of the technology of tomorrow.

(ii) In deciding on the scope and size of the production units for materials, the philosophy should be to combine, to the maximum extent, production of allied items involving similar technologies. For example, the Special Material Plant being set up at Hyderabad has been designed for the production of sixteen different items involving chemical processing, vacuum distillation, zone refining, vacuum sintering, electron beam melting techniques etc.

I

Similar undertakings should be possible for the production of special glasses, ceramics, plastics, solvents and chemicals.

(iii) For items such as grain-oriented silicon steels and capacitor-grade super-purity aluminium where the required capital investments are likely to be large, the responsibility for production of the special grades should vest with the allied parent industries, which will have the necessary technological background and financial resources. This would also apply to items such as gallium, cadmium or selenium which are obtainable as byproducts from the aluminium, zinc and copper industries, respectively.

(iv) A full-fledged central test house should be created, preferably at an existing laboratory, to evaluate and certify the quality of materials developed/produced. However, minimum necessary facilities for testing should also be provided at various active research centres. Regional centres for quality control of electronic materials may be considered on a co-operative basis by the industries requiring such service.

(v) With respect to special materials, two types of R&D programmes can be recognised:

(a) Programmes which are product-oriented, where the demands are established and solutions have to be rapid, and

(b) programmes which have a long-term projection, and which really belong to the realm of basic materials research leading to the generation of new materials, devices and systems.

(vi) A co-ordinating and, if possible, a production agency should be established for processing silicon devices, including silicon wafer. This agency could also function as a central certifying organisation for the materials which are already being produced and are being supplied to the electronics industry. A close check on the quality of materials would ensure consistency in the properties of the manufactured components. Most of these facilities already exist in one or the other laboratory in the country but the problem of utilising these effectively to meet the needs of production establishments will have to be considered.

(vii) The requirement of gallium arsenide (GaAs) is small and also since the control of the quality of GaAs is very difficult, the production of GaAs crystals to meet the needs of users can be best undertaken by a laboratory on a pilot plant scale.

(viii) Apart from the starting materials like silicon, germanium and gallium arsenide, several processing and packaging materials are needed in the production of semiconductor devices and integrated circuits. Even though some of these auxiliary materials are also required in other electronics industries, these do not meet the purity levels needed in the fabrication of semiconductor devices and integrated circuits. Hence special emphasis has to be laid in purifying the available materials to the levels of purity needed by the semiconductor industry.

(ix) Without superior quality or high purity, the semiconductor industry can grind to a halt in its operations. The Central Glass and Ceramic Research Institute or similar organizations may be requested to put up a pilot plant for the production of quartz-ware which is required not only in the semiconductor industry but also by many chemical industries.

(x) A survey of various research centres in India should be conducted and their potential for research and development activities on materials should

be evaluated. Specific research projects and sub-projects to different research centres should be assigned on the basis of the above survey.

(xi) A high-power "Committee on Electronic Materials", consisting of not more than five experts should be appointed, vested with adequate financial authority and sufficient funds to execute the programmes on development and provisioning of electronic materials.

1.3.7. Electronic Computers

The total projected demand of computer systems during the Fourth and Fifth Five Year Plan periods is of the order of Rs. 160 crores. This projection is partly prescriptive and partly based on actual estimates given by some of the major user agencies. It is recommended that one very large, and 3 to 5 medium-large to large installations should be set up as national and regional computing facilities. Except for these systems, all other requirements in the medium, small, very small categories and all the requirements of desk calculators, programmed processors, real-time processors etc., and all interface electronics needs should be met through indigenous production.

The highest priority should be given for reaching 100 per cent self-sufficiency (or as close to it as practicable) during the Fourth Plan period in the manufacture of the following:

- (a) digital logic IC modules and discrete active components for computer users,
- (b) ferrite cores for memory planes,
- (c) console typewriters,
- (d) items like line-printer ribbons, digital recording magnetic tapes, plotter paper, etc.,
- (e) hardware items like glass epoxy laminates, wires, cables, multi-pin edge and cable connectors, neon indicators, nixie tubes, relays, microswitches, etc.

Observations made in respect of the various areas in the field of computers are given below.

1.3.7.1. Software

A computer system is only as versatile as the software that is made available with it. Sophistication in software has grown so enormously in the last decade that it is estimated that in the computer systems of the 70's the hardware to software cost is likely to be in the ratio 30:70. Software development can be farmed out to several organisations. Like core-stringing, this also is a labour-intensive activity except that it requires intellectually skilled manpower. Except for the salaries of the staff and frequent access to a system for which the software is being developed, the activity requires very little overheads. Thus contracting software development would seem to have employment potential for intellectually skilled manpower in India.

The commercial system software writers are facing various difficulties. Firstly, the subject itself has not been fully systematised. There are no analytical and rigorous methods for specifying writing and debugging programmes. Current programming techniques require complete and precise specifications of the packages in the beginning of the development phase itself without which it may not be possible to write programs. Further, devising the solution structure from these specifications is itself an arduous task. There is not enough literature available to assist programmers in developing such structures.

I

In order to develop the software industry in India, the following steps must be taken immediately.

(i) Computer time should be made available to software firms by the Government and educational institutions at their internal rates. The present commercial rates are exorbitant.

(ii) Separation of hardware, software and teaching should be done away with. This will open up a local market to Indian software houses which is denied to them at present.

(iii) Total embargo should be placed on the purchase of any computer software or program packages which will be used within the territorial limits of India. Before any software is imported as a part of package or otherwise, Indian software houses should be asked to indicate if they can take up the work and should be given the first preference.

(iv) Computer-oriented foreign companies having offices in India should be required to do major part of their software development in India for the Indian market as well as development of software for use abroad.

(v) It must be obligatory for any program written to be available to any user on a payment basis. The protection extended to an author of a computer program should be limited to a minimum charge for the use of the program.

(vi) Hardware manufacture must be indigenous for a strong software industry to develop, the reason being that the major part of programming for a system is done while it is in the design stage. It also follows that once an indigenous hardware industry is established, India's exports can be substantially increased by export of hardware supported by associated software.

1.3.7.2. Systems Engineering Contracts

In many computer applications, interfacing between several sub-systems and/or interfacing between the main computer and other sensors and effectors are often needed. The near-complete and fabrication of this interface electronics can be carried out indigenously only if systems engineering is handled by Indian groups.

1.3.7.3. Manpower

The manpower requirements in the next 10 years are estimated to be:

System programmers and analysts	— 2,000
Maintenance engineers	— 1,000
Application programmers	— 1,500-3,000

It is estimated, on the assumption of reasonable multiplication factors, that there would be in the country, by the end of the ten years period, some 12 to 20 thousand users with some knowledge of computer programming.

In addition to the above, there is likely to be a need for large numbers (several hundreds) of design and development engineers, production engineers, assembly, testing etc. This problem can be tackled by:

- (i) integrating computer techniques in the teaching of all subjects. Thus management science, engineering, etc., should emphasize proper formulation of problems taking cognizance of the availability of computers.
 - (ii) continuously re-educating teachers, practising engineers, managers, etc., on the relevance of computers and their use in their areas of speciality.
-

In the next ten years, there is likely to be a need for about 300 M. Techs and about 50 Ph.Ds in the computer sciences and computer technology. So it is essential to start specialised Masters level programmes in this area in all the IITs and other major institutes. All undergraduates of IITs and science postgraduates of all major universities should be mandatorily required to be proficient in computer programming.

In no country can the education budget alone afford to pay for all the R&D activities in the universities, institutes of technology and other teaching institutions. The infrastructure needed for R&D work within the academic framework has to be paid for more or less completely through R&D contracts from user organisations, i.e., Government, quasi-government, and private sector agencies.

1.3.7.4. Computer Uses

The areas of computer use which need strengthening at the present stage are:

- (i) use in management decision-making, for example, consolidating and retrieving information, optimising production strategies, etc.
- (ii) use in engineering design, for example, optimal design in civil engineering structures, design of interconnected power systems, design of chemical process systems, etc.
- (iii) use in real-time control and communication, for example, on-line control of power systems, message switching systems, etc.
- (iv) use in physical and behavioural science, for example, predicting molecular structure, simulation of sociological systems, etc.

1.3.7.5. The Automation Problem

A fundamental problem that a developing country like India has to cope with is connected with organisations and management. Computers are equally essential for large scale engineering design as for real-time control which arise in defence and process control applications. These are strategic application areas vital for the economic growth and security of the country.

The labour-automation problem, as it is usually understood in the context of factory labour, does not arise in these applications at all. Office automation enters the picture only in computerisation of large data files, as in the case of inventory and insurance, is needed for efficient management purposes. The bulk of the applications and usage envisaged is in areas that currently do not even exist in this country. Thus, the problem of displacing white-collar labour does not arise. The problem to be faced is one of recruiting and training fresh workers or retraining existing workers, wherever redeployment is called for, to undertake these jobs which are, for the most part, yet to be created.

1.3.7.6. Regional Computer Centres

In a country such as ours with limited investment resources, computational capability cannot be significantly maximised by merely increasing the number of computer installations. This is because, most of the significant applications (R&D, planning, operations research, and information systems) require large to very large systems. In terms of current prices, a large system would cost Rs. 1 to 2 crores and a very large system Rs. 2 to 5 crores. The

annual operating expenses (3-shifts) are likely to be in the range of Rs. 5 to 10 lakhs for large and Rs. 10 to 20 lakhs for very large systems.

The educational sector cannot afford such expenses. Hence educational funding procedures must be set up so as to enable staff members and research students to make liberal use of these regional facilities. Such an arrangement is likely to guarantee better computational returns per unit investment in the educational sector than the present practice of setting up small systems acquired as gifts, aids, etc., and not being able to support their continued utilisation adequately. These regional centres should be maintained and run like public utilities in much the same way as electric power utilities. These utilities provide a technological infrastructure for individual entrepreneurs to engage in gainful activities. The returns from these activities feed back into the economy and contribute to its growth in various ways. The entrepreneur functions as a programmer, program consultant, systems consultant or analyst. Either individually or in association with others, he is able to take up contracts for custom-made software packages for the design and/or analysis of engineering and management systems, and so on. The regional centre should also be responsible for organising training courses, after advice on development of systems and generally be concerned with active built up of computer usage and spreading computer consciousness. The regional centres should be backed up by adequate data communication facilities. They should be attached to educational institutions as it will have a multiple effect of spreading education to a large class of students flowing through the institutions. Continuing education programme, consultancy etc., can be meaningfully carried out only with such an arrangement.

1.3.8. Micro-electronics

The advantages of using integrated circuits (ICs) in electronic equipment are well known. In the past, licensing has been done without taking into account the full specifications of the requirements of the industry. This had also resulted in slow progress of import substitution as and when the devices were replaced by indigenous ones. ICs are more customer-oriented in the matter of specifications, facilities, packaging, temperature range, etc. This is in contrast to the use of conventional components which are produced in large volumes by component manufacturers to standard specifications. The following lines of action are proposed for giving a proper direction to the growth of the micro-electronics industry.

(i) A full dialogue between equipment industry, IC manufacturers and the Government should take place to discuss the types of ICs, packaging, standardisation, temperature range, circuit types such as DTL, TTL, ECL etc., and phased production programme and technical tie-up with the foreign counterparts, etc.

(ii) Certain amount of standardisation in the field of ICs in the country between various users should be attempted.

(iii) Early action must be taken for licensing one or two manufacturers and starting production of ICs in the country.

(iv) Hybrid IC facility may be set up in the premises of as many equipment manufacturers as possible, as they would enable small quantity/large type production feasible using standard ICs available in the country.

The question of interfacing between the device producer and the equipment designer has to be resolved by considerable amount of education on

both sides. For example, one could consider that a transfer function of a sub-system could be specified and the design of the IC to suit the transfer function could be left to the device manufacturer. Another solution, perhaps, would be to educate the circuit designer to understand certain of the fundamental concepts of ICs, the various devices which are possible and which can be put on the substrate of an integrated circuit chip, so that even when he thinks of a sub-system and tries to specify a transfer function for a sub-system, he could take into account the possibilities of what can be achieved through IC technology. This kind of knowledge has to be built into the minds of our new students.

Today masks are not produced by drawing out the art work by hand, but are designed with the aid of a computer. The development of software for this area is now an important and very urgent requirement. It would be useful if some institution could take up the task of designing software to produce art work.

The IC technology moves so fast that in two years many changes occur. To keep abreast with the technology, the importance of R&D cannot be over-emphasised. However, research and development in micro-electronics being expensive and our market is not so big as yet that it will not be possible for industrial organisations to take up R&D totally on their own. So Government support should be forthcoming.

There are, today, laboratories in addition to universities, each specialising in some aspect or other of modern technology. Several projects are handled by them and probably, because there is no strong central co-operation, one finds a lot of redundancy in the activities. Unfortunately, because of the cost and complexity involved in micro-electronics, research and development cannot be divided into several branches and entrusted to a number of laboratories, even if good administration ensures the best co-operation. This work has to be done under one roof. An agency under the aegis of say, the Electronics Committee needs to be established for this purpose with clearly stated goals. Such an agency enables centralised, concentrated effort to be made by having under one roof all the equipment facilities and services required by the varied disciplines of micro-electronics.

Increased rapport between the industry and research laboratories can be achieved by (i) sponsoring of projects by industry in laboratories, (ii) associating the industry with the laboratories, when any particular project reaches a stage where such association would result in early large scale production.

1.3.9. Television: Strategies for Development

As regards technical innovation, it would be desirable for the Indian television industry to keep pace with the developments elsewhere in the world. Some of the important areas for technical innovations are:

- (a) circuit simplification and cost reduction,
- (b) partial or complete transistorisation,
- (c) development of sets for direct reception of satellite telecast and possibly multi-channel set, and
- (d) use of integrated circuits.

The following observations and recommendations were made during the discussions:

- (i) Government of India should come forward in a big way to invest a capital of Rs. 100 crores in establishing 15 to 20 terrestrial stations and satel-

lite TV and thus create a boom for TV industry with a turnover of Rs. 100 crores per annum and create employment for 100,000 workers—technicians, engineers, managers, servicemen and artists. This is one of the best ways of increasing the GNP, educating the people, raising the standard of living and opening a new line of exports.

(ii) Give production licences to local units which have developed their own design and the capability to set up plants using minimum foreign exchange for components and capital equipment. It will be highly regrettable to pay royalty in any form for an entertainment item.

(iii) Consortia of 40 to 50 small industries may be established to supply about 50 types of components that go into a TV set; the central assembly line of TV sets may be under a fully Indian-owned big industry either in the private or public sector. Thus the share of the small scale industry will be 60 per cent of the total turnover of the TV industry.

(iv) TV manufacturers should be asked to export a minimum of 30 per cent of their turnover. TV industry being labour intensive we are in a favourable situation to compete with Japan in another 4 to 5 years, if prices of indigenous components can be brought down to international levels.

(v) TV manufacture should be organised on the basis of a central assembly plant with several ancillary units to manufacture electronic components and hardware. Generally 15 to 20 viable ancillary units can be created to feed one main assembly plant.

(vi) In a fast growing industry with a doubling time of 2-3 years, licensing quantities should be looked upon as the minimum levels of production to be achieved rather than as the maximum to which they are to be limited.

(vii) Indigenous R&D should automatically receive a manufacturing licence provided that the unit is not otherwise in a prohibited category for that item, or the import content is not excessive.

After reviewing the progress of the industry since the submission of the Bhabha Committee Report, the panels of experts constituted during the National Conference emphasized that it is imperative to set up an organization to review the entire field of electronics in view of fast changing technology and to recommend ways for achieving self-sufficiency in the shortest possible time and in the best possible manner. It was further emphasized that such an organization should be free from all non-essential restrictions and in-elastic rules so that policies, free from politics and bureaucracy, may be made to steer the growth of electronics in India.

With these references, Government of India constituted Department of Electronics (DE) and set up Electronics Commission (EC) in February 1971 under the Chairmanship of Prof. M. G. K. Menon. EC/DE have been entrusted with responsibility of reviewing the entire field of electronics, for formulating policy and programme for development, and for implementing such programmes so as to achieve rapid and balanced growth of the industry. The details of the formation of the Electronics Commission and the Department of Electronics are given below.

1.4 Formation of Electronics Commission and Department of Electronics

Recognising the importance of developing an integrated and self-reliant electronics industry in the country, and the need for rapid progress in this regard, the Government of India constituted a separate Department of Electronics with effect from 26th June, 1970. In February 1971, Government constituted the Electronics Commission, under the Chairmanship of Professor M. G.

I

K. Menon, F.R.S., who is also the Secretary to the Government of India in the Department of Electronics.

On the composition of the Electronics Commission, the Government Resolution states:

- (i) The Electronics Commission shall consist of full-time and part-time members. The total number of members shall be not less than four but not more than seven.
- (ii) The Chairman of the Electronics Commission will also be Secretary to the Government of India in the Department of Electronics.
- (iii) A Member of the Commission will be the Member for Finance who shall also be *ex-officio* Secretary to Government of India in the Department of Electronics in financial matters.

The other members of the Commission were:

- (1) Shri T. Swaminathan, Cabinet Secretary
- (2) Shri B. D. Pande, Finance Secretary
- (3) Shri M. S. Pathak, Member, Planning Commission
- (4) Shri A. S. Rao, Managing Director, Electronics Corporation of India Ltd., Hyderabad

In the Resolution setting up the Electronics Commission it is stated: "Government attaches the highest importance to the development of an integrated and self-reliant electronics industry in the country, as rapidly as possible. Electronics occupies a key position in modern science and technology. It has a vital role to play in the fields of atomic energy, communications, defence, education, entertainment and space technology. It is assuming increasing importance in the monitoring and control of production processes in the engineering, chemical and metallurgical industries. Because of its dynamic character, its pervasive nature and its significant impact on science, industry and society, electronics is today in the vanguard of technological progress. Technological progress and obsolescence are both very rapid in this field. An intensive promotional effort relating to both production and research and development is, therefore, essential to ensure a rapid growth of self-confidence and of indigenous capabilities."

The Electronics Commission has been charged with full responsibility to review the entire field of electronics with regard to research, development and industrial operations, with full authority to formulate policies in this field and to direct implementation, on sound technical and economic principles, of all measures, both promotional and regulatory, that are necessary for the country to attain self-reliance in the shortest possible time and in the best possible manner.

In November 1972, Shri T. Swaminathan retired from his position as Cabinet Secretary; Shri B. D. Pande took over as Cabinet Secretary and Shri M. R. Yardi as Finance Secretary.

The Commission was re-constituted with effect from 21st November, 1972 and its members were:

- (1) Prof. M. G. K. Menon, Chairman
- (2) Shri P. N. Dhar, Secretary to the Prime Minister
- (3) Dr. B. D. Nag Chaudhuri, Scientific Adviser to Raksha Mantri
- (4) Shri A. S. Rao, Managing Director, ECIL, Hyderabad
- (5) Shri M. R. Yardi, Finance Secretary

The re-constituted Commission held office till 30th June 1973.

The latest constitution of the Commission is given below:

- (1) Prof. M. G. K. Menon, Chairman
- (2) Shri P. N. Dhar, Secretary to the Prime Minister
- (3) Dr. B. D. Nag Chaudhuri, Vice Chancellor, Jawaharlal Nehru University
- (4) Shri A. S. Rao, Managing Director, ECIL, Hyderabad
- (5) Shri H. N. Ray, Finance Secretary

1.4.1. Mandate of the Electronics Commission

The Electronics Commission is charged by the Government with the following tasks:

- (a) Call upon important users to present their short and long term requirements of equipment, with their specifications, with a view to determining the appropriate systems and technologies involved.
- (b) Make a comprehensive assessment, in both technical and financial terms, of national needs for all electronics products, and integrate such needs into a single overall framework.
- (c) Direct the promotional and regulatory measures required to ensure quality production of electronics equipment at satisfactory prices.
- (d) Design and implement policies and procedures for the provision of manufacturing technology for the electronics industry, through a mix of domestic design and development and imported know-how which will ensure that the industry develops on the basis of maximum self-reliance.
- (e) Survey, plan, initiate, financially support and monitor, an integrated national research and development programme, involving Government laboratories, public and private sector companies and academic institutions, that exist as also those which may come into being in the future aimed at generating all the know-how necessary for production programmes.
- (f) Take the lead in interfacing research and development with production, by amongst other measures:
 - (i) promoting the acquisition of technical capability and providing the finances for the design and engineering of pilot plants and prototype production facilities based on locally developed processes and designs;
 - (ii) taking special steps such as provision of subsidies, to ensure that the high cost of limited volume production, which our needs often call for, is not allowed to become an obstacle for starting commercial manufacture of products, based on local know-how;
 - (iii) providing risk capital and industrial support, for commercially exploiting electronics products devised by individual inventors.
- (g)
 - (i) Survey, plan and approve, programmes in the public, private and small scale sectors, for the production of those materials, components, equipment and systems, the need for which has been identified by (b) above, and the know-how for which has been generated through (d), (e) and (f), or otherwise.
 - (ii) Take steps to assist in the fabrication of as much of the plant and machinery needed for approved production programmes, as the Commission deems possible.
 - (iii) Be responsible for operating all necessary industrial and import licensing policies and procedures, as far as the Electronics Industry is concerned.
- (h) Make a determined effort to design and enforce the use of engineering

and materials standards, suited to our conditions, even in cases where production is based on imported know-how.

- (i) (i) Assess the qualitative and quantitative needs for manpower in the various sectors of the industry, such as research and development, production, marketing, maintenance etc., and take necessary steps to make such manpower available, in time.
- (ii) Make every effort to generate as many employment opportunities as possible for any given investment, whether in manufacturing or in other sectors of the industry, such as marketing and maintenance.
- (j) Take action to expand the fields of application of electronics in the national economy.
- (k) Advise Government on matters governing the issue by the Controller of Patents and Designs of patents affecting the industry in India.
- (l) Take all other steps which it deems necessary to promote a self-reliant electronics industry. The Commission shall, in pursuance of its responsibilities indicated in the above section, be free to set up laboratories, companies or other facilities and operate them directly under its own management, if it deems that existing facilities administratively located in other ministries/departments are inadequate; that no facilities of the desired kind are in existence in the country, or for any other reason.

1.4.2. Allocation of Duties to IPAG

The IPAG has complete responsibility for:

- (a) organising the collection, documentation, retrieval and dissemination of information on all aspects of the industry assisted by a computer-based information system;
- (b) analysing the statistical and technical information with a view to evolving optimal long term strategies for capital investment, technology acquisition, research and development, import substitution and export promotion;
- (c) planning the industry in the long term by periodically updating the Bhabha Committee Report on Electronics and evolving viable organisational mechanisms of implementation;
- (d) bringing out information reports, analysis reports and white papers for providing the background material for policy-making by the Electronics Commission and for the use of the Department of Electronics;
- (e) bringing out periodicals and brochures for providing useful information to those concerned with the industry; and
- (f) providing background material and coordination efforts for planning panels constituted by the Electronics Commission and arrange for necessary follow-up planning.

1.5 National Seminar on R&D Policy—A Summary

The Department of Electronics organised a "National Seminar on R&D Policy in Electronics" at Vigyan Bhavan, New Delhi, from 18 to 20 January, 1973. The principal objectives of the Seminar were:

- (i) to identify areas in the field of electronics calling for intensive R&D effort, together with their inter-se priorities,
- (ii) to recommend the basic mechanism for supporting, regulating and monitoring the R&D projects in the field of electronics, and
- (iii) to suggest measures for smooth and speedy transfer of technology developed by the R&D organisations to production agencies.

More than 200 people from various national laboratories, universities, R&D institutions and production units participated in the three day discussions. There were group discussions in parallel in different areas, namely, data processing systems, consumer electronics and broadcasting systems, instruments, materials, microwave components and instruments, navigational and signalling equipment, sonar and radar systems, precision electromechanical components and assemblies, general passive components, electron optics and components.

Six background information reports were prepared by the Information, Planning and Analysis Group (IPAG), for the Seminar. The areas covered by these reports were consumer electronics, professional equipment, computers and control, instruments and instrumentation, electronic components and primary materials. In each of these areas, aspects like, status of the industry, existing R&D infrastructure, priority areas for R&D, transfer of technology, level of import of technology, prototype to production problems, etc., were discussed. The discussions of the various Working Groups were initiated on the basis of the information given in these background reports.

The Working Groups identified the areas which need considerable R&D efforts and made specific recommendations regarding priorities and steps to be taken for the smooth transfer of technology from laboratories to production agencies.

During the plenary session of the seminar there were extensive discussions concerned with the manner of research and development which really dovetails into the total scheme involving the growth of the industry as a whole. These discussions helped to generate a better understanding of the role of the individual sectors, as well as their limitations, in the overall framework.

A summary of recommendations of the Working Groups is given below:

1.5.1. Data Processing Systems

The Working Group on Data Processing Systems has suggested only broad guidelines, as it was observed that the finer details have been amply treated in the IPAG background report. The major recommendations are given below:

- (i) It was generally accepted that the actual requirements for computers during the Fifth Plan period are more likely to be as follows:

Systems	Average price range	Nos.
Small	Less than Rs. 10 lakhs	1,500
Medium	Rs. 10-50 lakhs	240
Large	More than Rs. 50 lakhs	15

- (ii) Very large computers needed for national centres have to be imported. All the required mini computers and major part of the midi systems have to be produced indigenously.
- (iii) Sophisticated production technologies like those of printed circuit, fabrication, packaging, etc., have to be developed. If time considerations necessitate, the purchase of know-how from abroad has to be looked into.

-
- (iv) An appropriate machinery should be set up to achieve systematic growth of the manufacture of professional grade components, especially for central processors and other units, as the performance of the currently available components is unsatisfactory.
 - (v) Some methods should be devised to correct tax structure of certain raw materials, as many of the end products, like glass epoxy board, are prohibitively costly due to the excessive tax imposed on raw materials.
 - (vi) Adequate supply of tools, like wire wrappers, desoldering guns, etc., should be made available in the country.
 - (vii) Steps should be taken to grow semiconductor memory technology in the country, as it is already becoming cost effective and competitive compared to core memories.
 - (viii) As there will be a continuing need for core memories for some years, there is a good case for fabricating core stacks and memory systems in the country. A cost analysis should be made to decide at what level core stack fabrication should be started.
 - (ix) Small scale and medium scale ICs required for central processing units should be made available readily and cheaply through local production.
 - (x) A professional base for software engineering has to be grown in the country urgently. This requires systematic efforts to generate trained manpower, and to develop software tools such as simulation, testing aids, documentation aids, etc., and sophisticated application packages.

1.5.2. Consumer Electronics and Broadcasting Systems

The Working Group on Consumer Electronics and Broadcasting Systems has made the following recommendations:

1.5.2.1. Consumer Electronics

The Group found it difficult to suggest any relative priorities for the R&D programme in consumer electronics, since these would be primarily determined by "demand pulls" in the national and export markets.

- (i) Regarding strategy for R&D, it was the consensus that most of the work for meeting near term needs would essentially belong to the "Design and Development" realm which is best tackled as "Adaptive Research". There are, however, areas such as audio tapes, video tapes and video tape recorders which are most suited for production through foreign collaboration so as to permit an early take off. But, for this to yield lasting results, capability for original work in the country would have to be built up simultaneously.
 - (ii) Considering the long term socio-economic impact of TV sciences to the Indian community and the need for a very high order of service reliability, any "evolutionary" approach in the design of community receiving sets is unlikely to yield satisfactory results. It was therefore felt that system studies should be carried out to formulate new approaches to community receiver design.
 - (iii) Associated efforts to realise a new class of high reliability components, devices, packaging and production techniques would be
-

essential. Low cost AM/FM receivers is another area demanding original work.

- (iv) The problem of organization for R&D is of relevance mainly to the small scale sector. The idea of "Consortium", though attractive on paper, is unlikely to be a successful practical proposition. The need of this sector will be best served by a Government sponsored and supported "Advise and Assist (A&A)" organisation, say at the State level, with the following tasks: (a) design and development capability, (b) interfacing between other larger R&D organizations and the small scale sector units, (c) provide facilities for environmental and other performance tests and evaluation, on behalf of small scale sector, of designs available for exploitation and (d) guidance for production follow up.
- (v) The group recognised that one-time transfer of designs to small scale sector would be inadequate and means should be available for a continuing flow of information, atleast over a reasonable number of years, on updated designs, new versions, etc. The A&A organization suggested earlier could serve to fill in any unavoidable information gaps in this process.
- (vi) It should be the responsibility of the R&D agency originating the design for a product, to take follow-up action regarding development and availability of any special process machinery needed for productionising the design. The coil winding machine for deflection coils for TV receivers is an illustrative example.

1.5.2.2. Broadcasting

- (i) For medium-wave transmitters, the area of development work would primarily relate to indigenous substitution in respect of the components which are still being imported.
- (ii) Since some lead time is available for the introduction of FM sound broadcasting on a significant scale, attention should be focussed immediately on the design and development of transmitters and associated receivers. Propagation and field strength survey for such a service should also be initiated.
- (iii) Practically no work is under way in regard to transmitters for short-wave broadcast. Efforts in this direction for development and manufacture are necessary since a large demand exists for transmitters in the 30-50 kW range for national service and atleast upto 250 kW for external services are anticipated.
- (iv) For television broadcast in band 1 and band 3, the main area of activity would relate to indigenization of components for transmitters which are already in production in the country. Exploitation of bands 4 and 5 (UHF) within the next few years is clearly foreseen, if substantial national coverage is to be achieved. It was the consensus that a UHF-TV station be set up as a pilot project immediately, for a better appreciation of all the problems involved and to assist in the follow-up regarding development and manufacture.
- (v) Work on translators from one band to the other and solid state, low power TV transmitters in the different bands for small area coverage to fill in gaps in the national service would be called for.

-
- (vi) While manufacture is already under way in regard to electronic items for television studies, there are a number of ancillary items needed for the studio complex, e.g. lighting, lighting fixtures, etc. It was the considered view that all such items should be identified essentially by the user agency and followed up for indigenous development and production either as an inhouse activity of the user or this should be contracted to other agencies. For example, items such as pantographs can be developed by AIR and sub-contracted to small scale industries.
 - (vii) A matter of considerable importance relates to propagation studies particularly in the bands for television exploitation. For satisfactory service coverage, especially in urban areas, site noise studies to establish man-made and other interference effects would also be called for.

1.5.3. Instruments

After discussions, the Working Group decided to adopt the classification of instruments as indicated in the background report with the addition of geoscientific instruments, as given below:

Off-line instruments which include test and measuring, analytical, nuclear, medical electronics and geoscientific instruments. On-line instruments include process control instruments.

- (i) The following developmental activities during the Fifth Plan period for test and measuring instruments were identified. Further development in the area of oscilloscopes for DC to 15 MHz range for high reliability and ruggedness, design and development of DC to 150 MHz oscilloscopes, sampling and storage scopes, development of CRT, vector scopes, spectrum analysers, LEDs and liquid crystals are essential.

Signal generators in the range 450 MHz to 1000 MHz, power signal generators, AM/FM type with relevant percentage modulation deviation of international specifications, signal generators employing digital techniques, frequency synthesizers and level oscillators, sweep generators, bridges of accuracy upto 0.1 per cent and REF bridges require development efforts.

The other areas include digital test instruments, TV test instruments, 'Q' meters and voltage, current meters.

- (ii) Various types of analytical instruments listed in the background paper were identified for priority allocation. They are spectrophotometers (UV, IR & atomic absorption), spectrometers, chromatographs, analytical bridges, and thermocouple detectors.
- (iii) Nuclear instrumentation required for industrial applications should be supported. It was felt that in addition to the instruments listed in the background paper, development of electromechanical sub-assemblies is required.
- (iv) Though some organizations are currently engaged in development of medical electronics instruments, concerted efforts are needed to augment the development programmes in this field. It is needless to overemphasise the reliability and safety factor involved here.
- (v) Considering the urgent need for achieving self-reliance in the

field of geoscientific instruments, emphasis should be laid for the indigenous development of these instruments.

- (vi) In view of the stress on rapid industrialisation requiring greater productivity through increasing level of automation, development of process control instruments should be taken up at a faster rate. In this, different types of transducers, play an important part. Application of digital techniques in this field calls for the development of digital transducers. Standardisation of process control instruments is highly desirable. Development of process control instruments should be done in conjunction with control system specialists.
- (vii) Instruments of low cost, kit type should be developed for educational institutions.
- (viii) Servicing and maintenance facilities for imported sophisticated instruments should be created alongwith necessary spare parts for maintenance, so that effective utilisation of those is achieved.
- (ix) While considering the design and development aspects, environmental requirements should be suitably specified.
- (x) The Working Group accepted, in principle, the suggestion made in the background paper for a central R&D co-ordinating agency at a national level. Such an agency would make periodic updated assessments of the overall needs of the country for electronic instruments, identify areas of related R&D efforts as they exist in various organisations to coordinate those efforts and decide on the priorities to be assigned to each, review the latest techniques on a continuing basis in the areas and select those suitable for adoption, monitor and review the R&D activities periodically to assess the progress made by each research team.

1.5.4. Materials

The Working Group on Materials was further divided into eight subgroups, namely, Composites and High Pressure Techniques, Electronic and Magnetic Ceramic Materials, High Purity Materials and Chemicals, Crystal Growth, Testing and Characterisation of Materials, Compound Semiconductor Materials and Devices, Semiconductor Devices, and Thick and Thin Films. The recommendations of these subgroups are given below:

1.5.4.1. Composites and High Pressure Techniques

Glass fibre reinforced plastic (GFRP) is important because of its mechanical advantages and resistance to corrosion. The requirement will be approximately Rs. 3.5 crores per annum. The investment would be of the order of Rs. 1 crore. The following recommendations were made:

- (i) The Electronics Commission should look into the status of development and production of copper clad FRP printed circuit boards.
- (ii) Design and development work in cassegrain FRP antenna system, large steerable antenna dishes, waveguides and feed horns should be taken up.
- (iii) Accelerated environmental test should be carried out for large microwave dishes.
- (iv) Raw materials like glass fibre and plastic, and flexible and multi-

- layer printed circuit boards should be indigenously manufactured.
- (v) Fibreglass optical system is an important technology and should be given attention.
 - (vi) High pressure crystal growth techniques should be developed especially for electronic materials like GaP and magnetic and ferro-electric materials.
 - (vii) There is a need for production equipment for making precision tubes.

1.5.4.2. Electronic and Magnetic Ceramic Materials

These materials constitute about 20 per cent of the materials required in the electronics industry. The discussions were primarily based on the IPAG background report. Following are the important areas:

(a) *Glasses*: A need for the development of a variety of ceramic to metal seals and transparent high purity fused quartz as well as a substitute for quartz, like vycar, was recommended. Some research efforts were also recommended, especially at educational institutions, on amorphous semiconductors and infrared transmitting glasses.

(b) *Crystalline Ceramics*: The present efforts at CEERI and BEL on quartz crystals should be continued. Priority should be given for development and production of all grades of alumina. Electronic grade steatite for high frequency applications should be immediately taken up as it involves import worth of about \$40,000.

(c) *Ferroelectric and Piezoelectrics*: R&D efforts are recommended on barrier layer capacitors. Application engineering of lead zirconatetitanate piezoelectric ceramics should be developed.

(d) *Phosphors*: The areas of electroluminescent materials and rare earth phosphors should be examined for improved performance and utilisation of Indian resources of rare earth elements.

(i) Fundamental studies on exchange interaction between spins and crystalline fields and relation of microfunctions and projections.

(ii) Bubble magnetic materials, lithium ferrite for memory cores, high purity ferrites, rare earth cobalt magnets, CrO₂ for Hi-Fi and computer magnetic tapes, and preparation of special microstructures such as small grains and textured materials.

(e) *Conducting Oxides*: It was also suggested that some work should be carried out on conducting oxides.

Also the following areas are identified for R&D organisations and industries: better preparation methods such as coprecipitation and cryochemical or freeze drying techniques, isostatic and hot pressing, single crystal ferrites and garnets, and ferrites with higher energy product.

1.5.4.3. High Purity Materials and Chemicals

Various high purity materials are being produced at the Special Materials Plant at NFC, Hyderabad. A status report on these activities was submitted. It was suggested that the Electronics Commission may look into the realistic requirements of various high purity materials in the electronics industry, so that the production capacity for these materials would be revised accordingly. BARC along with NCL may take up any further development projects regarding these materials. It was further suggested that the Electronics Commission may take steps, so that DGTD may consult various R&D

organizations before giving clearance for import of high purity materials.

1.5.4.4. Crystal Growth

In the area of crystal growth, the facilities existing at various laboratories were taken note of. Some members were of the opinion that the country should aim at having a place which would serve as a nucleus for crystal growth. This place would house all types of crystal growth facilities and should be built to a stature where it can satisfy small scale needs of any of the important crystals. Special reference was made to silicon single crystals. BEL and ECIL offered to cater to the needs of other industries as far as single crystal silicon upto 30 mm diameter was concerned. The need for starting development work on dislocation free and higher diameter crystals was generally felt. The development of polycrystalline silicon was widely discussed and no concrete recommendation was evolved. One of the members expressed his unhappiness on the Semiconductor Committee's recommendation that the know-how for developing polysilicon should be imported.

1.5.4.5. Testing and Characterization of Materials

Regarding testing and characterization of materials, it was felt that since it would not be economical to set up a centre for this purpose, a central organization like the Electronics Commission could take up the task of coordinating this activity in the sense that it could advise or even arrange to get a particular item tested at the appropriate laboratory and also take the responsibility of certification.

1.5.4.6. Compound Semiconductor Materials and Devices

About gallium arsenide, whose requirement is estimated to be about 100 kg per year in the next 5 to 6 years, and gallium arsenide based devices, it was generally felt that this activity should be strengthened. SPL and TIFR were identified to be the only organizations involved in gallium arsenide work. While TIFR is engaged with epitaxial growth of GaAs by liquid phase epitaxy (LPE), and the development of Gunn diode, SPL has been involved in synthesis and crystal growth of gallium arsenide. SPL is known to have started a dialogue with SMP for production of gallium arsenide. The areas in gallium arsenide and other compound semiconductor work that need R&D effort were identified as LED packaging, large scale production of LEDs, GaP reflector design (packaging), InSb for infrared detection, GaAs FETs, GaAs microwave bulk effect devices, phosphors for IR to visible conversion, silicon carbide material study, II-VI compound synthesis and physical investigation, and InP growth and study of microwave properties. The last three have been recommended to be supported at academic institutions.

1.5.4.7. Semiconductor Devices

In the semiconductor devices, the areas that need intensive R&D effort are linear ICs for consumer applications like TV etc., high voltage and RF power transistors for TV and professional equipment, high power SCRs and rectifiers, ion and electron beam technology, GaAs based devices, avalanche diodes, varactors, acoustic wave amplifiers, microwave ICs, flip chip and beam lead technology, and ceramic and other special packages for ICs.

These R&D projects are recommended to be taken up only by those laboratories where a substantial expertise and infrastructure already exist.

I

Regarding the transfer of technology, it was felt that an improved procedure be evolved with DE/EC as a "third unbiased party". With regard to import of technology, it was felt that in order to quickly assimilate the imported technology and be able to develop the next generation technology indigenously, at least one R&D laboratory should be associated in such a transfer. It was also felt that it is not necessary to equip all the device manufacturers in the country with the mask making facility.

• 1.5.4.8. Thick and Thin Films

It was felt that there exists no recognised R&D facility for thin and thick film technology in the country. A limited thick film facility imported from abroad exists only at BEL. BEL has developed some thick film hybrid circuits. Facilities also exist at TIFR and IIT, Delhi. The facilities at all these centres are approaching the critical size and these centres, therefore, have the prospects of growing into viable centres.

It is recommended that two R&D centres and two production centres for thin and thick film technology be developed to the level of sophistication which will ensure a sustained innovation and growth. Also that the centres be located at places which already have the facilities approaching the critical size. These laboratories and production centres should be closely linked together. It is further recommended that a number of R&D centres be financially supported to reach the critical growth stage by offering them contractual R&D programmes on specific applications and devices. These applications should be in the areas of hybrid circuits, microwave circuits, surface wave devices, solar cells, epitaxial growth of materials, amorphous semiconductor switching devices, infrared detectors, integrated optical circuits, heterojunctions and passivation and incapsulation techniques. R&D facilities for thin and thick materials and instruments should be developed and supported.

It is suggested that IPAG should undertake the responsibility of compiling detailed, but critical information on the personnel, facilities, their functions and effectiveness, available in the various R&D centres in the country. This survey should form the basis of not only information for others, but also it should help the Electronics Commission to decide on the capabilities of the centres for contractual R&D. It is also suggested that a central extension service agency should be evolved to undertake analytical, test and standardisation service in areas requiring highly specialised instruments.

1.5.5. Microwave Components, Instruments and Antennae

The development of microwave components may be divided into two categories namely, design and development for immediate requirements, and research and development for futuristic applications. In the first category, areas that need immediate D&D work are high power components, cast components, ferrite devices, hybrid microwave ICs, solid state microwave sources, light-weight components, coaxial components, precision microwave components, the range of microwave components which go into transmitter-receiver chain in radar and communication systems, coaxial connectors and adapters, YIG devices, and flexible waveguides. The second category covers the areas like millimeter wave components, monolithic microwave ICs and microwave acoustics.

It is seen that the components required are of many varieties combining several technical features. It is possible to plan work in future so that a

class of components of common type is available, taking into account the process technology by which it is to be fabricated. For example, the whole class of filters or ferrite devices can be covered by one group. The variety of components is so large that a group chosen for development must be able to cover a large class of components of one type and come out with designs which can be adopted easily to possible future requirements.

The main types of antennae which are currently required for communications as well as radar systems are parabolic reflectors, shell antennae, horn antennae, and passive reflectors. The techniques usually employed for manufacturing such antennae are casting techniques, spinning and stretch-forming, hydro-forming technique, explosion-forming technique and fibre glass technique. The group felt that production of antennae in the country requires an intensive effort immediately.

The types of feeders required for various types of systems to be developed in the country are: rectangular waveguide feeders, circular waveguide feeders, flexible elliptical waveguide feeders and coaxial cables of both air and foam dielectric. Special effort is required to set up manufacturing process for flexible elliptical waveguides and coaxial cables.

The following classes of microwave instruments are required to be taken up for development. Some work has been done in this area but updating with solid state technology is necessary.

(i) Frequency measuring instruments like frequency counters, cavity wave meters, spectrum analysers.

(ii) Signal generating equipment like signal generators, sweep generators, noise sources, frequency synthesisers.

(iii) Impedance measuring instruments like VSWR meters, precision slotted lines, ratio meters, network analysers, time division reflectometers (TDR) and sampling scopes.

(iv) Power measuring instruments preferably with digital display.

(v) Receiving instruments like detectors, sensitive receivers and field strength meters.

(vi) Special purpose instruments for applications in the areas like plasma diagnostics, process control, and appliances like microwave ovens, doppler instruments.

To assess the requirement of microwave components, it is recommended that the Electronics Commission may form a small group of two or three persons to carry out a survey with the following objectives: (a) to identify the range of microwave components required in consultation with system designers and, (b) to rationalise the list of microwave components and instruments.

Once these lists of requirements are ready, the development responsibility for these components can be allocated to the agencies who have shown interest in such work. Such agencies may need further financial and technological backing to carry out these tasks which should be provided by the Electronics Commission. Whichever agency volunteers to take up such tasks, must also take up the responsibility for productionising such components, either by associating with the likely manufacturers from the very beginning or by setting up pilot plant or batch production units themselves. The choice to do one or the other would be governed by the quality required.

It is further recommended that even during the development of these components, discussions and dialogue between the development and the like-

ly user agency should continue with a view of expediting the task.

1.5.6. Navigational and Signalling Equipment

The Working Group examined the specific requirements of various departments of the Government, like the Directorate General of Civil Aviation (DGCA), as well as the more general requirements.

DGCA requirements cover ground based navigational and associated communication system installed at aerodromes, covering the items like, non-directional beacons (medium frequency band), very high frequency direction finding equipment, VOR, DME, instrument landing system, HF and VHF radio telephony transmitters and receivers, and ground controlled approach equipment. Radio Construction and Development Unit (RCDU) of DGCA can undertake the development and production of such equipment after proper strengthening of the unit. The Radio Construction Units of the Civil Aviation Department should be strengthened in accordance with the recommendations of the Bhabha Committee.

The representative of Naval Headquarters stated that they have a number of requirements listed below, on which, as far as he was aware, little development activity has been undertaken so far. Navy has raised QRs for echo sounders, which cost around Rs. 2 lakhs. However, work on this has to be strengthened. The other areas include logs, a device costing about Rs. 2 lakhs, which is fitted on ships for sensing and recording its speed from time to time, receiving equipment in ships to work with decca navigation chains, DF for ocean going vessels, HF-DF using CRT facilities, navigational gyros for stabilising platforms and position finding, plotting tables, computer aided reporting/attacking systems and wind instruments.

The Air Force requirements for airfield surveillance radar, precision radar, MF beacons, VHF and UHF DFs, etc., are being met by indigenous development in places like HAL, DGCA and LRDE. The Air Force representatives stated that the forecast of requirements for avionics equipment during the 1980's is under consideration and will be projected duly. Development work on certain types of sophisticated test equipment and test-rigs is in an advanced state of progress at HAL.

In view of the fact that product development in the avionics field requires a lead time between five to seven years, it was felt that design and development activities on the equipment like doppler and inertial navigation systems, multi-mode radar system, IC versions of transponder, radio altimeter, radio compass, VHF-UHF R/T set, HF SSB airborne ILS, etc., should be initiated most urgently.

The technology required, in terms of electronics, for various kinds of signalling equipment for railways may not be very difficult to develop in the country as the sensing elements are required to work at less than 10 kHz. The major effort required appears to be in the product engineering of custom made designs and their quality assurance.

While considering priorities in the R&D activities to be initiated, the group felt that one critical area in this endeavour needs to be tackled on top priority. This is in regard to the availability of professional components.

For the new projects which have been taken up, a large number of professional grade ICs are required. These are being imported now and it is vital that BEL's plans to manufacture the high grade ICs are accelerated on top priority.

The members of the Group explained that at present, the authority sanctioning funds for the various projects have devised comprehensive systems of regulating and controlling the same. Normally, this takes the form of submission of returns periodically. Sometimes, committees were appointed which periodically met at the location where the R&D activities were in progress. The members were therefore of the opinion that further monitoring was not necessary. However, members of the Electronics Commission could also visit the various locations where the R&D activities are being pursued to assist in overcoming difficulties, if any.

As regards transfer of technology, it was observed that where the production establishment had an inhouse R&D department, the procedure for transferring the technology developed was substantially smooth and easy. Where the development work is done by external R&D establishments (since all the R&D activities in the electronics field cannot be carried out on an inhouse basis), it is vital for the production agency to position the required number of production engineers at the concerned R&D laboratories, so that every step of design and development takes into account the techniques/technologies/tooling/standards which will have to be followed during production. The production engineers should in effect form part of the development group of the concerned project at a suitable stage of development.

The Group considered other points concerned with R&D activities and made the following recommendations:

- (i) There is an urgent need for strengthening the primary standard facilities available in the country.
- (ii) The requirements for the setting up of secondary standards in various parts of the country need urgent attention.
- (iii) Man-made noise regulations should be implemented effectively by the Radio Regulatory Authority.
- (iv) Test facilities for marine and allied equipment are virtually non-existent now. Steps may be taken to provide such facilities.

1.5.7. Sonar and Radar Systems

The Working Group felt that there is, in general, a shortage of skilled personnel in the fields of radar and sonar and more particularly so in the fields of microwaves and antenna. Therefore training effort in the different areas of specialisation must also be appropriately enhanced. This would be partly met by the financial support given to IIT's for organising advanced courses in radars and sonars. In addition, the organizations concerned would also have to enlarge the inhouse training activities.

The following specific observations were made in regards to sonars and radars.

1.5.7.1. Sonar

(a) The Group noted that the main application of sonar is for Defence (Navy), although there are some applications in civilian sector such as oceanographic research, geological survey and in commercial and fishing ships. The Group finds that as this know-how is both Defence oriented as well as commercially classified, it is very difficult to get contemporary know-how from foreign countries.

(b) The present requirements of sonar and allied equipment (e.g. echo sounders, ray tracers, doppler logs) are met by total import. The Group felt

I

that a production agency under public sector should be created for sonar and similar equipment.

(c) The Group noted that the primary handicap faced by the sonar designers is the lack of adequate data on sea conditions specially in respect of ambient sea noise, statistical properties of reverberation, thermal structures, acoustic wavefront stability, and fluctuation and propagation of signals. This handicap arises essentially from lack of an adequately equipped ship which can be used to collect the data systematically on a planned basis for correlation and analysis. It was reported that data collected randomly by ships have been of no significant use. The ship can also be used for testing the equipment under field conditions. The Group estimated that the cost of a small research vessel equipped with the necessary facilities will be of the order of Rs. 2 to 3 crores.

(d) To cater to the future needs as anticipated today, it is expected that investment in R&D will have to be of the order of Rs. 30 crores, spread over the next six years for radar.

(e) It was felt that a massive investment of the order of Rs. 15 crores in the next five years in manpower and infrastructure would be necessary for a meaningful programme.

1.5.7.2. Radar

Taking into consideration the overall requirements and the major gaps in radar development activity in the country, the following steps are necessary:

(a) The development of systems like airborne radars, marine radars, phased array radars, radar ECM and ECCM, clutter and clutter elimination systems and laser radars, and the subsystems and components has to be initiated.

(b) Under processes and materials work on high dielectric, low loss materials such as teflon, alumina, single as well as polycrystalline microwave ferrites such as YIG should be taken up. Facilities for making microwave components by investment casting to the required standards should be augmented. Development of honeycomb sandwich using metal as well as fibre glass should be taken up.

(c) Regional centres for antenna test facilities for development purposes are to be set up for both outdoor and indoor types. Also, regional centres for high power component testing facility and for repair and calibration of test instruments are to be set up.

(d) Other specific development areas include antennae, antenna drives, RF plumbing, modulators, receivers, signal processing, display units, special purpose computers, test instruments for radar systems (L to X band) and materials.

(e) To cater to the requirements of the future, it is expected that investment in R&D will have to be of the order of Rs. 30 crores, spread over the next five years.

1.5.8. Precision Electromechanical Components and Assemblies

The Working Group on Precision Electromechanical Components and Assemblies considered areas like computer peripherals, relays, and switches, guidance and servo components, etc.

1.5.8.1. Computer Peripherals

(a) According to the estimates made in the demand projections by the

I

Electronics Commission the total value of the peripheral equipment for mini computers in the period 1974-79 comes to approximately Rs. 30 crores.

(b) The facilities existing at HTL, BEL and HAL (Hyderabad) show that these units have the skill and equipment required for undertaking manufacture of ranges of peripheral equipment. Any additional capital investment necessary in these units would be determined by the type of peripherals to be handled in these units and the volume of production to be built up.

(c) HTL has developed a paper tape punch and is now nearly completing the development of paper tape reader. Work is also currently in progress in the development of new types of teleprinters and of 8 level machines.

(d) BEL is also developing paper tape reader, paper tape punch and I/O typewriter to meet the requirements of their mini computer and numerical control machines. They are also intending to take up the development of other peripherals like 200 lines-per-minute miniprinters, magnetic tape units and card readers, in order to meet the requirements of their own mini computer programme and that of ECIL.

(e) HAL (Lucknow) also has the necessary skill and capacity to manufacture some of the peripherals. The precision mechanical components for items like gyros are being made presently in the factory.

(f) While it may be possible and feasible to develop some of the more sophisticated varieties of peripherals within the country, the time factor would dictate the need of import of know-how.

(g) With the developments which have already taken place or are currently taking place, it was felt that teletypewriters, paper tape readers, paper tape punches and CRT displays can be made with indigenous know-how.

(h) Import of know-how would be required at this stage for line printers, magnetic tape units and card readers.

(i) As considerable amount of interaction is required between the designer, the pilot shops, the tool rooms, methods organizations and production engineering units, continued developmental work for upgrading the equipment and for designing new equipment should be left to the R&D organizations of the concerned industries.

(j) The activities of independent R&D organizations can be profitably directed towards new technologies and the new generations of special purpose peripherals or equipment using new technology.

1.5.8.2. Relays and Switches

(a) The types of relays required at present include telegraph relays, fast acting relays, reed relays, relays required for railway signalling, telephone relays and miscellaneous relays.

(b) ITI and IEC are making certain types of relays. BPL is making high speed telegraph relays, O/E/N, sealed type of relays and high quality wafer switches.

(c) Reed relays (mercury wetted and low current types) are required in very large numbers in the future. Special relays for railway signalling are also required in huge quantities.

(d) Technological gaps exist in the production in India of basic materials like soft iron for relay cores, nickel silver for springs, precision metal contacts, polyester films, copper wire above 47 SWG, phosphor bronze, beryllium copper, etc.

(e) In order to standardise and also to plan for the quantitative and

I

qualitative requirements of various types of relays and switches, a study group may be constituted, as early as possible. Only after the study group finishes its work, any realistic plan can be made to identify developmental and production agencies in the field.

(f) It is also reported that East European countries have competence in this field and, if necessary, their know-how can be supplemented for the manufacture of miniature type relays, sealed relays, railway signalling relays, etc.

(g) Any useful exercise regarding the plans for development or production of connectors could be done only after the Connectors Standardization Panel's report is available.

(h) It may be necessary for R&D efforts to be directed towards producing the required materials like DAP, some varieties of polycarbonate, and also for the development of suitable special contact and spring materials.

1.5.8.3. Servo Components

(a) ECIL and HAL (Lucknow) are identified as the general production agencies for some of the components like synchros, gyros, etc. ECIL, CSIO and a private unit in Madras (Electromechanical Components) are engaged in the development of some of the items.

(b) Too much diversification of models in this field would be a very uneconomical proposition and therefore, an immediate attempt is to be made to standardise, to some extent, the requirement of these items for the electronics industry, both in the public and private sector units, so that a realistic plan can be made and economic productions can be arranged.

(c) There are requirements of precision gyros, synchros and servo motors for the Control Guidance and Instrumentation Division of SSTC. This Division has also been engaged in the development of some of the items. It is recommended that a study group is to be set up immediately to plan for development and production of items in this field.

1.5.8.4. Tooling Facilities

(a) In the organised sector of the electronics industry, facilities exist for tool design and tool manufacture as well as for tool maintenance. However, it is felt that for achieving high volume production of precision components, the tool room facilities existing today have to be augmented considerably.

(b) The demand for precision tools and components is increasing both in our country and abroad and any efforts and investments directed towards development of the skill and production facilities in this field will yield very successful results. As a first step, it may be possible to expand the existing facilities in the public sector units concerned with the electronics production as well as some of the large organised industrial units who are prepared to expand. At a later stage, it may be necessary to consider the setting up of centralised tooling centres in each individual state.

(c) It is also necessary to import some sophisticated tool making machinery such as jig borers, jig grinders, optical grinders, numerically controlled spark erosion machines, precision milling machines and lathes with digital read outs, and allied mechanical test and measuring equipments.

(d) As a rough estimate, the cost of augmenting the existing tool rooms in the electronics industries in the public sector will be about Rs. 1 crore, mostly in foreign exchange for buying the sophisticated machines mentioned

I

above. For setting up a self-contained tool room in each state about Rs. 60 lakhs would be needed.

(e) Facilities are to be set up concurrently for precision investment casting, large volume pressure die casting for special carbide tool for manufacturing fine blanking and progressive functioning.

The Working Group also made the following general observations:

(a) It is desirable to have a central organization to collect statistical information from the users and diffuse it to the R&D organizations and manufacturing units. IPAG may consider this.

(b) It is generally felt that the equipment and system designs for bulk production should be done by the inhouse R&D of the production units, and the laboratories should concentrate on development of materials, components and devices which are presently being imported.

1.5.9. General Passive Components

The components considered by the Working Group include resistors, capacitors, transformers, chokes, coils, magnetic heads, loudspeakers, microphones, etc.

(a) Some subsidiary units apart from national test centres, providing test facilities should be set up near places where the electronic component industry is growing. These may be taken up in a phased programme.

(b) The manufacturing organizations which intend to produce defence grade components should be encouraged to have facilities for reliability evaluation (failure rate) of the components.

(c) There is a distinct need for setting up centres to develop the special purpose machines needed for the production of components in large quantities.

(d) Carbon film resistors, as such, do not need any R&D efforts. But efforts are required to develop the required machinery for mass production.

(e) For metal-film and metal-oxide-film resistors, the existing R&D efforts may be sustained with a view to developing components of use in allied fields (like thin and thick film circuits). There is a need to develop special purpose machinery to produce thick and thin film components. As far as possible, efforts should be oriented towards the development of modern machinery like laser trimming machines, precision printing machines, etc.

(f) High alumina substrates are needed for wire wound resistors and thick and thin film components. R&D efforts should be put in to produce this material.

(g) Carbon potentiometers, of the sealed type, for defence applications need R&D efforts. This however, has to be weighed against the cermet potentiometers which claim superiority in performance.

(h) The existing types of thermistors and varistors have to be improved from the point of view of reliability.

(i) Aluminium electrolytic capacitors having long life, higher reliability and which can withstand higher ripple currents are in demand and R&D efforts are essential in this regard.

(j) In view of the abundant availability of niobium at NFC, efforts to develop and manufacture niobium capacitors and anodes can be supported.

(k) Tantalum capacitors, both wet and foil type need R&D efforts. At present, the demand is not large and pilot plant facilities should be set up to produce these capacitors.

I

(l) Metallisation techniques and development of machinery are the areas where the R&D efforts should be concentrated in regard to polyester capacitors.

(m) R&D efforts are required to produce the hermetically sealed types of styroflex capacitors. Development work on ceramic to metal seals is necessary to achieve this.

(n) High temperature, conductive silver paste for ceramic capacitors, also useful in thick film circuits, needs to be developed.

(o) Development of ceramic trimmers of tubular and disc type, mainly for professional applications is to be encouraged.

(p) R&D work is recommended for high stability, zero temperature coefficient capacitors using alumina, glass or quartz. High voltage and high current ceramic and mica capacitors are in demand and efforts must be put in to support the existing R&D in this field. Development of commutating capacitors for applications in power electronics is being attempted and the existing R&D efforts must be supported.

(q) Development and standardization of transformers in the range 3 kVA-50 kVA for applications in power electronics is found necessary. R&D efforts are needed to develop better laminations (grade 41) and insulating materials.

(r) R&D efforts are required to develop the know-how for alkaline manganese and other types of battery cells having long life. R&D efforts are required to meet stringent defence specifications of nickel-cadmium cells, particularly with regard to temperature range, shock and vibration.

(s) R&D efforts are required for the development of magnetic heads for video tape recorders and computer peripherals. Encouragement may be given to the manufacturers of magnetic heads for audio tape recorders to develop these.

1.5.10. Electron Optics and Components

The Working Group considered the components like microwave tubes, TV picture tubes, image converters and intensifiers, photomultiplier devices, and lasers. Also the electron microscope and related items were discussed.

(a) The general types of electron tubes/devices, not likely to be replaced by solid state devices in the near future, include microwave tubes (medium and high power), optoelectronic devices (image converters, intensifiers, TV pickup tubes, TV picture tubes and CRTs), electron microscopes and other electron and ion beam devices, quantum electronic devices (gas lasers), power tubes (for broadcast and industrial applications), and X-Ray tubes.

(b) Looking at the technological picture, microwave tubes like coaxial magnetrons, crossed field tubes including crossed field amplifiers with cold cathodes, medium and high power travelling wave tubes and high power CW and pulsed klystrons will have considerable potential.

(c) The main R&D centres in the country in the area of microwave tubes are at BEL, CEERI and TIFR.

(d) In the area of image intensification, there are new possibilities introduced by the use of channel multipliers. Apart from strategic applications, intensifiers have also considerable use in medical and scientific fields. At present, work on image converters intensifiers is being done at BARC and there is collaboration between them and BEL for productionization.

(e) In the case of television pickup tubes, there are new developments

I

such as vidicons with silicon wafer targets and SEC vidicon.

(f) Photo-multiplier devices have special applications in the field of atomic energy and work on them is necessary.

(g) As regards R&D work on picture tubes, base exists at NPL and BEL. From a long range point of view, it would be desirable to develop competence in the area of colour picture tubes.

(h) R&D and production capability may be built up for scanning electron microscopes, followed by that for high resolution electron microscopes. Main organizations interested in the field are IISc, CEERI, CSIO and BEL.

(i) Work in the area of high power electron beam technology at BARC may be augmented and development work in the area of electron beam lithography may be taken up.

(j) Ion implantation has acquired considerable importance in the manufacture of semiconductor devices. Possible agencies for development are TIFR and IIT, Madras.

(k) It is suggested that there may be a national centre for quantum electronics, which should include in its scope of work, not only gas lasers of different kinds but also semiconductor and chemical lasers.

(l) BEL has in-house capability for design and development of power tubes for broadcast and industrial applications. CEERI has designed and developed a coaxial type power triode of 5 kW capability.

(m) Work on the development of slow wave structures particularly for microwave tubes (TWTs, CFAs, etc.), electron guns for microwave tubes, new types of cathodes, photosensitive surfaces and targets for optoelectronic devices, etc., could be undertaken at national laboratories, IITs and other institutions of higher learning.

(n) Development of ceramic to metal seals has to progress and the expertise already available in the country needs to be disseminated widely like in the case of glass to metal sealing technology.

(o) There is presently a scheme for importing components worth upto Rs. 2,000 (c.i.f.) without an import licence. It is necessary and desirable that this facility be extended also to cover materials required for research.

(p) It would be highly desirable for the R&D laboratories to set up in-house batch fabrication facilities for the types of tubes in their areas of specialization.

(q) The need for adequate R&D efforts in the area of methodology of industrial engineering and production of prototype electron tubes and devices, has to be stressed.

(r) For major projects where a large number of organizations are expected to collaborate, it may be desirable for the Department of Electronics to prepare and maintain a PERT/CPM chart for reviewing the progress. Of course, time targets and PERT charts can be operated only with assumed inputs at proper times.

One of the principal recommendations of the Working Groups constituted during the seminar was to set up a standing advisory body to identify areas requiring intensive R&D efforts in the field of electronics and to advise the Commission in matters like transfer of know-how, priority assignments, evaluation, financing and monitoring of projects, etc., from time to time. Accordingly, Electronics Commission set up a Technology Development Council, the constitution of which is given below.

1.6 Technology Development Council

Following the discussions at the National Seminar on R&D Policy in Electronics, held in January, 1973, the Electronics Commission set up a Technology Development Council (TDC) in October 1973 to assist and advise the Electronics Commission in fulfilment of its manifold tasks in the field of research and development in electronics. The Council is responsible for advising on the right type of know-how to be made available through an appropriate mix of indigenous efforts of know-how in selected fields and a coupling of imported know-how with indigenous efforts.

The composition of Technology Development Council is as follows:

- | | |
|---|------------------|
| 1. Prof. M. G. K. Menon,
Chairman, Electronics Commission. | Chairman |
| 2. Shri G. U. Menon,
Hindustan Teleprinters Ltd.,
Madras. | Member |
| 3. Dr. N. W. Nerurkar,
Department of Electronics,
New Delhi. | Member |
| 4. Dr. P. V. S. Rao,
Tata Institute of Fundamental
Research, Bombay. | Member |
| 5. Dr. R. P. Shenoy,
Electronics and Radar Development
Establishment, Bangalore. | Member |
| 6. Dr. Amarjit Singh,
Central Electronics Engineering
Research Institute, Pilani. | Member |
| 7. Prof. E. C. Subbarao,
Indian Institute of Technology,
Kanpur. | Member |
| 8. Shri T. S. Subramanian,
Telecommunication Research
Centre, New Delhi. | Member |
| 9. Dr. N. Seshagiri,
Electronics Commission,
New Delhi. | Member Secretary |

TDC is an advisory body and its principal functions are to assist the Department of Electronics/Electronics Commission in:

- (i) identification of areas requiring intensive R&D efforts in the field of electronics;
- (ii) assigning relative priorities;
- (iii) evaluating, assigning, financing and monitoring individual R&D projects;
- (iv) ensuring the transfer of know-how generated through R&D to production; and
- (v) identification of areas requiring import of know-how at the R&D or production levels to conform to financial and time targets laid down for the growth of the industry.

The Council also advises the Electronics Commission on the setting up of suitable management patterns, involving both R&D and production units, to achieve smooth transfer of know-how to production.

I

The following six Working Groups, each under the chairmanship of a member of the TDC, and consisting of members drawn from national defence laboratories, research and educational institutions, public sector undertakings and Government departments, etc., have been constituted to carry out a close and detailed examination of the relevant problems in different sectors of electronics.

Group I: Materials and Components

This Working Group broadly deals with materials of all types of relevance to the field of electronics; under materials it, in particular, deals with semiconductor materials, III-V compounds, ceramics and ferrites, plastics, metals, alloys and high purity materials including gases and chemicals and devices (including klystrons, TWT, carcinotrons) active and passive components, etc. The Group does not deal with components such as relays, connectors, etc., which are essentially electro-mechanical in nature and largely based on mechanical tooling.

Group II: Consumer Electronics (to include entertainment, medical, instruments and instrumentation)

This Working Group essentially covers the field of entertainment electronics (radios, television, taperecorders, sound and public address systems, etc.), medical electronics, general purpose instruments and instrumentation other than specific ones which would more naturally come in the field of industrial electronics or in the areas of microwave instrumentation or panel instrumentation.

Group III: Computers, Control and Industrial Electronics

This Working Group broadly covers aspects of hardware and software over the entire range of computational equipment from desk calculators to large computer systems. Specifically with the application of computer in a variety of areas of national interest. The specific area of peripherals for computers which are largely electro-mechanical in their operation are covered by Group VI. This Group coordinates with Group VI to ensure that the appropriate types and numbers of peripherals can be made in the country for the systems the Group has in mind. The scope of the Working Group thus goes beyond that of just computers and cover the general area of digital electronics and signal processing techniques including control aspects. Specific control devices which are largely electro-mechanical in nature are handled by Group VI.

Group IV: Radars, Sonars and Navigational Aids

The Working Group broadly covers the totality of radars, sonars and navigational aids from the view point of systems design. However, it depends largely on Group I on Materials and Components from the view point of high power tubes, such as klystrons and semiconductor devices, on Group III with regard to signal processing techniques, and on Group VI for requirements such as antennas, waveguides, etc.

Group V: Communication and Broadcasting

The Working Group broadly covers the area of HF, VHF, UHF, microwave communications, multiplexing, PCM techniques, all related to the field

of communications. It deals with the systems concepts in communication systems, as well as the needs of specific items of equipment in the area other than materials and components, and electro-mechanical devices including antenna, which come under the purview of the other Groups that have been listed. The Group also covers communications in aviation, navigation, etc., signalling equipment including those in railways and broadcasting equipment.

Group VI: Electro-mechanical Components and Equipment

The Working Group essentially covers all areas where electro-mechanical devices play a role in electronics. This will include computer peripherals where the Group interacts with the Group III from the view point of their requirements for specifications and numbers, switching in communication systems other than electronic switching, components such as relays, connectors, antennas and waveguides which are electro-mechanical and which depend significantly on tooling, the whole area of tools and tooling needed for production of electronic components and industrial electronics of an electro-mechanical nature.

As it is necessary to have good interaction between the Government and the manufacturers, academic institutions, research laboratories, etc. to form healthy policies in the field of electronics and to implement them successfully, Electronics Commission has set up a National Advisory Committee on Electronics (NACE) to act as a broad-based forum for discussion on all aspects relating to the growth and development of the electronics industry. Also, considering the strategic importance, the manufacture, design and development, as well as research in the area of radars have to be given a high degree of national priority. With the view to ensuring proper coordination of the various activities in this field so as to meet the defence and civil requirements in an integrated manner and on the basis of maximum self-reliance, the Electronics Commission has set up a National Radar Council (NRC). The details of NACE and NRC are given in the following.

1.7 National Advisory Committee on Electronics

In order to facilitate a regular exchange of ideas and mutually beneficial interactions among all concerned agencies in Government and outside Government, the Electronics Commission set up a National Advisory Committee on Electronics (NACE) in September, 1973, under the Chairmanship of Prof. M. G. K. Menon. NACE has been set up to act as a broad-based forum for discussion on all aspects relating to the growth and development of electronics industry. It consists of 80 members drawn from Government departments, associations of industry and trade, academic institutions, research laboratories, public sector undertakings and small scale sector. The Committee is responsible for discussing problems of general interest relating to research, development, industrial licensing, industrial operations, education, training and manpower, role of various sectors, etc., and provide a broad-based set of views to the Electronics Commission and the Department of Electronics on specific problems which may be brought to the notice of the committee from time to time.

The Committee will be meeting at least once in a calendar year. The first meeting was held on March 11 and 12, 1974 at New Delhi. The first plenary session discussed the Fifth Five Year Plan proposals formulated by the Electronics Commission and the Department of Electronics and accepted by the Planning Commission. Three Working Groups were formed to dis-

cuss problems of the industry, strategy for exports and training and manpower. The Working Groups discussed respective problems at length and made specific recommendations.

1.8 National Radar Council

It has been recognised by the Electronics Commission that the radar requirements in the country in numbers (of equipment) and financial terms are sizeable and that this particular requirement is for a single class of equipment of strategic importance. Sonars, which are allied to radars, are required by the Navy to detect underwater hazards as well as by merchant vessels for both navigation and fishing. It has been felt that the manufacture, design and development, as well as research in the area of radars, need to be given a high degree of national priority.

With a view to ensuring proper coordination of the various activities in this field so as to meet the defence and civil requirements in an integrated manner and on the basis of maximum self reliance, a National Radar Council (NRC) has been set up under the chairmanship of the Chairman, Electronics Commission. The NRC is composed of senior officers from major agencies concerned with the development, production and use of radars, such as DRDO, Department of Defence Production, Defence Services, Department of Space, Civil Aviation, etc. The major functions of NRC are to formulate a plan for radar systems and components: to ensure standardisation of components and building blocks to generate sub-assemblies and sub-systems that can be used on an inter-changeable basis for a family of radars; to evolve modular designs and construction practices; to coordinate efforts of various agencies of R&D and production aspect so that there is maximum information transfer and liaison; arrange for work on futuristic systems, components and technologies; and relate all this to user needs. NRC will function under the overall guidance of the Electronics Commission basically as a focal point to ensure that the direction, pace and quality of the overall efforts in the field of radars is such that the nation as a whole benefits from the efforts of the various agencies. In doing this, NRC will fully take into account plans and programmes already in existence.

The terms of reference of NRC are as follows:

- (a) To formulate, periodically review and update an integrated Radar Systems and Components' Plan covering both defence and civil requirements, taking into account plans and programmes already in existence;
- (b) to prepare and ensure the implementation of technology plan to meet the nation's short and long term requirements of radars;
- (c) to consider, as part of the technology plan, all proposals for import of technology and foreign collaboration relating to radars and allied equipment;
- (d) to formulate, also as part of the technology plan, an integrated programme of R&D, including futuristic aspects and undertake the promotion and coordination needed to have that programme implemented;
- (e) to coordinate production aspects of radar and allied equipment especially so as to ensure standardisation of components and building blocks to generate sub-assemblies and sub-systems that can be used on an interchangeable basis for a family of radars;
- (f) to relate the above tasks to ensure that specific user require-

- ments are met on the basis of maximum self-reliance; and
- (g) generally to act as a focal point to ensure that the direction, pace and quality of the over-all effort in the field of radars is such that the nation as a whole benefits from the efforts of the various concerned agencies.

1.9 Report of the Estimates Committee of Parliament —A Summary

The Estimates Committee of Parliament took up for examination during the year 1973-74 the programmes of the Department of Electronics. Preliminary material was forwarded to the Lok Sabha Secretariat in this connection in June, 1973. Subsequently, the Estimates Committee constituted two Study Groups which visited a number of electronics establishments both in the organised and small scale sectors in various parts of the country between June and October, 1973.

After the study tour, the Lok Sabha Secretariat sent to the Department a questionnaire for written reply. Based on the written replies to these questions and the oral evidence presented by the Department of Electronics, the Estimates Committee prepared a report which was presented to the Parliament on April 30, 1974.

The Estimates Committee in its report has appreciated the efforts of the Department of Electronics to stimulate the electronics industry in the country. The Committee has made important recommendations on many specific issues pertaining to the growth of electronics. A summary of its observations and recommendations follows.

1.9.1. Development of Electronics

- (i) The Estimates Committee felt that while there has been appreciable development in the manufacture of sophisticated equipment in the public sector undertakings, there has been insufficient progress in the field of defence electronics. It has, therefore, recommended that urgent attention should be paid towards the development and production of sophisticated components in this important area and in systems design. The Committee has suggested that an integrated, well coordinated and time bound programme may be drawn up for achieving self-reliance in these strategic areas.
- (ii) The Committee has also noted that the private sector has not come forward to participate in a big way in many sectors in electronics industry except in entertainment electronics, though no restraint exists in most of these areas under the Industrial Policy Resolution. It felt that even in the areas of defence and communication which are specifically reserved for the public sector undertakings, the constraint is only in regard to the end-products and not on the components and sub-assemblies. The Committee has, therefore, suggested that the Government may examine this matter to see how best resources and capabilities, both in the public and private sectors, could be utilised in the interest of achieving planned production.
- (iii) In regard to organisational pattern of the public sector undertakings, the Committee has suggested that there should be a mechanism which can periodically appraise the functioning of the public sector undertakings in electronics and provide them an

overall guidance and in such a set up it would be appropriate if the Department of Electronics has an important say. It has, therefore, been suggested that suitable machinery may be evolved to ensure that public undertakings operate in an integrated manner with the objective of rapid development of the electronics industry in the country. The Committee has recommended that the Government might review at the highest level, the question of placing units manufacturing electronic items under the Department of Electronics so that these units might become centres of growth for the development of the industry in the Fifth Plan period.

- (iv) The Committee has underlined the importance of detailed information being available to the Electronics Commission for the purpose of planning for the electronics industry. It has, therefore, recommended that effective measures may be taken by the Government to ensure that detailed information about imported items is available to the public to enable them to go in for import substitution in a meaningful manner.
- (v) The Committee has noted with appreciation the efforts made by the Department of Electronics to promote the growth of electronics in many states which are now backward in this respect. It has suggested that additional funds may be made available, if necessary, for this purpose after a mid-term appraisal of the Fifth Plan has been done.
- (vi) The Committee has emphasised the need for a strong and healthy ancillary sector under the public sector undertakings. It has recommended that energetic measures may be taken to identify suitable items at present being manufactured in the public sector undertakings and also in the large units of the private sector which could be farmed out to ancillaries profitably.
- (vii) The Committee has noted that the small scale sector has attained considerable growth in the electronics field and is producing many items of high sophistication. The Committee has urged the need for full utilisation of the potential of these units by removing existing constraints like shortage of raw materials.
- (viii) The Committee is greatly impressed by the potential of growth of the electronics industry and has urged that requisite funds may be made available in the interest of achieving the targetted growth rate. It has stated that the concrete measures taken by the Planning Commission and the Government in the implementation of its recommendations may be communicated to them.

1.9.2. Consumer Electronics

- (i) The Committee has recommended that radio and TV programmes should be made popular, entertaining and instructive. It has recommended that the Department of Electronics may take up with the Ministry of Information & Broadcasting the transmission of the popular AIR programmes on high-power transmitters. It has also expressed the need for tapping the rural market for radios and has suggested that surveys may be undertaken to determine how best sales can be augmented in the rural areas.
- (ii) As regards TV, the Committee has suggested that the Depart-

ment of Electronics may take effective steps to improve the production technology so as to reduce manufacturing cost. It has also recommended that the Government may examine the rationalisation of customs duty on imported material as well as the excise duty and sales tax on TV receivers so as to make their price less burdensome. The Committee has also desired that the Government may take an early decision in regard to the manufacture of glass bulbs for TV picture tubes.

1.9.3. Professional Equipment

- (i) The Committee has desired that a number of new units may be set up to augment the existing capacities for telecommunication equipment in such fields as switching, exchanges, telephone instruments, transmission equipment, high precision measuring and testing equipment, etc.
- (ii) The Committee has recommended that the area of transreceiver equipment may be re-examined and if additional capacity is required for this item, expeditious steps may be taken for creating it.
- (iii) In regard to mass communication equipment, the Committee has recommended that the Department of Electronics may prepare an integrated plan in consultation with the Ministry of I&B for indigenous production of radio and TV studio and transmission equipment so that the country can be self-reliant in this sensitive area at the earliest.
- (iv) The Committee has noted the several steps that have been taken to develop indigenous computer manufacturing programme. It has, however, suggested that the Government may entrust the responsibility for research and development in computers to the Department of Electronics so that meaningful long-term and well thought out programmes for the development of computers within the country are drawn up.
- (v) The Committee has noted the slow progress made in the area of industrial electronics and has suggested that the application of electronics to various sectors of industry may be studied in depth with a view to popularise these methods for the rapid growth of the industry in the country.
- (vi) The Committee has noted that in a Defence project, the first phase, demonstrating the capability of the software has been completed but the development of indigenous hardware requires expeditious action.
- (vii) The Committee has suggested that the Department of Electronics might take the lead in the key area of machine fabrication by drawing up a plan for the manufacture of production equipment in the country.

1.9.4. Components and Materials

- (i) The Committee has noted that there has been an impressive increase in the indigenous production of electronic components during the last 10 years. It has, however, suggested that an integrated approach may be adopted towards the development of the component industry in the country. It has agreed with the view of the Department of Electronics that the capacity for

-
- manufacturing components of professional standards be developed in the existing undertakings with suitable balancing equipment. It has also suggested that research and development efforts may be intensified in this area. In the semiconductor field, it has welcomed the proposal to set up a Semiconductor Production Corporation during the Fifth Plan period in the public sector.
- (ii) In the area of standardisation, the Committee feels that urgent measures need to be taken to evolve definite policies for the standardisation of electronic components and equipment to the maximum extent possible. It has endorsed the view of the Electronics Commission to set up a technical panel to suggest guidelines for standardisation in the electronics industry. These should be available for implementation during the Fifth Plan period.
 - (iii) The Committee has noted that the Fifth Plan requirement for materials is of the order of Rs. 190 crores while the production of the proposed units under the Department of Electronics is worth only Rs. 80 crores. The Committee feels that it is imperative that a detailed, systematic and well coordinated programme is drawn up so as to ensure that the entire demand for materials for the electronics industry is met through indigenous capability and where this is not possible by well regulated and planned imports. The Committee has also recommended that the Government may examine the desirability of having buffer stocks for easy availability of materials and to prevent escalation of prices till such time that the material is produced within the country.
 - (iv) The Committee has noted that due to allocation of foreign exchange amongst several credits, individual units find it difficult to obtain components and materials at reasonable prices particularly from the East European countries who need to be intimated of their requirement well in advance. The Committee has, therefore, welcomed the proposal for setting up an Electronics Trade and Technology Development Corporation to handle the procurement of materials and also for stockpiling such materials for release to individual entrepreneurs off the shelf. The Committee has, however, stressed that the staff and the over-head expenses on the Corporation be kept to the minimum so that the material can be supplied to the industry at competitive prices.

1.9.5. Research and Development

- (i) The Committee considered that the Electronics Commission/Department of Electronics may be regarded as a nodal authority for co-ordinating an integrated programme for research in the vital field of electronics. The Committee has noted the formation of a Technology Development Council and would like the Council to prepare a profile for R&D in electronics during the next three or five years and also an annual programme for the Fifth Plan. A review of the progress made in R&D should be made after two years or so in order that the performance during the remaining years of the Fifth Plan may be improved.
- (ii) The Committee has noted that funds earmarked for R&D during 1973-74, have not been fully utilised since the corresponding de-

tails of schemes had not been prepared in depth. While appreciating this view, the Committee has urged the Department of Electronics and all concerned to see that priority schemes for the research and development are taken up without further delays and the targets set are achieved.

- (iii) The Committee has recommended that the Government may consider a procedure whereby parties who take up development work in a particular field can be assured of a licence at a subsequent stage after the development work has been completed. It should be possible for the Department to indicate areas in which successful completion of development programme would entitle the party to preferential treatment in the issue of a licence.
- (iv) The Committee has desired that a systematic review may be made of the facilities available in the Government laboratories and organizations so as to indicate to the industry the availability of such facilities for the testing of electronics equipment. In this connection, the Committee was glad to note that Electronics Commission has decided to set up a Test and Development Centre in each State so as to make available facilities to the entrepreneurs, particularly in the small scale sector. The Committee, however, feels that such facilities should be set up in close co-operation with the industry and the State Government and the scheme should be self-financing with no profit and loss. The industry itself may be encouraged to set up such facilities by organising themselves into cooperatives.
- (v) The Committee was glad to note that in the planning and construction of new factories in electronics, foreign assistance is not being taken and it hopes that no such assistance will be needed henceforth for the new factories proposed to be established.
- (vi) The Committee has recommended that a well coordinated and integrated programme should be drawn up to provide training facilities to suitable persons at various levels for meeting the manpower requirements of the industry. It has also suggested that facilities for higher education in the leading Indian institutions should be continuously upgraded and expanded to provide requisite number of engineers of high quality to sustain the programme of development. The Committee would like the Department of Electronics to play an effective role in working out the requirements and in developing training facilities in consultation with other agencies such as Ministry of Education.
- (vii) The Committee has noted that the Department of Electronics is drawing up a scheme to facilitate return from abroad of highly qualified scientists and technologists. It hopes that the Department of Electronics will finalise the scheme quickly and identify the personnel and bring them back to the country with suitable assignments. In this regard, the Committee has emphasised the need for selecting the best persons available on merit and also to avoid the shortcomings that have been experienced in the pool scheme operated by the CSIR.

1.9.6. Industrial Licensing

- (i) The Committee has noted that under the new procedure, applica-

tions for industrial licensing are being processed quickly. It has desired that special efforts be made to clear the backlog of licensing applications. It has also recommended that in view of the fact that electronics is a highly specialised field for which the Department of Electronics is the nodal Ministry, the Government may examine the possibility of having a sub-committee for licensing items in this area. In any case, it has suggested that full responsibility for scrutiny and recommending applications should be squarely put on the Department of Electronics.

- (ii) The Committee has noted that the Department of Electronics has been conducting a comprehensive review of letters of intent by holding meetings at various State headquarters. It has urged that a procedure be evolved so that a periodic review of the situation is conducted at regular intervals so as to ensure that desired capacity in various categories is created according to schedule.
- (iii) The Committee has noted that according to the existing procedure for the issue of import licenses, the entrepreneurs get raw materials on six monthly basis. It has recommended that the Government may examine the feasibility of granting such licenses for a period of twelve months at a time.
- (iv) The Committee has desired the Government to examine the suggestion made by the National Advisory Committee on Electronics with regard to locating an officer of the CCI&E in the Department of Electronics so as to expedite the issue of import licences and minimise the time involved in the movement of files between the departments and the granting of import licences.
- (v) The Committee has noted that the electronics industry experiences special difficulty in regard to the import of canalised items such as plastic moulding powder, non-ferrous metals, steel, etc., because of their special nature and small requirements. It has suggested that the Government might examine this problem and take necessary measures to remove the difficulty including making changes, where called for, in the Import Trade Policy.
- (vi) In view of the fact that the Department of Electronics has built up considerable expertise in the field of electronics, the relationship of the DGTD and the DC(SS)I with the Department of Electronics may be reviewed in order to avoid overlapping of functions and duplication of efforts.

1.9.7. Exports

- (i) The Committee has noted with disappointment that India's position in the world export trade of electronics is very poor, in spite of an almost unlimited demand for components and a large export market for radios, data processing equipment, etc. The Committee has desired that the Department of Electronics might make a study of the way Japan has made big strides in the export field and take suitable steps. In particular, no time should be lost in taking concrete measures to remove all the hurdles standing in the way of export. Intensive efforts should be made to locate new parties who have the potentialities for export and to encourage them to produce exportable items within the short-

est possible time. A list of items for which there is an export potential may be drawn up and publicised widely.

- (ii) In view of the fact that a wide component base is essential for exports, the Committee has recommended that a crash programme may be undertaken to increase the production of components to meet the existing as well as the future requirements.
- (iii) The Committee has desired that the Government may examine various recommendations made by the National Advisory Committee on Electronics in regard to the strategy for exports, both short-term and long-term. It would like to be appraised of the decisions taken on the recommendation of that Committee.
- (iv) The Committee has suggested that a Working Group might be constituted immediately consisting of representatives from the TDA, Engineering Export Promotion Council and the Department of Electronics to keep a watch over the progress of exports and remove bottlenecks, if any, in the achievement of targets.
- (v) The Committee has considered that the progress made in regard to the setting up of the Export Processing Zone at Santa Cruz has been very slow. It has urged that effective and determined measures be taken immediately to accelerate the progress of work and the functioning of the industries there.

1.9.8. Organisational Set-up

- (i) The Committee was greatly impressed by the amount of work that has been done in the Department of Electronics since its inception, particularly in the field of planning. It has considered that it has been a great advantage that a scientist of international stature and reputation heads the Commission and the Department.
- (ii) The Committee has recommended that in view of the volume of work involved, adequate administrative and technical arrangements be made so that there may be a follow up of the approved policies and schemes selected for implementation.

II

Ten Year Profile

2.1 Introduction

One of the important tasks in planning is to arrive at appropriate priorities to different sectors of the national economy. Priorities may be assigned in such a manner as to maximize the socio-economic objective function specified, subject to the constraints imposed by a developing economy. There are at least two ways by which such priorities can be assigned.

(a) The proposals may be called from user and production organisations and reconcile several such reports through multi-lateral discussions, so as to prune individual programmes to fall within the total plan outlay.

(b) The sectorial planning bodies may undertake in-depth macro-economic analysis of the industry by giving explicit guidelines regarding objectives and constraints faced by the economy as a whole.

To fulfil the latter requirement, a macro-economic study was made to obtain the perspective profile of demand and investment for the electronics and communication industry. The approach adopted in this study is to search for invariants in the growth of the electronics industry which is equally applicable to developed and developing countries. This approach was made possible by the fact that such invariants are known to exist for fast-changing technologies like electronics for which the time-constant of technology change is of the order of five to six years. Details regarding the proposed invariants and their significance to planning are given in Section 2. A subsequent section quantifies the demand trends for three specific cases, viz., natural growth, phased growth for maximum priority, and limit growth. On the basis of these, the electronics profile for the ten year period 1974-84 has been worked out and is given in the subsequent sections.

2.2 Search for Invariants

A long standing controversy in macro-economic theory has been the possibility or otherwise of obtaining growth parameters which are equally valid for developed and developing countries and irrespective of size of the country. Whereas it is true that sectorial priorities may be different for different nations and different economic frameworks, certain extremal priority percentages may exist for particular sectors which may not change from country to country. It is the purpose of this section to show that such an extremal priority invariant exists for the electronics sector which is equally applicable to all countries.

The electronics industry is characterised by the following universal features:

1. It is a fast-changing industry where technology changes in about five to six years to such an extent that there is a clear economic advantage for changing over to the new technology. For example, computers designed with integrated circuits are superior to those based on discrete components.

II

Even though integrated circuit industry may be more capital intensive, its use in computers is as economical to developing countries as is to developed countries. A consequence of the fast change in technology is the high rate of obsolescence which does not discriminate developing countries from developed countries. If the country decides to live with an obsolete technology, it may pay more by way of lower productivity and hence higher cost than if it had opted for the transition.

2. Electronics pervades all areas of an industrial infrastructure, both contributing to it and drawing upon it. A higher level of industrial infrastructure gives a better base for the growth of the electronics industry. A better electronics base can in turn help increase the productivity of the industrial infrastructure. This virtuous-cycle makes electronics one of the core sectors which is given a high priority in all countries. Relative to the industrial component of GNP, therefore, this priority should not widely differ among countries who have opted for a natural growth of electronics.

3. Increase in industrial activity causes a corresponding increase in communication requirements. Whereas the whole populace is covered by the demand for communication facilities, the demand that can be met without undue strain on the total economy is predominantly proportional to the industrial component of GNP for the following reason. Communication demand can be classified into (a) passive communication and (b) active communication. Passive communication may be defined as that transmission of information which does not govern decisions affecting the economy, e.g., a telegram conveying congratulations, a phone call for enquiring welfare, etc. Active communication may be defined as that transmission of information which governs decisions affecting the economy, e.g., business telephone calls. Whereas both passive and active communication demands have to be met, the former for social reasons and the latter for economic reasons, a higher priority in favour of the latter is invariably assigned in every country. Further, a Parkinson-type law operates here: Demand increases, anyhow, to fill the communication facility provided for. Therefore neither a developed economy nor a developing economy can fully meet the entire communication demand of the society. A reasonable level of scarcity, consistent with the sectorial priority assigned, can help better utilization of the hardware; e.g., providing more public booths than individual telephones. It seems prudent to meet a demand proportional to the industrial component of GNP which is an index governing the active communication demand.

4. Mechanical substitutions for mental labour by electronic equipment like calculators and computers are again related predominantly to the industrial and commercial activity. Such substitutions may relate to low level mental labour like clerical jobs or high level mental labour like engineering design optimisation. In a developed country low level mental labour substitutions may be emphasised considerably in view of labour scarcity and high labour cost. On the other hand a developing country may emphasise the substitution of high level mental labour in view of its scarcity and training deficiencies, as well as the availability of ready-made 'products' of mental labour like computer programmes which is uneconomical to duplicate by human labour. The sum total of the two substitutions will be a constant proportion of the industrial and commercial activity in a developed or developing country.

5. Consumer electronics with its products like radio, television and stereo have two important complementary uses: entertainment and education.

A developed country may emphasise the former and a developing country the latter. The sum total of the demands of these two applications may again be a constant proportion of the total electronics demand.

6. Geopolitical balance of power dictates every country, developed or developing, to provide security to its citizens by a defence preparedness that the country can reasonably afford. Electronics has become an important sector and represents a fixed proportion of the total defence production for an optimal defence preparedness.

The foregoing six special features of the electronics industry all point to a common conclusion : The growth of the electronics industry is related to the growth of industrial activity and hence to the growth of the industrial component of GNP.

The international convention is to classify GNP components as : 1. manufacturing, 2. electricity, gas and water, 3. transport and communication, 4. public administration and defence, 5. mining, quarrying and construction, 6. trade and banking, 7. agriculture, forests and fishery and 8. other services. A careful examination points out that the industrial components of GNP which have a direct influence on the growth of electronics are the first four components listed above and more particularly the following : manufacturing, electricity and gas, communication and defence. In Table 2.1 the percentage GNP governing these items are given for twelve countries along with the total GNP for 1969. Electronics consumption defined as (production + import - export) is furnished in column 4. The ratio of this consumption to the portion of GNP representing the industrial activity of the country is given in the last column. It can be seen that the eleven countries get sharply divided into two classes :

1. USA, USSR and Japan, having a ratio around 0.075
2. West Germany, France, UK, Italy, Sweden, Netherlands, Denmark and Norway having a ratio very close to 0.033.

A further examination shows that considerable significance can be attached to the ratio 0.033. Most countries of the world, except USA, USSR and Japan, started their electronics industry, from a ratio zero till they attained a saturation value at 0.033. Those countries, who are governed by a natural growth of electronics, if they attained values higher than this due to over expectations, dropped back within a few years to the value 0.033 or thereabouts. Significantly, India too followed the natural growth as shown in Table 2.2 and was expected to reach the value 0.033 in 1973-74. Though the output grew from Rs. 175 crores in 1970-71 to only Rs. 185 crores in 1971-72, it is in tune with the constant acceleration of 0.003 in the ratio which has been maintained all through the evolution (except in 1969-70 which was 0.004). This points out that India has reached the turning point in electronics in 1972-73 and is poised for an all-important Government decision concerning reassignment of priorities.

Considering the higher priorities for electronics given by USA, USSR, Japan and China, for whom the ratios are about 0.075 or thereabouts, it is imperative for India to decide whether to continue with a natural growth like the West European Countries or to assign higher, artificial priority for electronics like USA, USSR, Japan and China.

In the case of USA and USSR the very heavy financial commitments in space technology and military preparedness have enabled them to assign a higher priority for electronics. In the case of Japan, the higher priority is due to its aggressive export trade in electronics which has invaded America and Europe. In view of the gigantic production base for electronics servicing the entire world, there is an inevitable sales pressure for local consumption also. The acceleration of local consumption for Japan, shown in Table 2.3, was entirely in step with the acceleration of export sales as shown in Table 2.4. It should be pointed out that whereas USA has sta-

II

bilised around the ratio 0.075 and USSR is fast approaching this, Japan crossed it in 1969 and paid a significant penalty for it by way of the present tape recorder glut and the trend of European embargo on Japanese colour TVs. It is significant to note that a trend of diminishing acceleration has started (see column 6 of Table 2.3) since 1969 when Japan exceeded the ratio of 0.075.

Table 2.1. Table for calculating the growth invariant.

Type	Country	GNP \$ million (1969) B	Ratio of GNP relevant to electronics C	Local consumption of electronic products 1969 (\$ million) (Prod-Exp.+ Imp.) A	Ratio = $\frac{A}{BC}$
Countries with crash programme in electro- nics	USA	950000	0.40	28,500	0.075
	USSR	300000	0.40	8,500	0.071
	Japan	170000	0.42	6,000	0.083
	China	80000	0.22	1,000	0.057
Countries allowing only a natural growth of electronics	W. Germany	160000	0.48	2,500	0.033
	France	140000	0.43	1,800	0.030
	UK	110000	0.44	1,700	0.035
	Italy	80000	0.38	900	0.030
	Sweden	29000	0.41	400	0.034
	Netherlands	28000	0.37	350	0.034
	Denmark	14000	0.35	160	0.033
	Norway	10000	0.37	130	0.035

Table 2.2. Natural growth trend for India. (All figures in Rs. crores)

Year	Local consumption of electronic products A	GNP (at f.c.) B	Ratio of GNP relevant to electronics C	Ratio = $\frac{A}{BC}$	Acceleration trend
1964-65	30	21200	0.19	0.007	
1965-66	43	21800	0.19	0.010	0.003
1966-67	60	25300	0.18	0.013	0.003
1967-68	80	29900	0.16	0.016	0.003
1968-69	106	30300	0.18	0.019	0.003
1969-70	138	33000	0.18	0.023	0.004
1970-71	175	34500	0.18	0.026	0.003
1971-72	185	36000	0.17	0.029	0.003

II

Table 2.3. Acceleration trend for Japan. (All figures in billion dollars)

Year	Local consumption of electronic products A	GNP (at f.c.) B	Ratio of GNP relevant to electronics C	Ratio = $\frac{A}{BC}$	Acceleration trend
1965	92	1.9	0.40	0.053	
1966	111	2.4	0.40	0.054	0.001
1967	130	3.1	0.41	0.058	0.004
1968	147	4.1	0.41	0.067	0.009
1969	170	6.0	0.42	0.083	0.016
1970	194	7.6	0.42	0.093	0.010

Table 2.4. Percentage distribution of electronic production in Japan:
A case study of certain invariants.

Activity	Major categories	Percentage distribution						Approximate invariants	
		1961	1963	1965	1967	1969	1970		
1. Production	Consumer	49	47	40	43	47	47	47	
	Industrial	25	27	32	30	27	27	27	
	Components	26	26	28	27	26	26	26	
2. Exports	Consumer	74	73	65	70	70	70	70	
	Industrial	7	8	14	11	12	11	11	
	Components	19	19	21	19	18	19	19	
3. Imports	Consumer	5	4	4	4	3	3	4	3
	Industrial	80	80	79	78	66	65	79	65
	Components	15	16	17	18	31	32	17	32
4. Local consumption	Consumer	44	41	30	33	36	32	35	
	Industrial	29	31	41	40	35	38	37	
	Components	27	28	29	27	29	30	28	
5. Export vs. local consumption	Export as a percentage of local consumption	18	24	32	32	33	32	32	

All these observations seem to indicate that there are two approximate invariants governing the growth of electronics; 0.033 for countries which have opted for a natural growth and 0.075 for countries which have opted for a limit growth. The option before India now is whether to saturate at 0.033 which does not require either any special assistance from the Government or whether to accelerate towards the limit ratio of 0.075 which would require a conscious effort on the part of the Government of India.

Many reasons indicate that India is left with no option but to adopt the latter course. Some of the more important reasons are the following:

1. Electronics is a labour intensive industry which gives the maximum returns for a given capital investment. This industry, therefore, has the

II

potential of reducing unemployment and accelerating capital formation.

2. The industry affords sizes of firms with 10 workers to a maximum desirable size of about 5,000 workers. This provides continuity in entrepreneurship starting from the lowest level possible enabling middle-income class entrepreneurs to enter the industry on their own. This also enables qualified electronic engineers having a business acumen to become entrepreneurs. This can widen the entrepreneurial base considerably tending to increase the distribution of wealth produced and to decrease monopolistic trends.

3. India can earn the much needed foreign exchange by boosting electronics export. As can be seen from Table 2.4, such a boost implies a commensurate increase in local consumption too. India, with its cheaper labour and considerable reserve of unemployed engineers, is intrinsically better placed than Japan provided organisational efficiency and flexibility is increased to a level not far behind that of Japan.

4. India being a nonaligned country which follows an independent course in world politics, its defence preparedness needs considerably high self-reliance. It is not difficult to attain this self-reliance in the vital field of defence electronics. Whereas Japan, West Germany and UK depend on a common NATO umbrella, India has to spend for her own security. Since Indian military policy is of a defensive character, ranging, detection, communication and navigation equipment, which are mostly electronic, get a high priority.

5. The ratio, 0.075, is multiplied by the industrial component of GNP for realising the limit-case consumption of electronic products. Therefore, consumption is proportional to the industrial component of GNP. That is the constant 0.075 only measures the relative priority given to electronics in the national economy. If the economies of countries like USA, USSR and Japan are not overburdened by this priority of 0.075, it cannot overburden the economy of any other country, big or small, developed or developing, provided there are other overriding reasons like (1) to (4) above, which dictate this priority.

There are several other invariants guiding the growth of electronics. An examination of Table 2.4 may suggest a few such, though they are not as universal as the foregoing invariants.

2.3 Natural, Feasible and Limit Growth Trends

Demand projections were made for the decade 1971-1981 for India for the following three cases:

1. Natural growth of electronics without assigning special importance to electronics relative to other sectors (Ratio: 0.033). The case of constant acceleration of 0.003 (see Table 2.2) is also briefly considered.

2. Phased growth of electronics and communication with a realistic acceleration programme for reaching the maximum desirable ratio of 0.075, thus assigning electronics the highest priority possible in the national economy.

3. A crash programme for achieving the ratio of 0.075 in the shortest possible time with a schedule aimed at maximum acceleration possible.

Table 2.5 gives the local demand projections for 1971-81 for the above three cases. It can be seen that in the process of natural growth, the relative priority ratio of 0.033 will be attained by 1973-74. Hence, any further growth of electronics in this case will only be proportional to the growth of the industrial component of GNP. The constant acceleration trend witnessed by

II

India. (see Table 2.2) may change to give rise to a zero acceleration trend. This would be the case if a conscious planning for electronics growth is not made and the industry is allowed to grow on its accord without any special priority being assigned by the Government. This can be seen from the near saturation of the urban radio market. If the radio industry has to grow, the penetration of the rural radio market has to be intensified. Such intensification would require more investment by AIR than is possible under conditions of natural growth. It is also possible to sustain the constant acceleration trend (case 2).

Cases 2 and 3 in Table 2.5 assume that the Government indeed gives a special status to the electronics industry by assigning the highest desirable relative priority index of 0.075. This implies an acceleration far in excess of that experienced by the country under the natural growth conditions. This would mean that giving a special status to the industry alone is insufficient to effect this acceleration. It should be made possible by a conscious and judicious investment with utmost importance being given to the time factor. Case 2 assumes a phased acceleration taking lessons from the Japanese experience of accelerating from 0.052 to 0.083 in about four to five years (see Table 2.3). The acceleration starts from 1973-74 and reaches the limiting priority index of 0.075 by 1977-78. In other words, case 2 had a precedence which ushered in the electronics boom in Japan. On the other hand, case 3 envisages a limiting case of acceleration from 1973-74 reaching the index of 0.075 by 1976-77, a year earlier to case 2. Case 3 represents the maximum possible growth which can be executed in principle provided necessary investments are made on a tight time schedule.

It has been argued in the past whether such accelerations as implied by case 2 and case 3 could be realised in a developing country like India with its foreign exchange, specialised manpower and regulatory constraints. It appears that for the electronics industry such objections are not valid for the following reasons:

1. Electronics is not very capital intensive. For a moderate initial capital it is possible to generate capital faster than in most other industries. Foreign exchange investment is also relatively low, but has the potential of generating large value exports which can more than offset the FE drain for acquiring technology. For a case 2 type programme, the break even with respect to FE can be achieved of simultaneously with the end of the acceleration period.

2. Specialised manpower is not difficult to find as there are more Indian electronics specialists abroad than are required for case 2 or case 3 conditions. As to nonspecialist engineering manpower, training on the job is one of the best practices followed all over the world in the field of electronics manufacture. It can be more easily followed in India with its vast reserve of unemployed engineers provided much thought is given to manufacturing planning so that each nonspecialist only handles a stereotype job which requires, on the average, about six months of on-job training. Explicit investments for on-job training have to be provided for, during the accelerating period.

3. Regulatory constraints which are inevitable in a developing country will not pose much difficulty if the blueprint for the acceleration is worked to the smallest possible detail, all fitting into a unified plan for the industry.

4. Case 2 and case 3 which represent a 'one-shot' growth has an im-

II

portant advantage. In a natural growth condition import of raw materials and parts is often to the tune of 33 per cent (see Table 2.6), because of bottleneck conditions obtaining in the component and material industry. Often, an equipment is not manufactured in India because of the momentum of importation which takes considerable time to subside unless consciously planned. In the 'one-shot' growth, most components, materials, instruments and subassemblies would be required to a sufficient scale of production so that a PERT chart of production schedule can be worked out for them with an assured market.

From the above, one can conclude that whereas case 1 will result with little or no planning, case 2 can be implemented realistically with meticulous planning and case 3 would require a crash programme. If the crash programme can be started only at the beginning of Fifth Five Year Plan, this rules out case 3. However, if an investment of about Rs. 52 crores with Rs. 26 crores in foreign exchange can be made earlier, case 3 can be executed if it is backed up by a determined effort. For case 2, such an order of magnitude of investment would be required only from the beginning of the Fifth Plan period. The constant acceleration trend of case 2 is also a serious alternative.

Table 2.5. Natural and limit growth projections for India.
(All figures in Rs. crores)

Year	Projection of GNP (G)	Ratio of GNP directly governing electronics growth (?)	Ratio tending to invariants			Annual turnover		
			Zero accn. Case 1 R ₁	Constant accn. Case 2 R ₂	Maximum accn. Case 3 R ₁	Case 1 =R ₁ GP	Case 2 =R ₂ GP	Case 3 =R ₁ GP
1971-72	36000	0.177	0.029	0.029	0.029	185	185	185
1972-73	37500	0.183	0.032	0.032	0.032	220	220	220
1973-74	39300	0.186	0.034	0.035	0.036	250	255	260
1974-75	41300	0.190	0.034	0.038	0.041	265	300	320
1975-76	43400	0.195	0.033	0.041	0.049	280	350	415
1976-77	46000	0.200	0.033	0.044	0.060	305	405	550
1977-78	48800	0.205	0.033	0.047	0.075	330	470	750
1978-79	51700	0.210	0.033	0.050	0.075	360	540	815
1979-80	54800	0.215	0.033	0.053	0.075	390	625	870
1980-81	58100	0.220	0.033	0.056	0.075	425	715	960

Table 2.6. Experience of a public sector undertaking in the licensed manufacture of electronic products.

Total production value under licensed manufacture	Royalty and technical assistance cost	Foreign exchange content of production
Rs. 100 crores	Rs. 3 crores	Rs. 33 crores

2.4 The Ten Year Profile

The Planning Commission set up a Task Force on Electronics and Communication under the chairmanship of the Chairman, Electronics Commission. Based on the report of this Task Force, the Electronics Commission (IPAG) prepared a report in consultation with the Department of Electronics giving a sectorwise and project-wise breakup of investment. This report was submitted to the Planning Commission. Two major modifications were suggested by the Planning Commission :

- (a) to confine the plan to civilian sector as the APEX body had separately considered Defence electronics
- (b) to delete the export programmes under the EPZs as the Ministry of Commerce had separately considered this.

The Fifth Five Year Plan Profile indicated in the following is identical to the one submitted in final form to the Planning Commission and accepted by the Commission. The investment proposed during the Plan period for each activity is the critical minimum, below which it is infeasible to start it during the Plan period. These activities were included on a national priority basis and on the assumption that the necessary funds, including the foreign exchange will be available. However, due to the critical financial position and acute foreign exchange situation at present, it is likely that the implementation of some of the programmes may not start in time as anticipated. In such cases either the initiation of the activities may be delayed or the anticipated time span of the activities may get elongated. As a consequence, all the investment and corresponding production figures given in the report are subject to the availability of funds to the specified extent and as per the specified time schedule. The time estimates given are, therefore, to be treated as desirable from the larger economic interest of the country and not necessarily as rigid targets. By year to year comparison of the proposed and actual outlay of the annual plan, the corresponding relaxation in the time targets can be worked out.

The Sixth Five Year Plan Profile given is an extrapolation of the Fifth Plan Profile maintaining the approach and guidelines suggested by the Planning Commission for the Fifth Plan. However, this picture is tentative because of the obvious uncertainties in demand, availability of resources for investment and the changes in technology expected to occur by 1980 in a number of areas, and hence it would be premature to quantify the profile for the eighties. The Sixth Plan outline given should therefore be regarded as a tentative extrapolation which has to be viewed periodically depending on the commercial introduction of newer technologies.

The above constraints and uncertainties should be borne in mind throughout this report.

2.4.1. Fifth Five Year Plan

The basic aims of the Plan for electronics and communication are the following :

- (a) To develop the infrastructure for production and development to such an extent that by the end of the Fifth Plan period the industry will be

Table 2.7. Summary of the ten year profile (Rs. crores).

	Fifth Plan	Sixth Plan	Ten year total
Total investment	202	496	698
Total estimated production	2608	6385	8993
Estimated terminal year production	782	1900	

completely self-sustaining and the import of capital equipment and raw materials is brought down to the lowest limit which is economically viable.

- (b) To develop a full-fledged industry spread over all parts of the country that will accelerate the process of capital formation of all the States of the Indian Union. It is acknowledged the world over, that this industry has the maximum capital formation ability.
- (c) To develop an industry spread over the public sector, organised private sector and small scale sector in such a proportion that the direct and indirect employment of technical, skilled and semiskilled manpower is maximised without effecting a diseconomy of scale.
- (d) To develop an industry that can make a significant contribution to self-reliance in the defence preparedness of the country by not only maximising import substitution across a broad front, but by promoting the philosophy of custom manufacture of critical components and equipment whose demand is above the scale of diseconomy calculated on the basis of scarcity of foreign exchange.
- (e) To promote the right kind of application of electronic equipment like computers, control systems, television, etc., which have a development catalysing effect on the national economy.

The salient features of the Fifth Five Year Plan profile are given below :

- (a) A total outlay of Rs. 202 crores during the Plan period is expected to result in a total production of about Rs. 2608 crores and a terminal year production of about Rs. 782 crores.
- (b) For the total profile, the investments in public and private sectors are respectively, 134 and 68.
- (c) Additional employment to 3.6 lakh persons will result from this investment (2.6 lakh direct + 1.0 lakh indirect). Capital to labour ratio for the industry is, on an average Rs. 6500 per person.
- (d) From the present level of Rs. 7 crores per year, the export from local production will increase to Rs. 23 crores by the terminal year. This represents only 5 per cent of the annual production. However, the output of the Export Processing Zones has not been taken into consideration here.

Table 2.8. Fifth Five Year Plan : Sectorwise investment and production in electronics and communication. (Figures in Rs. crores)

	Capital investment during the Plan period	Production	
		Plan period	Terminal year
1. Mass communication	9	52	17
2. Consumer electronics	7	692	199
3. Communication, radar and navigation systems	58	653	172
4. Computers	26	186	54
5. Control and industrial electronics	20	95	32
6. Medical electronics	8	45	14
7. Instruments	14	155	46
8. Components	33	595	200
9. Materials	17	125	45
10. General facilities	10	10	3
Total	202	2608	782

Table 2.9. Investment required for R&D during the Fifth Plan period.
(Figures in Rs. crores)

Sector	Consumer electronics	Mass communication	Computers and control	Control system and industrial electronics	Instruments and instrumentation	Components	Materials	Total (excluding plans of Defence Ministry and Commn. Min.)*	Telecommunication	Total (excluding Plan of Defence Ministry)
Investment	2.5	2.5	4.0	4.5	1.5	7.5	4.5	27.0	25.0	52.0

* Out of the Rs. 27 crores, a sum of Rs. 7 crores is expected to be raised from the resources from within the industry.

If the projected investment pattern is realised, the industrial capacity which would have been built up by the beginning of the Sixth Plan would be strong enough for further expansion and deepening of the industry to be undertaken largely out of the resources of enterprises themselves. It should also enable exports to be undertaken on such a scale that the electronics industry would not only meet its own import needs but constitute a net earning of foreign exchange for the country.

To achieve the production envisaged in the Plan, considerable research and development support is required. It has been planned to invest Rs. 52 crores in R&D efforts during the next five years. Sectorwise breakup of R&D investment is given in Table 2.9.

2.4.2. Sixth Five Year Plan

In an industry involving a fast changing technology like electronics, investment and production profiles are likely to depend considerably on factors like technological trend rather than on short term factors like demand. For example, the cost of a computer for the same performance in 1973 is only 20 per cent of the cost in 1968 due to a technological innovation in components. Whereas long term technological forecasting may attempt to quantify the profile, there is an inevitable uncertainty in the estimates for a fast changing technology, like electronics. All the estimates given for the Sixth Plan therefore should be considered as tentative. Changes in these estimates will be outlined periodically.

Demand in the consumer electronics area is dependent on various factors, like consumer income elasticity, price elasticity, etc. Any prediction in this area can at best be of qualitative significance. However, there exists a minimum datum demand in this area which has to be met irrespective of the market conditions. Investment shown for this area is that required for meeting this minimum demand. Any demand over and above this can be met through the resources generated within the industry. The production shown, however, is equal to the estimated total demand.

The estimated projection of sectorwise investment and production during the Sixth Plan period is given in Table 2.10.

2.4.3. Comparison of Electronics Commission Plan with Bhabha Committee Report Targets

The estimates of Bhabha Committee for the terminal year 1975 is compared with the planned targets of the Electronics Commission, in Table 2.11.

At the time the Bhabha Committee Report was written the pattern of the growth of the industry was still to crystallise. Therefore, the Committee indicated two

Table 2.10. Sixth Five Year Plan : Sectorwise investment and production in electronics and communication.
(Figures in Rs. crores)

	Capital investment	Production
1. Mass communication	27	135
2. Consumer electronics	15	1655
3. Communication, radar and navigation systems	129	1560
4. Computers	54	445
5. Control and industrial electronics	45	260
6. Medical electronics	19	170
7. Instruments	25	351
8. Components	125	1400
9. Materials	37	385
10. General facilities	20	24
Total	496	6385

Table 2.11. Comparison of Bhabha Committee estimates with the Fifth Plan estimates of the Electronics Commission, for the year 1975.
(Figures in Rs. crores)

(Equipment + components)	Bhabha Committee estimates		Electronics Commission Fifth Plan estimates
	Line	Geometric	
Consumer electronics	73	107	100
Professional electronics	232	439	220
Total	305	546	320

possible patterns of growth, viz., linear and geometric. However in actual practice the consumer electronics industry has taken the geometric growth pattern whereas the professional electronics industry has assumed the linear growth pattern. Nevertheless, the terminal year (1975) output on the basis of the Bhabha Committee estimates and the base year figure adopted by the Electronics Commission for the Fifth Plan projection are largely the same. However, it is estimated that the professional electronics area will gradually tend to the geometric growth pattern during the Fifth and Sixth Plan periods.

2.4.4. Mass Communication

In 1975, radio covers 67 per cent of area and 80 per cent of population by the medium wave network alone (assuming a minimum of at least one programme service) as compared to coverages of 82 per cent and 90 per cent, respectively expected to be reached by the end of the Fourth Plan. The ratio of the number of persons per receiver is 35 : 1 and is far from the optimum figure of 5 : 1, suggested by UNESCO.

Television has just made a beginning in the country. Delhi, Bombay, Calcutta, Madras, Amritsar and Srinagar stations are operational as also the relay station at Poona. Two more stations are expected to be operational during the next year.

The Planning Commission has recommended a programme of development for radio and TV network during the Fifth Plan period which suggested qualitative growth rather than a substantive quantitative growth. The same approach is assumed to be valid for the Sixth Plan period also, except that in view of the total indigenisation of the radio and TV industry expected to be attained during the Fifth Plan, a viable base for custom manufacture of radio and TV transmission systems during the Sixth Plan would have been built up.

The demand forecast for the Fifth Plan period for radio and TV transmission equipment is given in Table 2.12.

Table 2.12. Radio and TV transmission equipment demand for the Fifth Plan.

	Rs. crores
Radio :	
SW, MW and FM transmitters	7.8
Antenna systems	0.9
Studio and field equipment	1.5
Measuring instruments	0.4
Nonelectronic ancillaries	4.4
Television :	
TV transmitters and antenna systems	14.9
Camera chains	5.5
Telecine chains with multiplexers, etc.	3.3
Projectors and relay receivers	2.4
Switching, signalling and other instruments such as pattern generators, etc.	2.1
Consoles and recorders	9.6
Measuring instruments	1.0
OB vans and OB transmitting equipment	4.5
Total	58.3

Indian Space Research Organisation (ISRO) has carried out various systems studies for providing television in rural areas using satellite broadcasting techniques. ISRO has proposed a plan for providing such a satellite system (INSAT) as a follow up of SITE (Satellite Instructional Television Experiment). This plan was discussed in detail at the seminar on "The Indian Programmes for Space Research and Applications" held in Ahmedabad between the 7th and 12th August, 1972.

Since the INSAT system has been proposed as a national facility in the areas of television, telecommunications and remote sensing, a Task Force for INSAT was set up by the Planning Commission, under the chairmanship of the Chairman, Electronics Commission, to examine the relevance of INSAT to the plans of user ministries and to examine the extent to which financial allocations requested for by these user ministries during the Fifth Plan period for tasks that could be accomplished by INSAT could be re-allocated for making INSAT possible.

INSAT, as a satellite system has been optimised for purposes of providing television broadcasting from geo-synchronous altitudes for direct reception on community TV sets. Thus it is essentially a television oriented system. However, in addition to carrying out the functions of television broadcasting, additional capacity on the satellite has been proposed for long distance telecommunications. The position of the satellite at geo-synchronous altitude provides an ideal platform for carrying out observations of the earth, particularly for the purpose of meteorology.

The communications system of the satellite can also be used for purposes of data transmission from remotely located platforms.

The INSAT Task Force programme which is optimised primarily for purposes of television and telecommunications has the capabilities for helping in natural resources survey by obtaining information to generate thermographs or temperature maps of the earth. This along with the photographs of the earth can be used for a variety of purposes. Another application is in meteorology where it is possible to forewarn the onset of cyclones, floods, etc., well in advance besides aiding in weather forecasting. By deploying transmitters over the length and breadth of the country and linking them with the satellite system, data regarding temperature, humidity, wind velocity, salinity of soil, etc., can be continuously obtained. Such data is useful in hydrology, meteorology, forestry, etc. Another application is in data relay for aircraft remote sensing system. In this, low flying aircraft obtain data on the earth with resolutions of a few feet and relay the information through the satellite to the ground stations, thus minimising the load carried on the aircrafts and also providing for high resolution.

The total INSAT plan as proposed by the Task Force is given in Table 2.13.

Table 2.13. INSAT Task Force plan.

	Rs. crores
1. Satellite and launch vehicle	45.0
2. Ground stations (transmitting and receiving and terminals)	20.5
3. Standard and augmented TV sets	77.9
4. Power supply including batteries	50.0
5. Software development and production	100.0
7. Operation and maintenance	85.0
8. Others	21.6
Total	400.0

The estimated ten year production and investment envisaged for mass communication is given in Table 2.14.

Table 2.14. Production and investment in mass communication.
(Rs. crores)

1974-1979 (Fifth Plan)		1979-1984 (Sixth Plan)		1974-1984 10 year period	
Production	Investment	Production	Investment	Production	Investment
52.0	9.0	135.0	27.0	187.0	36.0

2.4.5. Consumer Electronics

The estimated incremental investment and total production for the Fifth Five Year Plan are Rs. 6.6 crores, and Rs. 692 crores respectively. The phasing of the capital investment of Rs. 6.6 crores in the consumer electronics field for the Fifth Plan is as given in Table 2.15A. This investment excludes resources generated within the industry in the private sector. Activitywise investment and production plan is given in Table 2.15B.

II

Table 2.15A: Phasing of incremental capital investment for consumer electronics during 1974-1979. (In Rs. crores)

1974-75		1975-76		1976-77		1977-78		1978-79		Plan period		Total
Rs.	FE	Rs.	FE	Rs.	FE	Rs.	FE	Rs.	FE	Rs.	FE	
1.2	0.4	1.2	0.4	1.2	0.4	0.7	0.2	0.7	0.2	5.0	1.6	6.6

Table 2.15B. Activitywise investment and production in consumer electronics. (In Rs. crores)

Activity/Project	Additional capital investment during the Plan	Production	
		Plan period	Terminal year
1. Radio receiver production	2.0	322.0	84.0
2. State agencies for rural market promotion	1.0	—	—
3. TV receiver production	—	226.0	73.0
4. Recorders & record players	0.7	67.0	20.0
5. PA systems & amplifiers	0.9	52.0	15.0
6. Miscellaneous consumer goods	2.0	25.0	7.0
Total	6.6	692.0	199.0

The investment profile for the Five Year Plan is drawn up such that more than 70 per cent of the total plan investment is made in the first three years and the rest in the following years. Heavier investment is needed in the initial period towards maximising the returns in the shortest possible time as well as to minimise foreign exchange drain due to direct imports of subassemblies and components.

Production of radio receivers has been approximately doubling every five years since 1951 and the trend is expected to continue in spite of fluctuations noticed annually. This expectation gives a figure of 5 million receivers per year to be produced annually on the average during the Fifth Plan. With the current capacity of 4 million receivers per year, this would require a figure of 6 million receivers per year to be realised at the end of the Fifth Plan.

The investment of Rs. 1.0 crore envisaged for the state agencies for rural market promotion is expected to reverse the declining trend in the off-take of radio receivers seen in the last two or three years.

In view of the All India Radio plan to cover 53 per cent of the country by population by the end of the Fifth Plan an annual production worth Rs. 73 crores is expected for the TV receiver industry by the end of 1974-79 period.

The expected total production in the Sixth Five Year Plan is put at Rs. 1655 crores with a total investment of Rs. 15 crores during the period and a terminal year investment of Rs. 5 crores.

The rural market for radio receivers which will be opened up as a result of the promotional measures taken during the Fifth Plan is not expected to maintain its growth by the end of the Sixth Plan. Also, the production of items such as record players, tape recorders, PA systems, etc., nucleated during the Fifth Plan is expected to make a substantial contribution to the overall production in consumer electronics. It is anticipated that the entire consumer electronics industry would be totally indigenised by the beginning of the Sixth Five Year Plan period.

2.4.6. Communication, Radar and Navigation Systems

2.4.6.1. Telecommunication

The Telecommunication Capacity Planning Committee set up by the Planning Commission has given detailed demand projections for 1974-84 for telecommunication equipment. Two projections have been made, viz., higher demand projection (HDP) and lower demand projection (LDP). Demand estimates, not including export demand, in respect of some of the major items are given in Table 2.16A.

Table 2.16A. Demand projection for major items of telecommunication.

Item	1974-79		1979-84	
	HDP	LDP	HDP	LDP
Switching equipment (in lakhs of lines)	24.06	22.22	45.38	30.00
Underground telephone cables (SKMS)	44150	43400	99825	61300
Telephone instruments (in lakhs)	26.05	26.05	51.13	40.18

The Committee has also identified several new facilities that would be required during the next few years. Some of these are :

- (i) facsimile services for police wireless, Meteorological Department, etc.,
- (ii) high speed data links for connecting regional computer centres,
- (iii) data links for private users like airlines,
- (iv) switching centres for air traffic control,
- (v) bearer channels for TV relay links,
- (vi) picture phone, data telephone, etc., and
- (vii) rural communication links.

The estimates of production and investment envisaged in this area during the Fifth Plan are given in Table 2.16B.

During the Sixth Plan the total production and investment envisaged are Rs. 1460 crores and Rs. 113 crores respectively.

II

Table 2.16B. Telecommunication—Investment and production profile for 1974-79.
(In Rs. crores)

Product category	Production		Capital investment	
	1974-79	1978-79	Total	FE component
Switching equipment	319	79.0	25.6	4.5
Underground telephone cables	101	23.0	6.3	4.0
Coaxial cables	23	5.5	2.5	0.6
Telephone instruments	34	8.5	6.6	0.9
Transmission equipment	133	37.0	10.0	3.0
Total	610	153.0	51.0	13.0

2.4.6.2. Telemetry and Telecontrol Equipment

Telemetry and telecontrol systems would be required in large numbers for application in areas like power supply distribution, water supply, railways, etc., during the next few years. It is estimated that the demand for these equipment during the Fifth Five Year Plan period would be about Rs. 25 crores. At present only a few firms manufacture some of the required items such as power line carrier communication equipment and telemetry and telecontrol equipment. There are several other items of equipment like cyclic telemetry systems that need to be taken up for manufacture.

2.4.6.3. Radio Communication Equipment

A wide range of two-way communication equipment in the HF, VHF, and UHF bands are required by the security services, Civil Aviation Department and several industries and public utilities. An estimate of the requirement of these equipment during the Fifth Five Year Plan comes to about Rs. 40 crores. Bharat Electronics Limited is the major manufacturer of two way communication equipment at present. The gap between supply and demand, especially for the civilian sector, has been growing continuously. It is planned to augment the production capacity during the Fifth Plan period.

2.4.6.4. Navigation Systems

Certain types of navigation equipment required for the Department of Civil Aviation that are currently planned for import can be manufactured in the country. BEL and HAL cater mainly for the needs of the defence services at present. Local manufacture of equipment for civil aviation can reduce imports of equipment worth about Rs. 9 crores during the Fifth Five Year Plan.

The estimated investment and production in the three areas during the Fifth Plan period are given in Table 2.16C.

2.4.6.5. Estimates for Sixth Plan Period

The demand during the Sixth Plan period will continue to grow in view of the expected growth of industries and public utilities in the country, which would require a commensurate growth of these facilities. To meet this demand, the total

II

production of these equipment during the Sixth Plan period would be about Rs. 100 crores with a corresponding capital investment of Rs. 16 crores.

Table 2.16C. Investment and production profile for telemetry and telecontrols, radio communications, and navigation systems during 1974-79 (Rs. crores).

Area	Total production 1974-79	Terminal year production 1978-79	Total investment 1974-79
Telemetry & telecontrol	10.0	4.5	2.4
Radio communication equipment	24.0	10.8	2.8
Navigation systems	9.0	3.6	2.2
Total	43.0	18.9	7.4

2.4.6.6. Investment and Production for the Ten Year Period 1974-84

Table 2.16D gives the investment and production during the Fifth and Sixth Five Year Plans in the areas of telemetry and telecontrol, radio communications, and navigation systems. The total capital investment and production during the ten year period 1974-84 are Rs. 23.4 crores and Rs. 143 crores, respectively.

Table 2.16D. Investment & production figures for 1974-84 in telemetry, and telecontrol and radio communications and navigation systems. (Rs. crores).

Period	Capital investment	Production
Fifth Five Year Plan (1974-79)	7.4	43.0
Sixth Five Year Plan (1979-84)	16.0	100.0
Ten year period (1974-84)	23.4	143.0

2.4.7. Computers

The general philosophy of computerisation in the country during the next two plan periods is as follows. Priority will be given to those programmes which are of national importance in the industrial and engineering fields, for vital sectors such as defence and for export-oriented activities. Projects which have a development catalysing effect on the economy, will get priority for the use of computers. Some such projects are being evolved, for example, projects on cultivator information system, science and technology information system, engineering design automation, optimal network design, etc. The users should first attempt to meet their in-house requirements through computers available indigenously and should avail of the regional computer centre facilities for any additional requirements. Com-

puters, other than those available through Indian manufacturing programmes, will be regarded as expensive items to import and hence the requirements have to be considered in terms of their relevance to national development programmes and related priorities. Applications which are purely in the nature of accounting automation will be discouraged. Applications which are in the nature of design automation, management decision information systems, data banks, computations aiding research and development, on-line control which directly increase productivity and computation which will boost exports will be encouraged.

A summary of the requirement for computers and calculators for the Fifth Plan period is given below and is followed by the production and investment profile for the Plan period. A projection of the demand and the required investment during the Sixth Plan period is given keeping in view the general philosophy of computerisation.

The Task Force VII Working Group on Computers has estimated that during the Fifth Plan period a total of 15 large systems (large system: more than Rs. 50 lakhs), 240 midi systems (Rs. 10-50 lakhs), and about 900 mini systems (less than Rs. 10 lakhs) will be required. The large systems with average price of Rs. 90-100 lakhs each, have to be imported. A number of these large machines are required for the regional computer centres. The demand for minicomputers and major portion of the demand for midi systems have to be met by indigenous production.

A significant percentage of the total cost of the computer system goes for peripherals. The peripheral requirement of mini and midi systems has to be met by indigenous production, if the computer programme is to make its full impact. An estimate of the requirements of mini- and midicomputer peripherals during the Fifth Plan period is given in Table 2.17.

Table 2.17. Peripheral requirement for mini- and midicomputer systems during the Fifth Plan period

Equipment	Total number
Teletypewriter (10 ch/sec)	1700
Paper tape reader (300 ch/sec)	750
Paper tape punch (110 ch/sec)	750
Line printers (300 lpm)	450
Line printers (600 lpm)	350
Card readers (300 cpm)	270
Card readers (600 cpm)	150
Low speed magnetic tape drives	1050
High speed magnetic tape drives	350

During the Plan period, an annual demand of 2000 million punch cards is anticipated from DP/EDP users. Of this, only about 800 million cards are made per annum by the two foreign concerns, viz., IBM and ICL. The Task Force

II

estimated that the demand for computer tapes during the period will be about 700,000 standard reels, i. e., about 170 million running feet.

Any country embarking on a computer production programme can ill afford to neglect development of system software as the economics of a computer is as much dependent on its software as on its hardware. Some of the regional computer centres proposed to be set up in the Fifth Plan should act as catalysts to the software production to meet the national requirements. This is much more relevant in the context of minicomputer networks as substitutes for costly imported maxi systems.

It is estimated that about 100,000 calculators will be required during the Fifth Plan period. The Electronics Desk Calculator Panel constituted by the Electronics Commission suggested a higher figure but subsequent experience indicated this estimate.

2.4.7.1. Production and Investment Profile for 1974-1979

A total production of Rs. 186 crores is envisaged during the Fifth Plan period for computers, computer accessories and calculators. A breakup of this and a brief description of the production and investment plan are given below:

Production of CPU, memory and the peripheral interfaces would amount to about Rs. 102 crores, during the period. A total investment of Rs. 8.5 crores will be required for this.

The basic peripherals like teletypes, paper tape readers and punches would require an investment of Rs. 0.90 crore. Sophisticated peripherals which include card readers, medium/high speed line printers and magnetic tape drives worth Rs. 25 crores have to be produced during the period for which investment of Rs. 5 crores is required. Import of know-how may be necessary for the manufacture of many of the sophisticated peripherals. Magnetic disc drives worth Rs. 2 crores have to be imported during the Plan period.

For production of computer tapes, know-how has to be purchased on a one-time basis. Separate units should be set up in the private sector for films and coating materials. An investment of the order of Rs. 2.6 crores may be required mainly in the private sector.

In order to meet the demand for punch cards and to introduce healthy competition, more units need to be set up during the Plan period. Three more new units, each with a production capacity of 300 million cards annually will be adequate to meet the demand. Since investment and running expenses are low they may be set up in the small scale sector. A total investment of Rs. 0.3 crores is estimated for this.

During the Fifth Plan, national/regional computer centres are proposed to be established at Bombay, Delhi, Bangalore, Calcutta, Kanpur and Hyderabad. In this, the national centre at Bombay has already been set up with UNDP assistance and the national centres at Delhi and Bangalore are also expected to receive UNDP assistance. The two centres, viz., Calcutta and Kanpur require the commitment of national resources to cover the cost of the computer. A total investment of Rs. 3.6 crores is planned for this.

The National Centre for Software Development and Computing Techniques (NCS DCT) has been established in Bombay with UNDP assistance with the primary objective of developing software and computing techniques to support the growth of a major self-reliant indigenous computer and semiconductor industry. An investment of Rs. 2.3 crores is estimated for this.

The hardware and software required for computer networks are being developed in the country. However, a number of development problems have to be solved in the meantime to make the network a commercial success. For this, a total investment of Rs. 3 crores would be needed. As the project would be partly funded by UNDP as a contribution towards NCS DCT, a complementary investment of Rs. 1.4 crores is estimated towards data transmission equipment, terminals, locally made computers, etc.

A Computer Maintenance Corporation of the Department of Electronics has been approved by Government and is expected to start operations in the next few months. An investment of Rs 1.0 crores was estimated initially. However, this has been updated to Rs 2.0 crores subsequently.

A turnover of Rs. 20 crores worth of electronic desk calculators is estimated during the period. As the industry is more than adequately licensed to take care of the above demand, even assuming a high mortality rate of licensed firms, no new units are required to be set up during the Plan period.

During the Sixth Plan, the total production in the field of computers and calculators is expected to rise by $2\frac{1}{2}$ times over that of the Fifth Plan. This will amount to a total production worth about Rs. 445 crores during the period. Assuming a greater production to investment ratio than that for the Fifth Plan, meeting this production requirement will call for an investment of Rs. 54 crores in the Sixth Plan.

2.4.8. Control and Industrial Electronics

Industrial electronics, control equipment and electromechanical control components like servos, synchros, resolvers, gyros, etc., and various types of sensors, transmitters and final control elements required in process industries are included in this section.

2.4.8.1. Control Equipment and Industrial Electronics

Presently there are about 60 units in the industrial electronics and control equipment manufacturing sector. The industry is fairly decentralised. The units in the small scale sector are distributed throughout the country. The total present annual capacity of the industry is around Rs. 10 crores. During 1972, the total annual production of the industry was around Rs. 7 crores. On an average, over the last five years, the growth rate of the industry has been around 20 per cent.

About 70 per cent of process control instruments and equipment required for various industrial process are being met from indigenous sources at present. As far as essential technological services, systems engineering, installation and commissioning are concerned, the country has the necessary expertise and is self-reliant. A nucleus exists for undertaking R&D and this base has to be augmented for sustaining the indigenisation plan.

2.4.8.2. Control Components

Because of their strategic importance in defence and productive automation, it is proposed to accord a high priority for the indigenous development and production and control components required by our electronics industry. These include electromechanical components such as servos, synchros, resolvers, gyros, etc., and various types of sensors, transmitters and final control elements required in process industries. The accent will be on judicious standardisation.

A sizeable portion of the total demand for control components is expected to arise from defence and aerospace applications. Defence and aerospace applications include (1) guidance and navigation systems for rockets, aircrafts, ships and submarines and (2) various types of radar and fire control systems used on land, sea and air. The industrial applications of control components are mainly in the field

of process control and instrumentation, where they are used for automatic and remote control, telemetry and computation. During the next decade, potential application areas would be :

- (1) process control systems,
- (2) numerically controlled machine tools,
- (3) voltage stabiliser systems,
- (4) strip chart and other recording equipment and
- (5) computer peripherals.

Indigenous production of control components required in servo systems has been recently established at ECIL. This unit is currently making about Rs. 0.50 crores worth of precision electromechanical components. ECIL can expand to Rs. 2.0 crores worth of production by 1978-79. Also a number of units in the private sector are producing some basic sensors and transmitters needed in instrumentation systems for process industries.

2.4.8.3. Demand Forecast

Control equipment have now found applications in the country not only in the relatively new process industries but also in the traditional industries. With both the vertical and horizontal growth in industrialisation, the investment in control equipment is expected to grow steadily. The current consumption of industrial electronics and control equipment (excluding components) is of the order of Rs. 9.0 crores per annum. On the basis of the indications of the development programmes for the major industries during the next five years, production is expected to reach Rs. 20 crores per annum by the end of the Plan period. It can be anticipated that with increasing productive automation of the industrial sector a continuous growth rate of 20 per cent per annum can be anticipated during the Fifth and Sixth Plan periods.

The current consumption of control components is of the order of Rs. 4 crores per annum and an annual demand for components worth about Rs. 13 crores is estimated by the end of the Fifth Plan. Annual demand for components worth Rs. 27 crores is anticipated by 1984-85. This demand has been estimated on the basis of OEM requirements in the industrial and defence sectors keeping in mind the ratios and trends in other countries. Although the total demand for control components has been estimated at only Rs. 30 crores during the Fifth Plan period, in view of the strategic importance, attainment of self-reliance in these would be a much higher priority than would be warranted by mere considerations of volume of requirements, economics of production or savings of foreign exchange.

2.4.8.4. Production Plans and Investment

Table 2.18 gives the production and investment profiles for industrial electronics, control equipment and components for the Fifth Plan. Table 2.19 gives the details of the production plans and promotional activities planned during this period. For launching the right kind of automation in India, it is proposed to start an organised effort during the Fifth Plan period by establishing a National Automation Promotion Centre.

The bulk of primary materials required for the control component production will have to be imported. However, the requisite skills for design and

II

development of these components exist in the country. In order to attain the projected targets, the existing R&D groups have to be augmented.

For meeting 75 per cent of the total demand for components, existing units will have to be expanded and some new units will have to be started during the Fifth Plan. The minimum level of investment for an individual unit may vary from Rs. 0.5 to Rs. 2.0 crores. It follows that the total planned investment of Rs. 9.5 crores for components will have to be divided in an appropriate manner between existing and new units.

Table 2.18. Ten year profile for control components and equipment.
(In Rs. crores)

	1974-75	1975-76	1976-77	1977-78	1978-79	1984-85	Total
Investment							
1. Control components	1.1	2.2	2.2	2.2	1.8	3.0	29.5
2. Control equipment	1.5	2.5	2.5	2.2	1.8	6.0	35.5
Total	2.6	4.7	4.7	4.4	3.6	9.0	65.0
Production							
1. Control components	2.5	3.0	4.5	8.0	12.0	23.0	110.0
2. Control equipment	8.0	10.0	12.0	15.0	20.0	45.0	245.0
Total	10.5	13.0	16.5	23.0	32.0	68.0	355.0

Table 2.19. Production programmes planned during Fifth Plan.

Project	Total capital investment	FE content of capital investment	Production	
			Plan period	Terminal year
1. National Automation Promotion Centre	1.8	—	—	—
2. High volume production of control equipment	4.1	1.8	35.0	10.0
3. Custom manufacture of control equipment	4.6	2.8	30.0	10.0

II

2.4.8.5. Sixth Plan Profile

The total demand of industrial electronics and control equipment during Sixth Plan is expected to reach Rs. 200 crores. At the beginning of the Sixth Plan, as a result of substantial investment in Fifth Plan, the industry would have established a viable base. This infrastructure will be able to produce industrial electronics and control equipment worth Rs. 35 crores annually. The total production of these equipment during Sixth Plan could be placed around Rs. 180 crores. The total investment required for this production would be about Rs. 25 crores. About 10 per cent direct import will be inevitable.

The total demand of control components during Sixth Plan is expected to be around Rs. 100 crores. This demand would be a consequence of the growing trend of introducing more and more automated process in almost all sectors of the industry. The percentage investments on instrumentation and control systems of the investment on new plants will increase from the present levels in most of the process industries.

At the beginning of the Sixth Plan, as a result of substantial investment in Fifth Plan, the control components industry would have established itself fairly well. The then available base will be able to produce components worth Rs. 15 to 20 crores annually. The total production during the Plan period could be conjectured as Rs. 70 to 80 crores.

During Sixth Plan period, the low-priced minicomputers are expected to invade many process industries. By the end of the Plan, the country might witness the introduction of direct digital control in some industries. In short, the trend of going digital will grow during this period. Since analog-to-digital conversion is a difficult, inaccurate and costly process, analog components will be progressively replaced by digital ones. New units will be needed to establish development and commercial production of digital transducers.

The total investment during the Plan period is expected to be around Rs. 20 crores, 50 per cent of this would be in FE. New materials will be required to extend environmental limits, improve reliability and life, and reduce costs. A major share of R&D would be required for this activity. Minimum expenditure on technology development needed would be around Rs. 7 crores.

2.4.9. Medical Electronics

The existing base for production of medical electronics equipment comprises mainly of small and medium scale manufacturers except for ECIL and Philips India Limited. Diagnostic and therapeutic X-ray equipment is being manufactured by three major firms. There are around 50 companies involved in the manufacture of medical electronics equipment.

Nearly 50 per cent of the total medical electronics equipment production is X-ray equipment. The rest of the equipment can be classified under three categories: equipment for cardiology, instrumentation for psychiatry and analytical instruments. Electrocardiography, pacemakers and defibrillators, intensive cardiac care units, electroencephalographs, electroconvulsive therapy units, audiometer, stimulator, hearing aids, pH meter, colorimeter, centrifuge, flame photometer, etc., are some of the equipment currently manufactured and marketed. Although a variety of equipment is being currently manufactured, the quantum of equipment manufactured is well below the demand. The production of medical electronic equipment for the year 1973-74 was Rs. 4.0 crores. This corresponds to roughly 2.2 per cent of the total electronics equipment of Rs. 187 crores manufactured in the country in that year.

Fifth Five Year Plan Projects

Units for Manufacturing High Volume, Low and Medium Cost Medical Electronic Equipment:

High volume (including X-ray) medical electronic equipment, like ECG, respirator, colorimeter, defibrillator, pacemakers, stimulators, etc., are needed to the extent of Rs. 45 crores in the Fifth Plan. The existing infrastructure may not be able to meet the demand. Hence the demand can only be met by expansion of existing units and by setting up new units during the Fifth Plan. The Ministry of Health had proposed to introduce medical electronics equipment in district, taluk and primary health centres to the extent of Rs. 25 crores.

Units for the Manufacture of Low Volume, High Cost Medical Electronic Equipment:

Equipment such as patient monitoring systems, intensive and cardiac care units, bed-side monitors, electronystagmograph polygraphs, etc., are needed for urban areas. The demand is estimated around Rs. 12 crores for the Fifth Plan. Manufacture of these systems and sub-systems need high capital investment in in-house R&D units. An investment of the order of Rs. 2.2 crores is estimated to achieve the target.

Units Manufacturing Medical Electronic Equipment for Mobile Health Services :

Since 70 per cent of population is living in villages, the Health Ministry, in the Fifth Plan, wants to promote the medical electronic equipment in rural areas for better health services. Portable intensive care equipment (including, defibrillator, electrocardiograph, respirator and monitor) equipped in a van could be used to render diagnostic and therapeutic facility to rural areas. A unit to manufacture these equipment to the tune of Rs. 3.0 crores is planned. An investment of Rs. 1.5 crores would be required to meet the requirement of Rs. 3 crore worth of equipment.

Table 2.20. Expected requirement of medical electronic equipment by various sectors in Fifth Plan period (1974-1979).

No.	Sector	Amount (Rs. crores)
1.	Health Ministry Hospitals of Central and State Governments, medical colleges, laboratories and research institutions	25
2.	Defence, railways, P&T, Central Government undertaking hospitals	15
3.	Private hospitals, nursing homes and clinics and others	10
Total		50

II

Table 2.21. Sectorial investment for projects proposed for medical electronics during Fifth Five Year Plan. (In Rs. crores).

Project	Total capital investment	Total production 1974-79	Terminal year production 1978-79
1. Units for the manufacture of high volume, low and medium cost medical electronics equipment	3.3	30	10
2. Units for the manufacture of low volume high cost medical electronics equipment	2.2	12	3
3. Units for the manufacture of equipment for mobile health services	1.5	3	1
4. Research and development	1.3	—	—
5. Medical electronics test and maintenance centres	2.2*	—	—
Total	10.5	45	14

*As the test and maintenance centres involve investments of a kind different from those related to production, this investment is not added in the investment production profile Table 2.8.

Medical Electronics Test & Maintenance Centres :

Since, as estimated recently, nearly 60 per cent of the equipment are idle or out of order, a strong back-up facility in the form of test and maintenance centre is essential. Inspection, test and maintenance centres similar to CSIO or CIL centres are proposed to be started in various states in the Fifth Plan. An investment of the order of Rs. 2.2 crores is essential to start such centres.

Research and Development :

Investment in R&D which will ultimately lead to production is estimated to be around Rs. 1.3 crores, during the Plan period.

Sixth Five Year Plan

To sustain the momentum generated in the Fifth Plan for medical electronics area, it is anticipated that there will be host of activities in this area.

Efforts for bettering health services in rural areas, initiated during the Fifth Five Year Plan, are expected to be intensified during the Sixth Plan.

Table 2.22. Sixth Plan profile for medical electronics.

Total production envisaged for Plan period (Rs. crores)	Total capital investment (Rs. crores)
170	19

Table 2.23. A ten year investment-production profile for medical electronics.
(In Rs. crores)

	1974-75	1975-76	1976-77	1977-78	1978-79	Total Fifth Plan	Total Sixth Plan	Total for 1974-85
1. Total production	5.0	6.5	8.5	11.0	14.0	45.0	170	215
2. Total direct capital investment for local production**	1.5	2.0	1.5	1.0	1.0	7.0	12.0	19.0

**As test and maintenance centres and R&D units involve investments of a kind different from direct capital investment for production, these are not included here.

2.4.10. Instruments

Based upon the recommendations of the Task Force VII, the broad field of instruments has been classified into two categories—off-line and on-line instruments. On-line instruments for process control are discussed elsewhere in this report. Off-line instruments comprise of test and measurement, analytical, geoscientific and nuclear instruments. The Task Force, after analysing the present status of the instrument industry, concluded that the trend towards instrumentation, as in the case of electronic production as a whole, is on the increase.

However, at the present production levels, some sophisticated instruments like high frequency oscilloscopes, polarimeters, spectrometers, physical/chemical analysis instruments, photometers, etc., are still being imported. The Task Force recommended a strategy for foreign collaboration and know-how acquisition so as to bring down import to a bare minimum level by the end of Sixth Five Year Plan. In the Fifth Five Year Plan for electronics and telecommunication, the field of instrumentation was divided into two categories :

- (a) High volume, low and medium cost instruments
- (b) Low volume, high cost instruments

The total profile, as well as break-up for high volume and low volume instruments, for the Fifth Plan period is given in Table 2.24.

At present, there are approximately 200 manufacturers of instruments in India. In the area of high volume, low and medium cost instruments, private sector has contributed to a great extent. Public sector organisations have been engaged in more sophisticated instruments while highly sophisticated instruments are still being imported. The Task Force has emphasised that existing manufacturers are in a position to meet local demand and, thus, should be encouraged to meet this demand. In addition, new units should be established to take up development work along with production.

Considering the urgent need for achieving self-reliance in the field of instruments (test, measurement, geoscientific and nuclear), the programmes initiated during the Fifth Plan period would be further strengthened to cut down the import of low volume, high cost as well as high volume, low and medium cost instruments. The new units that will be set up during Fifth Plan are expected to undertake development work alongwith production to help the local instruments

II

industry in achieving self-reliance. The Task Force has realised the difficulties that hinder progress in this field and has made recommendation to streamline coordination between R&D units and industry. The Task Force has stressed the need for standardisation in this area of the electronics industry.

The total investment for Sixth Five Year Plan is expected to be Rs. 25 crores with production going upto Rs. 351 crores, thus giving a production to investment ratio of 14 as compared to 11.4 envisaged for Fifth Plan.

Table 2.24. Investment pattern for instruments for Fifth Five Year Plan (in Rs. crores).

	Total capital investment	FE content of capital investment	Raw materials and component import		Production	
			Plan period	Terminal year	Plan period	Terminal year
High volume, low and medium cost instruments	9.5	4.2	8.4	1.0	119	36.5
Low volume, high cost instruments	4.1	2.0	4.8	0.8	36	9.8
Grand total	13.6	6.2	13.2	1.8	155	46.3

Table 2.25. Phased investment and production pattern for instruments for Fifth Five Year Plan (in Rs. crores).

	1974-75	1975-76	1976-77	1977-78	1978-79	Total
Investment	1.9	3.4	3.4	2.7	2.2	13.6
Production	19.0	22.8	28.5	38.4	46.3	155.0

2.4.11. Electronic Components

The electronic component industry in india started in the early fifties with about two small scale industries producing some resistors and capacitors. By 1955 some radio manufacturers had started making a few components like paper capacitors, band change switches, IF transformers, etc., essentially for their own use. The production of active components was initiated when BEL. started the production of receiving valves in 1961. The present status of the component industry may be seen from Table 2.26 which gives the production of components for the years 1971-72 to 1973-74.

Table 2.26. Production of electronic components during the years 1971-72 to 1973-74 (in Rs. crores)

Components	1971-72	1972-73	1973-74
Electron tubes	3.4	4.8	5.2
Semiconductor devices	7.4	7.5	10.1
Passive components	16.8	17.2	21.1
Resistors	1.8	2.0	2.8
Capacitors	5.5	5.6	6.3
Others	9.5	9.6	12.0
Electrical and mechanical components	13.4	14.5	18.6
Connectors, relays and switches	3.5	5.0	8.3
Others	9.9	9.5	10.3
Total	41.0	44.0	55.0

Electron Tubes : As regards electron tubes, BEL is the only major manufacturing organisation in the country. Having started with receiving tubes, it now produces many other types of tubes, viz., transmitting tubes, TV and CR tubes, magnetrons, X-ray tubes and digital display tubes. Efforts are now being put in to produce high power magnetrons, power klystrons, TV camera tubes and gas lasers.

Semiconductor Devices : The production of semiconductor devices in India was started in 1962 by Semiconductors Limited, Poona. Today, there are few other concerns, including Bharat Electronics Ltd., Continental Devices (India) Limited and Electronics Corporation of India Limited, producing semiconductor devices. Most of the production today is of Ge and Si discrete devices; the production in 1971 being about 16 million and 18 million number of Ge and Si devices, respectively. In the area of integrated circuits, BEL has, only recently, started the production of TTL integrated circuits with indigenous know-how and will be starting the production of CMOS integrated circuits with RCA know-how. A few other firms are being licensed to produce integrated circuits.

Passive Components : The production of passive components in the country has been keeping pace with the growth of consumer electronics and has reached a stage where it is possible to not only meet the domestic demand of consumer grade components but also export them. The production of professional grade components is, however, lagging behind and efforts are being put in to meet all the professional grade components requirements from indigenous sources. There are about 40 firms, both in organised and small scale sectors, producing resistors of almost all types and about 70 firms producing various types of capacitors. Regarding other

passive components that include crystals, transducers, magnetic components, etc., many of them are being produced in the country though there are certain items like magnetic tapes, TV deflection components, where production is just being established.

The commercial production of microwave passive components like couplers, attenuators, terminations, bends, etc., is yet to be established. However, in-plant manufacture of some of these exists in some telecommunication equipment manufacturing units and significant development work is in progress.

Electrical and Mechanical Components : This class of components includes components like connectors, relays, switches, printed circuit boards, etc. The connector industry in the country is just coming up. There are about a dozen firms, nearly all of them in the private sector, producing various types of connectors. Relays are being produced in a fairly wide range in the country by over 10 firms. About three firms are already licensed to produce reed relays. Switches are being produced in the country by over 25 manufacturers. Most of the production of printed circuit boards is meant for captive use and some independent units are also producing such boards. The production base for DC micromotors is also being established in the country.

2.4.11.1. Demand Forecast for Fifth Plan

The estimated demand for electronic components during the Fifth Five Year Plan is given in Table 2.27. This demand also includes the requirements for defence electronics. The total requirement of components will increase by nearly two and half times during the Plan period. The electron tubes demand is expected to increase from Rs. 14 crores to about Rs. 26 crores, semiconductor devices requirements is expected to go up from Rs. 12.5 crores to Rs. 40 crores, the passive components demand is expected to grow from Rs. 45 crores to Rs. 111 crores and electrical and mechanical components demand is expected to grow from Rs. 27 crores to Rs. 63 crores by the end of the Fifth Five Year Plan. The maximum increase of three fold in demand is registered by semiconductor devices. This is because of the increasing use of integrated circuits in various electronic products. The demand of integrated circuits is expected to increase almost five fold during the Plan period. The total demand for components will be around Rs. 240 crores by the end of Fifth Five Year Plan. It must be noted that this profile does not consider the export requirements.

2.4.11.2. Production Plan for Fifth Plan

As against the total demand of Rs. 240 crores for electronic components, the total production by 1978-79 is planned to be of the order of Rs. 200 crores. This will be able to meet 85 per cent of the total demand of components.

The annual production for electron tubes worth about Rs. 20 crores is planned for the terminal year of the Fifth Plan, as against the demand of nearly Rs. 26 crores. The existing production base will be strengthened by suitably augmenting facilities to achieve the Plan targets. The production of special tubes like photo tubes, high power rectifiers etc., will be taken up during this Plan. For producing special electron tubes, which have strategic importance and are extremely costly, a separate new organisation is being planned with a total investment of about Rs. 2.1 crores.

During the Fifth Five Year Plan, demand for semiconductor devices is expected to increase three fold. An annual production of semiconductor devices worth about Rs. 35 crores is planned for the terminal year of the Plan. The production of discrete semiconductor devices will be achieved mostly by fully utilising the existing capacity of the industry. Some existing manufacturers will also start producing integrated circuits. In the area of MOS technology, a major step is being

II

Table 2.27. Demand projection for electronic components during the Fifth Plan.
(in Rs. crores).

Components	1974-75	1975-76	1976-77	1977-78	1978-79
Electron tubes, total	14.0	16.9	20.0	23.2	26.4
Receiving tubes	3.0	3.5	4.2	4.8	5.5
Other tubes	11.0	13.4	15.8	18.4	20.9
Semiconductor devices, total	12.5	17.0	22.0	30.0	40.0
Discrete devices	10.7	14.2	17.2	20.5	25.3
Integrated circuits	1.8	2.8	4.8	9.5	14.7
Passive components, total	45.3	56.7	71.5	90.5	110.8
Resistors	3.6	4.6	5.8	7.3	8.8
Capacitors	9.7	12.1	15.2	18.7	22.0
Others	32.0	40.0	50.5	64.5	80.0
Electrical and mechanical components, total	26.9	33.4	41.4	51.1	62.5
Connectors, relays and switches	14.9	18.4	22.4	27.1	32.5
Others	12.0	15.0	19.0	24.0	30.0
Total (rounded)	99	124	155	195	240

taken by way of setting up a Semiconductor Production and Research Corporation in the public sector. Besides producing MOS LSI for calculators, computers and other applications, the Corporation is expected to produce bipolar LSI devices at a later date. The Corporation is also likely to undertake the production of GaAs based devices. In the area of hybrid microcircuits, BEL is fairly well equipped to undertake the production of some of the circuits. BEL proposes to produce active filters for multi-channel carrier system in the near future.

The passive and electro-mechanical components industry has an established base and almost all types of components are being produced in the country. The total production envisaged in the terminal year of the Plan is around Rs. 145 crores. During the Plan period, considerable efforts will be necessary both in terms of improving the quality of existing components manufactured in the country and to step up the production to meet Plan targets. Presently, bulk of professional grade components are imported by defence and other users and therefore emphasis will be on producing defence and industrial grade components to reduce import bill and achieve self-reliance. In the area of electro-mechanical components like connectors, relays, and switches, the production base will be widened to meet the diversified demand. The major production activity is in private sector; public sector participation is very small in this area. Public sector activities will mainly concentrate on producing high quality components. During the Plan period a good base for microwave components is expected to be established.

2.4.11.3. Investments for Fifth Plan

The total investment on components during Fifth Five Year Plan was estimated to be around Rs. 33 crores as given in Table 2.28.

Table 2.28. Investment on electronic components during Fifth Five Year Plan (in Rs. crores).

Electron tube	5.6
Semiconductors	9.6
Passive and electro-mechanical components*	17.6
Total	32.8

*Including the investment of Rs. 7.1 crores for the production of microwave components and instruments during the Plan period.

Out of the total investment of Rs. 5.6 crores for producing electron tubes, nearly Rs. 2.1 crores will be invested in producing special electron tubes. The total investment in producing semiconductor devices was initially estimated to be around Rs. 9.6 crores. However, this has been revised to Rs. 18.5 crores subsequently. Bulk of this amount will be invested in starting the production of special integrated circuits. Even though passive and electromechanical components make major share of the components, the fresh investment required for them will be relatively modest and will be around Rs. 10.5 crores. This is due to the fact that a well established infrastructure already exists in the country. Most of the investment will be in importing special types of machines. For the production of microwave components and instruments, an investment of Rs. 7.1 crores has been envisaged during the Plan period.

2.4.11.4. Sixth Five Year Plan Profile

Due to rapid and revolutionary changes in technology, the newer types of components may dominate over the older types. However, it is expected that the overall demand of components will continue with same ratio with respect to equipment profile. The impact of integrated circuits will be substantially felt during this period and consequently the demand for certain types of tubes and passive components like resistors and capacitors will decline. A detailed profile taking all the techno-economic aspects into consideration is being worked out. It is estimated that the demand for electronic components, total production and the total investment during the Sixth Five Year Plan will be as follows :

Total demand for components	: Rs. 1650 crores
Total production of components	: Rs. 1400 crores
Total investment	: Rs. 125 crores

2.4.12. Materials

As the quality and reliability of a device depend upon the quality of the materials which go into making it, electronic materials have become an integral part of the electronics industry. Various metals and alloys, ultra-pure materials,

chemicals and plastics and glasses, ceramics and other insulators are required by the industry.

Although the importance of the availability of raw materials for the growth of the electronics industry has been stressed now and then, the development and production in this area is not very significant. As against the estimated requirement of about Rs. 16 crores worth of materials for the year 1973-74, the estimated production of the raw materials would be around Rs. 7 crores only. The major areas in which successful production has been started are low grade chemicals, some phenolic moulding compounds, some plating chemicals, etc., where purity and quality control conditions are not stringent. While some development/production efforts are being started in the areas like electronic grade chemicals, semiconductor materials, epoxies, OFHC copper, etc., the imports are still being continued.

Table 2.29 gives the demand, production and investment as envisaged during the Fifth Five Year Plan. The Table also gives similar figures for the Sixth Plan. It should be noted here that these demand and production figures are only rough estimates as they will very much depend upon the trend in component industry as well as future development and production plans for materials industry as a whole. This is especially true for the estimates for the Sixth Plan.

Table 2.29. Fifth and Sixth Plan profile for materials.
(in Rs. crores)

	Fifth Plan	Sixth Plan
Demand	200	500
Production	125	385
Investment	17.3	37.0

2.4.13. General Facilities

For rapid growth of electronics industry, it is essential to have certain general facilities to provide a special kind of infrastructure in the country.

Some examples of such facilities are :

- (i) facilities for bridging information gaps to increase international trade;
- (ii) centralised facilities for testing; and
- (iii) facility for producing specific kinds of capital equipment needed for the electronics industry.

At present there is one major test centre, CIL, Bangalore and smaller centres at NPL, BARC and NTH. However, these centres do not have all the facilities required for environmental and reliability evaluation and hence do not cater to the above needs.

The total investment in the electronics industry during the Fifth Plan has been assumed to be Rs. 202 crores. For effective utilisation of these funds to achieve the Plan targets the following facilities will be needed during the Fifth Plan.

- (a) Standardisation facilities
- (b) Units for custom production of capital equipment
- (c) Test and development facilities for small scale manufacturers

The investment profile for these projects is given in Table 2.30.

So as to cater to the needs of the industry, it is necessary to have the facilities in full operation as early as possible. For that purpose a major portion of the investment should be made during initial periods of the Plan.

As the size and sophistication of the electronics industry increase, it is anticipated that more elaborate and larger number of general facilities will be needed.

Based on the Sixth Plan investment and production profiles for the entire electronics industry, it is estimated that an investment of the order of Rs. 20 crores will be needed for general facilities.

Table 2.30. Investment for general facilities during the Fifth Plan period (in Rs. crores).

Project	Investment
1. Standardisation activity	3
2. Units for custom manufacture of capital equipment	2
3. Electronics test and development facilities for small scale manufacture	3
4. Electronics Trade and Technology Development Corporation	2
Total	10

III

Mass Communication

3.1 Introduction

The role of mass communication in the modern world, particularly in the developing countries, is well recognised. Among the media of mass communication, radio and television are perhaps the most powerful, reaching, as they do, large audiences with the spoken word and the visual image.

Even though this view has had wide acceptance, the growth of sound and television broadcasting in India has not been as rapid as it should have been owing to lack of resources. The Indian Space Research Organisation (ISRO), has carried out various system studies for providing television in rural areas using satellite broadcasting techniques.

The area of mass communication is divided in this chapter into two sections viz., the ground segment and the space segment, the former corresponding to the terrestrial systems of sound and television broadcasting coming under the jurisdiction of Information and Broadcasting Ministry and the latter corresponding to the SITE and the other programmes of ISRO, which come under the jurisdiction of the Department of Space.

A. Ground Segment

3.2 Current Status

3.2.1. Broadcast Coverage

At the time of independence there were only six radio stations covering a population of about 33 millions. By 1951, the country had 25 radio stations which provided a coverage of 20 per cent of the population. Development of broadcasting from 1951 onwards has been forming part of the Five Year Plans of the country. The primary accent upto the Fourth Five Year Plan has been on extending the internal service on medium wave. The installation of super power transmitters at Calcutta and Rajkot, two 250 kW shortwave transmitters at Aligarh, introduction of Vividh Bharati service on low power transmitters for urban areas, provision of additional permanent studios at a number of centres, installation of transmitters specially meant for border coverage, conversion of auxiliary centres into programme originating centres, the setting up of TV stations at a number of places are some of the important features of the planned development so far. The growth of the AIR network and the coverage obtained during these plans are indicated in Table 3.1.

Television made a rather delayed beginning in the country. Even though an experimental TV centre was set up in 1959, the progress in the initial stages was rather slow. At present there are TV mother/relay centres at Delhi, Bombay, Poona, Amritsar and Srinagar. Work on the establishment of such centres at Lucknow, Kanpur, Calcutta, Kharagpur, Midnapur Asansol, Madras, Jullundur, Kasauli and Mussoorie is on hand. When these projects are completed the coverage would be about 16.8 per cent by population.

Table 3.1. Growth of All India Radio network since independence.

	No. of broadcast centres	No. of transmitters			Total radiated power MW (in kw)	Total radiated power SW (in kw)	Primary coverage per cent area	Broadcast in MW per cent population
		MW	SW	Total				
1. At the beginning of the First Five Year Plan (1-4-51)	25	29	17	46	109	312	12	20
2. At the end of the First Five Year Plan (31-3-56)	26	29	17	46	427	314	31	46
3. At the end of Second Five Year Plan (31-3-61)	30	33	26	59	660	715	37	55
4. At the end of Third Five Year Plan (31-3-66)	54	82	28	110	1070	920	52	70
5. Fourth Five Year Plan target	69*	122	34	156	5350	2150	82	90

*This figure is as of December 1972.

3.2.2. Production of Hardware

The High Power Equipment Division of BEL, Bangalore has been manufacturing HF communication equipment and broadcast equipment including studio and transmitter equipment both for sound and television broadcasting.

Equipment currently under production at BEL, both of BEL design and of foreign collaborator's design are listed below.

BEL design

- (i) Console tape recorder
- (ii) Heavy duty tape deck
- (iii) Preamplifiers, power units, etc.
- (iv) Programme amplifier
- (v) Monitoring amplifier
- (vi) Equalised line amplifier

Foreign collaborator's design

- (vii) 1 kW, 10 kW, 100 kW MW broadcast transmitters
- (viii) 10 kW TV transmitter
- (ix) TV studio equipment like image orthicon, vidicon, camera, switching equipment

Equipment proposed to be added in the production range includes the following:

- (i) Portable tape recorders
- (ii) Switching and announcer consoles
- (iii) Certain items of TV studio equipment required for specific system setups
- (iv) FM transmitters
- (v) OB Vans
- (vi) Paralleling equipment

The production figures for broadcast equipment according to BEL sources for 1972-73 and 1973-74 are Rs. 3.76 and 1.87 crores, respectively. The latter figure does not include TV studio equipment. The production of broadcast equipment for the calendar year 1974 is around Rs. 3 crores. An investment of Rs. 8 lakhs in 1972-73 (mainly for capital expenditure for TV broadcast equipment manufacture) was envisaged towards replacement/modernisation/augmentation of capital items. Marginal investment of the order of Rs. 5 lakhs per annum has been envisaged for updating production facilities and for renewal and replacements.

AIR has produced a few low power FM transmitters for utilisation in its network as studio transmitter links. AIR has developed the know-how for several items including distortion and noise level meter and the AM monitor and transferred it to ECIL for commercial exploitation. Also, AIR has acquired over the years transmitters from different sources that use various types of transmitting valves. While it has been possible to make indigenous substitution for a considerable proportion of these valves, some high power valves continue to be imported involving large FE expenditure.

Many of the test and measuring instruments like CROs, VTVMs, low distortion oscillators, modulation monitors, etc., and non-electronic ancillaries like antenna towers, cables, etc., required in this area are available from indigenous sources.

3.2.3. Research and Development

In 1970, BEL set up a separate group for undertaking development of equipment required by AIR. Since then the development of modern fully transistorised professional quality audio tape recorders and playback consoles has been completed and the same has been produced and supplied to AIR. BEL has also completed development of broadcast studio consoles and announcer consoles and a family of high quality solid state audio amplifiers. BEL is now engaged in developing portable tape recorders, professional quality turn tables, limiting amplifiers, a new generation of equalised line amplifiers and remote consoles.

Though the broadcast transmitters and TV equipment are being made under licence, in view of the very substantial gaps in the know-how received, generation of know-how through development for maximising the indigenous content of such equipment was necessary. Modulation transformers, modulation chokes, combining units, audio switchers, video switchers, TV studio sound consoles, video demodulators, aural demodulators, vestigial sideband filters, etc., are examples of such equipment taken up for development for maximising indigenous content.

At present AIR is engaged in the development of items such as low power TV translators and transmitters.

3.3 Technological Trends

3.3.1. Sound Broadcasting

The development of transmitters has been towards compactness and higher efficiency. The overall efficiency of modern transmitters is well above 80 per cent and is expected to improve still further.

The ever increasing powers of transmitters has been adding pressures on the available frequency spectrum especially in the MF band. Reduction in channel spacing and protection ratios, operation of synchronous transmit-

ters, using different network of transmitters during day and night times are some of the solutions considered.

A few other technological trends are the increasing use of trepezoidal modulation, specially in the case of short wave transmitters, steerable and rotatable log periodic antennae, use of separate aerials for day time and sectionalised medium wave vertical aerials so as to reduce night time interference in the MF band, improvement in the design of aerials with a low standing wave ratio and large power handling capacity. Aluminium and galvanised iron could replace copper for fabrication of feeder lines in the future. Other trends in sound broadcasting are: (i) use of solid state devices for frequencies below 1 GHz except in high power sound and TV transmitters which will continue to have vacuum tubes in the output stages and (ii) fully automatic, unattended transmitters with remote control systems.

3.3.2. Television

In India, though there are no plans to introduce colour television in the near future, comparative studies on different colour TV systems will be carried out and standards to be adopted for colour TV as and when it is to be introduced would be finalised.

Among the future trends are: (i) portable colour cameras without interconnecting cables, (ii) stereophonic TV, (iii) increased use of community antenna TV system, (iv) portable 1/4 inch video cassette recorders with portable colour cameras, (v) "sound in synch" system for optimal channel utilisation, (vi) introduction of digital systems right from the camera tube to the transmitters, (vii) use of light sensitive and light emitting semiconductor devices in the TV camera tube and the TV picture tube respectively, (viii) systems using liquid crystal displays, light valves and laser beam scanning for large scale TV projection, and (ix) resolution of the problem of "standards conversion" which is the main hurdle for international exchange of TV programmes.

3.4 Demand Profile

With the completion of the Fourth Plan schemes the MW coverage of the country will be 82 per cent by area and 90 per cent by population. It looks reasonable to expect 100 per cent coverage in the not too distant future. This could be achieved by setting up new transmitters, enhancement of the power of the existing transmitters and providing relay transmitters at remote locations.

Introduction of FM service could relieve the congestion in the MW band and the FM service could eventually be extended to stereophonic broadcast.

Resources in terms of power and the number of transmitters could be made available to external services so that India is not outpaced by the other countries in this important area.

3.4.1. AIR Fifth Plan Schemes

The revised shelf of projects for the Fifth Plan of All India Radio envisages an outlay of Rs. 57 crores on sound broadcasting and Rs. 75 crores on television, thus bringing the overall total to Rs. 132 crores. These figures do not include the spill over from the Fourth Plan of approximately Rs. 37 crores which is now envisaged. At the same time it is likely that an equal amount may spill over into the Sixth Plan period.

The proposals put forward under sound broadcasting come under the following categories:

- (i) Enhancement of existing transmitter powers to 2 x 100 kW at five centres.
- (ii) Setting up of new medium/low power transmitters with studio facilities at five centres and only low power transmitters at nine centres.

At the present stage in the development of broadcasting, what is urgently required is the rationalisation of available channels to meet the needs of the people. It is proposed to rationalise the channel structure by providing two channels at each station. The primary channel will be used for disseminating programmes in the regional language of the widest appeal and of use to the mass audience. The second channel at each station will be utilised to provide sophisticated programmes for urban audiences.

Coverage on the alternate channels can be effectively extended only by setting up FM broadcasting stations which operate in the VHF band. In view of the similarity of technology, development of FM will be carried out in step with development of TV. The proposals cover FM channel at 4 centres.

Improvement is also proposed to be effected by upgrading the existing internal shortwave services. The proposals for the Fifth Plan include installation of two 50/100 kW shortwave transmitters at Jaipur and Srinagar. Improvement is effected in studio facilities at certain centres where existing facilities are found inadequate and remaining auxiliary centres are to be converted to full-fledged stations.

Television programme production centres have been planned at Hyderabad, Patna and Cuttack. In the augmentation of Fourth Plan Schemes additional studios are to be provided at Bombay, Poona and Srinagar. TV centres and one TV studio complex is planned at Mandi House.

3.4.2. Task Force Recommendations

The Working Group on Mass Communication set up by Task Force VII has made the following observations.

The coverage figures provided by AIR in terms of area and population take into account coverage only in a technical sense i.e., overall availability of medium wave reception of at least one programme service. There is a positive need for setting up additional channels for meeting the special needs of the various sections of the community through school broadcasts, rural broadcasts, farm broadcasts, etc. A certain measure of rationalisation and augmentation of the existing broadcasting system would also be necessary to take into account the linguistic, cultural and social needs of the specific groups addressed. There is thus considerable scope for further growth in broadcasting.

In order that the full benefits of the transmission system are derived, it would be necessary to increase the number of receivers available with the public. The UNESCO has recommended that an optimum figure for receivers would be one for every five persons. The existing radio receiver licences (of around 13 millions) would suggest that the receiver industry will have to grow many fold to achieve this target as at present only one receiver is available for every thirty five persons in the area served by the medium wave network of All India Radio.

With regard to projections beyond 1979, it may be appropriate to assume that in so far as television is concerned, the projects included in the original ten year perspective plan of AIR which cannot be taken up during the Fifth

III

Plan period would form the core of television development during the Sixth Plan. A beginning may also be made in the later years of introduction of colour TV at least on an experimental basis. There would be a possibility of TV transmission in the UHF bands.

In the field of sound broadcasting, development would mainly be directed towards: (i) filling up of remnant coverage gaps by setting up low power medium wave transmitters, (ii) provision of alternate programme channels by synchronous operation, of medium wave transmitters, (iii) intensive usage of FM or utilisation of the satellite, if established by then, and (iv) introduction of stereophony on a large scale.

3.4.3. Planning Commission Recommendations

While the original AIR shelf of projects and the report of the Task Force VII have outlined the desirable and relevant targets for nearly complete coverage (above 95 per cent) in sound broadcasting and a substantial coverage on TV broadcasting during the Fifth Plan, due to scarcity of resources the Plan outlay has been pruned by the Planning Commission. The revised outlay for the Fifth Plan is tentatively fixed to the tune of only about 30 per cent of that proposed earlier.

3.4.4. Some Factors Relevant to Long Range Planning

Introduction of FM transmission will release MW frequencies now utilised for high power transmitters. Also the FM transmission has the characteristic of high fidelity and is capable of eventual conversion to the stereophonic transmission by the incorporation of a few additional modules.

With the acceptance, in principle, of the ultimate goal of achieving 100 per cent MW coverage the objective of at least 92.5 per cent coverage by the end of the Fifth Plan appears very reasonable. The task of increasing effective population coverage by lowering the prices of AM receivers could complement the efforts at the transmitting end and as such should be followed with equal zeal.

The short term and long term plans for the expansion of the external services of AIR give top priority for broadcast to neighbouring countries such as Pakistan, Bangladesh, Burma, Sri Lanka, Nepal, Bhutan, the Arab world, countries of South East Asia and China. Unless adequate resources are provided, the external services programme would be severely handicapped.

The impact of television as the most powerful medium for mass communication has been well recognised. Having accepted television as the most effective medium for mass education and entertainment and having set the pace for television industry in the country, vigorous efforts for increased coverage would be most desirable. While cost considerations and limitations of resources may impose some restrictions, every effort for increased TV coverage would go a long way in the social upliftment of the masses in the country.

What appear to be of relevance in the area of mass communication are the ultimate requirements. The planning should therefore bear in view the long range requirements.

3.4.5. Long Range and Fifth Plan Hardware Requirements

The Task Force VII has made a detailed analysis of the hardware requirements for the Fifth Plan period based on AIR's original shelf of projects and its original ten year perspective plan for TV. However, in view of

III

the pruning by the Planning Commission of AIR's Fifth Plan to the tune of 30 per cent of the original plan outlay, and considering the needs of the country, it appears reasonable to suggest that at least the hardware requirements as projected by the Task Force should be met in the long range.

The list of hardware requirements for the Fifth Plan is given in Table 3.2. The list of items required has been divided into the following categories:

- (i) items already under production (List A),
- (ii) items currently under development (List B),
- (iii) items for which indigenous know-how is not available (List C), and
- (iv) nonelectronic ancillary items (List D).

As regards FE content, even for items for which production facility already exists and which are under production, foreign exchange is involved in the import of raw materials and components required for production. In the case of items for which production facility is to be established the FE content shown is based on complete import (FE content estimated is only approximate and could vary depending on factors such as indigenous availability, sources of supply, exchange fluctuation, etc.). In the case of items where indigenous production has been established, FE content would be naturally less. The TV equipment items such as camera tube, fixed focus and zoom lenses, special types of tripods and dollies, optical multiplexer equipment, 16 mm and 35 mm projectors, etc., are all required to be imported and account for significant FE drain.

3.5 Proposed Guidelines

3.5.1. Production

Production facilities with regard to items under lists A and B of Table 3.2 already exist at BEL and it appears possible to meet the demands fully. For items under C(i) of Table 3.2, development activities should be initiated without delay. With regard to items under C(ii) of the same table it would be desirable to acquire know-how from abroad. The 500 kW short-wave transmitter would involve a considerable amount of systems engineering activity at the installation site rather than in the equipment production centre. Considering the factors such as power supply requirements for the equipment which would be more easily available at site, employment of certain fabrication operations by an approach of final assembly and testing of the equipment at the installation site, the portion of the equipment to be actually manufactured in the production centre can be significantly reduced. By this technique the additional production facility and investment that may be required may not become significant.

3.5.2. Research and Development

In respect of items in list A of Table 3.2, R&D activity will primarily have to be concerned with (i) increase in indigenisation and (ii) updating of technology, where necessary. With regard to items in list B, the development programme should take into account the indigenous availability of components. Items should be standardised and the pace of development should be accelerated by intensive efforts especially in cases where the requirement is large. These points are also applicable to items under C(i) and C(ii). In respect of items under C(iii), development would involve considerable effort and expenditure. Each item should be considered on its merits

Table 3.2. Projection of hardware requirements during Fifth Plan.

List A—Items already under production

Item	Production availability	Estimated requirement	Estimated unit (in Rs. lakhs)		Total cost (in Rs. lakhs)	Total FE content (in Rs. lakhs)
			Total	FE content		
1. 100 kW MW transmitter (capable of parallel operation)	Manufactured at Bharat Electronics Ltd.	10	20.00	8.00	200.00	80.00
2. 10 kW MW transmitter (capable of parallel operation)		2	4.08	1.60	8.16	3.20
3. Aerial tuning unit of 20 kW rating		1	0.50	0.08	0.50	0.08
4. Combining unit (with dummy load) for 2 x 10 kW Tx.		1	1.00	0.45	1.00	0.45
5. 1 kW MW transmitter		5	1.50	0.30	7.50	1.50
6. ATU of 1 kW rating		5	0.20	0.04	1.00	0.20
7. MW Synthesisers		10	0.50	0.15	5.00	1.50
8. Preamplifiers		206	0.02	—	4.12	—
9. Programme amplifiers		116	0.02	—	2.32	—
10. Power supply unit for preamplifiers and program amplifiers		82	0.02	—	1.64	—
11. Monitoring amplifiers		198	0.03	—	5.94	—
12. Switching consoles		42	0.12	—	5.04	—
13. Announcer consoles		86	0.25	—	21.50	—
14. Console tape recorders		120	0.25	—	30.00	3.00
15. Tape playback consoles		157*	0.20	0.02	31.40	3.14
16. Ultra portable tape recorder		108	0.08	0.05	8.64	5.40
17. Communication receivers		54	0.15	—	8.10	—
18. SSB adaptors		7	0.16	0.05	1.12	0.35
19. 10 kw TV transmitter		12)	42.00	13.00	1260.00	390.00
20. 10 kW TV transmitter (Band III) including input and monitoring equipment		18)				
21. TV antennas (Band I)		6)				
22. TV antennas (Band III)		9)				
23. 3 inch image orthicon camera chains with fixed focus lenses		40	9.00	3.60	360.00	144.00
24. 3 inch image orthicon camera chains with zoom lenses		14	10.15	4.06	192.10	56.84
25. Plumbicon camera chain with zoom lens		6				
26. Telecine chains with optical multiplexers including projectors)		15	22.00	8.80	330.00	132.00

III

27. Slide projectors	15	11.60	4.64	174.00	69.60
28. Video switching and mixing equipment	33	1.40	0.20	46.20	6.60
29. Signalling, I/C and controlling equipment	18	1.87	0.75	33.66	13.50
30. Master switching and video equipment	5	10.35	4.15	51.75	20.75
31. Pulse equipment	6	0.81	0.30	4.86	1.80
32. Pattern generators					
(a) Grid	3	0.38	0.17	1.14	0.51
(b) Test	3	0.10	—	0.30	—
33. Picture monitors	485	0.07	0.03	33.95	14.55
34. Waveform monitors	67	0.56	0.23	37.52	15.41
35. Measuring instruments					
(a) Audio oscillators	13	0.12	—	1.56	—
(b) Distortion and noise level meters	13	0.12	—	1.56	—
(c) Modulation monitors (MW)	15	0.10	—	1.50	—
(d) Oscilloscopes	10	0.20	—	2.00	—
(e) VTVM	15	0.05	—	0.75	—
Total				2829.63	957.78

*Including requirement for TV.

List B—Items currently under development

1. Control consoles for s x 100 kW MW transmitters	Under development at BEL.	5	1.10	0.45	5.50	2.25
2. Combining equipment (including dummy load) for 2 x 100 kW MW transmitters		5	5.00	2.00	25.00	10.00
3. Antenna tuning units for 200 kW operation		5	1.60	0.75	8.00	3.75
4. 3 kW FM transmitters		4	13.00	5.20	52.00	20.80
5. Portable tape recorders		52	0.15	0.02	7.80	1.04
6. Disc Playback consoles		111	0.15	0.05	16.65	5.55
7. TV relay receivers (including aerials)		26	2.50	1.25	65.00	32.50
Total					179.95	75.89

List C—Items for which indigenous know-how is not available

(i) Items for which know-how could be developed indigenously

1. Phasing & branching units for directional antenna systems (200 kW MW operation)		2	3.35	1.34	6.70	2.68
--	--	---	------	------	------	------

III

2. Steerable log periodic HF antennas					
(a) for 250 kW operation	—	—	—	—	—
(b) for 50/100 kW operation	2	3.00	2.00	6.00	4.00
3. (a) antenna change over for 500 kW operation	40	0.65	0.35	26.00	14.00
(b) Beam reversal switches	38	1.00	0.50	38.00	19.00
4. HF dipole panel arrays (G-5) for FM transmitters	4				
5. Aural FM demodulator	4				
6. Limiting amplifiers	23	0.20	—	4.60	—
7. Remote OB amplifiers	40	0.15	—	6.00	—
8. Equalised line amplifiers	98	0.02	—	1.96	—
9. Console tape recorders (Stereo)	—	—	—	—	—
10. Tape playback consoles	—	—	—	—	—
11. Mobile OB vans (for TV)	9	50.00	30.00	450.00	270.00
12. Audio mixers (for TV studio)					
(a) 16 channel	14	3.00	1.86	42.00	26.04
(b) 12 channel	6	2.50	1.40	15.00	8.40
(c) 4 channel	14	0.95	0.38	13.30	5.32
13. 250 W under attended transmitters	18				
Total				609.56	349.44

Development not yet taken up

(ii) Items for which it would be desirable to acquire know-how from abroad

1. 500 kW SW transmitter (including 1 control console and 3 synthesisers for each transmitter and 1 dummy load for every 3 transmitters)	2	225.00	120.00	450.00	240.00
2. 50/100 kW SW transmitter (including 1 control console, 1 dummy load and 3 synthesisers for each transmitter)	2	20.00	9.50	40.00	19.00
3. Broadcast quality microphone	653	0.02	0.01	13.06	6.53
4. Video tape recorders	146	6.00	3.00	876.00	438.00
5. MW field intensity meters	6	0.20	0.10	1.20	0.60
Total				1380.26	704.10

Indigenous production not taken up

III

(iii) Items for which indigenous development/production may not be viable unless additional demands are generated in sectors other than broadcasting

1. Perforated tape recorders (1 master, 2 slaves)	3	2.25	1.10	6.75	3.30
2. Measuring instruments					
(a) for sound broadcasting					
(i) HF field intensity meters	2	1.25	0.65	3.50	1.30
(ii) VHF field intensity meters	4	2.80	1.45	11.20	5.80
(iii) Harmonic measuring instrument	7	1.00	0.50	7.00	3.50
(iv) Impedance bridges MW	6	0.60	0.30	3.60	1.80
(v) Impedance bridges VHF	2	1.00	0.50	2.00	1.00
(vi) Frequency / measuring sets	2	0.40	0.20	0.80	0.40
(b) For television					
(i) Admittance bridges	2	1.00	0.50	2.00	1.00
(ii) VHF/wave meters	—	—	—	—	—
(iii) FS meters	—	—	—	—	—
(iv) Side band analysers	15	0.78	0.39	11.70	5.85
(v) RF sweep generators	15	0.75	0.36	11.25	5.40
(vi) VHF field intensity meters	2	2.80	1.40	5.60	2.80
(vii) Valve characteristic meters	15	0.08	—	1.20	—
(viii) Pulse and bar generators	15	0.35	0.14	5.25	2.10
(ix) Rectangular pulse generators	15	0.26	0.11	3.90	1.65
(x) Sawtooth generators	15	0.32	0.13	4.80	1.95
(xi) Multiburst frequency generators	15	0.21	0.09	3.15	1.35
(xii) Synchronous pulse generators	15	0.23	0.08	3.45	1.20

Development not yet taken up

III

(xiii) Sweep generator/polyscope	2	1.25	0.65	2.50	1.30
(xiv) TV receiver testing unit	15	0.20	—	3.00	—
(xv) Dual trace oscilloscope with sweep delay	15	0.50	—	7.50	—
(xvi) Teleprompters	15	2.05	1.02	30.90	15.30
(xvii) Carrier deviation meter	15	0.40	0.20	6.00	3.00
(xviii) RF attenuator (DC to 150 MHz)	15				
(xix) Balun 75 to 300	15				
(xx) Adjustable band pass Filter (50 Hz to 15 KHz)	15				
(xxi) AM/FM VHF signal generator	2	0.30	—	0.60	—
(xxii) Counter converter for freq. measurements	2	0.50	0.25	1.00	0.50
(xxiii) Microwave test set consisting of calibrated RF signal generator & microwave power meter	1				
(xxiv) Group delay test assembly (25-250 MHz)	15				
(xxv) Insertion signal generator with VIT-inserter for in-service testing	2				
(xxvi) Audio output meter	15	0.02	—	0.30	—
3. Studio/transmitter microwave link (dual set equipment)	15	9.00	4.50	135.00	67.50
4. Carrier offset equipment	15	6.25	3.10	93.75	46.50
5. Video distribution amplifier	44	0.11	0.04	4.84	1.76
Total				372.54	176.20

Development yet not taken up

III

List D—Items which are not electronic but are essential ancillaries to electronic equipment

1. Self radiating MW antenna masts							
(a) 200 kw rating	)	Manufactured	7	9.00	0.75	63.00	5.25
(b) 100 kw rating	)	by Hindustan	—	—	—	—	—
(c) 20 kw rating	)	Brown Bovery	1	4.00	0.50	4.00	0.50
(d) 1 kw rating	)		14	1.50	0.15	21.00	2.10
2. R.F. Cables (RG 17 or equivalent)		Indigenous production has been initiated	2,000 metres	0.50 per km.	—	1.00	—
3. V.H.F. Cable 3½" G-D) for TV and FM broadcasting		Indigenous production/development not yet taken up	7,000 metres	19.00 per km.	11.00 per km. (by total import)	133.00	77.00
4. Self supporting masts							
—30 M	—		2	7.0 lakhs	—	14.0	—
—50 M	—		2	8.5 lakhs	—	17.0	—
70 M	—		2	10.0 lakhs	—	20.0	—
90 M	—		2	12.0 lakhs	—	24.0	—
120 M	—		4	16.0 lakhs	—	64.0	—
140 M	—		4	18.0 lakhs	—	72.0	—
5. 12" & 15" rod insulator		—	4,000 Nos.	0.05 for 100 Nos.	—	2.0	—
Total						435.00	84.85

and strategy for know-how acquisition, etc., should be decided keeping in view the requirement of the electronic industry as a whole.

With regard to the development/production of the major items, the following guidelines may be observed.

(a) High Power and Super Power Shortwave Transmitters: Shortwave broadcast transmitters have not been so far manufactured in the country though shortwave communication transmitters and MW broadcast transmitters are being produced. The development of shortwave transmitters of 50/100 kW and 500 kW power output would call for an intensive development effort and location of sources of supply of special components. The transfer of technology from abroad for both these items as a single package would be preferable.

(b) Video Tape Recorders: The video tape recorder field is in a state of flux. At present there are more than three types of tape recorders commercially available. It would be necessary to effect standardisation before initiating indigenous production. The video tape recorders represent highly sophisticated technology which even advanced countries like Japan are acquiring from others. It is therefore felt that a decision should be taken about the adoption of 1 inch VTRs and production should be established as early as possible on the basis of imported know-how.

- (c) Tube: For the setting up of an extensive television system it would be necessary to take up manufacture of camera tubes as well as tubes for transmitters (as the Indian TV will be using monochrome while most of other countries would have changed to colour). It is considered desirable to opt for a single type of camera tube, image orthicon or plumbicon. The general opinion is favourable for image orthicon (IO) in black and white TV, because of the aesthetic appeal of its picture. Since the Indian broadcast system requirements would be large enough it is considered that the manufacture of IO tubes will be viable in the country. The know-how for this purpose would have to be acquired from abroad. This may also be true about the transmitting tubes which will be needed for the super-power MW transmitters and high power and super power shortwave transmitters.

As an established manufacturer of electronic equipment, development work may have to be initiated by BEL at the earliest for items like phasing and branching units for directional antenna systems, dipole arrays for FM transmitters, FM demodulators, remote amplifiers, stereo tape recorders, television OB van and the like. Development work for steerable log periodic HF antennas and changeover and beam reversal switches, etc., should be considered by All India Radio, which possesses a number of high power transmitter installations, in association with national laboratories, as necessary. AIR will also be the proper agency for development of items which are required in small quantities. In the fields of components and materials detailed lists of items which are presently imported should be made and development possibilities explored by the national laboratories. The Department of Electronics/DGTD could play a significant role in this. There are also a number of non-electronic items which are of importance, like lenses, film projectors, slide projectors, film editing and processing equipment, cine cameras, cine projectors, lighting equipment and lighting control equipment, camera stands, dollies, video tapes, etc. It is necessary to identify the probable agencies for development and production of these items.

Even in respect of items for which it has been suggested that know-how should be acquired from abroad, R&D would have to play a significant role in indigenisation and import substitution. The manufacturing agencies would have to set up strong R&D departments for this purpose.

3.6 Investment

The total hardware requirement as per the Fifth Plan schemes is to the tune of Rs. 58 crores. The existing facilities at BEL, it appears, could take care of about 50 per cent of this value. The investment for the rest of the requirements may amount to about Rs. 5.2 crores with about Rs. 2.6 crores in FE. However, this additional investment will have to be considered taking into account the overall perspective of requirements of various types of equipment required by such other sectors as Police Wireless, Civil Aviation, Border Police, OCS, etc., during the Plan period, availability of capacity in the existing manufacturing units and based on this data, the necessary strategy for determining the additional production facilities that may have to be set up, should be evolved by the Department of Electronics and suitable steps taken. The investment profile would become clear at that stage only.

For the envisaged R&D programme an expenditure of about Rs. 2.7 crores may be necessary.

B. Space Segment

3.7 Current Status

3.7.1. Satellite On-board Systems

A synchronous communication satellite consists of various subsystems, viz., transponders, antennas and feeds, power systems including solar arrays and batteries, attitude control systems to point the whole antenna beam towards a given point on the earth, solar array orientation and power transfer systems, spacecraft propulsion systems for attitude control and orbit position control, thermal control subsystems, telemetry, tracking and command subsystems for operating the spacecraft, and structural subsystem housing all the above with proper harnesses for interconnecting various subsystems.

The INTELSAT series shows progressive and rapid improvements like global beam to spot beam coverage providing higher channel capacity, increasingly accurate antenna pointing systems, both electronically despun and mechanically despun, stabilisation techniques ranging from simpler spinner to dual spin gyrostaf systems, station keeping systems upto $\pm 0.1^\circ$ accuracy and efficient RF subsystems. The INTELSAT V satellite is planned to have three axis stabilisation system, driven solar arrays and narrow spot beams enabling high channel capacity and frequency reuse

Efforts made in the development of large roll-out solar arrays with power levels in kilowatts, large deployable antenna with high gain, solid state and tube type microwave devices with efficiencies of the order of 50 per cent and above at output levels of 20-100 W, and attitude control systems and station keeping systems with accuracies of less than $\pm 0.1^\circ$ have culminated in the realisation of high power satellite for FM-TV broadcast for community viewing. Programmes like Applications Technology Satellite (ATS-F) and Communications Technology Satellite (CTS) will demonstrate the broadcasting concept in UHF, S-band and 12 GHz frequency bands.

Important aspects of space systems technology are surveyed in Table 3.5. The current spacecraft technology especially for synchronous spacecraft has overcome many of the critical problems. INTELSAT IV has been designed with a lifetime goal of 7 years and INTELSAT V and US domestic systems are configured for a maximum lifetime of 7 years.

The first Indian Satellite designed and built by ISRO was launched from USSR on April 19, 1975. The satellite weighs about 360 kg. and measures 1.6 m from end to end. It is placed in a near-circular orbit of 594 kms. altitude and 50.4° inclination and orbits the earth every 96.41 minutes. Besides photovoltaic power supply and housekeeping subsystems the satellite carried experimental packages for X-ray astronomy, solar physics and aeronomy.

The indigenously developed techniques for ARYABHATA on-board systems are: low power telemetry encoders and telecommand decoders, power conditioning systems, reliable VHF command receivers/transmitters and turnstile antennas, certain sensors for temperature monitoring, instrumentation system for the scientific experiments and testing techniques for space quality and reliability.

3.7.2. Ground Based Systems

An operational domestic communication satellite system for India will

III

have the major share of investment in ground system. A ground system of hybrid satellite system to provide television and telecommunications for space communication system would consist of the following:

- (i) TV uplink with stations (five or more rebroadcast transmitters)
- (ii) TV receive only earth stations and rebroadcast transmitters
- (iii) Receive/Transmit earth stations for point-to-point communication
- (iv) Transportable earth stations for remote area and emergency communications
- (v) Program generating facilities
- (vi) Terrestrial microwave links between transmitter/studios and earth stations
- (vii) Augmented direct reception TV sets
- (viii) Power sources in unelectrified villages

India is already using INTELSAT communication satellite for overseas communication. One earth station at Arvi and another at Dehradun being built with Indian engineering expertise will also need modernisation as the technology improves.

The present status of ground subsystems and their projected development are given in Table 3.6.

The salient ground based systems and techniques which are indigenously developed for ARYABHATA are: satellite automatic checkout equipment built around PDP-11 and TDC-12, ground telecommand transmitter and encoders, toneranging, doppler and interferometer equipment, test jigs for checking subsystems, satellite telemetry data display and ground station system management.

3.7.3. Mobile Terminals

Mobile terminals on aircraft and ships pose problems of base motion isolation and orientation control for the receiving antennas. Ship-borne terminals with gyrostabilised platform mounts have been developed for satellite communication. Recently 'Queen Elizabeth II' carried an experimental system to communicate through INTELSAT-IV over the Atlantic. Antennas with hemispherical pattern are proposed to solve similar problems in aircrafts for both navigation and communication related functions.

Fairly extensive studies are contemplated on a national basis on maritime satellite communications and systems in the context of the discussions currently underway for the establishment of an International Maritime Satellite System (INMARSAT).

3.7.4. Digital Communication Techniques and Multiple Access Systems

ISRO and the Ministry of Communications (MOC) are contemplating to conduct experiments in advanced digital communication techniques and systems with multiple access capability in 1977-79 with the Franco-German SYMPHONIE satellite. The equipment for this experiment will be developed indigenously by ISRO and MOC and the entire effort is aimed at eventually developing a Time Division Multiple Access (TDMA) system to Intelsat prototype specifications.

Development of modern high quality data lines to and from the transmitting and receiving centres and remote processing techniques will have to be immediately developed if the satellite channels are to be used for nation-wide data gathering purposes. Also, the systems will be needed for

linking the users to the regional computing centres proposed to be set up by the Electronics Commission.

3.7.5. SITE Programme

The Department of Atomic Energy (DAE) and the United States National Aeronautics and Space Administration (NASA) signed an agreement on 18th September 1969 to conduct a joint experiment for broadcast of instructional TV programmes through a satellite. This is expected to provide a system test of satellite TV broadcast for national development and enhance our capability in the design, development, manufacture, installation, operation and maintenance of ground systems.

Applications Technology Satellite (ATS-6) was launched successfully by NASA and injected into a parking orbit on May 30, 1974 from Cape Kennedy. The ATS-6 has been moved in June 1975 within view of India for the Satellite Instructional Television Experiment (SITE). The signals transmitted from the satellite are being received by specially augmented TV sets in villages or by conventional sets through rebroadcasting from ground based TV stations at Delhi, Amritsar and Nadiad. For instantaneous transmission of 1975 Independence Day celebrations in New Delhi, both Calcutta and Bombay transmitters of AIR were connected with the system with the help of 10 foot antennae.

Some 2400 direct community receivers for SITE are located in selected areas of Bihar, Orissa, Madhya Pradesh, Rajasthan, Karnataka and Andhra Pradesh. AIR-TV transmitters at Delhi and Amritsar are also connected with SITE through a receive/transmit station at Delhi and a receive only station at Amritsar. ESCES at Ahmedabad is the prime earth station for SITE. Delhi earth station is used as a backup for ESCES and for beaming common programmes to the satellite. In addition, 1 kW transmitter at Nadiad in Gujarat has been established by ISRO with ITU assistance as a part of the SITE system. The direct community receivers have been produced by ECIL, which was awarded a contract for their production. A limited rebroadcast transmitter at Sriharikota Range of ISRO has been set up for limited rediffusion of satellite signal to conventional TV receivers. The direct community receivers, limited rebroadcast transmitters and much of the earth stations are of ISRO design. AIR is responsible for some 1500 hours of programming for SITE, and has established base production units at Delhi, Cuttack, and Hyderabad for SITE programme production. ISRO is responsible for social and communication research related to SITE software as well as a limited production of SITE software and has set up studios at Bombay and Ahmedabad.

As part of SITE, ISRO will be conducting an experiment, besides the beacon and data collection experiments, to study the nature and magnitude of scintillation fades in 2.5 GHz with ATS-6. Also, 13/18 GHz propagation experiments will be conducted with ATS-6 under the cooperative efforts of ISRO, MOC and the Indian Meteorological Department.

3.7.6. Hardware for SITE

Regarding the hardware development for SITE, significant progress has been made in ESCES for the development of various systems and sub-systems required for making it the primary earth station for SITE.

At the systems level the following have been assembled and tested.

- (i) 860 MHz receive chain
- (ii) 4 GHz down-converter, and
- (iii) 6 GHz transmit chain

At the subsystems level the following units have been developed.

- (i) 3 kW-6 GHz air cooled high power amplifier (HPA)
- (ii) 860 MHz and 2.5 GHz low noise transistor amplifiers
- (iii) Tunnel diode amplifier at 4 GHz

Development work on the 4 GHz parametric amplifiers using 15 GHz pump source is in progress. Various feed components like transit-reject filter, rotary joint and polariser for the existing 14 metre parabolic antenna have been developed. While corrugated low noise feed-horn for 14 metre cassegrain antenna for C-band operation has been fabricated, a conical log spiral wideband feed for a new 9 metre diameter chickenmesh antenna along with a low noise 860 MHz bandpass filter is under development. A 20 ft diameter chickenmesh antenna to be used for receive only earth station for SITE has also been designed and built. Production of 70 MHz modulators and demodulators and associated baseband processing units has started. Waveguide directional couplers, circulators, isolators and pin diode switches and attenuators have been developed and tested. The Electronics System Division of Space Applications Centre (SAC) has developed a limited rebroadcast system.

3.8 Technological Trends and Alternatives

3.8.1. Satellite versus Terrestrial Technologies

The advantages of satellite technology are the following:

- (i) Faster introduction of communication services in new areas
- (ii) Potentially lower cost of providing full coverage
- (iii) Extension of programme choice

Satellite effectively offers overnight attainment of coverage which makes it attractive for covering areas having no existing service or only partial service. This is because it takes only 2 to 4 years to produce and launch a satellite. This factor is, however, relatively unimportant for developed countries since most of them have already reasonably complete coverage. The available data also indicates that satellite broadcasting is more efficient in its use of frequencies than terrestrial broadcasting when a wide area of national programme is desired.

It appears, therefore, that emerging areas could consider satellite as a means of completing their coverage plans and the developed areas could consider satellite as a method of reducing costs and equalising coverage.

3.8.2. Distribution versus Broadcasting Satellite

As for the question of whether a broadcast or a distribution satellite should be deployed, a pure distribution satellite will be relevant only in a situation where there exists extensive terrestrial network of transmitters which can be interconnected by a distribution satellite. This situation does not prevail in India at present. In order to maximise rural coverage a hybrid system in which a broadcast satellite will beam signals to community receivers, either directly or through limited rebroadcast, for the rural population, would be desirable for India.

3.8.3. Polar Orbit versus Synchronous Orbit

For the purpose of natural resources survey, it is necessary to carry out repeated observations of the earth not only of the same area but also at

the same time of the day to provide proper correlation between various observations. Thus, it is necessary to carry out natural resources survey using orbits which are sun-synchronous. Such orbits are generally the retrograde polar orbits very close to the surface of earth which provide better resolution for earth observations.

The polar orbit has a period of about 102 to 104 minutes and as such for communication purposes an antenna which will continuously follow the satellite will be required. Such a system will not be useful and economical for the purposes of television broadcasting or continuous communication. On the other hand, in the geosynchronous orbit the satellite is synchronised with the rotation of the earth making it useful for continuous communications and regular synoptic meteorological observations.

3.8.4. Frequency Allocation

The single most critical parameter, the one most influencing the design of domestic satellite communication system, is the selection of the operating frequency. India is conducting the SITE experiment in collaboration with NASA in the 860 MHz frequency. The World Administrative Radio Conference (WARC) has permitted the frequency only for the duration of the experiment. For an operational system like INSAT, ISRO has chosen 2500-2690 MHz for TV broadcast from considerations of the level of semiconductor technology needed for direct reception receivers and other ground systems. Although 11.7 to 12.2 GHz is promising for the future, in the next few years India may not be in a position to have an operational direct broadcast satellite system in that band. However, since the band has no flux density limitations, ISRO is investigating the possibility of using this band in the future for which propagation and other studies will be undertaken. The implications of the EIRP value is in the choice of the ground system antenna diameter, front-end noise figure values and hence the total system cost.

In terms of hardware considerations, the equipment cost, reliability of operation, size and efficiency depend heavily upon the choice of operating frequencies. As far as satellite communication is concerned, the use of frequencies below 1 GHz demands bulky and heavy equipment but has higher efficiency, whereas for higher frequencies the equipment size is considerably reduced but efficiency also decreases. Only in the 1 to 10 GHz frequency band, for the given time frame, cost, size, efficiency and reliability and factors influencing radio wave propagation are at a balance. Above 10 GHz advantages gained by reduced size and weight are offset by the tremendous increase in cost and atmospheric attenuation. Frequencies higher than 10 GHz are more amenable to highly directional radiation which makes them more stable for purposes of point to point communication links in telecommunication rather than for general distribution and broadcast purposes. From the point of view of natural environment the frequency band 1 to 10 GHz is the most suitable for space communication purposes. Below 1 GHz cosmic noise increases and above 10 GHz oxygen, water vapour and atmospheric absorption produce difficulties.

3.8.5. Spot Beam versus Area Coverage Beam

With the frequency allocations available in the S-band, a spot beam satellite design appears to maximise utilisation of the satellite in that the viewer will have a larger programme choice. Also, the incapacitation of a spot beam would result in total TV blackout of the area in question which

would not be desirable socially or politically. However, the spot beam technique is particularly attractive from software considerations, as it can respond to regional needs without affecting the requirements of national coverage. From the security angle interference of any spot beam would have repercussions to reception only in the area in question. Technical and economic studies in this regard are being carried out by ISRO.

3.8.6. Direct Reception versus Limited Rebroadcast

In areas where village density is high and particularly in areas which are not covered in the AIR Fifth Plan terrestrial network, there will be an economic trade-off to be considered in the costs of front-end converters along with chicken-mesh antenna as against the cost of low power limited rebroadcast transmitters. In this context, it appears worthwhile to consider the whole problem of optimal area/population coverage on a national scale utilising various receive/rebroadcast transmitters.

3.8.7. Interference

Coordination procedures have been set up for sharing the same frequency bands between satellite communication earth stations and line of sight microwave facilities. It will be required that every earth station draw a coordination contour and show by analysis that existing microwave facilities within the coordination contour do not cause or suffer harmful interference. The same requirement will be imposed on each new microwave facility to be installed inside the contour. In this manner, reasonable protection is extended to operating and planned installations.

The existing minimum coordination distance is 100 kms. But recent studies have revealed the inadequacy of the existing methods of determining coordination contours and suggest that coordination distance be extended from the 100 km minimum to a 25 km minimum.

Another important cause of interference viz., that from pointing line of sight beams at the stationary satellite, has been pointed out. In this connection the XIth Plenary Session of the CCIR advised (vide recommendations 406-1) radio-relay system planners to avoid pointing antennas at the geo-stationary orbit. CCIR Report No. 393 describes a computational method to be used by these planners. This report is difficult to implement. An easy graphical method for computing whether a proposed link will point at the orbit is now available.

Another important CCIR recommendation affecting total system design, for communication satellites using band-spread modulation techniques, is that the power flux at the surface of the earth should not exceed—130 dBW/m² and the power flux density should not exceed—152 dBW/m² per 4 kHz channel. In the case of radio relay systems, it was recommended that effective radiated power (e.r.p.) should not exceed +55 dBW and the transmitter power exceed +13 dBW in order to keep interference produced at the satellite within acceptable limits.

3.8.8. Power Sources

Every satellite television proposal for India has shown awareness of the need for providing TV receivers, in un-electrified villages. The report on "Advanced System for Communication and Mass Education for India's Development (ACME)—1969" suggests the use of wind driven power generators in such cases. In this connection it needs to be ensured that the wind

velocities in the relevant parts of India are sufficient to provide a reliable source of electricity. A Stanford Study (ASCEND) favours an animal driven generator. This study visualises availability of about 10 hours of free-of-cost animal service every day in a village. It remains to ensure the economic viability of the animal-driven generator.

Motor generator has been proposed wherever wind generator cannot be installed. The estimated cost for the motor generator varies from \$60 (ASCEND) to \$120 (USTAD) and \$500 (Prasada and Singh). Once an estimate of the number of such generators is made their unit cost is calculated according to the scale of production.

In course of SITE, ISRO, in collaboration with NASA, is planning to conduct a small experiment to test the technical and economic feasibility of using photovoltaic power to operate standard SITE Direct Reception Sets.

3.8.9. Telecommunications

INSAT-I as proposed to the INSAT Task Force established by the Planning Commission, was envisaged to have a total of five transponders available for telecommunications. As a first option four of the five transponders could be used to provide direct channels via satellite between the four metropolitan cities—Bombay, Calcutta, Delhi and Madras. The fifth communication transponder would be utilised for remote area communication. These areas include Andamans, Nicobar, Lakshadweep and Ladakh.

As a second option the same five transponders would be used in a multiple access mode. This mode of operation will have a strong rural orientation.

According to the P&T, the economic break-even point between terrestrial and satellite circuits is of the order of several thousand kilometres, whereas, most of the telephone calls which originate in a given area terminate within a radial distance of 500 km and the calls originating in rural areas are not expected to go beyond a radius of coverage of 50 km except in rare circumstances. So it was argued by the P&T Department that the use of satellite circuits even with one transponder used for area coverage and the remaining four transponders used for interconnecting the four major metropolitan centres is not an economically attractive proposition even when these are offered as incremental facilities on a TV satellite.

The question of using all five transponders for area coverage does not therefore arise.

3.9 Demand Profile— INSAT System

As an immediate follow up of the SITE, ISRO had proposed a plan to set up a domestic satellite system for nationwide TV and telecommunication service called INSAT which is still awaiting go-ahead from the Government.

INSAT, as a satellite system, has been optimised for the purpose of providing direct community TV broadcasting from synchronous altitudes. In addition to carrying out the functions of TV broadcasting, additional capacity on the satellite has been proposed for long distance telecommunications. The position of the satellite at geosynchronous altitudes provides an ideal platform for carrying out observations of the earth particularly for the purpose of meteorology. The communications system of the satellite can also be used for the purpose of data transmission from remotely located platform. Some main features of the INSAT system, as proposed to the INSAT Task Force, are indicated in Table 3.3.

III

According to the report of the INSAT Task Force, after initiation of work, it takes about 27 to 30 months for fabricating the satellite. The lead time required for launch vehicle procurement is also of the same order. The ground stations required for the INSAT system can be fabricated and commissioned for service in a time duration of about 20 to 24 months. The deployment of various earth stations, required number of television sets, provision of power sources for unelectrified villages, etc., requires about 14 to 18 months.

Table 3.3. INSAT-I spacecraft performance parameters.

Television capability	
Number of channels	5
Number of beams	5
Coverage of beam width	1.5°—1.6°
EIRP per channel	51 dBW
Usable bandwidth per channel	25 MHz max.
Channel separation	30 MHz
Telecommunications	
Number of spot beams	4 (aimed towards 4 metropolitan centres)
Number of transmitters	4
Number of carriers per transmitter	3
EIRP per carrier	38 dBW
Number of one wave channels per carrier	450
Beam width	1
Multiple access systems	
Number of beams	1
Beam width	6°
Number of transmitters	22
EIRP per transponder	33.8dBW
Remote sensing and meteorological package launch vehicle	Thor-Delta class

The total cost for the particular satellite system proposed to the Task Force has been estimated at Rs. 400 crores according to the INSAT Task Force Report. The detailed breakup of the estimate is given in Table 3.4. The electronic hardware requirement for the programme is estimated around 40 per cent of the above estimate. It should be mentioned that in certain aspects like provision of TV sets, their deployment and maintenance, the State Governments are expected to play a major role. Also, according to ISRO, the INSAT system concept is an integrated one oriented specially towards the rural areas. It has been indicated that the system will have a tremendous impact on the development of agriculture, health, education, etc., in the country and will in fact have a significant overall impact. In this regard, the question remains whether funds could be diverted from the plans of the ministries of education, health, agriculture, family planning, etc., to meet the cost of the satellite system.

In the event that the INSAT programme cannot be taken up in toto due to lack of funds, it could be considered to have at least the core of the programme taken up in the Fifth Plan. Though this would have the effect of seriously restricting the TV coverage of the satellite system, it will at least have the benefit of securing technological advancement in this field, reaping full benefits on the ground being deferred to a later period. Towards this, ISRO has developed a number of system options with varying capabilities and cost and further system definition studies are continuing.

3.10 Technological Aspects and Indigenous Capabilities— Guidelines for Production

3.10.1. Satellite On-board System

With regard to the on-board system of INSAT-I, the system proposed to the INSAT Task Force, the particular configuration makes use of the technology which has by and large already been space proven through several space missions, except in a few cases, like deployable antennas on spacecraft, which

Table 3.4. Cost estimate for the INSAT satellite system.

No.	Item	Rs. crores
1.	Satellite and launch vehicles	45.00
2.	Satellite station keeping, tracking stations, etc.	5.00
3.	Standard TV sets 125000 at Rs. 2200	27.50
4.	Augmented TV sets 126000 at Rs. 4000	50.40
5.	Major TV & telecommunication earth stations	6.00
6.	Receive only terminals (a few with multiple access capability)	3.00
7.	Multiple access terminals	0.50
8.	Operating costs for TV sets for VLV, labour, maintenance of TV sets, etc.	60.00
9.	Maintenance and transport organisation	25.00
10.	Power supply including batteries	50.00
11.	Software production	100.00
12.	National resources survey	8.00
13.	Limited rebroadcast system—200 transmitters	6.00
14.	Contingency	13.60
	Total	400.00

have been space proven for synchronous altitude by NASA communication satellite ATS-6. The communication transponder design both for television and telecommunication is more or less identical. These transponders are similar to the INTELSAT transponders which are already in orbit rendering round-the-clock reliable commercial service. For none of the components to be used in INSAT transponders any new basic development need to be undertaken abroad.

Since INSAT-I is to be procured from abroad, it is proposed to commence development effort as a part of the programme of space research to enable large portions of subsequent spacecrafts to be developed and produced indigenously. This work will be undertaken concurrently with the procurement of INSAT-I.

The remote sensing and meteorology package proposed on INSAT-I has been space proven by several meteorology and earth resources payloads of satellites launched abroad. The latest in this series is the ATS-6 satellite of NASA. The sophistication of the package proposed here

III

is somewhat less. The package is available with current space proven technology.

Other important areas of space technology proposed on INSAT such as three axes stabilisation, large deployable solar power arrays, 0.1° pointing accuracy have been proven separately on various civilian and military space crafts by other countries. Most of these are together space proven by ATS-6 satellite of NASA.

It is proposed to use a highly reliable launch vehicle similar to the Thor-Delta which has been used on several missions in the past and has demonstrated a very high success rate.

3.10.2. Ground Based System

Most of the ground based systems involved in the INSAT system can now be designed and developed indigenously.

3.10.2.1. Major Earth Stations

The construction of three to four major earth stations each having a capability of transmitting to INSAT alongwith receiving facility is envisaged. It is possible to build such earth stations indigenously in about 30 months from the go-ahead.

3.10.2.2. Interfaces with Satellite Network

The development of interface between the satellite equipment and the terrestrial network is within the indigenous capability. Small earth receive-only terminals required for limited rebroadcast of TV signals will be constructed indigenously and proven during SITE. It is proposed to design and develop multiple-access terminals indigenously in the next couple of years.

3.10.2.3. Front-end Converters

The chicken-mesh antenna and front-end converters for both 860 MHz and 2.5 GHz are being developed and ECIL, Hyderabad, is to produce 860 MHz antennas and converters for SITE. The cost estimates for these are expected to be validated during SITE.

3.10.2.4. Television Sets

The TV industry has already demonstrated its capability to design and develop TV indigenously. For SITE a fully solid state TV receiver has already been developed and will be produced by ECIL. During INSAT time frame, it is expected that there will be adequate manufacturing capacity in the TV industry to meet the total demand of TV receivers envisaged in the programme.

3.10.2.5. Power Sources

There exist considerable indigenous experience in the field of battery manufacture. The battery envisaged here is of the storage type similar to that used in automobiles. Power supply consists of two 12 volt batteries in series, each with a capacity of about 100 Ah. The battery life is assumed to be two years at best under field conditions. There is a need for a large scale expansion of battery manufacturing capacity.

Concurrently efforts are to be undertaken to design alternative power sources and to study their economics so as to reduce the large dependence on storage batteries for community TV sets. These include power generation through oil engines, windmills, watermills, and animal power. Efforts for improving the design of TV sets to consume less power will also have to be undertaken.

III

Table 3.5. Space segment technology status for synchronous communication satellite

Spacecraft subsystem 1	Components/technologies 2	Current status 3	Problem areas 4	Projected developments 5	Remarks 6
1. Power	Solar cells	N-on-P silicon cells extensively used; Cds cells have been space qualified; violet cells have been developed upto 18% efficiency	Radiation damage; cost reduction; efficiency improvement	Ribbons development; low cost fabrication techniques; bonding and improved current lead connections; chevrons shaped cell; welding technique.	Cost is about \$60/watt in cylindrical panels; ribbons development for low cost power
	Deployable solar arrays	Solar array have been successfully deployed in orbit on ATS-6; roll out arrays have been flight tested	Radiation damage; thermal and structural problems	Thermal flutter; roll out, fold out arrays with light weight, elastic modulus and damping coefficient	CTS synchronous satellite of Canada is employing flexible deployable arrays
	Array orientation and power transfer systems	No flight proven system for synchronous altitude. CTS and fleet comsat are incorporating driven solar panels using stepper motor reduction gear drive.	Low angular rate drive ($\frac{1}{4}^\circ/\text{min}$); cold welding and lubrication problems; slipping assemblies	Harmonic drives are developed; liquid metal slipping technology being developed; reduction of thermal dissipation, stability of low impedance distribution	LES-7 sliding contact slipping has been qualified in ground tests; CTS will test the liquid metal slipping technology
	Power conditioners	Shunt regulators and over voltage and over current regulators of qualified design are available.	Voltage transients; high efficiency voltage converters	High voltage solar arrays are developed for TWT supplies; electric propulsion and high voltage components	
	Nuclear power sources	Radio-isotropic, thermoelectric generators of 150-600 W level in planetary probes and near earth satellites	5-7% thermal to electric conversion efficiency; radiation shielding	High power (100 kW range) closed Brayton cycle systems under development in SNAP program	LES-8, LES-9 will employ RTG power sources
	Batteries	Development program for Ni-Hydrogen batteries: 50 watt-hour/kg for Intelsat satellite	Charging, discharging efficiency; life energy density improvement; heat transfer problems; temperature gains	Better charging systems; high energy density designs; improved heat transfer by heat pipes; cell pressure vessel; weld design	Needed for eclipse and overload condition operations; weight is a major factor in determining the eclipse operation capability

III

1	2	3	4	5	6
	Rechargeable fuel cells	H ₂ -O ₂ cells under development about 20W. hr/lb.	Catalyst life time problems	Expected to be available by 1975-80 period	Does not require stringent temperature conditions; can be stored in odd places and operated
2. Antenna	Rigid antenna	Fully developed and space qualified in many programs; dual-polarised antenna	Polarisation purity	Misalignment; distortion; depolarisation; pointing errors; polarisation isolation	Needed for frequency reuse
	Electronically despun antenna	Used in Early Bird and LES satellites	—	—	—
	Mechanically despun antenna	Successfully used by Intelsat series, and skynet, TAC, SAT and DSCS, Ph-2 communication satellites	Beam pointing accuracy for spot beams; control problems to correct for orbital inclinations	± 0.1° pointing accuracy systems are feasible	—
	Deployable antenna	30 feet antenna has been successfully deployed in orbit on ATS-6	Mechanical and thermal problems; flexible body coupling with control system	Multibeam operation; side-lobe controls; antenna diameters upto 100 feet may be available for narrow beam antennas; frequency ranges from VHF to 12 GHz may be easily possible	Frees the communication satellite designs from the launch vehicle shroud constraints
	Phased array antennas	Development program has been taken up for Intelsat Communication Satellite at 11/14 GHz and 20/30 GHz	Switching matrix deployment	Beam isolation and better side-lobe control; beam positioning; graceful degradation of the service; complete independent steerable multibeam operation with frequency reuse	Planned uses are for tracking and data relay and military navigation satellite communication with increased capacity
3. Critical communication components	Solid state power amplifiers	Space proven in ATS-6; active development being carried out in S-band	Semiconductor quality control and reliability; medium noise figure; large dynamic range with large output power to replace TWT	High power output, efficiency; multi-carrier operation	Heat transfer problem is easier because of high efficiency and non-localised nature of the sources; weight and power requirements are low

III

1	2	3	4	5	6
	Tube type power amplifiers	Tubes at 25% efficiency available; tubes with efficiency slightly higher than 25% under development; 20W TWT with 35% efficiency using multistage collector under development	Sensitivity; linearity; heat dissipation problems; lower efficiency operation need for high voltage	High efficiency (50% or above) tubes being developed for S-band and 12 GHz, to be flown in 2 years	Heat pipe designs solve thermal problems; tubes design improvements being made; high efficiency technology being developed
	Tunnel diode preamplifiers	6-7 dB noise figure 6 GHz TDA space tested; 4.5 db TDA space qualified, to be flown shortly	Devices are extremely sensitive to transients and overload	High efficiency; low noise figure	Will be replaced by transistor amplifier at 4 GHz
	Parametric amplifier	No flight proven system; paramp with 3.5 dB noise figure, 500 gm, 3W dissipation under development	Weight and power consumption	High efficiency; low noise figure; low weight/power consumption	Save the total cost of overall communication system
	Low noise down converter	No flight proven system; 7.0 dB n.f. down converter under development	New devices; minimum signal losses; correct image and harmonic rejection	Diodes and transistors are being developed	Can be used as front end of the receiver, simplifying the repeater; increase in reliability, saving in mass and power; overall improvement in noise figure
	Solid-state microwave sources	Efficient direct generation and locking to stable reference	Low noise; source stabilization; reliability		Weight reduction due to direct generation (without multiplier chain); light local oscillator unit
	Microwave filters and multiplexers	Space proven in Intelsat IV; linear phase filter with low phase/amplitude distortion under development	Closely spaced channel output combiners with good stability; low loss, low phase and amplitude distortion	Lightweight Invar components under development	Weight reductions upto 70% expected by new fabrication techniques
4. Attitude control	Sensors 1. Horizon	Two axis scanning with an accuracy of 0.03°.	Limitation from earth edge definition		Systems for laser communication need more accurate attitude sensing by 2 orders of magnitude

III

1	2	3	4	5	6
	2. Star	Electronically gimballed with an accuracy of 0.01°	Contamination and stray illumination effects		
	3. Sun	Digital and analog types 0.125-0.01°			
	4. Inertial	Gas bearing gyros with drift rates of .001°/hr. or better	Power consumption and need for updating		
	5. Monopulse	0.1-0.5° accuracy systems developed	Earth based beacon needs; complex computation for 3 axis information		
	6. Interferometer	0.1-0.03° accuracy systems under development	Matched elements; thermal isolation from other components		
	Controllers				
	1. Analog	Space tested on ATS-6	Multiple mode operation need independent designs for each mode	Redundancy improvement	Well-established techniques are available
	2. Digital	Space tested on ATS-6	Reliability; development	Modular multi-computer systems being evolved	
	Actuators				
	1. Momentum wheels	100 NMS- magnetic bearing momentum wheels and gas bearing have been developed and space qualified	Space lubrication; long bearing life	Single momentum for 3-axis stabilisation (space qualified)	A wide range of proven wheels are available
	2. Propulsion systems	Cold gas; monopropellant hydrazine; hydrogen peroxide systems; 10 milli-pound —51 lb hot and cold Ammonia jets; 1-20 milli-pounds; electric propulsion in micro cesium ion engine experiment is carried out in CTS Canadian Satellite; Intelsat	Valve life contamination; minimum impulse bit; delays; catalyst bedlife feed system	Heated hydrazine jets without catalyst; operational electric propulsion system cesium ion engines; colloid engines; etc. charge-exchange erosion; cathode failures; chamber sputtering, interference; etc.	Extended orbital operation demands high sp. impulse (of the order of 1000-5000 secs) propulsion system with low impulse bits for stationkeeping and momentum dumping; electron thruster offers advantage of weight reduction

III

1	2	3	4	5	6
		has a development plan for the use of electro-static ion thruster for N-S stationkeeping in operational communication satellite (spinner and 3-axis) using Hg. or Cesium			
	3. Station keeping	Ground based Autonomous	Ground station tie up; orbit computation time Using sun-earth pulse coincidence technique	Trilaterisation ranging with PN sequence 0.01° accuracy stationkeeping	Full utilisation of orbital space depends on efficient stationkeeping; autonomous systems preferred for minimising the burden on ground systems
	4. Stabilisation technique	Spin stabilisation; dual spin stabilisation; gravity gradient stabilisation; 3 axis stabilisation by gimbaled momentum wheel; 3 axis stabilisation by reaction wheels	High power systems with large antennae need 3 axis stabilisation; laser communication systems and small spot beam need better systems	Improved 3 axis control systems using high speed momentum wheels; electric thrusters and digital controllers	COMSAT has funded a development contract for a digital computer controlled double gimbaled momentum wheel system; Lockheed has assembled a similar system for INTELSTAT V systemmode; accuracy requirements 0.001-0.1 will be needed
5. Thermal control	Coatings	Passive thermal control; space qualified products available; mirrors are used for thermal control	Radiation damage and behaviour for long life time	High coatings (OSR type)	Better systems needed for high power dissipating communication satellites
	Louvers	Space tested in ATS-6	Mechanical failure	Improved mechanical	A new technology by itself
	Heat pipes	High capacity passive heat transport device used already in space program including manned flights	Local hot spots; 'O' g heat transport problems	Variable conductance heat pipes	Heat pipes have been qualified in manned Apollo flights

III

1	2	3	4	5	6	
6. Structures and materials	Spacecraft structures; deployable structures; light-weight high strength materials for subsystem; beryllium and graphite fibres structures are developed	Presently structures form about 15% of the spacecraft compared to 18% in the beginning	Vibration; structural coupling with control; weight penalty	Trend is to bring down the structures to 12%; graphite fibre reinforced plastics are being developed		
7. Telemetry and command	Signal conditioners Encoders Command distributors	Modular organisation Low power integrated circuits and digital organisation	Suspectability to malpractice and intentional jamming	Improved secure command and control systems are evolved	Very much	

Table 3.6. Ground segment technology status for synchronous communication satellites

Ground Sub-system 1	Components/ technologies 2	Current status 3	Problem areas 4	Projected developments 5	Remarks 6
1. Antenna	Reflector	97 feet ARVI antenna, built in India; 30 feet, 20 feet and 15 feet antennas are designed in India for SITE experiment; antenna for transportable and mobile terminal under development at ISRO	Large structure with high (1.5 mm rms) accuracy under environmental conditions of wind; thermal distortions; self loading; etc.	<ol style="list-style-type: none"> Standard steel sections substitution Structural design capability Antennas for P&T microwave system Tropo antennas Torus antenna Antenna with elliptical aperture Mount 	Vikram Earth Station (ARVI) exceeded the Intelsat specification requirements; G/T 41.3 dB/°K against 40.7 dB/°K; beamwidth C band 0.2°-0.3°
	Subreflector	Under development at ISRO	High accuracy contour surface manufacturing and alignment		Alignment and setting up know-how available only with ISRO
	Feeds	Under development at ISRO	Power handling; maximising the gain; proper alignment; etc. polariser development	R&D work undertaken by ISRO for P&T microwave and troposcatter system	Monopulse narrow beam development needs more effort

III

1	2	3	4	5	6
	Bearings; support assembly; gears and brakes	Large diameter bearing imported; gears and brakes indigenous	Materials fabrication facilities	—	Facilities in public sector engineering units can be tapped for fabrication
2. Tracking system	Motors; encoders, power supply	Amplidyne for W.2 system imported; not available	High accuracy	SCR system under development for Dehradun station	Hydraulic drives are available in India; AC servomotor system development at EPEL of BARC
	On line computer	TDC 12 can be used	Software and integration; HA-DEC as well as AZ-EL mounts	Will be needed by many projects	Radio astronomy; tracking stations for space communication low orbits
3. Low noise preamplifiers	Liquid nitrogen cooled parametric amplifiers	30° K Indian design and development feasible	Wideband performance difficult to achieve; varactors; pump sources to be imported	R&D efforts at ISRO; Defence	—
	Helium cooled parametric amplifiers	18°K gaseous (-255°C) cryo-generator to be imported	Cryogenic hardware and helium supply	—	BARC has the R&D facilities
	Uncooled preamplifiers	Transistor type 3 dB; TDA, 4.5 dB; paramp 60°K transistor type developed in India; TDA/uncooled paramp under development	Semiconductors to be imported	R&D by ISRO and P&T	High EIRP makes uncooled paramps possible for use
4. Up/down converters	—	Developed by ISRO; made in ITI for P&T microwave network & OCS station at Dehradun; 7 dB n.f. under development; integrated up/down converters under development	Low noise figure devices to be imported	R&D by ISRO and P&T	Integrated up/down converter will simplify the ground station equipment
	Local oscillators	Gunn diode oscillators under development; direct generation without multipliers under development	Semiconductors to be imported; stability; reliability	ISRO	—

III

1	2	3	4	5	6
	IF amplifiers	Indian capability exists	—	—	—
5. High power amplifiers	TWTs; Klystrons; high power transformers; high voltage rectifiers.	3 KWHPA developed at ISRO for SITE	Microwave components to be imported	—	High voltage insulation for HPS transformers requires attention
6. Wideband modulators/demodulators	FM: Demodulation at RF offers economies in design and superior performance	Developed at ISRO for SITE	Wideband critical problem; varactors needed to be imported	—	—
Threshold extension techniques, tracking receivers	—	In operation	Checked for critical C/N (3-6 dB gains); wideband high frequency passive components imported; stripline not available	No R&D in wideband	No effort so far (quantity needed will be large); auto-tracking need for radars, earth stations
7. Digital communication equipments	—	TRC some R&D; 24 ch RCM; Delta modulation at TRC	High frequency not generally available	ISRO, DLRL OCS	Data transmission; higher channel capacity operational satellite data transmission
8. Multiple access controllers	—	OCS studying the use of SPADE system of COMSAT	System design hardware for digital computers	Defence, P&T, OCS	Maximal utilisation of channels
9. Mobile stations	—	Under development at ISRO for limited re-broadcast during SITE	High power lower capacity non optimum PA cooling etc; weight; power; cryogenics not possible	Defence; BSF; exploration parties need these systems	—
10. Manpack terminals	—	—	Power considerations; frequency; uplink power channel capacity	Defence	—
11. Front ends for direct broadcast TV	UHF	6 dB & 3.2 dB developed at ISRO for SITE	—	I S R O	—
	S-band	6 dB n.f. under development at ISRO	Cost; reliability; thin-film technology	I S R O	—
	12 GHz	under development at ISRO	Cost; low noise figure	I S R O	—
12. Antennas for direct broadcast TV	10 inch chicken mesh antenna	Developed at ISRO	Production capacity; cost	I S R O	—

III

1	2	3	4	5	6
	12 GHz	X-band capability exists; mixing diode will have to be imported	Cost; low noise figure	ISRO	—
13. Power sources, earth station	—	No break power supply 50-75 kVA (Arvi)	High capacity Mi-Cd batteries; high power SCRs for inverter	—	No substitution effort has been done; reaction time for MG set
14. Microwave links	antennas	Indian capability exists	Initially some antennas imported	Fibre glass antennas being developed by ISRO, NAL	Lighter system is preferred for accessibility
	Repeaters	Antenna: MASEC, repeater: ITI, components: imported	—	—	Maintenance
15. Power sources	For microwave links	Battery charged by mains and standby diesel generator	—	Indian	—
	For village TV sets	Batteries charging problem	Facilities; generators	Indian	Large number may create problems of maintenance
16. Solid state TV receivers	ECIL, ISRO, Private sector, CEERI, AIR	Picture tube made in BEL with imported bulbs; ferrites	Ruggedisation; maintenance	In 2 years all the components will be progressively made; picture tube bulbs will be made in a separate factory in 3 years time	80-85 W consumption achieved in units developed by ISRO and ECIL; goal is for 50-60 W
17. TV receivers with integral front-end	—	Development	—	ISRO	In microwave region development has to be undertaken
18. VHF TV transmitters and aeri-als	—	ISRO-low power solid state upto 100 watts	—	CEERI, NPL	—
		BEL-high power 10 kW; low power	—	—	—
19. Components manufacture	Semiconductors, coils, trimmers	Imported	—	CEERI, NPL	—

III

1	2	3	4	5	6
	High voltage components; high power microwave components; miniaturisation in components; TV components; telecommunication components	Component production for radio industries in quantities needed	Materials technology; manufacturing process; test and standardisation facilities	TRC, BEL, ITI, ECIL, CEERI, NPL, SPL, DLRL, TIFR; private sector for R&D and production	Manufacturing, reliability and quality control and raw material problem are to be solved
20. TV studio equipment	Cameras	Developed by ECIL	—	BEL will make 3 in. image orthicons and plumbicons; camera control unit monitors; manufacturing may be licensed by the Electronics Commission	Large numbers will be needed in near future
	VTRs	No Indian capability	—	—	—
	Voice recorders for AIR and Defence	Indian capability exists	—	—	BEL design; AIR needs, Defence needs
	Microphone telecine	Made in India	Not of broadcast quality	Vidicon and electronics for telecine by BEL	—
	Transmitter	Development and production at BEL	—	Complete transmitter except for feeder cable	—
	Lighting	Capability exists	—	Optics-CEERI, BARC	—

IV

Consumer Electronics

4.1 Introduction

During the early stages of growth, the electronics industry in India was synonymous with the production of equipment like radio receivers, audio equipment and electronic components. The growth in the consumer sector was the starting point of expansion of the electronics industry.

In the mid sixties the growth rate was faster than the one originally assessed in the Bhabha Committee Report. Since 1969, the growth rate in the consumer electronics area has slowed down due to a variety of reasons.

The production of consumer electronics equipment during 1971-72 and 1972-73 was about 38 per cent of the total electronics production. It dropped to about 30 per cent in the fiscal year 1973-74, while the total production during the same period increased by 20 per cent. The production statistics is given in Table 4.1.

The following products are identified to be falling within the scope of consumer electronics.

1. Radio receivers
2. Television receivers (including closed circuit TV)
3. Tape recorders (audio and video), record players and record changers
4. Audio amplifiers and public address systems
5. Miscellaneous devices such as electronic musical instruments, electronic watches, electronic toys, etc.

More than 75 per cent of the total production in the consumer electronics is in the field of radio receivers. The radio receiver industry can claim a solid measure of self-sufficiency, making indigenously over 500 components and parts representing around 96 per cent of an average receiver. At present, radio receiver requires, on an average, less than a rupee worth of imports per

Table 4.1. Production of consumer electronic equipment

Item	Production during 1972-73		Production during 1973-74	
	Quantity (Nos.)	Value (Rs. crores)	Quantity (Nos.)	Value (Rs. crores)
Radios	30,20,000	47.3	26,20,000	37.1
TV receivers	39,000	6.5	75,000	14.6
Tape recorders	36,000	1.8	50,000	2.7
Record players	88,000	1.5	99,000	2.3
Amplifiers	83,700	2.8	90,000	3.4
Others		1.3		1.6
Total		61.2		61.7
Total production of electronic equipment		162.0		187.0

unit as compared to the assembly of a monochrome TV receiver which requires about Rs. 60 worth of imported components. The short-lived boon of the radio receiver industry which marked the year 1968 fell off by the end of 1970. Sales, both in organised and small scale sectors, have ever since been declining. As a result, the manufacturers have been forced to cut down their production. The total production of radio receivers during 1973-74 was worth Rs. 37 crores compared to Rs. 47 crores in 1972-73. Later in this chapter, this slump in the radio receiver industry has been analysed.

4.2 Current Status

4.2.1. Radio Receivers

The demand for radio receivers, which are used for educational, entertainment and information purposes, has increased considerably during the last decade and a half. The main factors governing this increase in demand are, a rise in per capita income, massive electrification programme of rural and urban areas, opening of additional broadcasting stations, introduction of diversified programmes and availability of radio receivers at a price acceptable to the common people. An indication of this growth is the yearly increase in broadcast receiver licences issued by the P&T department which is shown in Table 4.2.

The production of radio receivers is more or less assembly based and the technology involved is also of a simple nature. This industry is highly labour intensive and consequently investment in machinery and equipment is low. There is also no dearth of technical personnel and skill in this field for the production of quality goods. All these factors have undoubtedly contributed to a sizeable progress of production of this item both in the small scale and in the organised sectors. In fact, while in the post-independence period there were only very few units operating in the organised sector for the manufacture and assembly of radio receivers, there has been a considerable growth during the last fifteen years in this field, particularly in the small scale sector. There are more than 1500 units at present registered with the State Directorates of Industries for this item.

Table 4.2. Radio licences issued by the P&T Department

Year	Total licences issued (cumulative)	Increase over the previous year
1951	6,85,508	
1956	11,76,520	
1961	25,98,608	
1966	64,83,896	
1967	75,79,468	10,95,572
1968	92,82,349	17,02,881
1969	1,05,08,112	12,25,763
1970	1,17,46,602	12,38,490
1971	1,27,72,297	10,25,695
1972	1,28,94,535	1,22,238

It has been observed that the evolution of the radio industry in the country upto 1971 can be categorised into three phases namely, (i) the phase, when the organised sector had a total monopoly, (ii) the phase, when the small scale sector entered in a big way by introducing transistor sets, and (iii) the phase, when the organised sector utilised the advantages of their large size in tilting the market again in their favour.

IV

Although assembly of radio receiver sets was started in the late forties by a few units and some more were added in the early fifties, not much progress was made in the initial years, as the industry had to depend almost entirely on imported components. It was around 1960 that the production of radio receiver sets reached a figure of about 2.7 lakh sets per year. There has been a significant progress during the last decade because of the growth of the component industry in India. Prior to 1958-59, there was no organised indigenous production of components such as carbon resistors, paper, ceramic and mica capacitors, loudspeakers, gang condensers and potentiometers. Hence, prior to 1958, due to difficulties in importing components, only a few units for assembling radios were set up. This led to the creation of an exclusive class of manufacturers and contributed to the belief that assembling of radio receiver sets is a sophisticated technology. Further, manufacturers such as Philips, Murphy, Bush, Telefunken, to cite a few, had foreign collaboration in addition to having foreign equity participation. This created an image in the minds of the public that the stamp of a foreign name was synonymous with quality. A low supply and a high demand situation permitted the manufacturers to control the prices of their products. Consequently, only a small segment of the population was benefited by broadcasting.

With the advent of transistor technology, the assembly of valve sets was gradually substituted by assembly of transistor sets. The firms in the organised sector were not quick to change over from valves to transistors. As a result, they soon had to face competition from small scale units who availed of this opportunity presented by the new technology. The competition to large scale from small scale units was further intensified by the indigenous production of components and their easy availability in large quantities. The circuits being simple and capable of connection on printed boards, sets could be produced with small investments on plant and machinery. Though the small scale units did not have an established brand name, their sets generated a great demand because of attributes like portability and battery operation. These new small scale entrepreneurs, who competed with the large

Table 4.3. Production of radio receivers (nos. in million)

Year	Organised sector			Small scale sector	Grand total
	Valve sets	Transistor sets	Total		
1951	NA	NA	0.083	NA	
1955	NA	NA	0.081	NA	
1960	NA	NA	0.268	NA	
1961	NA	NA	0.326	NA	
1962	0.291	0.047	0.338	NA	
1963	0.288	0.110	0.408	NA	
1964	0.286	1.184	0.470	NA	
1965	0.304	0.279	0.583	0.31	0.893
1966	0.284	0.423	0.712	0.39	1.102
1967	0.236	0.616	0.852	0.45	1.302
1968	0.243	1.132	1.375	0.75	2.125
1969	0.215	1.523	1.738	0.85	2.588
1970	0.245	1.525	1.770	0.90	2.670
1971	0.199	1.783	1.982	1.04	3.022
1972	NA	NA	1.980	1.04	3.020
1973	NA	NA	1.620	1.00	2.620

scale units, generally sold their product in localised market near their factories and enjoyed the semblance of monopoly in a small way. In the five years between 1964 and 1969, their total production increased nearly three times as shown in Table 4.3. According to the Dutt Committee Report, in 1965-66, nearly 55 per cent of the total production was contributed by the small scale sector. About 85 per cent of the total production of radio receiver sets in the small scale sector has been in the range of low priced sets and consequently within the reach of a large number of people. During the years 1962 to 1969, the proportion of transistor sets increased from 13.9 per cent to 87.6 per cent with the share between valves and transistors being nearly equal in 1965 as shown in Table 4.4.

Table 4.4. Production of radio receivers by units registered with DGTD

Year	Percentage of total production	
	Valve sets	Transistor sets
1962	86.1	13.9
1963	70.6	29.4
1964	61.3	38.7
1965	52.1	47.9
1966	39.9	60.1
1967	27.7	72.3
1968	17.7	82.3
1969	12.4	87.6

The small scale units, however, did not establish themselves in terms of brand names, optimum costs or economic scales of production. These units did not employ the correct strategy following the initial windfall and were soon caught unawares. Since facilities for production and marketing were already in existence for the large scale units, they could easily effect a transition from valve sets to transistor sets and also supply the latter in large numbers at low prices. Their very size tilted the market again in their favour. The manufacturers of radio receiver sets have largely diversified the range of their products. At present, it extends from the one band MW sets to thirteen band stereo tuners. MW sets costing less than Rs. 70 are also available.

4.2.2. Television Receivers

TV broadcasting was introduced in the country in 1959 with the setting up of a transmitter in Delhi. Besides this, at present we have TV centres at Bombay/Poona, Amritsar and Srinagar. When the work on the establishment of TV centres at Lucknow/Kanpur, Calcutta, Kharagpur/Midnapur, Asansol, Madras, Jullundur, Kasauli and Mussoorie is completed, the TV coverage would be about 17 per cent by population.

The annual increase in the number of TV receiver licences show a tendency of approximately doubling every year as indicated in Table 4.5. The production of TV receivers was worth Rs. 14 crores during 1973-74 as compared to Rs. 7 crores in 1972-73.

In the organised sector, the production of television receivers is currently done by three companies. A fourth one is expected to go into production shortly. A number of public sector agencies such as State Industrial Development Corporations have also been issued letters of intent for this purpose.

IV

Table 4.5. Television licences issued during 1969-73

Year	Total number of TV licences
1969	12,303
1970	24,833
1971	44,055
1972	86,070
1973	1,62,794

Table 4.6. TV receiver production in the organised sector

Year	Production (in nos.)
1970	5,128
1971	7,790
1972	14,778
1973	27,824

The total licenced capacity in this sector is around 1,10,000 sets per annum. Actual production figures for TV receivers are shown in Table 4.6.

In the small scale sector, several parties (as many as 71) have been approved to produce 2,500 sets each. In a few cases where consortia have been formed, this number has been enhanced to 5,000. The total number approved so far in the small scale sector is of the order of 2 lakh sets. The production in the small scale sector during 1972 was about 16,000 sets. By the end of 1973 it had increased to about 47,000. Thus, by 1974 the total production of TV receivers in the country was about 75,000 sets per annum against the licenced/approved capacity of the order of 3,10,000 sets.

4.2.3. Tape Recorders and Record Players

BEL is the dominant manufacturer of professional console type tape recorders. As of March 1973, fourteen parties have been issued letters of intent with a total capacity of 2.5 lakh tape recorders per annum. In the small scale sector a capacity of 5.4 lakh tape recorders has been approved. But actual production, till December 1972, was barely 36,000 and is estimated to be 50,000 during 1973-74.

The total production of record players in the organised sector was around 85,000 in 1972, shared by two parties. In the small scale sector, production is extremely limited, although a total capacity of 1.25 lakhs has been approved. During 1973-74 the production was about one lakh and is expected to go up to 2.5 lakhs per annum by the end of the Fifth Plan period.

There are two types of tape recorders, the reel to reel type and the cassette type. The tape recorder industry is now mainly centred around the cassette type. Even the high quality sets, which are now of the reel to reel type, are being made in the cassette type.

There are a number of local manufacturers who have introduced cassette tape recorders in the market. All of them import most of the basic units viz., the tape deck mechanism, the micromotor, the magnetic head and the microphone, in the form of kits and assemble them here along with the locally manufactured electronics unit and the cabinet. Recently efforts are afoot to manufacture even the above basic units which are at present being imported.

IV

4.2.4. Audio Amplifiers and Public Address Systems

This is an area in which considerable expertise has been built up in the country particularly in the small scale sector. The actual production in the organised sector is comparatively limited but in the small scale sector as many as 75 parties are active and production is around 85,000 nos. per year. Currently the production is about one lakh units and is expected to double by the end of Fifth Plan period.

4.2.5. Miscellaneous

There is a variety of devices such as electronic musical instruments, electronic clocks, watches, toys, automatic washing and drying machines for most of which the technical capability exists in the country. Their production is expected to grow substantially in the not too distant future.

4.3 Demand Profile

4.3.1. Radio Receivers

While there is a steady increase in the total number of radio receiver licences in the country, the annual increase has been steadily declining. However, if one were to take a macroscopic view of the situation, it would be seen that there has been approximately a doubling of the radio receiver licences every five years. Thus, as shown in Table 4.2, in 1951 the number of licences was about 0.69 million, increasing to 1.2 million in 1956, 2.6 million in 1961, 6.5 million in 1966 and 12.7 million in 1971. If adequate promotional measures are initiated in time, it is expected that this trend of doubling of radio receiver licences every five years would continue in spite of the fluctuations noticed annually. On this basis, the figures by 1976 would go up to about 23 million and by 1981 to about 40 million. By the end of the Fifth Plan period, this figure may be around 30 million which would mean an increase of about 19 million receivers during the Fifth Plan. Adding another 3 million receivers for replacement and 2 million for exports, one arrives at a figure of 24 million receivers to be produced in the Fifth Plan period at an average of about 5.0 million receivers per year.

Table 4.7 gives the demand profile, for the Fifth Plan period as well as the terminal year and the cumulative demand for the Sixth Plan. The

Table 4.7. Demand profile for consumer electronics items
(Demand figures in Rs. crores)

Item	Average unit cost (Rs.)	Demand					Fifth Plan total (1974-79)	1983-84	Sixth Plan total
		1974-75	1975-76	1976-77	1977-78	1978-79			
Radio receivers	140.0	49.0	56.0	63.0	70.0	84.0	322.0	140.0	588.0
Television (includes CCTV)	1750.0	21.0	32.0	44.0	56.0	73.0	226.0	220.0	736.0
Tape recorders	500.0	5.0	7.0	10.0	12.0	15.0	49.0	30.0	125.0
Record players	200.0	2.5	3.0	3.5	4.0	5.0	18.0	9.0	36.0
Amplifiers and PA systems	500.0	6.0	8.0	10.0	13.0	15.0	52.0	30.0	120.0
Miscellaneous consumer goods						7.0	25.0	15.0	50.0
Total						199.0	692.0	444.0	1655.0

demand for radio receivers is likely to be 6 million during 1978-79 and 10 million in 1983-84. While arriving at these figures, the setting up of State rural promotion agencies and the diffusion of radio receivers into the rural market are assumed.

The radio receiver industry is expected to get a boost with the introduction of FM broadcasting in the country. Since the FM service is linked with the TV service, it will be taken up in the initial stages, at the major metropolitan centres, such as Delhi, Bombay, Calcutta and Madras. As the demand for AM/FM receivers depends on the implementation of AIR plans, it is difficult at this stage to give any reasonably accurate estimate of the demand. The AM/FM receivers may also find a wide market abroad. The cost of an ordinary AM/FM receiver (with a MW and an FM band) in the initial stages of the growth of the industry is expected to be about twice the cost of a conventional AM receiver, eventually coming down to about one and a half.

4.3.2. TV Receivers

The demand for TV receivers would depend upon the speed with which new television stations come up in the country. All India Radio has a Fifth Plan programme by which every state capital is to be provided with a TV station by 1978 with relay stations in nearby towns to radiate the programmes to other parts of the State. In terms of population about 53 per cent of the country is expected to be covered by the end of the Fifth Plan. All India Radio has also a community viewing programme by which 2,00,000 community sets are to be installed to enable programmes to be seen by a large number of people. In addition, the Satellite TV programme which is expected to operate on an experimental basis in 1975-76 may also be expanded to enable programmes to be fed at a number of points through coaxial cables. Taking all these factors into account and also the impact of television as a medium for entertainment and instruction, a likely figure of 4 lakh sets per annum is estimated to be the demand by the end of the Fifth Plan period. This may sound perhaps too optimistic. However, one must keep in mind that television has just begun to make an impact on the public in India and would certainly have a tremendous mass appeal if the experience of other countries is any indication. It is estimated that the demand for TV receivers will treble in the Sixth Plan period increasing from about 0.4 million in 1978-79 to 1.2 million in 1983-84.

In regard to the closed circuit television systems, a beginning has been made both in the organised sector and in the small scale sector. Such systems are expected to find wide applications in a variety of fields such as hotels, banks, educational institutions, airports and hospitals. More efforts are, however, required to make them comparatively cheaper which would enable their use on a large scale. The demand for this item is likely to be worth Rs. 3 crores by the end of the Fifth Plan period.

4.3.3. Tape Recorders, Record Players and Amplifiers

In the case of tape recorders, the growth is expected to treble in the Fifth Plan period from 0.1 million nos., in 1974-75 to 0.3 million nos., in 1978-79 and twice the latter figure in 1983-84, namely, 0.6 million nos. In the case of record players and amplifiers, the demand is estimated to increase from 0.12 million nos. in 1974-75 to 0.25 million nos. and 0.30 million nos..

respectively, in 1978-79 and 0.44 million nos. and 0.6 million numbers, respectively, in 1983-84.

In terms of value, the total production of consumer electronics is anticipated to increase from Rs. 62 crores in 1973-74 to Rs. 199 crores in 1978-79 and Rs. 444 crores in 1983-84. During the Fifth Plan, a 25 per cent annual growth is anticipated.

4.4 Analysis of Gaps

Of late, the demand for radio receiver sets has been steadily declining. In fact, it is seen that even taking only the production in the organised sector into consideration, the increase in the radio receiver licences has not kept pace with it. The production during 1971-72 and 1972-73 reached a saturation and has decreased in 1973-74 (see Table 4.3). The decline in sales during the first seven months of 1972-73 was as much as 13 per cent compared to the corresponding period in 1971-72 although the market recovered considerably in the following five months.

The reasons for the present slump in the radio industry seem to be many, thereby making it difficult to associate it with any particular cause. It would appear that a combination of factors such as the general economic situation of urban market, lack of penetration of rural market, the difficulties in bringing down the prices any further have all contributed to the slump in the industry.

Whereas the rural area has 80 per cent of the population of the country, it accounts for only 25 per cent of the broadcast receiver licences issued. Hence the main internal market for radio receiver is in the urban area. Presently, the poor sales of radios in the rural area are because of the reasons like, (i) inadequate marketing efforts by manufacturers, (ii) poor medium wave broadcast coverage (programme content wise) in the rural areas, and (iii) non-availability of low priced radio sets.

The overall production efforts of the industry being guided by the demand, the large scale manufacturers have, of late, diversified into more sophisticated areas of electronics. The small scale manufacturers, however, continue to play an important role in the radio industry.

The remedial actions which should be directed towards generating demand would perhaps require the efforts of both the Government and the manufacturers.

Improving the quality of broadcast in terms of the programme content, reduction of excise duty, abolition of broadcast radio licences particularly for cheap radio sets, setting up of the State rural promotion agencies, etc., are some of the aspects which will provide incentives to prospective consumers.

Nonavailability of TV picture tubes is at present a bottleneck in the production of TV receivers. As against the licenced approved capacity of over 3 lakh TV receivers per annum, the production of picture tubes is less than 80,000. To meet the increased demand for this item the following short term and long term measures have been taken.

- (i) The expansion of the capacity at BEL to 2 lakhs per annum has been approved.
- (ii) Two parties in the private sector have been granted industrial licences for 40,000 tubes per annum each and two more parties have been given letters of intent for a similar quantity.
- (iii) Import of picture tubes upto 25 per cent of the face value of the licence had been allowed in the import policy of 1974-75.

A capacity of 7,92,000 has already been approved/licenced for tape recorders both in the organised (2,60,000) and small scale sectors (5,32,000). The low production of tape recorders in spite of the large approved/licenced capacity appears to be due to difficulties in developing the necessary tooling facilities for precise mechanical parts required for them. While the technical know-how for tape recorders is available in the country there seems to be a need for standardisation of the tape deck mechanism and also in the design of other parts such as heads, micromotors and microphones. There is also a need for a greater amount of R&D effort in the cassette type tape recorders which is becoming increasingly popular.

4.5 Proposed Guidelines

4.5.1. Guidelines for Production

4.5.1.1. Radio Receivers

The current capacity for production of radio receivers is around 4 million, of which a little more than 3 million is in the organised sector. By the terminal year of the Fifth Plan the capacity of 6 million radio receivers is to be established. The exact ratio of production between the organised and the small scale sectors is difficult to determine at this stage. However, in view of the present policy of the Government to encourage the manufacture of radio receivers, particularly the low cost sets (less than Rs. 200), in the small scale sector, one can assume that a major proportion of the increase will come from the small scale sector. The current capacity in the organised sector, of 3.2 million receivers, may, therefore, go up to 4 million receivers by the end of the Fifth Plan period, while the capacity in the small scale sector of one million receivers will go up to 2 million in the same period.

4.5.1.2. Television Receivers

The Electronics Commission decided that the following guidelines might be observed in processing the pending applications for the manufacture of TV receivers:

- (i) There is no need for any foreign collaboration or know-how for the manufacture of TV sets.
- (ii) No TV sets with foreign brand names should be allowed to be manufactured and no licences need be given to companies with foreign equity holdings.
- (iii) Fifty per cent or more of the total capacity should be reserved for the small scale sector and even here, preference should be given to technical entrepreneurs and consortia of small scale units.
- (iv) Reasonable capacity should be licensed in both Central and State public sector undertakings.
- (v) Efforts should be made to distribute the manufacturing units equitably throughout the country.

In view of the cost involved in advertising and marketing, it would be desirable to expand the capacity of those who have gone into production and demonstrated their capability to produce good quality TV sets. The Department of Electronics has already allowed in such cases, the existing capacities to be enhanced from 2,500 to 5,000 sets per annum. The Department is also encouraging the formation of consortia of two or more units in the small scale sector, whereby it is possible to use a common brand name and circuit design,

IV

share the cost of marketing and advertising and also use common after-sales service facility. In fact, such consortia have already been formed in Bombay, Madras and Nagpur. It may be noted that formation into consortia will enable small scale units to compete effectively with large units.

4.5.1.3. Tape Recorders and Record Players

The internal demand for tape recorders is expected to reach a figure of 3 lakhs per year by the end of the Fifth Plan period. In view of the large capacity already approved/licensed, there seems to be no need for creation of any further capacity. Video tape recorders may find a limited market in India and may need imported know-how for further development.

For record players, there is no need for any import of technical know-how or collaboration as foreign companies are major producers of this item. There is, however, a need for development of good drive systems and micro-motors which are required for an increased production of low cost record players in the medium and small scale sectors.

4.5.1.4. Audio Amplifiers and PA Systems

The projected demand of 3 lakh numbers for these items is expected to be catered to by the existing units. There is a gap in production of professional quality and stereo amplifiers which may find sizeable market in the country as well as abroad. There is also some scope for intercommunication systems, of the professional type, for which there is likely to be increasing demand in future.

4.5.1.5. Miscellaneous Devices

Kits for educational purposes in schools and colleges, electronic organs, watches and the like can find growing market both within the country and abroad. Efforts should, however, be made to reduce their cost.

4.5.2. Guidelines for Technology Development

The strategy to be adopted for R&D should be to achieve the following objectives:

- (i) to develop the products within the shortest possible time,
- (ii) to incorporate maximum utilisation of indigenous components and materials,
- (iii) to incorporate latest innovation in design, and
- (iv) to minimise the foreign exchange expenditure.

Broadly speaking, there are three courses open for R&D activities in this area, viz.,

- (i) completely original research, design and development work,
- (ii) development based on improvement of existing designs, and
- (iii) R&D through foreign collaborations.

The first alternative can be deemphasised, as the main objective of development in a very short period will not be achieved by this approach. However, the choice between the second and the third alternatives will depend much on the products concerned. This is further discussed below.

(a) Products for which complete know-how is available in the country (e.g. radio receivers): For these products, to meet the basic requirement of satisfying the needs of the whole spectrum of consumers, continuous improvements in design and styling features is necessary. However, in this direction no additional effort is needed as presently most of the manufacturing organisa-

IV

tions are doing this type of work in order to improve their position in the competitive set up.

(b) Products for which know-how is available in the country but still some imported components are being used (e.g. TV, tape recorders, record players/changers): In this area, the R&D efforts should be directed towards indigenisation. The case of TV receivers and tape recorders is discussed below:

(i) Television Receivers

Two items that require development efforts are the phosphor and the deflection components. NPL has been working on the development of phosphor for TV picture tubes. Steps should be taken to expedite its production. Development of know-how for deflection components has been in progress in several organisations including CEERI. Time and specification targets should be set for these developments, taking care to avoid any duplication.

(ii) Tape Recorders and Record Players

The record player industry is fairly well established in the country. Developmental efforts are required in achieving high quality sets.

The tape recorder industry on the other hand requires considerable efforts in R&D activity. To date, except for the cabinet and the electronics part, all the other parts namely, tape deck mechanism, motor, magnetic heads, microphone, tape, etc., are being imported.

A number of units have initiated move to manufacture the above listed parts in India with locally developed know-how. The progress is satisfactory in the case of tape deck mechanism only. Intensive efforts are still required to be made to translate the know-how available in the case of micro motors, magnetic heads and microphones into production know-how.

The cassette tapes are yet to be made and efforts to manufacture the same is an urgent necessity as the demand is likely to be large.

(c) Products for which know-how is not available in India or no substantial developmental work has been initiated (e.g. stereo tape recorders, electronic kits, toys, hearing aids): For all such products it is best suitable to modify the design of equipments manufactured in developed countries by incorporating indigenously produced components. The existing level of technical know-how in the country will form a very suitable base for such activity.

Electronic kits and toys require only development work as the technology associated is not complex. In most of the toys, the electronic portion involves simple transistor circuits like portable voice amplifier. More sophisticated radio controlled toys can be developed for export purposes.

(d) Export Oriented Products: The products that fall in this category are Colour TV receivers, video record players, video tape recorders, electronic musical instruments, FM radios, electronic ovens, electronic air conditioners, automatic washers, driers, etc. The idea of developing these products, which do not have substantial market in the country in the near future, is to boost our export.

For doing R&D work in these areas again we have the same three options mentioned earlier. In this particular case the development through the third alternative appears to be most attractive. Such projects should be considered for the free trade zones devoted to 100 per cent export. If such collaboration is allowed at present, we would be equipped with the know-how as the domestic market builds up.

4.6 Investment Profile

4.6.1. Fifth Five Year Plan

The estimated profile for investment and production (activity-wise) for the Fifth Five Year Plan is given in Table 4.8. The phasing of the capital investment of Rs. 6.6 crores for consumer electronics field for the Fifth Plan is as given in Table 4.9. This investment includes resources generated within the industry in the private sector. The investment profile for the Five Year Plan is drawn up such that, more than 70 per cent of the total plan investment is made in the first three years and the rest in the following years. Heavier investment is needed in the initial period in order to maximise the returns in the shortest possible time as well as to minimise foreign exchange drain due to direct imports of subassemblies and components.

The investment of Rs. 1 crore envisaged for State agencies for rural market promotion is expected to reverse the declining trend in the offtake of radio receivers seen in the last two or three years.

Table 4.8. Activity-wise investment and production in consumer electronics during the Fifth Plan period (Rs. in crores).

Activity/Project	Capital investment			Production	
	Public	Private	Total	Plan period	Terminal year
Radio receivers		2.0	2.0	322	84
State agencies for rural market promotion	1.0		1.0		
TV receivers				226	73
Tape recorders and record players		0.7	0.7	67	20
Amplifiers and PA systems		0.9	0.9	52	15
Miscellaneous consumer goods		2.0	2.0	25	7
Total	1.0	5.6	6.6	692	199

Table 4.9. Phasing of capital investment for consumer electronics during the Fifth Plan period (Rs. in crores).

1974-75	1975-76	1976-77	1977-78	1978-79	Plan period (1974-79)
1.6	1.6	1.6	0.9	0.9	6.6

4.6.2. Sixth Five Year Plan

The expected total production over the five year period (1979-84) is Rs. 1,655 crores for which a total investment of Rs. 15 crores with a terminal year investment of Rs. 5 crores is anticipated.

The rural market for radio receivers which will be opened up as a result of the promotional measures taken during the Fifth Plan may not maintain its growth by the end of the Sixth Plan. However with the introduction of Satellite TV, the TV receiver industry is expected to receive a boost. Also, the production of items such as record players, tape recorders, PA systems, etc., nucleated during the Fifth Plan is expected to make a substantial contribution to the overall production in consumer electronics.

Communication, Radar and Navigation Systems

5.1 Introduction

The pre-eminent role of communication and transportation systems in the efficient management of the administration of a vast country like ours has been given due acknowledgment by planners and administrators alike. An extensive network of modern communication systems helps in rapid exchange of information leading to quicker decision making. Likewise, a well operated transport system is essential for better mobility of materials, products and personnel. Navigational aids form the backbone of an economically and reliably operated transport system. With the rapid growth in traffic density and speed of modern transport vehicles, navigation systems are gaining increasing importance.

India has made considerable progress in the development of telecommunication facilities during the successive Five Year Plans. For example, in the local area telephone systems, as against 1.7 lakh direct exchange lines at the beginning of the Second Five Year Plan, about 13 lakh lines existed in the country as on March 1974. Telegraph and long distance telephone services have also grown, though to a lesser extent than the local area systems. The foundation has been laid for modernisation and automatising of long distance switching with the installation of about 20,000 kms of coaxial cable and microwave systems upto March 1974, and with the plans for trunk automatic exchanges at the major centres in the country. Apart from the quantitative growth in the existing services, there has also been diversifications of the types of facilities. Teleprinter and telex services, point-to-point subscriber trunk dialling, on-demand trunk services, and facsimile transmission services are some examples.

To manage these services the Ministry of Communications has two departments under it—the Post and Telegraphs Department (P&T) and the Overseas Communication Services (OCS). The P&T Department installs and maintains these facilities for the general public as well as for users such as All India Radio (AIR), Department of Civil Aviation (CAD), Defence Services, India Meteorological Department (IMD) and a few private organisations. In addition, some of the larger Government users own and maintain their own network. For example, the Indian Railways have their own telephone and telegraph network; CAD has an international communication network of its own; the Security Services under the Ministry of Home Affairs have their communication network employing a large number of low power radio communication equipment.

In accordance with the Industrial Policy Resolution of the Government, production of communication equipment is mainly in the public sector. The major manufacturers of equipment are Bharat Electronics Limited (BEL), P&T Telecommunication Workshops, Hindustan Cables Limited (HCL), Hindustan Teleprinters Limited (HTL), Indian Telephone Industries Limited

(ITI), and Hindustan Aeronautics Limited (HAL). BEL manufactures a variety of low power and high power radio communication equipment. The P&T Telecommunication Workshops at Bombay, Calcutta and Jabalpur manufacture telegraph and telephone manual exchange equipment and a variety of line materials. Wires and cables are manufactured by HCL besides a few units in the private sector. HTL is the only manufacturer of teleprinters. ITI is the largest manufacturer of line communication equipment that includes automatic telephone exchange equipment, telephone instruments and transmission equipment. The signalling equipment required to regulate road and rail traffic are being manufactured by ITI and the Railway Signalling and Telecommunication Workshops.

In spite of the considerable growth in the telecommunication facilities, the demand for these services has outstripped the supply as indicated by the large waiting list of about 3.5 lakhs subscribers for telephone and the average waiting period of 3 to 4 years. The primary reasons for this wide gap between the demand and supply have been the limited indigenous availability of telecommunication stores and materials, lack of adequate investible funds due to the constraints of the economy and scarce foreign exchange resources for import of equipment. Despite the stringent foreign exchange resources, direct imports during the Fourth Five Year Plan amounted to about Rs. 60 crores as against Rs. 20 crores during the Third Five Year Plan. The demand for telecommunication services is likely to grow even more rapidly in the coming years in view of the anticipated growth of economy. The demand for telecommunication equipment, the existing supply position, the resulting shortfall and the plans to bridge the gap are described in the subsequent sections.

The transportation systems in the country, and with these, the navigation systems for supporting their operation, have grown significantly in recent years. All the airports now have the basic navigational aids and the international airports are well equipped with sophisticated navigation, approach and landing aids. Major seaports are equipped with appropriate navigational aids. The Directorate General of Civil Aviation (DGCA), the agency responsible for the coordination of air transport operations in the country, provides navigational aids at the airports. While the coastal navigational aids are under the control of the Directorate General of Lighthouses and Lightships (DGLL), the aids required at the major ports are installed and maintained by the respective port authorities. Radars, in addition to their use as navigational aids, are also used by the India Meteorological Department (IMD) for weather observations, and Indian Space Research Organisation (ISRO) for satellite tracking.

Most of the equipment required for navigational purposes have so far been imported. It may be mentioned here that some of the equipment in this category required for Defence services are manufactured by HAL. BFL manufactures some of the radars for civilian applications such as weather radars.

Equipment covered in this chapter have been grouped under the following broad headings:

1. Telecommunication
2. International communication
3. Radio communication
4. Telemetry and telecontrol
5. Radar and navigational aids

5.2 Telecommunication

"Telecommunication" as used in this section, covers telephone instruments, manual and automatic circuit switching equipment, open wires, cables, coaxial cables, antennas and waveguides; multiplexing equipment, transmission equipment for open wire, cable, coaxial cable, VHF, UHF and microwave systems, teleprinters, facsimile systems, data transmission systems, PCM equipment, railway signalling equipment, associated test and maintenance instruments.

5.2.1. Current Status

In this section, data on production capacity, actual production, major imports and research and development activities in this field are given.

5.2.1.1. Production

Switching Equipment

Autoswitching equipment is at present being manufactured at ITI, Bangalore. Its annual production capacity of strowger and crossbar equipment is as follows:

- (i) 1,50,000 lines of strowger switching equipment (2½ shift capacity).
- (ii) 1,00,000 equivalent lines of pentaconta crossbar equipment (single shift capacity).

Underground Telephone Cables

At present, HCL, Rupnarainpur manufactures underground telephone cables. Its annual manufacturing capacity is 5000 SKM (3 shift basis). Its capacity is being augmented to 10,000 SKM (3 shift). Another factory at Hyderabad has been established with a production capacity of 5,000 SKM underground cables per year expandable to 8,000 SKM per year.

Telephone Instruments

These are being manufactured in ITI, Bangalore. Another unit at Naini has been established. As of today, annual capacity of ITI, Bangalore is 2,75,000 telephone instruments of different types and of Naini is 2,75,000 numbers. Actual production at Bangalore in 1973-74 was 2,35,905 numbers and at Naini 22,080 numbers.

Transmission Equipment

At present transmission equipment is being manufactured mostly by the Bangalore unit of ITI. The second unit set up at Naini has also started production since 1971-72. The current annual production of these equipment amounts to about Rs. 8 crores from the Bangalore unit and Rs. 3 crores from the Naini unit.

Coaxial Cables

At present coaxial cables are being manufactured by HCL, Rupnarainpur, which has an annual manufacturing capacity of 2,500 TKM of large tube and 1,000 TKM of small tube coaxial. HCL, Hyderabad is expected to produce 2,000 TKM of coaxial cables per year.

Antennas and Waveguides for Microwave/UHF Systems

Electronics Corporation of India Limited, Hyderabad has a letter of intent for the manufacture of 250 numbers antennas and associated feed sys-

tems. Manufacture of waveguides on a small scale is being done in the country.

Teleprinters

The requirements of the country for teleprinters are being met by HTL, at present. HTL has an annual production capacity of 6,000 teleprinters and spares for about 1,200 units. The unit can manufacture about 8,500 teleprinters by working on two shifts. Currently, the unit is manufacturing about 5000 teleprinters per annum.

Railway Signalling and Telecommunication Equipment

The Ministry of Railways have departmental signalling and telecommunication workshops located at Podanur, Gorakhpur, Secunderabad, and Bombay with smaller units at Howrah, Ghaziabad and Sabarmati. Status of production of signalling and telecommunication equipment from these factories is as follows:

Unit	Production in 1973-74 (Rs. lakhs)
Central — Byculla	62.80
Eastern — Howrah	19.44
Northern — Ghaziabad	33.00
Northeastern — Gorakhpur	50.00
Northeast frontier — Gauhati	2.11
South central — Mettuguda	72.55
Southern — Podanur	90.00
Western — Sabarmati	34.00
Western — Ajmer	11.05
Total	374.95

Telecommunication Equipment at P&T Telecom Workshops

The P&T Departmental Telecommunication Workshops manufacture a wide range of telecommunication materials at Calcutta, Jabalpur and Bombay. The total production of these workshops amounted to Rs. 3.2 crores, Rs. 4.8 crores and Rs. 2.0 crores, respectively in 1973-74.

5.2.1.2. Import of Telecommunication Equipment

As mentioned in an earlier section the domestic production of telecommunication equipment has not been able to meet fully the demands in the country. Also, some raw materials and components needed for equipment manufacture are not available in the country. As a result, there has been a significant amount of import of telecommunication equipment and materials.

The imports by the P&T Department during the period 1969-1974 were as follows:

	Rs. crores
1. Underground telephone cables	30
2. Copper weld wire	4
3. Switching equipment	3
4. Long distance transmission equipment including coaxial, microwave equipment and testing and research and training instruments	17
5. Raw materials and components, plant and machinery of P&T factories	5
Total	59

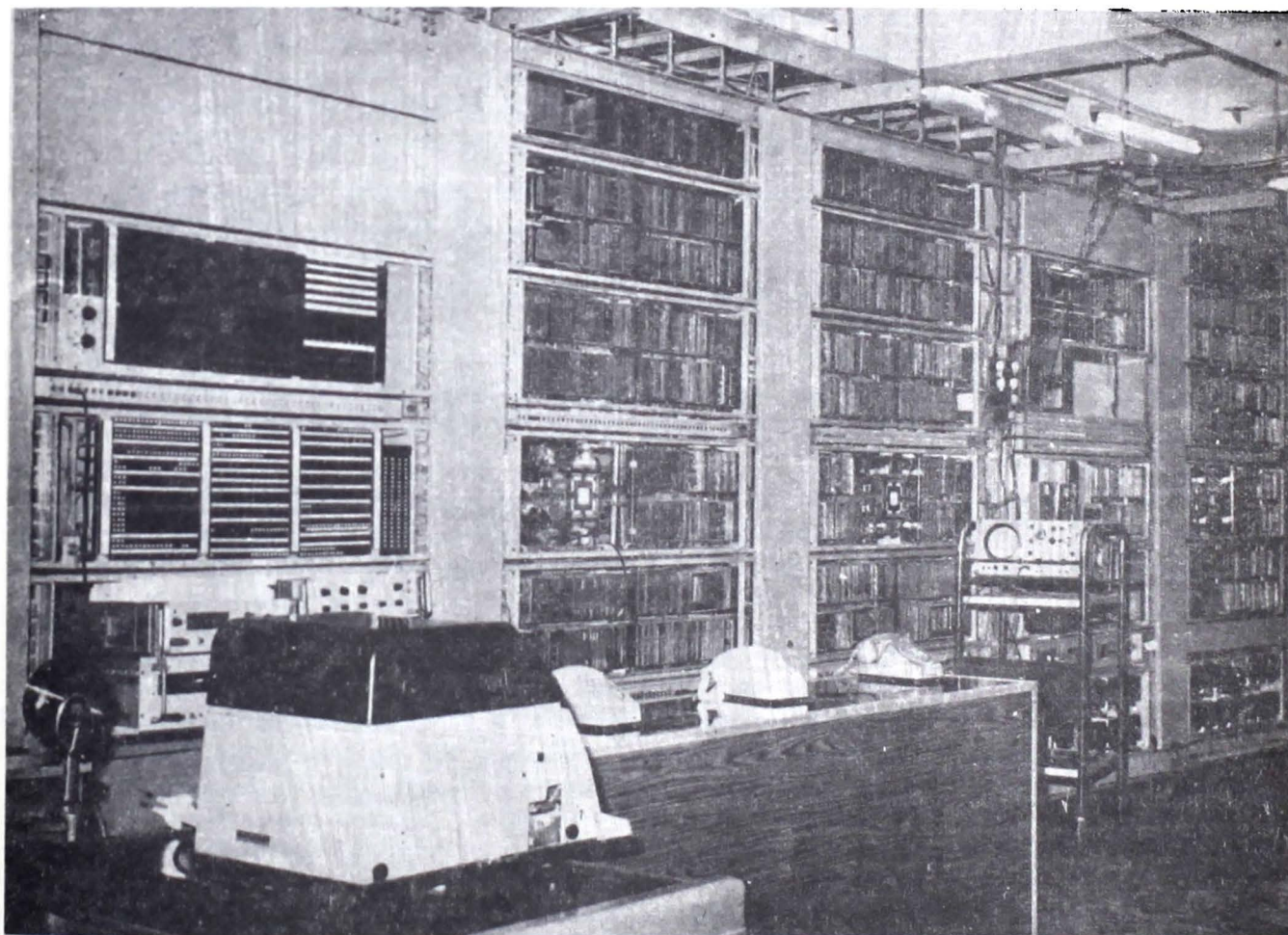
5.2.1.3. Research and Development

Organisations engaged in R&D activities in the field are TRC, DRDO, HR&U, TIFR, ESCES, ISRO, CEERI, NPL, BARC, VSSC, R&SO, PRL, academic institutions like the IITs, IISc, etc.

In addition to the above, research and development is a distinct function in ITI, HTL, BEL and ECIL. Developmental work is being carried out in Hindustan Cables Limited and in the Telecom Factories of the P&T Department. In the field of telephone exchange equipment, there has not been appreciable indigenous development as a result of licensed manufacture and foreign technical participation. In the field of transmission equipment where such licensed manufacture or foreign technical participation was not readily available, substantial progress in indigenisation has taken place covering a wide range from conventional equipment for line communication to ground equipment for space communication. While the progress in these fields is substantial, there has always been a steadily increasing technology gap between design and manufacture in the country and that in technologically advanced countries.

5.2.2. Demand Profile

The forecasting of telephone demand and the type and quantity of materials required to an acceptable degree of accuracy are considered infeasible



Experimental Electronic Telephone Exchange controlled by a Computer designed by Telecommunication Research Centre.

for a period more than 10 years. Hence, the estimation of requirements of different telecommunication materials has been limited to the period 1974-1984 (Fifth and Sixth Five Year Plan durations).

The P&T Department is a major user of telecommunication equipment and stores. They also cater to the needs of other Government departments like Defence, AIR, Railways and IMD by leasing out telephone and telegraph circuits. However, these departments are also setting up their own telecommunication networks to meet their specialised needs. Wherever specific quantitative requirements of other departments are not finalised, these have been covered by adding suitable percentages to the requirements projected by the P&T Department for various items of telecommunication materials. Exports of telecommunication equipment have been estimated at 5 per cent of the indigenous production during the Fifth Plan period and at 10 per cent of the indigenous production during the Sixth Plan period.

For the purpose of estimating the requirements of telecommunication equipment, the Telecommunication Capacity Planning Committee (TCPC) setup by the Ministry of Communications, has worked out two projections of telephone demand. These are: (a) Higher Demand Projection (HDP) which is based on the telephone demand as per sum of the microprojections (sum of the projected demands of the individual P&T Circles and Districts) during the period 1974-80 and as per the medium macro-economic projections (projection based on average growth of economy during 1954-70 but excluding the depression during 1966-68) for the period 1981-86, and (b) Lower Demand Projection (LDP) which is based on the growth of telephone demand according to the sum of micro-projections for the entire period 1974-86.

Based on the above demand projections corresponding physical programmes have been worked out. The alternative forecasts of the requirements of automatic switching equipment, underground telecommunication cables, and telephone instruments are worked out as these are directly correlated to the telephone demand and annual physical programmes. Demand for transmission equipment has been worked out based on past trends in the development of the long distance transmission media in the country and the long-term service objectives of the trunk network proposed by the P&T Department.

The demand for switching equipment for local telephone systems consists of (a) equipment for new installations and (b) equipment for replacement in exchanges which are 25-30 years old.

Besides local telephone systems, auto switching equipment is required for setting up of trunk automatic exchanges, gentex, PABX, point-to-point subscriber trunk dialling and operator dialling facilities. Total requirements of switching equipment based on the HDP and LDP are given in Tables 5.1 and 5.2, respectively. In addition to the requirements of P&T, there is a considerable demand for telephone exchanges by other departments like, Railways, Defence and large industrial and business organisations. It is anticipated that auto equipment to the extent of 20 per cent of the annual P&T requirements will be needed to meet these demands. Corresponding requirements of underground telephone cables and telephone instruments based on HDP and LDP, are given in Tables 5.3 to 5.6, respectively. Demand for coaxial cables is indicated in Table 5.7.

Table 5.1. Switching equipment demand during 1974-84 (HDP) (All figures in lakhs of lines).

Year	Expansion	Auto replacement	PABX	Maintenance on spares	Total for local	TAX	STD/CTD	Telex, genex	Total for trunk	Grand total	Requirements of other departments (20% of col. 11)	Total indigenous requirement (col. 11+12)	Requirement for exports	Capacity required for exchanges	Total requirement (col. 13+14+15)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1974-75	1.98	0.05	0.20	0.12	2.35	0.45	0.06	0.16	0.67	3.02	0.60	3.62	0.18	0.72	4.52
1975-76	2.01	0.10	0.25	0.14	2.50	0.75	0.06	0.17	0.98	3.48	0.70	4.18	0.21	0.84	5.23
1976-77	2.24	0.15	0.29	0.15	2.83	0.79	0.06	0.09	0.94	3.77	0.75	4.52	0.23	0.90	5.65
1977-78	2.97	0.20	0.34	0.17	3.68	0.79	0.06	0.06	0.91	4.59	0.92	5.51	0.27	1.10	6.88
1978-79	3.57	0.25	0.43	0.19	4.44	0.62	0.06	0.07	0.75	5.19	1.04	6.23	0.31	1.25	7.79
1979-80	4.11	0.03	0.47	0.22	4.83	0.14	0.10	0.20	0.44	5.27	1.05	6.32	0.63	1.26	8.21
1980-81	4.77	0.08	0.82	0.25	5.92	0.42	0.10	0.20	0.72	6.64	1.33	7.97	0.80	1.59	10.36
1981-82	5.33	0.13	0.84	0.28	6.58	0.70	0.10	0.20	1.00	7.58	1.52	9.10	0.91	1.82	11.83
1982-83	5.87	0.18	0.96	0.32	7.33	0.98	0.10	0.20	1.28	8.61	1.72	10.33	1.03	2.07	13.43
1983-84	6.44	0.24	1.06	0.37	8.11	1.31	0.10	0.20	1.61	9.72	1.94	11.66	1.17	2.33	15.16

Table 5.2. Switching equipment demand during 1974-84 (LDP) (All figures in lakhs of lines).

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1974-75	1.98	0.05	0.20	0.12	2.35	0.45	0.06	0.16	0.67	3.02	0.60	3.62	0.18	0.72	4.52
1975-76	2.01	0.10	0.25	0.14	2.50	0.75	0.06	0.17	0.98	3.48	0.70	4.18	0.21	0.84	5.23
1976-77	2.24	0.15	0.29	0.15	2.83	0.79	0.06	0.09	0.94	3.77	0.75	4.52	0.23	0.91	5.66
1977-78	2.41	0.20	0.34	0.18	3.13	0.79	0.06	0.06	0.91	4.04	0.81	4.85	0.24	0.97	6.06
1978-79	2.59	0.25	0.43	0.19	3.46	0.62	0.06	0.07	0.75	4.21	0.84	5.05	0.25	1.01	6.31
1979-80	2.76	0.03	0.47	0.22	3.48	0.14	0.10	0.20	0.44	3.92	0.78	4.70	0.47	0.94	6.11
1980-81	2.76	0.08	0.82	0.24	3.90	0.42	0.10	0.20	0.72	4.62	0.92	5.54	0.55	1.11	7.20
1981-82	2.76	0.13	0.84	0.27	4.00	0.70	0.10	0.20	1.00	5.00	1.00	6.00	0.60	1.20	7.80
1982-83	2.76	0.18	0.96	0.29	4.19	0.98	0.10	0.20	1.28	5.47	1.09	6.56	0.66	1.31	8.53
1983-84	2.77	0.24	1.06	0.32	4.39	1.31	0.10	0.20	1.61	6.00	1.20	7.20	0.72	1.44	9.36

Notes: (1) Lead time for supply spread and construction time has been taken as:

- (a) Main auto exchange/TAX/STD — 2 years
- (b) PABXs — 1 year

(2) 1 TAX line is equivalent to 2.5 MAX — 1 line.

(3) Maintenance spares have been provided at 1% of the total capacity existing in the beginning of the year.

(4) Provision for exports has been made at 5% of total indigenous requirements for the period 1974-79 and 10% for the period 1979-84.

(5) The requirements of other Government departments and private organisations are estimated to be 20% of P&T requirement.

Table 5.3. Underground telephone cables demand during 1974-84 (HDP).

Year	DELS provided during the year (10 ³)	For provision of DELS	For miscellaneous requirements	Total requirements	Requirements of other departments	Total indigenous requirement	Provision for anticipated export	Provision for shortfall in production due to unforeseen circumstances or higher rate of demand	Total requirement (SKM)
1	2	3	4	5	6	7	8	9	10
1974-75	1.30	6,500	500	7,000	1,400	8,400	420	1,680	10,500
1975-76	1.30	7,200	500	7,700	1,540	9,240	460	1,850	11,550
1976-77	1.57	8,200	500	8,700	1,740	10,440	520	2,090	13,050
1977-78	1.72	9,000	500	9,500	1,900	11,400	570	2,280	14,250
1978-79	1.90	10,750	500	11,250	2,250	13,500	670	2,700	16,870
1979-80	2.40	13,400	600	14,000	2,800	16,800	1,680	3,360	21,840
1980-81	2.95	16,125	800	16,925	3,385	20,310	2,030	4,060	26,400
1981-82	3.50	19,000	900	19,900	3,980	23,880	2,390	4,780	31,050
1982-83	4.10	22,000	1,000	23,000	4,600	27,600	2,760	5,520	35,880
1983-84	4.70	25,000	1,000	26,000	5,200	31,200	3,120	6,240	40,560

Table 5.4. Underground telephone cables demand during 1974-84 (LDP).

1	2	3	4	5	6	7	8	9	10
1974-75	1.30	6,500	500	7,000	1,400	8,400	420	1,680	10,500
1975-76	1.30	7,200	500	7,700	1,540	9,240	460	1,850	11,550
1976-77	1.57	8,200	500	8,700	1,740	10,440	520	2,090	13,050
1977-78	1.72	9,000	500	9,500	1,900	11,400	570	2,280	14,250
1978-79	1.90	10,000	500	10,500	2,100	12,600	630	2,520	14,750
1979-80	2.09	11,000	600	11,600	2,320	13,920	1,390	2,780	18,090
1980-81	2.30	11,500	800	12,300	2,460	14,760	1,460	2,950	19,170
1981-82	2.30	11,500	900	12,400	2,480	14,880	1,490	2,980	19,350
1982-83	2.30	11,500	1,000	12,500	2,500	15,000	1,500	3,000	19,500
1983-84	2.30	11,500	1,000	12,500	2,500	15,000	1,500	3,000	19,500

- Notes: (1) The requirements of other Government departments and private organisation have been estimated to be 20% of P&T requirement.
- (2) Provision for export has been made at 5% of indigenous requirement for 1974-79 and at 10% of indigenous requirement for the period 1979-84.
- (3) Figures in columns 2-10 in SKMs; 1 SKM=1 km of 100 pair cable.

Table 5.5. Telephone instruments demand during 1974-84 (HDP). (All figures in lakhs of numbers).

Year	DELs provided during the year	Instruments required for expansion	Instruments required for maintenance	Total requirements of P & T	Requirements of other users	Total indigenous requirements	Provision for anticipated exports	Provision for unforeseen short-fall in production or increase in demand	Total manufacturing requirements
1	2	3	4	5	6	7	8	9	10
1974-75	1.30	1.78	1.83	3.61	0.72	4.33	0.22	0.87	5.42
1975-76	1.30	1.78	2.01	3.79	0.76	4.55	0.23	0.91	5.69
1976-77	1.57	2.11	2.19	4.30	0.86	5.16	0.26	1.03	6.45
1977-78	1.72	2.35	2.41	4.76	0.95	5.71	0.28	1.14	7.13
1978-79	1.90	2.60	2.65	5.25	1.05	6.30	0.31	1.26	7.87
1979-80	2.40	3.36	2.92	6.28	1.26	7.54	0.75	1.51	9.80
1980-81	2.95	4.13	3.25	7.38	1.48	8.86	0.79	1.57	11.22
1981-82	3.50	4.90	3.67	8.57	1.71	10.28	1.03	2.06	13.37
1982-83	4.10	5.74	4.16	9.90	1.98	11.88	1.19	2.38	15.45
1983-84	4.70	6.58	4.73	11.31	2.26	13.57	1.36	2.71	17.64

Table 5.6. Telephone instruments demand during 1974-84 (LDP) (All figures in lakhs of numbers).

1	2	3	4	5	6	7	8	9	10
1974-75	1.30	1.78 ¹	1.83	3.61	0.72	4.33	0.22	0.87	5.42
1975-76	1.30	1.78	2.01	3.79	0.76	4.55	0.23	0.91	5.69
1976-77	1.57	2.11	2.19	4.30	0.86	5.16	0.26	1.03	6.45
1977-78	1.72	2.35	2.41	4.76	0.95	5.71	0.28	1.14	7.13
1978-79	1.90	2.60	2.65	5.25	1.05	6.30	0.31	1.26	7.87
1979-80	2.09	2.93	2.92	5.85	1.17	7.02	0.70	1.40	9.12
1980-81	2.30	3.22	3.21	6.43	1.29	7.72	0.77	1.54	10.03
1981-82	2.30	3.22	3.53	6.75	1.35	8.10	0.81	1.62	10.53
1982-83	2.30	3.22	3.85	7.07	1.41	8.48	0.85	1.70	11.03
1983-84	2.30	3.22	4.17	7.39	1.48	8.87	0.89	1.77	11.53

Notes: (1) Requirements of telephone instruments for expansion are 1.4 times the DELs provided during the year.

(2) Requirements for maintenance have been worked out at 10% of the total instruments existing at the beginning of the year. The number of connected telephones in a year is assumed to be 1.4 times the number of DELs in that year.

(3) Provision for other users is made at 20% of P&T requirement.

(4) Provision for exports is made at 5% for the period 1974-79 and 10% for 1979-84.

(5) Provision has been made at 20% of total indigenous requirement for unforeseen shortfall in production or increase in demand.

Table 5.7. Demand for coaxial cables during 1974-84.

Year	Large tube TKMs	Small tube TKMs
1974-75	3000	1600
1975-76	3644	2256
1976-77	5762	3200
1977-78	6578	4900
1978-79	5298	5332
1979-80	5500	5300
1980-81	5500	5300
1981-82	5500	5300
1982-83	5500	5300
1983-84	5500	5300

Table 5.8. Requirements of transmission equipmen for P&T.

Product line	1974-75	1975-76	1976-77	1977-78	1978-79	1979-80	1980-81	1981-82	1982-83	1983-84
1. Microwave radio equipment (in route kms)										
(a) 4/6 GHz 1800 channel	9129	4128	5503	9850	9935	10000	15000	15000	20000	23100
(b) 7 GHz 300 channel	130	400	700	1024	1163	1500	1500	1500	1500	1500
(c) 2 GHz 120 channel	60	200	360	492	597	600	700	700	700	700
2. UHF radio equipment (in route kms)										
400 MHz 60 channel	400	1020	1440	1700	1830	2000	2500	3500	3500	3500
3. Coaxial line equipment (in route kms)										
(a) 2.6 MHz small tube cable	1500	—	—	—	—	—	—	—	—	—
(b) 4 MHz small tube cable	400	550	578	1100	1208	2500	2500	2500	3000	1500
(c) 12 MHz small tube cable	—	—	—	—	—	500	1000	1500	1500	—
(d) 6 MHz large tube cable	846	804	226	1100	—	—	—	—	—	—
(e) 12 MHz large tube cable	—	719	2126	3854	3859	3500	3500	3500	3500	2600
4. Multiplexing equipment (in numbers of channel ends)	11136	17016	23688	26616	27144	35000	45000	60000	75000	75000
5. VHF systems (in numbers)										
(a) Single channel	200	200	200	200	200	500	500	500	500	500
(b) 6+1 channel	20	20	20	20	20	50	50	50	50	50
6. Interstice carrier cable line equipment (in numbers)										
(a) Terminals	50	50	50	50	50	100	100	100	100	100
(b) Repeaters	150	150	150	150	150	300	300	300	300	300

7. Openwire carrier equipment (in numbers of channels)											
(a) 3 channel	720	720	720	720	720	720	720	720	720	720	720
(b) 8 channel	480	480	480	480	480	480	480	480	480	480	480
(c) 12 channel	24	24	24	24	24	24	24	24	24	24	24
8. PCM equipment (in numbers)											
(a) 24/120 channel-terminals	200	200	200	200	200	300	300	300	300	300	300
(b) 24/120 channel-repeaters	1200	1200	1200	1200	1200	1800	1800	1800	1800	1800	1800
9. VFT equipment (in numbers of channels)	500	600	700	800	900	1000	1000	1000	1200	1300	

Table 5.9. Valuewise requirements of transmission equipment during 1974-84 (in Rs. crores).

Year	Requirements of P & T										Requirements of other users & exports (40% of col. 11)	Total for the country
	Radio equipment for microwave systems	Radio equipment for UHF systems	Coaxial line equipment	Multiplexing equipment	VHF systems	Interstice carrier cable line equipment	Open wire carrier systems	PCM equipment	VFT systems	Total P & T		
1974-75	9.88	0.03	0.86	4.67	1.36	0.93	2.20	1.20	0.032	21.16	8.5	29.66
1975-76	4.90	0.16	0.90	7.14	1.36	0.93	2.20	1.20	0.038	18.83	7.5	26.33
1976-77	6.75	0.23	1.50	9.95	1.36	0.93	2.20	1.20	0.044	24.16	9.6	33.76
1977-78	11.82	0.27	2.68	11.17	1.36	0.93	2.20	1.20	0.050	31.68	12.7	44.38
1978-79	12.05	0.31	2.66	11.40	1.36	0.93	2.20	1.20	0.057	32.17	12.9	45.07
1979-80	12.17	0.32	3.00	14.70	3.40	1.85	2.20	1.80	0.063	39.50	15.8	55.30
1980-81	17.82	0.40	3.30	20.90	3.40	1.85	2.20	1.80	0.063	51.73	20.7	72.43
1981-82	17.82	0.56	3.60	25.20	3.40	1.85	2.20	1.80	0.063	56.49	22.6	79.09
1982-83	23.15	0.56	3.81	31.50	3.40	1.85	2.20	1.80	0.076	68.35	27.3	95.65
1983-84	24.38	0.56	3.81	31.50	3.40	1.85	2.20	1.80	0.082	69.06	27.6	96.66

Notes: I. Cost estimates given below are first order approximations.

II. Costs of different transmission equipment required are calculated on the following basis:

- (1) The average unit cost per RF channel km for microwave systems is assumed as (a) for broad band system—Rs. 10650 and (b) for narrow band system—Rs. 8400.
- (2) For UHF systems—Rs. 1600 per RF channel km.
- (3) For multiplexing equipment, unit cost per channel end—Rs. 4200.
- (4) For VHF systems, unit cost for (a) single channel—Rs. 60,000 and (b) multichannel—Rs. 80,000.
- (5) For interstice carrier cable line equipment, unit cost for (a) terminals—Rs. 16,500 and (b) repeaters—Rs. 6500.
- (6) For open wire carrier systems, average unit cost per channel—Rs. 18,000.
- (7) For PCM equipment, unit cost per system—Rs. 1,20,000.
- (8) For VFT system—Rs. 640 per channel.
- (9) For coaxial line equipment (cost per route km).

Small tube type	Large tube type
2.6 MHz—Rs. 2700	6 MHz—Rs. 4000
4 MHz—Rs. 2700	12 MHz—Rs. 6000
12 MHz—Rs. 6000	

Table 5.10. Demand for microwave and UHF antennas for the period 1974-84.

Year	For 4 & 6 GHz wide band system for P & T	For 7 GHz narrow-band system		For 2 GHz narrow-band system for P & T	For microwave systems used by other agencies	Total requirements of microwave antennas	For UHF systems		
		P & T	Railways				P & T	Railways	Total
1	2	3	4	5	6	7	8	9	10
1974-75	139	8	60	4	32	243	22	35	57
1975-76	96	24	60	10	42	232	56	35	91
1976-77	156	36	50	18	47	307	80	35	115
1977-78	204	54	40	24	52	374	100	35	135
1978-79	189	64	40	30	62	385	110	35	145
1979-80	185	70	50	30	70	405	112	35	147
1980-81	185	70	50	30	70	405	112	35	147
1981-82	185	70	50	30	70	405	112	35	147
1982-83	185	70	50	30	70	405	112	35	147
1983-84	185	70	50	30	70	405	112	35	147

Table 5.11. Consolidated requirements of different types of microwave and UHF guides (in metres).

Year	Elliptical waveguides			Circular waveguides 4/6 GHz systems (P&T)	Rectangular waveguides			Coaxial feeders 2 GHz systems (P&T, CWPC, OCS)	Feeder cables for UHF systems (P&T, Railways)
	4/6 GHz broad band microwave systems (P&T)	7 GHz narrow band microwave systems (P&T, Railways)	Total		4/6 GHz systems for horizontal run for circular feeders (P&T)	For manufacturing waveguide components and other applications in various bands	Total		
1	2	3	4	5	6	7	8	9	10
1974-75	20320	7200	27520	5420	1360	4200	5560	3400	2930
1975-76	14320	8700	23020	3820	960	3000	3960	3500	6140
1976-77	19620	9900	29520	5240	1310	4000	5310	4300	7700
1977-78	22400	11400	33800	6040	1510	4600	6110	4400	8840
1978-79	26700	12400	39100	7120	1780	5400	7180	5000	9130

- Notes: (1) For 2 GHz systems, normally low loss coaxial feeders would be used.
 (2) For 7 GHz narrow-band systems, normally elliptical feeders are used.
 (3) For 4/6 GHz broad-band systems, the use of 75% elliptical, 20% circular and rectangular feeders is assumed; this is based on users' demand and the present world trend.
 (4) The requirement of elliptical waveguide as projected by users works out to be more than 80% of the total feeder runs requirement.

5.2.2.1. Transmission Equipment

Apart from the local telephone network, the development of a reliable and modern long distance network is essential for providing satisfactory telecommunication facilities for general administration, maintenance of law and order, Defence and business activity. Keeping the need for the next 10-15 years in view, the country has been divided into 4 main centres i.e., Bombay, Madras, Calcutta and New Delhi, 40 primary centres and 305 secondary centres. The main transmission network will connect the hierarchical backbone chain and the transverse high usage direct route. Besides provision of modern transmission systems like coaxial, microwave, UHF, etc., provision has also been made for adequate openwire carrier equipment viz., 3 channel, 8 channel and 12 channel systems to meet the increase in demand on the routes which are not covered by coaxial/microwave schemes. It is anticipated that with more and more stations being covered by coaxial/microwave/UHF systems, the requirement of openwire carrier systems will stabilise around the requirement of Fifth Five Year Plan. It may taper off towards the end of Sixth Five Year Plan. Quantitative requirements of P&T for these during 1974-84 are given in Table 5.8. The product range covers coaxial line equipment, microwave radio equipment, VHF and UHF radio equipment, openwire carrier equipment, VFT equipment, interstice carrier cable equipment, FCM equipment, multiplexing equipment, and data transmission equipment. Table 5.9 consolidates the valuewise requirements of transmission equipment for the country during 1974-84. The requirements of the other users like Railways, Defence, OCS, CWPC, etc., and for exports are estimated on the basis that these would be requiring about 40 per cent of the P&T requirement.

5.2.2.2. Waveguides and Antennas

Demand for microwave and UHF antennas required for various systems used by P&T, Railways, CWPC and other users is given in Table 5.10. The requirements during the Fifth Five Year Plan of various types of microwave and UHF guides are given in Table 5.11. The Sixth Five Year Plan requirements of these items are estimated to be of the order of 70,000 metres per annum. The breakup in terms of the types of waveguides would depend upon the system design.

5.2.2.3. Test and Measuring Instruments

A large number of instruments would be required for testing and maintenance of the different types of telecommunication systems. A list of standard sets of instruments so required for each system is given below.

List of standard set of test and measuring instruments required for
different types of telecommunication systems

I. Coaxial Systems (The list is only typical)

A. Terminal stations and dropping stations

1. Selective level meter (14 MHz)
2. HF oscillator 8 MHz DNTE 50037-S
3. High voltage fault locator, wheatstone bridge DNTE 50074-S
4. 5 kV breakdown tester DNTE 50030-S
5. Selective level meter 100 kHz DNTE 50075-S
6. ISGP generator 6 MHz DNTE 50133-S

7. ISGP receiver 6 MHz DNTE 50147-S
8. G & SG reference pilot receiver, DNTE 50053-S
9. dB meter with oscillator, DNTE 50020-S
10. 600 kHz wideband meter
11. RC oscillator 0-150 kHz DNTE 50017-S
12. Signal panel testing, DNTE 50057-S
13. Insulation tester, DNTE 50026-S
14. Wheatstone bridge (D-30A)
15. Pads 75 ohms balanced 1 to 50 dB
16. AVO meter Mark III, Model 8
17. De-emphasis level meter DNTE 50054-S (for small coaxial routes only)

B. Attended station (power feeding but not having dropping facility)

1. Selective level meter (14 MHz)
2. HF oscillator 8 MHz DNTE 50037-S
3. High voltage fault locator, wheatstone bridge DNTE 50074-S
4. 5 kV breakdown tester, DNTE 50030-S
5. ISGP generator 6 MHz DNTE 50133-S
6. ISGP receiver 6 MHz DNTE 50147-S
7. Wheatstone bridge (D-30A)
8. AVO meter Mark III Model 8

C. Coaxial maintenance division

1. Oscilloscope precision type 10 MHz DNTE 50039-S
2. Psophometer (transistorised) DNTE 50085-S
3. Frequency counter ITI DNTE 50098-S
4. Valve tester

II. Microwave Systems

A. For each attended station

1. Basic power meter 10 MHz—10 GHz with thermistor mount
2. Waveguide frequency meter 5.3 GHz—8.3 GHz adapter coaxial cable (6 ft cable with 'N' male connector)

B. For each system

1. Coaxial attenuators
 - Low power (2W) DC to 12.5 GHz
 - 3 dB
 - 6 dB
 - 10 dB
 - 20 dB
2. VSWR measuring instruments including
 - (a) AM signal generator 7 GHz—11 GHz with adapter
 - (b) Slotted line carriage
 - (c) Slotted line
 - (d) Broad-band probe
 - (e) Detector
 - (f) VSWR meter
3. HP link analyser
 - HP 3701 A

HP 3702 A

HP 3703 A

4. Wave analyser 10 kHz—18 MHz: level range—97 dBm to +22 dBm f.s.d., tracking oscillator 10 kHz—22 MHz
5. DC clip-on milliammeter 10 mA to 10 A
6. Inverter waveform and frequency—CRO
7. Shift converter

Note: For base band equipment refer to list for coaxial systems.

III. 8/12 Channel Open Wire Carrier Systems or RF Cable Systems

1. VTVM 150 kHz DNTE 50022-S (or wideband level meter 600 kHz DNTE 50019-S)
2. RC oscillator 600 kHz DNTE 50131-Grp.I
3. dB meter (with 800 Hz oscillator) 150 kHz DNTE 50019-S
4. Signal panel tester DNTE 50057-S
5. Cathode ray relay tester DNTE 50013-S
6. Channel synchroniser DNTE 50015-S
7. Selective level meter 600 kHz 50057-S
8. Line fault locator, DNTE 50006-S (for line testing station)
9. Insulation tester DNTE 50026-S
10. AVO meter Model 8 or Model 7
11. dB meter 35 kHz DNTE 50020-S

IV. VFT Station

1. VTVM 150 kHz DNTE 50022-S
2. Cathode ray relay tester DNTE 50013-S
3. Insulation tester DNTE 50026-S
4. AVO meter Model 7 or 8
5. Telegraph bias and distortion meter DNTE 50052-S
6. Telegraph speed and synchronous distortion tester DNTE 50014-S
7. TP signal generator DNTE 50049-S (only for large stations having TP monitoring facility)
8. Telegraph text sender (for large VFT stations only) DNTE 50092-S

V. Carrier Stations having 3 Channel/S+3DX Systems

1. VTVM 150 kHz DNTE 50022-S
2. RC oscillator 150 kHz DNTE 50132-Grp.I
3. AVO meter Model 7 or 8
4. dB meter Type 208 DNTE 50020-S
5. Channel synchroniser DNTE 50015-S

VI. Long Distance Systems

1. Frequency counter DNTE 50098-S
2. Psophometer DNTE 50085-S
3. CRO DNTE 50062-S or DNTE 50039-S
4. Bridge megger

VII. Trunk Exchange

1. dB meter Type 208
2. Insulation tester
3. AVO meter Model 7 or 8

VIII. Telegraph Offices

1. Teleprinter speed and synchroniser distortion tester
2. Stroboscope
3. Telegraph text sender (in charge station only)
4. Insulation tester
5. Cathode ray relay tester (where S&M teleprinter machines are available)
6. AVO meter Model 7 or 8
7. Telegraph bias test set

IX. VHF Station

A. For first line maintenance (of single channel system)

1. AVO meter

B. For second line maintenance of single channel system and regular maintenance of multi-channel systems

1. GMC (routine overhauls & fault rectifications)
 - (a) AVO meter
 - (b) VTVM
 - (c) Audio oscillator
 - (d) Reflectometer
 - (e) RF signal generators
 - (f) Modulation meter
2. Repair centre
 - (a) RF signal generators
 - (b) Modulation meter
 - (c) Reflectometer
 - (d) Frequency connector
 - (e) VHF field strength meter
 - (f) Audio oscillator
 - (g) VTVM
 - (h) CRO
 - (i) Power supply
 - (j) Clip-on ammeter
 - (k) Coaxial cables
 - (l) Adapters
 - (m) Signal samplers
 - (n) AVO meter
 - (o) Distortion analyser
 - (p) Directional RF meter

X. PCM Stations

1. Fault locating test set—One per station
2. Quantisation distortion test set—One per station
3. Bipolar violation meter—One per terminal
4. Logis probe—5 per station

Estimated year wise requirements of test and measuring instruments for various systems is given in Table 5.12. Based on the past experience of P&T, etc., total cost of the instruments required has been estimated at 20 per cent of the total cost of transmission equipment.

5.2.2.4. Teleprinters

The annual requirement of teleprinters for P&T during the Fifth Five Year Plan is 2000. From the plans of other departments, it is anticipated that their requirement is likely to be of the same order as that of P&T. Thus, the total requirement for teleprinters during the Fifth Five Year Plan is about 20,000 units. The value of this amounts to about Rs. 10 crores. In addition to conventional teleprinters, teletypes needed by computer industry for man-machine communication will be required in large quantities during the decade.

A summary of the annual valuwewise requirements of telecommunication materials for the ten year period 1974-84 is given in Table 5.13. In estimating the value, average prices have been assumed in some cases, which cover a range of equipment or material at different prices. The total requirements of telecommunication materials during 1974-79 amount to about Rs. 900 crores. The corresponding figure for the period 1979-84 comes to about Rs. 1415 crores.

Table 5.12. Testing and measuring instruments demand for 1974-84 (All figures in numbers of sets*)

Year	Coaxial systems				Microwave systems		UHF systems	PCM systems	Instruments for multiplexing equipment on coaxial, microwave and UHF routes (Sum of radio terminals plus 2xno. of UHF systems + 80% of no. Of coaxial attended stations)				Open wire carrier systems and VFI systems	VHF systems
	4/6 MHz routes		12 MHz routes		For each attended station	For each maintenance division			M/w	UHF	Coaxial	Total		
	For each attended station	For each division	For each attended station	For each division										
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1974-75	16	4	1	—	39	13	14	40	47	16	12	75	120	54
1975-76	17	3	11	3	25	9	34	40	28	37	24	89	120	54
1976-77	14	3	31	6	34	12	40	40	37	53	41	131	120	54
1977-78	21	4	56	12	54	10	56	40	60	62	70	192	120	54
1978-79	22	4	56	12	56	19	62	40	62	68	71	201	120	54
1979-80	43	8	71	14	56	19	60	60	62	75	92	229	120	132
1980-81	43	8	80	16	70	26	84	60	86	92	98	276	120	132
1981-82	43	8	90	10	78	26	116	60	86	128	107	321	120	132
1982-83	51	9	90	10	96	32	116	60	106	128	113	347	120	132
1983-84	62	11	70	16	106	35	116	60	117	128	113	358	120	132

*Set corresponds to the standard set of instruments for each system given in the list.

5.2.3. Analysis of Gaps

In the previous sections the demand profile and the current status of production and imports of telecommunication equipment were discussed. It was pointed out that about Rs. 60 crores worth of telecommunication equipment had to be imported during the period 1969-73. Some aspects of the supply-demand gap are discussed in this section.

Although in absolute terms the growth of telecommunications has been remarkable, the demand for services has grown faster, resulting in a widening gap between demand and supply. Table 5.14 gives the position in respect of waiting periods for obtaining telephone connection on an all India basis.

Table 5.13. Summary outline of the perspective demand for telecommunication materials in India (in Rs. crores).

Year	Switching equipment	Underground telephone cables	Telephone instruments	Coaxial cables	Transmission equipment	Test and measuring instruments (20% of col.6)	Total
1	2	3	4	5	6	7	8
1974-75	78	20	6	4	29	5	145
1975-76	92	22	7	5	26	5	157
1976-77	102	24	8	7	33	6	184
1977-78	108	27	8	9	44	8	207
1978-79	111	28	9	8	45	9	212
1979-80	85	33	11	8	55	11	205
1980-81	113	36	12	8	72	14	257
1981-82	144	36	13	8	79	15	297
1982-83	147	37	13	8	95	19	321
1983-84	159	37	14	8	96	19	335
1974-84	1139	300	101	73	574	111	2320

Table 5.14. Waiting period during the Five Year Plans.

Plan	Date	Working connections DELs (in lakhs)	Waiting list (in lakhs)	Total demand (in lakhs)	Average waiting period (in years)
2nd Plan	1-4-1956	1.73	0.29	2.02	0.9
	1-4-1961	3.32	1.65	4.97	1.8
3rd Plan	1-4-1961	3.32	1.65	4.97	1.8
	1-4-1966	6.51	3.49	10.00	3.2
4th Plan	1-4-1969	8.14	4.28	12.42	3.5
	1-4-1974	13.03	3.70	16.76	2.8

It may be observed that the waiting period had steadily increased from a year at the beginning of the Second Plan to about four years at the beginning of the Fourth Plan.

The long distance network is also far from adequate to meet the actual requirements of the country. This has resulted from inadequate coverage of stations, circuitous routings and non-adherence to standard switching and transmission plans. As a consequence, the long distance service suffers from (a) varying extents of delay in establishing trunk telephone calls and transmission of telegraph messages, (b) sub-standard performance, and (c) low reliability. On the one hand there is heavy usage per telephone (500 people per telephone) and on the other, the number of trunk calls per channel is about 20,000, one of the highest in the world. To connect a large number of telephone exchanges scattered thinly over a vast land mass by a standard long distance network of high reliability and performance is one of the most

challenging problems faced by not only designers and system planners but also by those entrusted with the task of mobilising resources.

A statistical summary of telecommunication services in the country is given in Table 5.15, indicating the progress made in the Fourth Plan period. Due to various factors there has been a slippage of targets to various extents during the Fourth Plan. For the coaxial and microwave schemes and a few others, there has been a spill-over of about two years into Fifth Five Year Plan.

A major constraint in the implementation of the Fourth Plan has been the shortage of material resources. Supply of telecommunication materials from ITI and HCL was not adequate to meet fully the Fourth Plan targets. The items for which there was an acute shortage included switchboard cables and plugs, battery and power plant, subscriber's meters, transmission wires, insulators, microwave towers and high frequency measuring instruments, apart from major equipment and stores such as switching and transmission equipment and underground cables. Cable deliveries were greatly affected by chronic labour problems. In the case of coaxial cables, problems associated with impedance matching of cables to specific repeater stations cause gaps between production and supply. This gap in the past has been of the order of 20 to 25 per cent.

The current status of technological know-how in the field of telecommunication equipment manufactured in the country is substantially behind the status of contemporary technology in advanced countries. In the field of switching and transmission equipment itself the gap is of the order of 5 to 8 years. Advances in communication equipment manufacture in Europe, USA and Japan have been in the direction of innovation, versatility, greater reliability and cost reduction, miniaturisation in design and automation in manufacture. Gains in this field have been as much a result of competitive environment as of large investments in advanced research and development. Large groups of scientists work for 5 to 6 years on projects that would lead to production in the following decade.

Investments on research and development as a percentage of sales turnover has varied from about 2 to 3 per cent in ITI, 0.6 per cent in HTL and less than 0.2 per cent in the P&T Telecommunication Factories. Corresponding comparable figures of expenditure on R&D in advanced countries vary from 8 per cent to as much as 15 per cent, which, considering the volume of production of these manufacturers, is a substantial amount. It is essential that similar investments in R&D be made by the manufacturing agencies in India, to bridge the gap in technology as rapidly as possible.

In view of the rapid obsolescence of technology in this field, a substantial effort in R&D has to precede any attempts at manufacturing contemporary equipment. Continual R&D effort is also necessary for updating technology so as to be competitive in the world market. This would call for substantial investments in R&D oriented towards development of equipment, components and technology likely to be used 5 to 8 years hence.

5.2.4. Proposed Guidelines

The guidelines suggested below are based almost entirely on the recommendations of the Telecommunication Capacity Planning Committee.

5.2.4.1. Guidelines for Production

As mentioned in the previous section, there is a clear need for aug-

Table 5.15. Telecommunication facilities—A statistical summary.*

Name of the item	Cumulative as on	
	1.4.1969	1.4.1974
1. Local telephone systems		
Switching equipment (capacity in lines)	1032421	1471082
Underground cables pair kms	4716775	7236398
Direct exchange lines	813815	1244169
Subscribers installation connected to departmental network telephone stations	1077856	1637426
No. of exchanges	3432	4711
2. Long distance switching systems		
Trunk automatic exchanges	2	4
Trunk automatic exchange lines	3500	7100
Subscribers trunk dialling routes, point to point	18	43
No. of subscribers dialling lines	22	—
Manual trunk boards	3026	4837
No. of circuits connected to trunk boards	10040	20899
3. Long distance transmission systems and multiplexing equipment		
Cable system coaxial & other trunk cables		
No. of channels	3924	11986
Route kms	8295	12833
Microwave systems		
No. of channels	699	2463
Route kms	2270	4648
VHF/HF systems		
No. of channels	—	293
Route kms	—	42394
Open-wire carrier systems		
No. of channels	6213	9965
Open-wire telegraphs		
No. of telegraph offices (CTOs, DTOs & COs only)	10425	12487
Voice frequency telegraphs, No. of channels	6325	8968
Voice frequency telegraphs, channel kms	3529095	4951674
Telex exchanges	20	49
Capacity in lines	5960	12440
Subscribers connected	3351	8518
Teleprinters, No. of units	10881	24678
Long-distance PCOs	3011	5009

*Statistics furnished by Ministry of Communications.

menting the production capacity during the Fifth Five Year Plan. Several alternatives for achieving this objective were studied and the following guidelines have resulted therefrom:

(a) The increase in production capacity is best achieved by setting up new plants and achieving optimum production from the installed capacity in the existing units by operating two shifts per day. In a precision engineering industry like that for the manufacture of telecommunication equipment, a third shift is not always practicable.

It may be noted in this connection that ITI has about 15000 workers under one roof. Setting up a third shift would involve employment of 2000

to 3000 workers. The total work force in the factory, as it is, poses difficult management and productivity problems. Also for a third shift, some additional equipment would be required to balance the total output. It would be difficult to find space for these at present. The incremental output expected from a third shift would be only marginal under these circumstances and from a cost-benefit analysis would not appear to be justified.

(b) While setting up new units, an attempt should be made to group products requiring like means of manufacture, thus reducing diversified production lines as also the impact of obsolescence of the means of production. The basic objectives to be achieved are therefore;

(i) a rate of expansion of manufacturing facilities which would result in a doubling of the output of telecommunication equipment by the end of the Fifth Plan period and

(ii) to ensure the setting up of a substantial research and development base so that the manufacturing line could be continuously upgraded based on reliable designs meeting the users' requirements.

(c) New units that are to be setup, while being viable in size, should not employ more than 5000 to 6000 people in any one unit so as to be compact, well managed and efficient. This would also be strategic in the sense that any adverse development like labour unrest, power break-downs, etc., would not seriously affect the total production of telecommunication equipment in the industry as a whole.

(d) The export market potential should be exploited by setting up production units which are entirely export oriented taking advantage of the special facilities available for such units for import of capital machinery, transfer of know-how, etc. This would result in substantial gain in expertise, which would be passed on to other manufacturing units from time to time.

(e) It is well known that most of the major manufacturers of telecommunication equipment either own or control, units manufacturing the system-based components that they use. Examples are M/s. Philips, Siemens, the ITT Group, the GTE Group, the Sumitomo Group, etc. This has given the designers access to components of high accuracy and reliability, thus resulting in reduced costs. Component manufacturers in the country cater mostly to the entertainment electronics field, and the special requirements of professional electronics do not receive the requisite attention. Therefore, manufacture of components for professional equipment may be licensed in the public sector during the Fifth Plan either in the existing units manufacturing communication equipment or in new units. Purchase of know-how should be permitted to such units as a one-time acquisition to ensure contemporary technology as also an R&D base for further research and development. The possibility of joint sector approach in such fields should be explored.

(f) Telecommunication manufacture is a precision industry where a large volume of components is to be manufactured to high precision and at reasonable cost. Traditionally this has been a fertile field for automation resulting in lower costs, high quality and reliability and reasonable freedom from the effects of industrial unrest. Capital machinery required for automation of these manufacturing processes are imported. Urgent action should be taken by the larger manufacturing units of telecommunication equipment to setup special units for designing and manufacturing special purpose machines. In most cases, this requires only adaptations of standard machine tools. Till this is achieved, a more liberal policy may be followed in allowing import of such special purpose machinery.

(g) In many cases, the gestation period in setting up of new manufacturing units is substantially large due to procedural delays. In view of the vital role played by the manufacturing industries in the field of telecommunication, it would be desirable that projects should be examined for clearance as one integrated proposal.

5.2.4.2. Guidelines for Technology Development

Realising the important need to bridge the gap in technology as rapidly as possible, the Ministry of Communications constituted the Telecommunications Research Review Committee, (TRRC) under the chairmanship of the Chairman, Electronics Commission, to review the status of research and development in the field of telecommunication, and to recommend the steps to be taken for accelerating the progress of research and development and to reach a stage of self-sufficiency at the earliest. This Committee in turn had constituted Working Groups in the various areas of telecommunication to examine in depth the current status of development and of the world at large and the inputs required to bridge this gap.

The Working Groups identified development projects that need to be taken up. A list of the important projects is given below:

A. Line Communication:

- (i) 12 MHz coaxial systems with TV capability
- (ii) 60 MHz coaxial systems
- (iii) Studies on millimetric waveguide and optical fibre systems

B. Electromechanical Switching:

- (i) Strowger system redesign
- (ii) Crossbar system redesign
- (iii) Pushbutton dial telephones
- (iv) Coin-collecting boxes with STD call-in-charge collection facility
- (v) New design of PBX/PABX
- (vi) Rural exchange design
- (vii) Mobile exchange design
- (viii) Shadow exchange design
- (ix) Line concentrators
- (x) Traffic measuring equipment
- (xi) International switching equipment

C. Electronic Switching:

- (i) Stored programme controlled (SPC) electronic local exchange
- (ii) SPC electronic trunk exchange
- (iii) SPC electronic tandem exchange
- (iv) SPC electronic telex exchange
- (v) SPC electronic PCM tandem exchange

D. Digital Communication:

- (i) Digital transmission systems
- (ii) Integrated switching and transmission
- (iii) Data transmission
- (iv) Satellite communication
- (v) Telemetry and telecommand

E. Microwave Communication:

- (i) 6 GHz, 1800 channel/TV system (updating current 960 channel TV design in production) with scope for full band exploitation (6+2)
- (ii) 4 GHz, 960 channel/1800 channel/TV system
- (iii) 11 GHz, 960 channel/TV system
- (iv) Outside broadcast links for TV (solid state)
- (v) 1.5 GHz, 60 channel, solid state system
- (vi) 7 GHz (upper) 300 channel, solid state heterodyne system
- (vii) 8 GHz 120 channel solid state system for Defence
- (viii) 2 GHz (1.7—2.1), 120 channel troposcatter system
- (ix) 5 GHz (4.4—5.0) 12/24/60 channel troposcatter system
- (x) Standard earth stations in 4 and 6 GHz bands, with SPADE terminals
- (xi) Large capacity domestic earth stations for message
- (xii) Receive only earth stations in 2.5 GHz for TV distribution from programme originating points
- (xiii) Receive only earth stations in 2.5 GHz for low power TV rediffusion.
- (xiv) Small capacity earth stations (message) for 'Demand Assigned Multiple Access working in 4 and 6 and/or 2.5 GHz band
- (xv) Low capacity, transportable/mobile earth stations for DAMA working in 6 and 4 and/or in 2.5 GHz band
- (xvi) 2 GHz (1.9—2.3), 600 channel/TV solid state system
- (xvii) 6 GHz (upper) 2700 channel system

The TRRC Working Group reports can form the fundamental document for preparing action plans for accelerating the pace of development work in the field of telecommunications.

5.2.5. Production and Investment Profile

5.2.5.1. Interim Production Plan

(a) Switching Equipment

Products in this category include local telephone systems, long distance systems and rural communication systems. ITI has annual production capacity of 1,50,000 lines of strowger switching equipment (2½ shift capacity) and 60,000 P&T lines (1,00,000 equivalent Jorbagh lines) of Pentaconta crossbar equipment on single shift basis. (1) ITI should increase the production capacity of crossbar equipment at Bangalore to 2 lakhs equivalent lines (2½ shift capacity) at the earliest. This may be achieved by (a) extensive farming out of the components required for manufacture of equipment and (b) by increasing the number of shifts to the maximum extent feasible. (2) The production capacity of strowger equipment should be increased to 2,00,000 lines in 3 years by increasing marginally, assembly and testing capacity of ITI, Bangalore. (3) Project report has already been prepared for setting up a new telephone switching factory in Rae Bareilly to produce 3,00,000 direct exchange lines per year when in full production in 1980-81. Since the production capacity would be inadequate to meet even the lower demand projection, it would be essential that this project is expedited and all-out efforts are made to achieve the full production by 1977-78 at the latest. (4) The project for 60,000 lines RAX equipment should be taken up immediately so that it starts production latest by 1977-78. (5) A third switching factory with an annual

capacity of 3,00,000 lines expandable to 5,00,000 lines should be set up so that it may stabilise by 1979-80.

(b) Underground Telephone Cables

HCL, Hyderabad with an annual rated capacity of 5,000 SKMs, (3 shift basis) expandable to 8,000 SKMs (3 shift basis) has already been approved and should go into production by 1975-76.

Besides the above unit, Traco Cable Co. (a Kerala State Government Undertaking) which has a letter of intent for manufacture of 2,000 SKMs per year should go into production in 1974-75.

According to lower demand forecast of requirement of underground telephone cables, there would be shortfall in the availability of about 3,000 SKMs of cables per year during the first three years of the Fifth Plan.

The project report for the second cable factory at Hyderabad provides for full capacity of 5,000 SKMs to be achieved by 1978-79. There is a definite need to reduce this long gestation period and hence it is strongly recommended that all efforts should be made to achieve the full rated capacity by 1976-77. The project for expansion of the Hyderabad unit from 5,000 SKMs to 8,000 SKMs should be initiated immediately so that the additional capacity is available at the latest by 1978-79.

(c) Telephone Instruments

Telephone instruments are at present being manufactured at ITI, Bangalore, the capacity being 2,50,000 numbers per year. Another unit at Naini has gone into production in 1973-74 and is expected to produce 5,00,000 telephones per year by 1978-79. It is recommended that all out efforts be made to achieve the full rated capacity of Naini unit at the latest by 1976-77. Extensive farming out for subcontract of components should be resorted to, if necessary, to achieve this target. A project for the third telephone instruments factory with an annual capacity of 3,00,000 instruments expandable to 5,00,000 instruments should be initiated by 1976-77 and the factory should start production in 1979-80.

(d) Transmission Equipment

Product range includes coaxial line equipment, microwave radio equipment, UHF radio equipment, openwire carrier equipment, VHF equipment, VFT equipment, interstice carrier cable equipment, PCM equipment, multiplexing equipment and data transmission equipment.

1973-74 production capacity of ITI, Bangalore unit was about Rs. 9 crores per year, out of which the average production of coaxial line and microwave radio equipment in the past two or three years was worth about Rs. 1 crore. Naini unit of ITI has just started production of limited number of multiplexing and open wire carrier equipment. With the augmentation of capacity of the Naini unit, ITI is proposing to transfer the production of multiplexing, open wire carrier, VFT equipment etc., from the Bangalore unit to the Naini unit. The Bangalore unit will be concentrating on production of coaxial line and microwave radio equipment and the development of new equipment.

Transmission division of ITI, Bangalore should expand its microwave and coaxial system division to achieve a total production of about Rs. 12 crores per year by 1978-79, and transmission division of ITI, Naini should expand to manufacture radio, VHF and digital equipment and efforts should be made to achieve production level of Rs. 10 crores by 1978-79.

A second unit for line equipment and microwave radio equipment should start production from 1976-77. This unit should reach its maximum capacity of Rs. 10 crores per annum by 1979-80.

A second unit for manufacture of multiplexing equipment with a production of Rs. 10 crores per annum should commence production by 1976-77 and reach its maximum capacity of Rs. 10 crores per annum by 1979-80.

(e) Coaxial Cables

At present, coaxial cables are being manufactured at HCL, Rupnarainpur which has an annual capacity of manufacturing 2,500 TKMs of large tube and 1,000 TKMs of small tube coaxial cables. The project for setting up manufacturing capacity of 2,000 TKMs of small tube cables at Hyderabad has already been started and it is expected to reach an annual production of 2,000 TKMs by 1976-77. Production of Rupnarainpur unit should be augmented by 1,000 TKMs of large tube type and 1,000 TKMs of small tube type coaxial cables per year.

(f) Antennas for Microwave and UHF Systems

So far, the requirement of microwave LOS antennas has been met by import. ECIL, Hyderabad has been given a letter of intent by the Government for manufacture of antennas for microwave systems to meet part of the requirement of P&T and Railways during the Fifth Five Year Plan. P&T is also planning to take up production of antennas in departmental Telecom Factories in collaboration with Budavox of Hungary. BEL unit at Ghaziabad (GAD) is also establishing comprehensive manufacturing facilities for metal type antennas and the associated testing facilities mainly to meet defence requirements. Though the requirement of antennas in certain defence projects is not very large, for the sake of indigenisation, comprehensive facilities had to be planned, thus resulting in considerable surplus capacity. This can be used to manufacture LOS antennas required by P&T, Railways, etc. BEL (GAD) antenna test range at Sohna in Haryana State should also be able to cater to the need of Telecom Factories' antenna manufacturing unit though with suitable augmentation of facilities for high performance antennas.

(g) Microwave Guides

There is a significant requirement of microwave guides used as feeder runs in antenna systems and in manufacturing microwave components, during the Fifth Five Year Plan period. Rectangular and circular waveguides in some of the frequency bands are productionised by Kamanis, Industrial Tube Manufacturers, and KLB Electronics in close association with AFD, BARC and NPL respectively. Seamless Steel Tube Plant (NFC) also provides facilities in this direction. Other guides like coaxial cables for microwave applications and elliptical waveguides are not manufactured in the country at present. So far, the entire requirement of waveguides for feeder runs has been met by import.

Since the requirement of flexible waveguide constitutes the major part, adequate production capacity for this should be established taking into consideration the export market. As regards the manufacture of low loss coaxial cables for VHF, UHF and microwave applications, RF cable manufacturers like HCL, Delton Cable, etc., should take up its production. The existing manufacturing know-how for rectangular and circular waveguides

should be utilised to manufacture complete feeder runs required for microwave antenna systems.

(h) Testing Instruments for Transmission Systems

A good deal of high frequency testing instruments required for installation and maintenance of coaxial, microwave and UHF systems are being imported at present. ITI is planning to invest Rs. 2 crores (0.5 in FE) for establishing manufacture of these instruments during Fifth Plan. Detailed suggestions for establishing production of these items have been discussed in the chapter on 'Instruments'.

Tables 5.16 and 5.17 give the optimistic and conservative production profiles for telecommunications during the Fifth Plan period. The profiles are essentially based on the recommendations of the Telecommunication Capacity Planning Committee.

5.2.5.2. Long-term Production Plan

Assuming that the conservative production programme for the Fifth Plan period as indicated in the previous section is implemented, the production capacity for various telecommunication items by the year 1978-79 would be as follows. Starting with this, the production plans needed to meet the demands of the period 1979-84 are discussed below. These estimates are based essentially on the recommendations of the Telecommunication Capacity Planning Committee.

(a) Switching Equipment

- (1) ITI, Bangalore plans to manufacture 2,00,000 lines of strowger equipment per annum during the period 1979-84.
- (2) ITI, Bangalore plans to manufacture 2,00,000 lines of crossbar equipment per annum during the period 1979-84.
- (3) Second switching factory at Rae Bareilly with an annual production capacity of 3,00,000 lines per year is expected to attain full capacity by 1980-81.
- (4) The project for 60,000 lines RAX equipment is expected to manufacture at full capacity during 1979-84.
- (5) A project for the third switching factory with annual capacity of 3,00,000 lines per annum expandable to 5,00,000 lines per annum should be taken up at the latest by 1976-77. It is recommended that the case should be reviewed keeping in view the demands in the intervening years. By that time, it is expected that electronic switching equipment would have fully developed for commercial use in India.

(b) Telephone Instruments

- (1) ITI, Bangalore, is expected to manufacture 2,50,000 telephone (full capacity) instruments per year during 1979-84.
- (2) ITI, Naini, is expected to produce 5,00,000 telephone instruments (full capacity) per year during 1979-84.
- (3) A project for the third telephone instruments factory with an annual capacity of 3,00,000 instruments expandable to 5,00,000 instruments should be initiated by 1975-76 or latest by 1977 (with lead time reduced to 2 years from 3 years by extensive farming out) and full capacity should be achieved by 1979-80 with

Table 5.16. Production profile for 1974-79 (optimistic estimate).

	1974-75	1975-76	1976-77	1977-78	1978-79	Total
(a) Switching equipment						
Strowger						
ITI, Bangalore	175,000	200,000	200,000	200,000	200,000	975,000
Crossbar						
ITI, Bangalore	150,000	175,000	200,000	200,000	200,000	925,000
ITI, Rae Bareilly	50,000	100,000	200,000	300,000	300,000	950,000
RAX factory	—	—	—	30,000	60,000	90,000
Total lines	375,000	475,000	600,000	730,000	760,000	2,940,000
Value in Rs. crores (average Rs. 1400/line)	52.50	66.50	84.00	102.20	106.40	411.60
(b) Telephone instruments						
ITI, Bangalore	250,000	250,000	250,000	250,000	250,000	1,250,000
ITI, Naini	100,000	300,000	500,000	500,000	500,000	1,900,000
Total	350,000	550,000	750,000	750,000	750,000	3,150,000
Value in Rs. crores (average Rs. 125/instrument)	4.38	6.88	9.38	9.38	9.38	39.40
(c) Transmission equipment						
(Value in Rs. crores)						
ITI, Bangalore	10.20	10.50	10.75	11.00	11.50	53.95
ITI, Naini	6.50	7.00	8.00	9.00	10.00	40.50
2nd unit for microwave/coaxial equipment	—	—	2.00	5.00	7.50	14.50
2nd unit for multiplexing equipment	—	—	2.00	5.00	7.50	14.50
	16.70	17.50	22.75	30.00	36.50	123.45
(d) Underground telephone cables in SKMs						
HCL, Rupnarainpur	6,000	7,200	8,400	10,000	10,000	41,600
HCL, Hyderabad	1,000	2,500	5,000	5,000	5,000	18,500
TRACO	500	1,000	2,000	2,000	2,000	7,500
Total	7,500	10,700	15,400	17,000	17,000	67,600
Value in Rs. crores (average Rs. 19100/SKM)	14.33	20.44	29.41	32.47	32.47	129.12
(e) Coaxial cables in TKMs						
(1) Large tube:						
HCL, Rupnarainpur	2,500	2,500	2,500	2,500	2,500	12,500
Augmentation Rupnarainpur	—	500	1,000	1,000	1,000	3,500
Total	2,500	3,000	3,500	3,500	3,500	16,000
Value in Rs. crores (average Rs. 11150/TKM)	2.79	3.35	3.90	3.90	3.90	17.84

	1974-75	1975-76	1976-77	1977-78	1978-79	Total
(2) Small tube:						
HCL, Rupnarainpur	1,000	1,000	1,000	1,000	1,000	5,000
HCL, Hyderabad	600	1,200	2,000	2,000	2,000	7,800
Augmentation Rupnarainpur	—	500	1,000	1,000	1,000	3,500
Total	1,600	2,700	4,000	4,000	4,000	16,300
Value in Rs. crores (average Rs. 4500/ TKM)	0.72	1.22	1.80	1.80	1.80	7.34
Total value in Rs. crores (1+2)	3.51	4.57	5.70	5.70	5.70	25.18
Grand total in Rs. crores	91	116	151	180	191	729

Table 5.17. Production profile for 1974-79 (conservative estimate).

	1974-75	1975-76	1976-77	1977-78	1978-79	Total
(a) Switching equipment						
Strowger						
ITI, Bangalore	1,75,000	2,00,000	2,00,000	2,00,000	2,00,000	9,75,000
Crossbar						
ITI, Bangalore	1,50,000	1,75,000	2,00,000	2,00,000	2,00,000	9,25,000
ITI, Rae Bareilly	—	—	—	1,00,000	1,50,000	2,50,000
RAX factory	—	—	—	30,000	60,000	90,000
Total lines	3,25,000	3,75,000	4,00,000	5,30,000	6,10,000	22,40,000
Value in Rs. crores (average Rs. 1400/line)	45.50	52.50	56.00	74.20	85.40	313.60
(b) Telephone instruments						
ITI, Bangalore	2,50,000	2,50,000	2,50,000	2,50,000	2,50,000	12,50,000
ITI, Naini	1,00,000	2,00,000	3,00,000	4,00,000	5,00,000	15,00,000
Total	3,50,000	4,50,000	5,50,000	6,50,000	7,50,000	27,50,000
Value in Rs. crores (average Rs. 125/instrument)	4.33	5.63	6.88	8.13	9.38	34.83
(c) Transmission equipment						
(Value in Rs. crores)						
ITI, Bangalore	10.20	10.50	10.75	11.00	11.50	53.95
ITI, Naini	6.50	7.00	7.50	8.00	8.50	37.50
2nd unit for micro-wave/coaxial equipment	—	—	2.00	5.00	7.50	14.50
2nd unit for multiplexing equipment	—	—	2.00	5.00	7.50	14.50
Total	16.70	17.50	22.75	30.00	36.50	123.45

	1974-75	1975-76	1976-77	1977-78	1978-79	Total
(d) Underground tele- phone cables in SKMs						
HCL, Rupnarainpur	6,000	7,200	8,400	10,000	10,000	41,000
HCL, Hyderabad	—	560	1,440	4,000	5,000	11,000
TRACO	600	750	800	1,000	1,600	4,750
Total	6,600	8,510	10,640	15,000	16,600	57,350
Value in Rs. crores (average Rs. 19100/ SKM)	12.61	16.25	20.32	28.65	31.71	109.54
(e) Coaxial cables in TKMs						
(1) Large tube:						
HCL, Rupnarainpur	2,500	2,500	2,500	2,500	2,500	12,500
Augmentation Rupnarainpur	—	—	500	1,000	1,000	2,500
Total	2,500	2,500	3,000	3,500	3,500	15,000
Value in Rs. crores (average Rs. 11150/ TKM)	2.79	2.79	3.35	3.90	3.90	16.73
(2) Small tube:						
HCL, Rupnarainpur	1,000	1,000	1,000	1,000	1,000	5,000
HCL, Hyderabad	600	1,200	2,000	2,000	2,000	7,000
Augmentation Rupnarainpur	—	—	500	1,000	1,000	2,500
Total	1,600	2,200	3,500	4,000	4,000	15,300
Value in Rs. crores (average Rs. 4500/ TKM)	0.72	0.99	1.58	1.80	1.80	6.89
Total value in Rs. crores (1+2)	3.51	3.78	4.93	5.70	5.70	23.62
Grand total in Rs. crores	83	96	111	147	169	606

3,00,000 numbers per annum. Expansion of the same to achieve 5,00,000 telephones per year should be initiated in 1979-80 to achieve the same by 1982-83.

(4) Keeping in view the telephone demand trend in the preceding years and the progress achieved in setting up Naini unit and the 3rd telephone factory, the need for setting up a 4th unit should be considered before 1978-79.

(c) Transmission Equipment

(1) ITI, Bangalore division, is expected to manufacture microwave and coaxial systems at Rs. 12 crores per year throughout 1979-84.

(2) III, Naini division, is expected to manufacture multiplexing equipment and openwire carrier equipment worth Rs. 10 crores per annum throughout 1979-84.

(3) The second unit for production of line equipment and microwave radio equipment should produce about Rs. 10 crores worth per annum throughout 1979-84.

(4) The second multiplex factory should produce about Rs. 10 crores worth per annum throughout 1979-84.

- (5) A third factory for multiplexing equipment with an annual capacity of Rs. 10 crores should be initiated during the Fifth Plan so as to attain full production capacity at least by 1982-83.
- (6) A separate plant should be setup for production for miscellaneous transmission equipment like VHF, VFT, interstice equipment, etc., so as to reach its maximum capacity of about Rs. 10 crores per year by 1982-83.

So far the limitation in production of coaxial line and microwave equipment has been the lack of availability of suitable proven design. There is an inherent high rate of obsolescence in the technology of transmission equipment and the R&D cycle for new equipment requires a minimum period of five to six years. In view of this, there would be a need to examine the possibility of technical collaboration with advanced foreign manufacturers in this field for the manufacture of coaxial lines and microwave equipment for which adequate designs are at present not available. As the production of multiplexing equipment at ITI has already been established, the production capacity for these items can be easily augmented with the indigenous know-how available. As the production units for transmission equipment are predominantly labour intensive, it would be advantageous to set up specialised small units for the manufacture of individual items of equipment like microwave radio equipment, coaxial line equipment and multiplexing equipment. This would reduce the product mix and help in proper production planning and inventory control of the concerned factories. It is felt that the size of the production units should generally be limited to an output of about Rs. 10 crores per unit.

(d) Underground Telephone Cables

- (1) HCL, Rupnarainpur is expected to manufacture 10,000 SKMs (3 shift basis) during 1979-84.
- (2) For HCL, Hyderabad, which is expected to produce 5,000 SKMs (3 shift basis) in 1978-79 and which is expandable to 8,000 SKMs per year (3 shift basis), action should be initiated in 1977-78 so that it can produce 8,000 SKMs per year (3 shift basis) throughout 1979-84.

(e) Coaxial Cables

- (1) HCL, Rupnarainpur is expected to produce 3,500 TKMs per annum of large tube coaxial cables throughout 1979-84.
- (2) A separate coaxial cable factory with a rated capacity of 2,500 TKMs of large tube and 2,000 TKMs of small tube coaxial cables should be initiated immediately so that production to full capacity is achieved during the Sixth Plan.
- (3) HCL, Rupnarainpur is expected to produce 2,000 TKMs of small tube cables per year throughout 1979-84.
- (4) HCL, Hyderabad is expected to produce 2,000 TKMs of small tube coaxial cables per year throughout 1979-84.

5.2.5.3. Investment Plan

In the previous section the production programme to meet the indicated lower and higher demand projections were discussed. The estimates of corresponding investments required for implementing the conservative production programme (to meet lower demand projection) are given in Table 5.19.

Table 5.18. Production profile for 1979-84 (Assuming the conservative programme for 1974-79)

	1979-80	1980-81	1981-82	1982-83	1983-84	Total
Switching equipment						
Strowger						
ITI, Bangalore	2,00,000	2,00,000	2,00,000	2,00,000	2,00,000	10,00,000
Crossbar						
ITI, Bangalore	2,00,000	2,00,000	2,00,000	2,00,000	2,00,000	10,00,000
ITI, Rae Bareilly	2,00,000	3,00,000	3,00,000	3,00,000	3,00,000	14,00,000
RAX factory	60,000	60,000	60,000	60,000	60,000	3,00,000
3rd switching factory	1,00,000	2,00,000	3,00,000	3,00,000	3,00,000	12,00,000
Total lines	7,60,000	9,60,000	10,60,000	10,60,000	10,60,000	49,00,000
Value in Rs. crores (average Rs. 1400/line)	106.40	134.40	148.40	148.40	148.80	686.00
Telephone instruments						
125/teleph.						
ITI, Bangalore	2,50,000	2,50,000	2,50,000	2,50,000	2,50,000	12,50,000
ITI, Naini	5,00,000	5,00,000	5,00,000	5,00,000	5,00,000	25,00,000
3rd telephone unit	3,00,000	3,00,000	3,00,000	5,00,000	5,00,000	19,00,000
4th telephone unit	—	—	1,00,000	2,00,000	3,00,000	6,00,000
Total	10,50,000	10,50,000	11,50,000	14,50,000	15,50,000	62,50,000
Value in Rs. crores (average Rs. 125/ instrument)	13.13	13.13	14.38	18.13	19.38	78.15
Transmission equipment						
(Value in Rs. crores)						
ITI, Bangalore (micro- wave/coaxial)	12.00	12.00	12.00	12.00	12.00	60.00
ITI, Naini (multiplex- ing/openwire)	10.00	10.00	10.00	10.00	10.00	50.00
2nd radio factory	10.00	10.00	10.00	10.00	10.00	50.00
2nd multiplexing factory	10.00	10.00	10.00	10.00	10.00	50.00
3rd multiplexing factory	2.00	5.00	7.50	10.00	10.00	34.50
Total	46.00	52.00	57.00	62.00	62.00	279.00
Underground telephone cables in SKMs						
HCL, Rupnarainpur	10,000	10,000	10,000	10,000	10,000	50,000
HCL, Hyderabad	8,000	8,000	8,000	8,000	8,000	40,000
TRACO	2,000	2,000	2,000	2,000	2,000	10,000
	1,000	3,000	5,000	10,000	10,000	29,000
Total	21,000	23,000	25,000	30,000	30,000	129,000
Value in Rs. crores (average Rs. 19100/ SKM)	40.11	43.93	47.75	57.30	57.30	246.39

	1979-80	1980-81	1981-82	1982-83	1983-84	Total
Coaxial cables in TKMs						
(1) Large tube (375 type):						
HCL, Rupnarainpur	3,500	3,500	3,500	3,500	3,500	17,500
New factory	1,000	2,000	2,500	2,500	2,500	10,000
Total	4,500	5,500	6,000	6,000	6,000	28,000
Value in Rs. crores (Average Rs. 11150/TKM)	5.02	6.13	6.69	6.69	6.69	31.22
(2) Small tube (174):						
HCL, Rupnarainpur	2,000	2,000	2,000	2,000	2,000	10,000
HCL, Hyderabad	2,000	2,000	2,000	2,000	2,000	10,000
New factory	1,000	2,000	2,500	2,500	2,500	10,500
Total	5,000	6,000	6,500	6,500	6,500	30,500
Value in Rs. crores (average Rs. 4500/TKM)	2.25	2.70	2.93	2.93	2.93	13.73
Total value in Rs. crores (1+2)	7.27	8.83	9.62	9.62	9.62	44.95
Grand total (in Rs. crores)	214	252	277	296	297	1335

It is estimated that about Rs. 100 crores investments during the Sixth Five Year Plan period (1979-84) will yield a production of Rs. 1,335 crores (which is based on a lower demand projection for the decade 1974-84).

Table 5.19. Investment plan for telecommunications (1974-1979).

Product category	Capital investment (Rs. crores)
1. Switching equipment	
(a) ITI, Bangalore	2.60
(b) ITI, Rae Bareilly	16.00
(c) RAX factory	1.60
(d) Third switching factory	5.40
Total	25.60
2. Underground telephone cables	
(a) HCL, Rupnarainpur	5.00
(b) HCL, Hyderabad	0.30
(c) TRACO, Kerala	1.00
Total	6.30
3. Coaxial cables	
(a) HCL, Rupnarainpur	—
(b) HCL, Rupnarainpur augmentation	1.44
(c) HCL, Hyderabad	1.03
Total	2.50
4. Telephone instruments	
(a) ITI, Naini	3.65
(b) 3rd telephone factory	3.00
Total	6.65

5. Transmission equipment	
(a) ITI, Bangalore	1.80
(b) ITI, Naini	1.20
(c) 2nd radio factory and 2nd multiplexing factory	7.00
Total	10.00
<hr/>	
Grand total	51.00
<hr/>	

5.3 International Communication

Whereas Posts and Telegraphs Department maintains the domestic telecommunication network, international communication links are looked after by Overseas Communication Services (OCS). Besides serving the general public, OCS caters to the need of Meteorological Departments, Press Broadcast Services, Programme Transmission Services, etc., by leasing channels/circuits. Civil Aviation Department maintains its independent international communication network for the rapid exchange of messages with the neighbouring countries for ensuring safety, regularity and efficiency of air service operation. At present, they are maintaining HF radio teletype circuits with adjacent countries.

With the establishment of the Vikram Earth Station at Arvi and the associated terminal complex at Bombay, and with the simultaneous growth of the domestic telecommunication network, the prime objective of the OCS Fourth Plan viz., provision of stable wideband telecommunication channels to satisfy country's rapidly growing needs for external telecommunication facilities has been almost achieved, though it is only the beginning considering the overall requirements of the country. With the commissioning of the second earth station at Dehradun and associated terminal complex at New Delhi one more step would be taken in this direction. It would be clear from Table 5.20 that the introduction of satellite communication service provided a quantum jump to the demand for overseas communication service.

A summary of the Fourth Plan expenditure on communication equipment and spillover to Fifth Plan is given in Table 5.21.

Table 5.20. Progress of India's overseas telecommunications (1947 to 1973)

Service	Number of channels as on						IVth Plan		Total
	1.1.1947	1.4.1951	31.3.1956	31.3.1961	31.3.1966	31.3.1968	via satellite	via HF radi	
1. Telephone	1	2	17	26	43	46	57	15	72
2. Telex	—	—	—	1	14	25	81	12	93
3. Telegraph	5	—	19	30	33	35	15	23	38
4. Leased channels	—	—	—	13	24	32	39	19	58
5. Radio telegraph	1	1	5	20	19	24	23	7	30
6. Slow speed submarine telegraph cables	3	3	3	3	2	2	(discontinued from service)		

Press Broadcast Service:

OCS handles press broadcast service for the benefit of India legations/embassies stationed in 39 countries throughout the world on behalf of the External Affairs Ministry, Government of India. This service is operated from the New Delhi centre on two frequencies simultaneously radiated on daily schedule. Newscast service is also handled from the Bombay Centre on behalf of press agencies. The service from New Delhi was started on 1-7-1958 and that from Bombay on 9-6-1952.

Programme Transmission Services (PTS):

PTS is a service which enables press correspondents and others visiting India to transmit audio programmes from India to their home countries for rebroadcasting purposes on their home networks. Simultaneously it enables AIR to receive voicecasts from overseas to hook up on our national service.

Table 5.21. Summary of Fourth Plan expenditure on communication equipment (in Rs. lakhs).

Schemes	Estimated scheme cost	Approximate expenditure during the Plan period	Spill-over to Fifth Plan
1. Vikram (Arvi) earth station project	830	550* ¹	Nil
2. Addition to Vikram earth station	110	50	45
3. New Delhi earth station project	920* ²	185	735
4. Additions to switching centres; conversion to fully automatic operation	100* ³	20	80
5. Non-satellite P&M	110	70	40
Total	2070* ⁴	875	900

*1. In addition, expenditure of about Rs. 171 lakhs was incurred in the pre-Fourth Plan period.

*2. Excluding telex exchange.

*3. Telephone exchange only.

*4. Cost estimates are based on 1973 figures and are correct only upto first order approximation.

5.3.1. Demand Profile

Estimated requirement of international telephone circuits and telex traffic channels is given in Table 5.22.

Table 5.22. Estimated requirement of international telephone circuits and telex traffic channels.

Source	No. of circuits/channels estimated		
	1976	1978	1980
1. The long-term network planning group (LTNPG) for telephone	259	368	518
2. In house (OCS) traffic studies on telex traffic demand	280	650	840

Table 5.23 gives the estimated forecast of traffic as anticipated by OCS. This includes the channels required for general public, India Meteorological Department, Press Broadcast Services, Programme Transmission Services

and Civil Aviation. A comparison of Tables 5.20 and 5.23 reveals that the requirement of international telecommunication services is increasing rapidly.

5.3.2. Guidelines for Meeting the Demand

In order to cope up with the increasing demand, OCS during the Fifth Plan period has plans to provide for:

(a) The consolidation of the second satellite earth station project, to carry out phased additions to terminal exchanges and equipment to meet forecast traffic demands and for optimum exploitation of the installed satellite capacity.

(b) The establishment of wideband outlets in the eastern and southern regions to form an integrated all India OCS to serve the country's international telecommunication needs.

(c) Complete preliminaries towards establishment of the third earth station in the eastern region by 1980-81.

(d) Ensure diversity and security of the country's international telecommunication service by the installation of a wideband submarine telephone cable link in the Indian Ocean area, proposed Madras and Penang link, would give access to the wideband global submarine cable/satellite communications system in the Pacific and Atlantic. The cable would also carry bulk of the all India east-bound telephone, telex and telegraph traffic to countries in the east.

(e) Modernise to current standards, the existing HF radio communication facilities to meet requirements of (i) back-up service during contingencies and (ii) continuing demand of broadcast services, etc., for news agencies and Meteorological Departments.

(f) Providing stable communication links with USSR and Afghanistan by troposcatter systems, as they are not accessible via INTELSAT satellite communication system. The link with USSR could handle a large volume of traffic with other Asian countries which at present suffer considerable frustration due to lack of adequate facilities. As regards India-Afghanistan troposcatter link, the need was felt, in view of significant estimated circuit requirements, which are given below:

Year	1975	1980	1984	1989
Circuits	8	14	19	32

The economic feasibility of such links was established by International Telecommunication Union under the auspices of the United Nations Development Programme technical assistance mission.

The time schedule and estimated eventual distribution of total international telephone and telex trunks capacity planned for the Fifth Plan period, are estimated as in Table 5.24.

As regards Civil Aviation Department, the old and obsolete HF radio teletype equipment are to be replaced by higher power HF ISB equipment to improve the circuit reliability and to reduce the outage due to interference. This would also provide the speech circuits required for the Air Traffic Control Service.

5.3.3. Guidelines for Technology Development

With the objective of achieving self-reliance, it is necessary to augment very significantly OCS R&D activities. Development work in OCS should consist of systems integration including interfacing and installation of major units, as well as development and construction of units whose specifications

and quantity required for OCS would be such as to preclude development and economically viable manufacture by other agencies like ITI; such list of R&D projects along with the development and manufacturing cost is given in Table 5.25. Such R&D work would help introduce sophistication and new technologies to the extent necessary and feasible, to achieve optimum utilisation of invested resources, and a grade of service otherwise not obtainable, and to foster technological growth in the country.

Table 5.23. International traffic forecasts 1974-1979.

	1971-72	1972-73	1973-74	1974-75	1975-76	1976-77	1977-78	1978-79
1. Telephone (million paid minutes)	1.82	2.30	2.99	3.89	5.83	6.99	9.79	13.22
2. Telex (million paid minutes)	2.15	2.50	3.50	4.90	6.86	9.60	14.40	21.60
3. Message telegraph (million paid words)	123.00	125.40	131.20	137.70	144.60	151.80	159.30	167.00
4. Leased channels (Nos.)	52.00	58.00	63.00	70.00	78.00	86.00	95.00	103.00
5. Phototelegrams (thousand sq cms)	74.00	78.00	82.00	86.00	90.00	94.00	99.00	104.00

Table 5.24. Time schedule for commissioning the international telephone and telex trunks during the Fifth Five Year Plan.

	Telephone (trunks)	Likely commissioning year	Telex (trunks)	Likely commissioning year
1. Bombay (2nd stage)	180	1976/77	450+message telegraph switching (MTS)	1976/77
2. New Delhi (1st stage)	80	1977/78	400+MTS	1978/79
3. Madras (1st stage)	80	1978/79	150+MTS	1979/80
4. Bombay (3rd stage)	350	1979/80	850	1980/81
5. Calcutta (1st stage)	80	1981/82	200	1981/82

5.3.4. Investment Pattern

The major requirement of communication equipment for the international communication links during the Fifth Plan is summarised below giving an indication of the broad order of magnitude of investments involved.

Item	Anticipated expenditure in the Fifth Plan (Rs. lakhs)
1. Spillover from IV plan	900
2. Development of equipment	70
3. Submarine telephone cable in the Indian Ocean region-Madras/Penang cable	500
4. Third earth station near Calcutta	200
5. Tropo schemes with USSR/Afghanistan	450
6. HF and other terminal equipment	100
7. Terminal switching equipment	550
8. Small capacity earth station at Andamans	220
9. ISB circuits (Civil Aviation)	200
Total	3,190

Table 5.25. R&D projects envisaged for the decade 1974-84/estimated prototype development costs and manufacturing costs to meet OCS requirements (in Rs. lakhs).

Systems	V Plan estimates		VI Plan estimates		Remarks
	Develop- ment costs	Manu- facturing costs	Develop- ment costs	Manu- facturing costs	
I. HF radio equipment	3.0	65.0	2.0	140.0	Comprises of transmitters, receivers, Lincompex terminals
II. Stored programme controlled (SPC) switching system	28.0	150.0	30.0	300.0	Comprises of intercontinental telex exchanges, message relay system, data exchange, etc.
III. CCITT No. 6 telephone signalling and switching system and peripheral subsystem	13.0	5.0	16.0	265.0	Comprises of intercontinental telephone exchange, automatic transmission measuring equipment (ATME), call progress indicator (CPI)
IV. SPADE equipment for use in satellite communications systems	15.0	15.0	5.0	30.0	
V. Additional customer facilities to be provided on existing BTMC intercontinental telex exchange	3.0	5.0	—	—	Comprises of code 100 facilities R79 equipment, etc.
VI. Continuing programme for development fabrication of interface and peripheral equipment	4.0	25.0	2.0	30.0	Comprises of echo suppressor and tester; start-stop regenerator and tester; pix convertors; ADA and print-out telegraph test generator; TDMS TP concentrator, manual signalling units, etc.
	66.0	265.0	55.0	765.0	

5.4 Radio Communication

5.4.1. General

Radio communication equipment working in the HF/VHF/UHF band for both fixed and mobile operations and with power level ranging from a few hundred milliwatts to a few kilowatts are used by several agencies in the country. Low power radio communication equipment in significant numbers are used by the security services under the Ministry of Home Affairs, the Posts & Telegraphs Department and the Ministry of Railways. Equipment in small numbers are also used by the All India Radio, power distribution networks, oil and gas pipeline systems, road transport systems, survey and construction projects, and some industries. Medium and high power radio communication equipment are used by the Civil Aviation Department to meet their operational requirements. All India Radio and

the Overseas Communication Services are the other major users of high power equipment. But these have been covered in the sections on Mass Communications and International Communications, respectively.

5.4.2. Current Status of Production and R&D

Radio communication equipment are manufactured in the country by Bharat Electronics Limited, Electronics Corporation of India Limited, Hindustan Aeronautics Limited, and Indian Telephone Industries Limited. The low power equipment division of BEL manufactures a variety of HF and VHF communication equipment primarily to meet defence needs. Equipment have also been supplied to the MHA in significant numbers, and to private users, like mines and industries, in small numbers. Supply of low power equipment to non-defence users was of the order of Rs. 5 crores in 1973-74. BEL plans indicate increased supply of these equipment to the civilian sector beyond 1974. Medium and high power equipment are manufactured in the High Power Equipment Division of BEL. Most of the items relate to TV and broadcast transmitting equipment. A few items are supplied to the Civil Aviation Department.

Indian Telephone Industries Limited, manufactures single channel VHF transreceivers for rural trunk telephone links, in addition to the range of microwave radio relay equipment. Hindustan Aeronautics Limited (Hyderabad) manufactures, under collaboration, VHF air to ground transreceivers mainly for defence use, and, VHF single channel transreceivers based on indigenous know-how have been taken up by ECIL.

Research and development work relating to radio communication equipment has been carried out at BEL, CEERI, TRC, VSSC and several defence laboratories. BEL has developed and produced several fixed, mobile, and manpack communication equipment in the 68-88 MHz band. TRC has developed two solid state transreceivers working at 75 and 150 MHz for use in the rural trunk telephone links. BEL and TRC have jointly taken up development of multichannel VHF and UHF transreceivers. Fully solid state multichannel HF SSB transreceiver for portable and manpack use and a single channel HF AM walkie-talkie set have been developed at VSSC. CEERI has developed a HF AM transreceiver and a VHF FM transreceiver. A multichannel VHF transreceiver with frequency synthesiser has been developed at BARC. Thus considerable development expertise exists in the country.

5.4.3. Demand Profile

Radio communication equipment in use are of a wide range of power level, frequency of operation, bandwidth, etc., depending on the application areas. In this section, equipment are grouped departmentwise for the purpose of forecasting the demand.

5.4.3.1. Ministry of Home Affairs (MHA)

The internal security services under the MHA have extensive radio networks, which include the interstate radio telegraph networks, long distance border network of the Border Security Force, long distance internal networks of the Central Reserve Police, long and short distance networks of the intelligence units and the networks of the State police forces. Among them they employ an estimated 30,000 radio communication equipment of various types—fixed, mobile, manpack, etc., working in the HF and VHF

bands. The list below gives the various types of radio communication equipment normally required by the security services.

HF sets	
(i) SSB manpack transreceiver	(5 watts)
(ii) SSB portable transreceiver	(15-20 watts)
(iii) SSB transreceiver	(100 watts)
(iv) SSB transmitter	(400 watts)
(v) SSB transmitter	(1 kw)
(vi) SSB receiver	
(vii) General purpose communication receiver	
VHF sets	
(i) Transreceiver	(400 mW)
(ii) Manpack transreceiver	(2 watts)
(iii) Motor-cycle transreceiver	(7 watts)
(iv) Portable transreceiver	(15-20 watts)
(v) Transreceiver	(50 watts)
(vi) Pocket receiver	
(vii) Monitoring receiver	

During the Fifth Five Year Plan period and subsequent years considerable enhancement of their communication network for achieving more extensive coverage as well as higher reliability of communication is planned. The total requirement of the above types of equipment for implementing their plans during 1974-79 adds up to about 90,000 sets valued at Rs. 40 crores. It is estimated that about the same number of equipment would be required during the Sixth Plan period.

5.4.3.2. Civil Aviation Department

Aeronautical communication service is an essential service in the field of aviation. There are nearly 100 aeronautical communication stations in the country providing over 200 aero-mobile channels for air/ground communication and about the same number of radio circuits in the aeronautical telecommunication network. They employ radio transmitters/receivers in the HF and VHF bands for telegraph, telephone and teletype circuits. Equipment worth about Rs. 20 crores would be required by the Civil Aviation Department during 1974-79 for setting up new communication links, improvement of domestic circuits and replacement of equipment by new version as per ICAO standards. The break-up of equipment required is given in Table 5.26.

5.4.3.3. Ministry of Railways

During the Fifth Five Year Plan, Railways require a number of 6/12/24 channel UHF systems working in the frequency band 450-470 MHz for fixed and mobile communication. Their immediate requirements also include single channel fixed/mobile communication links in the VHF band. The total requirement of communication equipment for the Railways is given in Table 5.27.

5.4.3.4. Other Departments

Among other departments who require radio communication equipment in significant numbers are the Shipping and Transport, CWPC and

ONGC. Details of radio communication equipment required for these departments are given in Tables 5.28 and 5.29, respectively.

5.4.3.5. Posts & Telegraphs Department (P&T)

During the Fifth Plan period the P&T Department has plans to introduce on a large scale, radio communication links to rural and remote areas as also establish trunk circuits in feeder and secondary routes. For implementing these plans a large number of single channel and multi-channel (6 to 120 channels) VHF/UHF radio communication equipment are required. Details of the requirements of the P&T Department are given in the section on telecommunication.

The total requirement of the communication equipment as given above for the period 1974-79 adds upto over Rs. 60 crores. It may be assumed that equipment worth about 5-10 per cent of this amount would be required in addition for relatively small users such as, for example, road transport systems, industries, etc. Thus the total demand for radio communication equipment during the Fifth Plan period is about Rs. 65 crores.

The use of VHF/UHF low power radio communication equipment in the country has been very limited so far. In recent years there has been a phenomenal growth in the use of VHF/UHF two-way and one-way radio communication equipment in the countries abroad. These equipment are used in a variety of applications such as (a) land mobile service—taxi services, ambulances, fire fighting services, traffic control and public transport, (b) highway mobile system—connecting passengers in trains or cars to the public telephone network, (c) maritime mobile telephone services for ship-to-ship and ship-to-shore communications and (d) personal paging services in hospitals, hotels, factories, etc. The limited use of these equipment in the country till now appears to be largely due to the inadequate availability of these equipment within the country. Radio amateur and Citizen's Band activities are also at a very low level. Thus there is a large latent demand for these equipment and when equipment become freely available, the demand would grow considerably. In view of this latent demand it is difficult to make an exact forecast of requirements during the period 1979-84. A conservative estimate of the requirements during 1979-84 would be about one and a half times that during 1974-79.

5.4.4. Guidelines for Planning Production

Of the total demand of Rs. 65 crores for radio communication equipment, medium and high power equipment constitute nearly Rs. 20 crores. The existing production capacity is adequate in most cases and where necessary the manufacturing units are taking steps to create additional capacity.

In view of the anticipated increase in demand for low power radio communication equipment during the Fifth Five Year Plan, the Task Force VII on Electronics and Telecommunication has recommended setting up of additional manufacturing capacity in the country. Some alternative plans for stepping up production are suggested below:

- (1) The production capacity of BEL can be expanded adequately.
- (2) In respect of large captive demands, such as that of MHA, a central-public sector unit may be set up.
- (3) Public sector units under the State government may be encouraged to take up the manufacture of communication equipment.

Table 5.26. Requirement of radio communication equipment for the Department of Civil Aviation during Fifth Plan Period.

Sr. No.	Items	Quantity in numbers	Total cost (in Rs. lakhs)
1.	HF transmitter (medium power—1 kW to 5 kW)	100	120
2.	HF radio telephone trans/receive terminal (400 W—3 kW)	29	290
3.	VHF radio equipment trans/receive (50 W—100 W)	100	50
4.	HF receivers (DSB)	200	30
5.	HF radio trans/receive (RTT)	2	20
6.	HF radio trans/receive (SSB) (medium power)	156	480
7.	HF radio trans/receive (SSB) (high power)	9	103
8.	HF radio telephone trans/receive (DSB/SSB) (medium power)	4	16
9.	NDB, HF/VHF trans/receive, etc., at new airfields	—	60
10.	Automatic relay systems for message handling	3	180
11.	Trans/receive (for improvement of domestic circuits)	—	160
12.	Air-to-ground and ground-to-ground communication systems for company channels and communication network	—	300
13.	VHF trans/receive	35	22
Total			1831

Table 5.27. Railway requirement for UHF and VHF communication equipment during Fifth Plan period.

Sr. No.	Item	Quantity in numbers	Approximate cost (in Rs. lakhs)
1.	UHF multichannel equipment (450-470 MHz)	200 terminals	100
2.	VHF single channel duplex equipment (146-174 MHz)	250 terminals	50
Total			150

(4) Manufacture of communication equipment has been predominantly reserved for the public sector under the Industrial Policy Resolution. However, there are many applications, which do not involve any security risk as, for example, taxi-call systems and paging systems. These applications are yet to be introduced in the country. The extent to which such demands grow, depends to a large extent on the promotional efforts of the manufactures. In these cases one can explore, within the framework of IPR, the possibility of associating the private sector in the manufacture of subsystems initially and later systems also.

Alternatives 2 and 3 would call for higher initial capital investment as compared to alternative 1. However, the main objectives in suggesting these alternatives are to avoid concentrating all the manufacturing capacity in a single unit as also to direct the expertise of a large unit like BEL

towards development and manufacture of more sophisticated items such as airborne multichannel communication equipment.

It is anticipated that additional investment of the order of Rs. 2 crores would be required during the Plan period to increase production of low power radio communication equipment.

During the Sixth Plan period even if the demand grows to fifty per cent over that during the Fifth Plan period, the production capacity generated during the Fifth Plan period should be able to meet this demand. It is anticipated that any additional investment required would be marginal, unless it is planned to enter the export market in a big way.

Table 5.28. Requirement of communication equipment for ocean liners, fishing vessels and ports.

Item	Approximate numbers	Approximate cost (in Rs. lakhs)
A. Fishing vessels		
1. HF or VHF (SSB) R/T sets (low power)	5500	55
2. HF or VHF (SSB) R/T sets (about 100 W)	160	32
B. Ships		
1. Radio telegraph transmitter (400 W)	15	12
2. Radio telegraph transmitter (less than 15 W)	15	1
3. Radio telegraph receiver	30	2
4. Radio telephone (50 W)	25	4
5. R/T alarm signal generating device	25	5
6. Portable radio equipment for survival crafts	—	10
C. Ports		
1. Transmitter (MF/HF) DSB/SSB	12	3
2. Receiver DSB/SSB	13	4
3. VHF FM transreceivers (156-174 MHz)	50	7
4. R/T equipment (SSB, 100 W)	6	1
5. Walkie-talkie sets	30	1
Total		137

Table 5.29. Requirement of radio communication equipment for ONGC and CWPC

Users	Item required	No.	Approximate cost (in Rs. lakhs)
1. ONGC	WT/RT sets	57	12
2. CWPC	VHF sets	390	78
Total			90

5.4.5. Enhancement of Existing R&D Base

It has been mentioned that a substantial base for R&D in this area exists in the country today. Also, the type of systems envisaged for introduction in the country have been in commercial use in many countries and the system designs and allied problems are well known. Development of

equipment would largely involve adaption of equipment design to suit local environments and use of locally available components. Thus, the development should present no difficulty. However, in view of the large variety of equipment that need to be developed, investment in R&D for additional technical work force, prototype fabrication facility, instruments, etc., will have to be increased. The TRRC Working Group on VHF/UHF fixed and mobile communication systems has studied the R&D requirements in detail. The Group has assessed the requirement of technical personnel, who would be directly involved in the development projects, to be about 150 in number during the next two to three years.

It should also be noted that both R&D and production, so far, have largely been in the HF and VHF bands. The VHF bands will become saturated soon and it will be necessary to employ equipment operating in the UHF bands for many of the applications. Some organisations have planned for development in the UHF band. Intensive efforts in this direction are required to get ready suitable models for production by 1980. Efforts should also be directed towards development of solid state and IC versions of these equipment.

5.5 Telemetry and Telecontrol 5.5.1. General

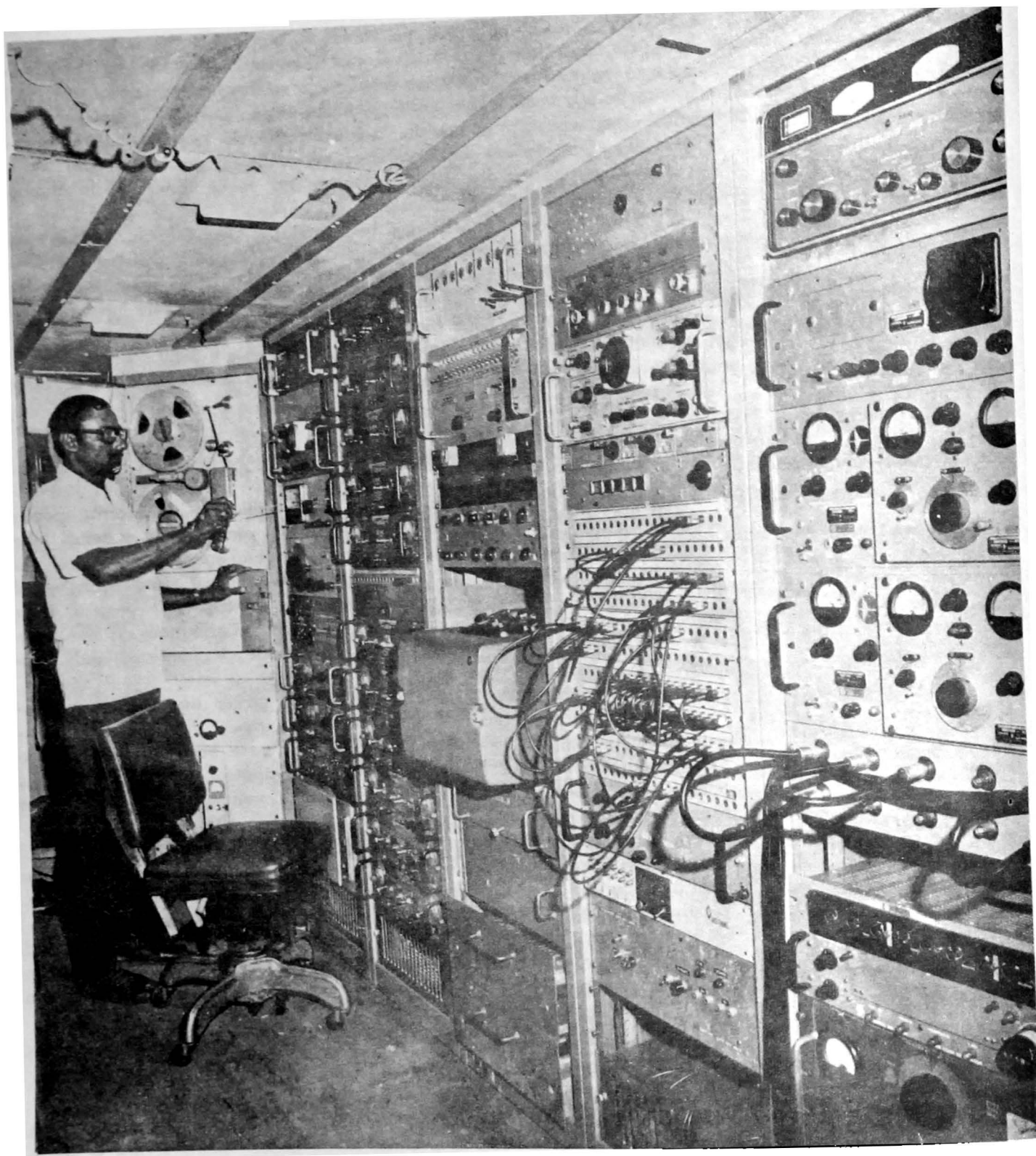
Telemetry and telecontrol systems find application in electric power generation and distribution systems, water supply and sewage systems, long distance communication systems, off-shore oil drilling operations, oil and gas pipelines, mining and in-plant operations, meteorological and hydrological data acquisition, utility metering and aerospace systems. At present, their application in the country is mainly in electricity distribution systems, railway electrification projects, meteorology, aerospace programmes, and communication systems.

Many of the State Electricity Boards use power line carrier communication (PLCC), protection and telemetering equipment in their power distribution networks. While the PLCC equipment have been supplied by the local manufacturers most of the telemetering equipment such as continuous telemetering transmitter and receiver, cyclic telemetering transmitter and receiver have so far been imported. In addition to the electricity distribution systems, some of the power generating stations have also installed PLCC and telemetering equipment. Supervisory remote control equipment have been used in the railway electrification projects of the Indian Railways. Weather stations of the India Meteorological Department use a large number of 'radiosonde' equipment for measurement of temperature, pressure and humidity in the upper atmosphere. Vehicle borne telemetry packages in substantial numbers are used by the Indian Space Research Organisation (ISRO) in their rocket flight programme.

5.5.2. Current Status of Production and R&D

Equipment in this category are manufactured in the country by Hindustan Brown Boveri, Indian Telephone Industries, and Siemens (India). A list of telemetry, telecontrol and allied items under manufacture is given below.

1. Power line carrier communication equipment including wave traps, line matching units, audio frequency shift couplers, audio frequency shift



Telemetry Ground Receiving Centre at Thumba Equatorial Rocket Launching Station.

channels, single and two channel fixed frequency carrier sets, wave change-over carrier sets.

2. Supervisory remote control (SRC) systems employing frequency signalling.

3. Supervisory remote control systems employing DC signalling.

4. Supervisory remote control system with on-demand telemetering facility employing frequency signalling.

5. Supervisory remote control system with on-demand telemetering and tap indication facility employing DC signalling.

The telemetry package required for the rocket flights is produced by the Electronics Production Division of VSSC. Likewise, the radiosonde equipment required for the IMD are produced by their Instrumentation Division.

Among the organisations carrying out development work in this area are the R&D (switching) Division of ITI, Electronics Development Division of VSSC and Instrumentation Division of NAL. Some private manufacturing units have also developed telemetering equipment. Work at ITI relates mainly to systems for railway electrification and signalling, and power distribution networks. Their future plans include development of a remote control system for application in industrial plants, water supply systems, etc. A short range telemetry system for measurement of torque, temperature and vibration in rotating shafts has been developed by NAL. Systems using PCM/FM techniques and capable of simultaneous measurement of upto five parameters, which will find application in wind tunnel measurements, process control systems and in-flight instrumentation have also been developed. Included in their future projects are development of FM/FM telemetry systems, PCM systems with higher accuracy and channel capacity, digital data bus, flight test data acquisition systems. The Electronics Development Division of VSSC has developed the telemetry package that is used in the rockets.

The list below gives major products/systems developed or planned for development at the various units.

1. Solid-state cyclic telemetering and alarm reporting equipment
2. Solid-state continuous telemetering system
3. Solid-state coding for centralised traffic control equipment
4. Solid-state SRC system for railway electrification projects
5. Solid-state, high speed versions of supervisory remote control equipment developed earlier and now in production
6. Remote meter reading equipment
7. Train describer systems
8. Remote control systems with telemetering facility for application in industrial plants, oil, water, gas distribution networks, etc.
9. Rocket borne telemetry package
10. Transponders operating at 2.7 GHz
11. Telemetry systems for airborne instrumentation and ground segment
12. Short range telemetry systems
13. PCM/FM telemetry systems for applications in wind tunnel, process control, and in-flight instrumentation
14. Five channel FM/FM telemetry systems
15. PCM systems for higher accuracy and higher 'channel capacity'
16. Digital data bus system for application in computer controlled industrial automation and interconnection of aviation subsystems

5.5.3. Demand Profile

The demand for telemetry and telecontrol equipment during the Fifth Five Year Plan, based on requirements projected by the Central Water and Power Commission for the power distribution network, is given in Table 5.30. An estimate has been made of the demand in other application areas and the same is given in Table 5.31. This estimate is a conservative one. The actual demand can grow considerably depending on the promotional efforts and successful application of telemetry systems in these areas.

The total demand for telemetry and telecontrol systems during the Fifth Plan period is Rs. 26 crores. An additional investment of Rs. 2.4 crores would be required during the Plan period to generate the necessary production capacity. During the Sixth Plan period continued growth of the industrial activity and public utilities can be anticipated. Another area which is bound to expand significantly is off-shore and other oil drilling operations and the associated distribution networks. Telemetry and telecontrol systems will have a good market in these operations. A conservative estimate of the demand for telemetry and telecontrol systems during 1979-84 would be about Rs. 40 crores. To achieve a production of this value, an additional investment of about Rs. 2 crores during the Sixth Plan period would be required.

Table 5.30. Requirement of telemetering equipment for power systems during 1974-79.

Sr. No.	Description	No.	Value (Rs. lakhs)
1.	Wave traps and coupling capacitors	1600	350
2.	Line matching unit and protection	2200	50
3.	Carrier sets	1110	500
4.	Telemetering transmitter and receiver	220	100
Total			1000

Note: The associated telecommunication items, like telephone exchange VHF sets, teleprinters, teleprinter exchange, etc., are included in the respective sections.

Table 5.31. Estimated applicationwise requirements of telemetry and telecontrol equipment during 1974-79.

Sr. No.	Application area	Value (Rs. lakhs)
1.	Water supply/sewage systems	150
2.	Oil/gas production and pipelines	150
3.	Supervisory control for AC traction lines	1000
4.	In-plant telemetry	50
5.	Microwave systems monitoring	200
6.	Telemetry systems for rockets and satellites	80
Total		1630

5.6 Radar and Navigational Aids

The effectiveness of marine and air transport operations from considerations of safety, speed and economy is dependent upon the navigation systems employed. Presently, all sea-going vessels are equipped with one or

more radio location systems; diverse radio/radar navigational aids are provided to aircrafts for enroute navigation, approach and landing. Equipment falling under the category of 'Radar and Navigational Aids' are used in the country in defence as well as non-defence applications. For reasons of security, the defence requirements have not been covered in this section. Besides functioning as navigational aids, radars find applications in various civilian departments like the India Meteorological Department and the Department of Space. Though the requirements for such radars are small, they are included here so as to cover most of the civilian radar requirements.

5.6.1. Navigational Aids to Civil Aviation

The increasing density of air traffic, introduction of power types of aircraft and changing route patterns call for efficient navigational aids in addition to a reliable telecommunication network. India is a member of the International Civil Aviation Organisation (ICAO) and therefore has certain obligations to fulfil with regard to the facilities to be provided and also with regards to the standards to which they should operate. This necessitates replacement of obsolete navigational aids and providing upto date facilities from time to time. The following activities have been taken up by the Department of Civil Aviation in the recent past:

(i) To replace, the then existing obsolete instrument landing system (ILS) equipment at the international airports with Cat. II type.

(ii) To provide gap-free VHF omnidirectional range (VOR) coverage for en-route flights among major airways and near important airports.

(iii) To replace some of the MF location beacon facilities in the control areas by terminal VORs (low power)/distance measurement equipment to facilitate greater precision in landing. They are particularly required for installation at selected locations in the terminal areas of the international airports.

(iv) To provide surveillance radar control at selected airports. Air-route-surveillance radars (ARSR) for long range navigation have been installed at major international airports. Airport surveillance radars (ASR) for air traffic control in the immediate vicinity of some of the busy international airports have been commissioned.

Demand for the Next Ten Years

During the Fifth Plan period, the endeavour to meet the standards prescribed by ICAO and ITU would be continued. Activities in addition to those covered during the Fourth Plan include provision for secondary surveillance radar (SSR) for existing air traffic control for positive identification of aircrafts and also to obtain information regarding the flight automatically, and provision of navigational facilities at new airfields proposed to be established during the Plan.

Schemes on radio and radar navigational aids envisaged by the Civil Aviation Department during the Fifth Plan are given in Table 5.32.

It may be anticipated that navigational aids worth about Rs. 35 crores will be required during the Sixth Plan period. At this stage it may not be possible to give the breakup and phasing of procurement during the Sixth Plan period.

Indigenous R&D and Production of Equipment

Before considering the possibilities of indigenous development/

production of radar/radio navigational aids, it may be worthwhile to mention certain special features of these items. The ICAO prescribes performance standards to be met by the equipment used in aviation especially items such as ILS, VOR, DME and NDB. These specifications are very stringent in view of the safety requirements in these services. Likewise, even in the case of airborne equipments of buyer furnished category, it is necessary that such equipment meet the ARINC specifications. These equipments are complex and sophisticated ones incorporating the latest developments in design and manufacturing techniques. As a result, it may not be possible to develop or produce some of these equipment indigenously for immediate use. Also in some cases, the requirement is so small that it may be highly uneconomical to take up development/production.

Table 5.32. Radio and radar navigational aids—Fifth Five Year Plan (Civil Aviation Department)

S.No. Description	Unit cost (Rs. lakhs)		Total no.	Phasing					Total cost involved during (Rs. crores)	
	FE	Total		1974-75	1975-76	1976-77	1977-78	1978-79	Fifth Plan period	Sixth Plan period
1. Precision approach radar (PAR)	—	70	3	1	1	1	—	—		
2. Secondary surveillance radar (SSR)	3	26	4	—	1	1	2	—		
3. Airport surveillance radar (ASR)	—	100	5	2	—	3	—	—		
4. Air route surveillance radar (ARSR)	—	120	4	1	1	1	1	—		
5. Instrument landing system (ILS) cat. II	16	30	14	2	4	2	2	4	23	35
6. Very high frequency omni range (VOR)	5	8	22	2	5	5	5	5		
7. Terminal VOR (TVOR)	5	8	12	2	5	5	—	—		
8. Distance measuring equipment (DME)	5	8	21	—	6	6	4	5		
9. Visual direction finders	4	7	4	—	4	—	—	—		
10. Non-directional beacons	—	3	15	—	5	5	5	—		

The following development and procurement programmes are envisaged for various radio and navigational aids required by Civil Aviation Department during the Fifth Plan period.

(i) Precision Approach Radar: HAL, Hyderabad Division, is manufacturing precision approach radar equipment with foreign collaboration. As the equipment conforms to the ICAO standards and recommended practices, the requirements of DGCH as far as PAR is concerned, may be met by them.

(ii) Secondary Surveillance Radar: BEL, Ghaziabad Division, has embarked on a project of manufacture of secondary surveillance radar equipment. They should be ready for supply by around 1976-77. The details of the performance and circuitry of the equipment and the associated data processing equipment for air traffic control to be manufactured by them in the light of ICAO standard and recommended practices, are under discussion

among the concerned agencies. It is expected that BEL, Ghaziabad would be able to meet the entire needs of Department of Civil Aviation by making suitable modification wherever necessary.

(iii) Airport Surveillance Radar: HAL, Hyderabad Division is at present manufacturing airport surveillance radar equipment working on the L band under licensed production agreements to meet the defence requirements. The possibility of this radar being used to meet the operational requirements for Civil Aviation purposes is a subject of direct relevance.

(iv) Air Route Surveillance Radar: HAL, Hyderabad Division is at present manufacturing ATCR 2T radar under licensed production agreements for meeting defence requirements. This equipment will need certain modifications for the purpose of meeting the requirements of the Civil Aviation Department.

(v) Instrument Landing System: At present, instrument landing systems are not manufactured in the country and the requirements of Civil Aviation Department is met by imports. Manufacture of ILS may be considered by BEL as the requirement of Civil Aviation Department itself is significant.

There is a need for evolving a microwave instrument landing system (MILS) which is more adaptable for smaller airfields and is less complicated in design and is easier to install. Department of Civil Aviation could draw broad specifications for such a system.

(vi) VORs/TVORs: The requirement of VORs is likely to last for quite some time, VOR being a standard ICAO navigational aid. Since TVORs and VORs have a common antenna system, similar control units etc., the production of VORs/TVORs to conform the ICAO specifications should be taken up in the country with maximum advantage.

The Electronics Commission through its Technology Development Council is funding a project at BEL, Bangalore for the design, development and production of VORs/TVORs to meet the requirements of the Civil Aviation Department.

(vii) Distance Measuring Equipment: DME is an internationally standardised ground based pulse ranging system for aircraft operation in 960 MHz to 1215 MHz. DMEs are generally colocated with VORs and the VOR DME combination gives instantaneously the direction and distance from the ground station. At present, this equipment is imported. Their indigenisation should also be looked into.

(viii) Non-Directional Beacons: These are omni-directional transmitters operating in the 200 to 1600 KHz band. The corresponding equipment on the aircraft is the MF receiver which gives an indication corresponding to the direction of NDB with respect to the longitudinal axis on the aircraft. These beacons are also known as compass indicator. The standard power for the NDBs required by CAD would be 75/100W for locator beacons, 400/500W for medium power beacons. Design, development and production of NDBs have been initiated at BEL, Bangalore.

The Radio Construction and Development Unit (RCDU) of the DGCA has been engaged in the planning and installation of projects, commissioning and periodic flight inspection of navigational aids. This unit plays an important role in implementing the schemes of CAD.

5.6.2. Maritime Navigational Aids and Allied Equipment

With the advent of giant tankers and bulk-carriers, the demands for accurate position have become more exacting. The navigation problem becomes more acute as a vessel approaches coastal waters and enters restricted channels. Dredgers and survey vessels also need constant and accurate position fixing. Apart from normal navigation and port operations, there are other multifarious marine activities such as off-shore oil exploration which demand accurate position fixing. Fortunately, the increasing requirement of accuracy of position determination has been more than matched by the technological progress made in the development of electronic systems and devices.

Apart from the various visual aids such as light houses, beacons, leading transit, buoys of various types, light vessels, etc., a variety of sophisticated electronic navigational aids is available. Radars are commonly used on board for detection and range finding (in avoiding collision and in position finding) within 0.5° laterally and about 100 metres in distance off. Coastal radar stations are used for providing information and warning to ships. Radio beacons and CONSOL are used for direction finding within about 2° in good weather conditions. Integrated radar chains are used for guidance through narrow channels in foggy weather. LORAN system is used for long range positioning in transoceanic navigation. LORAN-C is a relatively new addition to this family operating at a frequency of 100 MHz with a ground wave coverage of 1000 to 1500 miles. DECCA system is used for coastal navigation and position finding at distances upto about 250 miles. HI-FIX system is developed for position finding in estuaries, post approaches and other restricted waters. This is intended primarily for use at ranges shorter than those at which the DECCA navigation is used. The system is designed for hydrographic, geophysical, constructional and other surveys and dredging, etc., which call for nonvisual position finding within a few feet. Microwave survey system (MSS) is designed to make possible precise navigation along a predetermined course. HI-FIX track plotters are developed to provide a continuous visual position fix and to maintain a complete track record along a predetermined course. A new low cost, single channel satellite receiver system has been developed recently to provide precise, worldwide, all weather navigation for the general shipping and fishing industries.

In addition to above coastal and shore-based aids, navigational/operational aids are required on-board the vessels depending upon their uses. For example, some of the big vessels are equipped with marine navigational radars, direction finders, echo sounders and side scan sonars in addition to various navigation systems receiver sets; fishing vessels are equipped with fish finding sonars. Different types of sonars are required for varieties of underwater applications involving targets detection, communication, listening and surveillance. Besides its traditional use for submarine detection and depth sounding, equipment operating on the principles of sonar are used in mapping of the ocean bottom, fish finding, underwater telemetry and control, doppler logs and acoustic navigation beacons. The equipment needed for civil applications such as fisheries, commercial navigation, and oceanography do not call for that high degree of sophistication and accuracy as those required by naval systems. For the reasons of security, the defence requirements are not covered in this report.

5.6.2.1. Current Status

A list showing the electronic navigational aids available on the Indian coast by the end of 1973 is given in Table 5.33. The aids provided for coastal navigation come under the control of the Director General of Light House and Light Ships (DGLL). They have recently set up 'Decca Chains' in the Bay of Bengal and the Gujarat coast. The navigational aids for the approaches to the major ports are set up and maintained by the respective port authorities. The requirements of the minor ports are looked after by the respective Maritime States. For off-shore oil exploration, the contractors engaged by the Oil & Natural Gas Commission have been making their own arrangements by setting up mobile units. Most of the navigational aids and allied equipment, including those on-board have been imported so far.

5.6.2.2. Demand Over the Next Ten Years

(i) Coastal and Shore-based Navigational Aids

The Planning Group on Equipment of Panel on Marine Resources set up by National Committee on Science and Technology (NCST) in 1973 assessed the requirements of navigational aids for the next fifteen years, which are as follows:

(a) DGLL would be setting up 18 additional radio beacon stations. They have no plans for setting up any more Decca Chains but they intend to update and modernise the existing chains.

(b) Growth of Indian coastal shipping and deep sea fishing in the course of the next fifteen years will justify covering the entire coastal region with Decca Chain.

(c) All the major ports have undertaken large scale development programme for the oil and/or ore trade. These ports will have to augment/improve their navigational aids to cater to the larger ships.

(d) In view of the world-over oil crisis in the recent past, off-shore oil exploration under the aegis of the ONGC has assumed added significance and pace. Normally, such activities are carried out by hiring services and equipment like SHORAN from foreign contractors. It may be more economical if the navigational aids set up by the DGLL could cover these activities at a later date. As activities of ONGC and other off-shore activities extend to a considerable distance from shore, DGLL should be in a position to cope up with the high degree of precision that is required by such agencies by providing more Decca Chains to cover the entire coast of India. Only when Decca Chains become ineffective or prove to be inadequate for the required accuracy, the organisations engaged in special off-shore activities resort to special arrangements such as SHORAN, TORAN, microwave survey system, etc.

In light of the above anticipated demand, the total requirement of navigational aids has been worked out by the NCST Panel on Marine Equipment which is given in Table 5.33.

(ii) Specialised Equipment for the Exploitation of Marine Resources

The NCST Panel for the Equipment for Marine Resources contemplated that to make a beginning towards the exploitation of marine resources available near the coast line of the country, a vast range of specialised equipment are required. The anticipated demand, falling under the purview of this chapter is as follows:

Table 5.33. Present status and the future demand projection for navigation aids.

Sr. No.	Type	Existing No.	Additional requirement during the period	
			1974-79	1979-84
1.	Radio beacon	8	6	12
2.	Racon	—	10	20
3.	Decca master station	2	4	8
4.	Decca slave station	6	—	—
5.	Decca receiver sets	7	12	45
6.	Hi-Fix master station	4	1	—
7.	Hi-Fix slave station	7	2	—
8.	Hi-Fix receiver set	20	2	—
Total approximate cost in FE (in Rs. lakhs)			160.0	315.0

(a) Elaborate survey of the off-shore areas is essential for accurate planning and successful execution of the exploration programmes of marine resources. Approximately, 15 ships and boats from 13 metres to 70 metres LOA of various categories would be required during the next 5 years. This may have to be supplemented by another 25 ships during the following ten years. Amongst other oceanographic equipment, these ships would be requiring echo sounder, side scanning sonar, precision depth recorder, etc.

(b) The Panel estimated that a large number of fishing vessels will be required during the Fifth Five Year Plan. The type of vessels includes stern trawlers, purse-seiners, long liners and cill netters. Depending upon the purpose (like survey, exploration, etc.), the vessels are equipped with some of the equipment like, sonars, net-recorders, radio direction finders, marine radar and fish finders.

(iii) Electronic Aids on-board the Vessels

Maritime operations employ a variety of vessels covering the super-tankers for carrying oil, large passenger liners, barges, tugs, floating oil rigs, high-speed patrol-crafts for antismuggling activities, fishing trawlers, mechanised and non-mechanised boats for a wide variety, pleasure crafts and yachts. Depending upon the purpose, each vessel is provided with a set of communication and navigational equipment along with the required aids.

The estimated requirement of electronic aids going on-board the ocean going liners, fishing vessels and patrol-crafts for antismuggling activities during the Fifth Plan period for civilian uses is consolidated in Table 5.34.

5.6.2.3. Analysis of Gaps and Suggested Course of Actions

(i) Coastal and Shore-based Navigational Aids

The existing electronic aids cover only a small portion of the vast Indian coastal waters. On the eastern coast, the Decca system covers the head of the Bay of Bengal from Visakhapatnam to Calcutta extended further whereas on the western coast, it covers from about 200 nautical miles west of port Okhla to Morniugao. With the anticipated development of the deep sea fishing industry, increase in the home-trade coastal traffic and other off-shore exploration activities, the requirements of coastal and in-shore navigational and communication aids would further increase thereby leaving a significant gap.

Any type of position fixing equipment can be adopted in Indian coastal waters. However, the phase comparison technique has been adopted so far. The technical know-how for such electronic aids does not exist in the country at present except for the related communication equipment which are being manufactured by BEL, Bangalore.

(ii) Specialised Equipment for the Exploration of Marine Resources

The vessels needed for research and survey can be broadly categorised into oceanographic research ships, hydrographic survey vessels, ships for geological, geophysical, seismographical and biological surveys, ships for meteorological data collection, exploratory and experimental fishing and training ships. Depending upon the purpose of the ships, the instruments are installed on board. However, communication and navigational equipment such as VHF transreceiver, echo sounder, direction finder, marine navigation radar, etc., are mostly common.

It may be required to standardise the communication and navigation equipment for research and survey vessels with the larger requirements (for ship building industry) and the commonality aspects should be looked into for long term plan.

(iii) Electronic Aids on-board the Vessels

As regards the electronic equipment going on-board the ships, the purchaser of the ship usually specifies the equipment even if the ship is built abroad. In so far as the fish finders and communication equipment required for fishing vessels are concerned, the orders are normally placed by the fishing concerns and the Ministry of Food and Agriculture only plays the role of coordinator and is responsible for the clearance for the import of equipment. Therefore, the problem of forecasting their requirements and launching a meaningful manufacturing programme is confronted with the following:

- (a) Diverse users have no coordination amongst themselves
- (b) Lack of standardisation of the equipment to be used
- (c) Uncertainty of actual requirement
- (d) Decision on the type of the equipment to be fitted even before ships/ trawlers are manufactured
- (e) Need to have world-wide service facilities for the equipment if built indigenously

Hence, at present, most of the demand for marine equipment is met by import.

BEL has plans to take up the development and production of some of the maritime communication equipment. As regards marine navigational radar, there is already an existing production programme at BEL under licensed production agreement. With the expertise available in the country in the field of radar development and production, design, development and manufacture of marine radar required for civilian marine and the low-power radars required for patrol boats can be taken up in the country.

In order to facilitate the manufacture of marine electronic equipment for the ships built in the local shipyards, it is necessary to identify a single agency which should be responsible for coordinating and placing orders on the manufacturers. In this regard, the requirements of ocean-going ships, ports and other shore-based installations may be coordinated by Ministry of Shipping and Transport whereas Fisheries Department can take care of the firming of the requirements for fishing vessels. Further, the set of electronic equipment for each type of vessel should be standardised conforming to

Indian Merchant Shipping Radio Rules. Even if some of the equipment are proposed to be imported in view of their limited demand and sophistication, it may be worthwhile to standardise on a manufacturer/manufacturers for specific equipment/equipments. A single agency may be nominated for the type approval of the marine electronic equipment.

A few equipment are being manufactured in small quantities for the Navy but these are not used in civilian marine, even though their specifications are much stringent. Therefore there is a need to analyse the commonality between marine and naval electronic requirement. Since the requirements are somewhat diverse in nature, the development programme should be broad-based catering to the need of most of the users having flexibility and capability to diversify the development activities, and also taking into account the extent of commonality that is required and is achievable.

Table 5.34. Requirement of electronic aids going on-board the vessels during the period 1974-79.

Sr. No.	Requirements	Equipment	Total estimated requirements during the Fifth Plan period
1.	Fishing trawlers (For Fisheries Deptt., under Ministry of Food and Agriculture)	(a) Echo sounder (Fish finder) (b) Echo-scope (optical) (c) SSB radio telephone	Estimated at 200 nos. with a possible demand of 80 more. Out of 200, orders for 120 have already been placed by Ministry of Agriculture; 60 to be built indigenously.
2.	Merchant maritime fleets	(a) Main transmitter (b) Emergency transmitter (c) Main receiver (d) Emergency receiver (e) VHF FM transreceiver (f) Transreceiver for life boats (g) Automatic keying unit (h) Automatic alarm (i) Echo sounder (j) Radio direction finder (k) Loran receiver (l) Decca navigator (m) Marine radar (n) Walkie-talkies (6 nos. in one ship)	The major shipyards in the country are (1) Garden Reach Workshops Ltd, Calcutta (2) Mazagaon Docks, Bombay and Goa (3) Hindustan Shipyards, Visakhapatnam (4) Cochin Shipyard It is expected that by the end of 1978-79, 29 big ships would be built in the country which is about 30% of the total requirements of the country, remaining 70% of the ships would be imported. List of the equipment given in column 2 are mandatory for passenger ships. However, for cargo vessels less than 300 DWT, it is optional.
3.	Patrol crafts for anti-smuggling activity	(a) Communication equipment (b) Radar	100

5.6.3. Radars for the India Meteorological Department

The need for more accurate and reliable weather information for optimum operation of weather sensitive activities such as agriculture, irrigation, flood control and management of water resources, aviation, shipping and for issuing warning against violent weather phenomena for protection of life and property has become imperative. India Meteorological Department (IMD)

has been endeavouring to improve its service to meet the increasing and varied demands of various meteorological aids. In the present section, radars in the role of cyclone warning, wind finding and tracking equipment amongst other meteorological purposes are discussed.

So far, India Meteorological Department has been operating its radar on X, S and L frequency bands. The X band radars are generally situated in the vicinity of different airports for the purpose of providing information to aircraft regarding cloud formation around the airport. However, recent practice has been to use S band frequency for such purposes which provide range upto 500 km. The third type of radar equipment used by this Department is the L band radio theodolite network. The radio theodolite network is used to track transponders (radio-sondes), which are launched with the help of balloons from different stations located all over the country. The radio-sondes provide information regarding the atmospheric pressure, temperature and density at different altitudes. The radar network of the IMD. by the end of 1973, consisted of 11 X-band storm detecting radars, 7 wind finding cum storm detecting radars and 4 S-band cyclone warning radars.

Till 1969, all the needs of the IMD were met by improving these radars. Thereafter, most of their requirement has been met by BEL, Bangalore.

5.6.3.1. Demand for the Next Ten Years

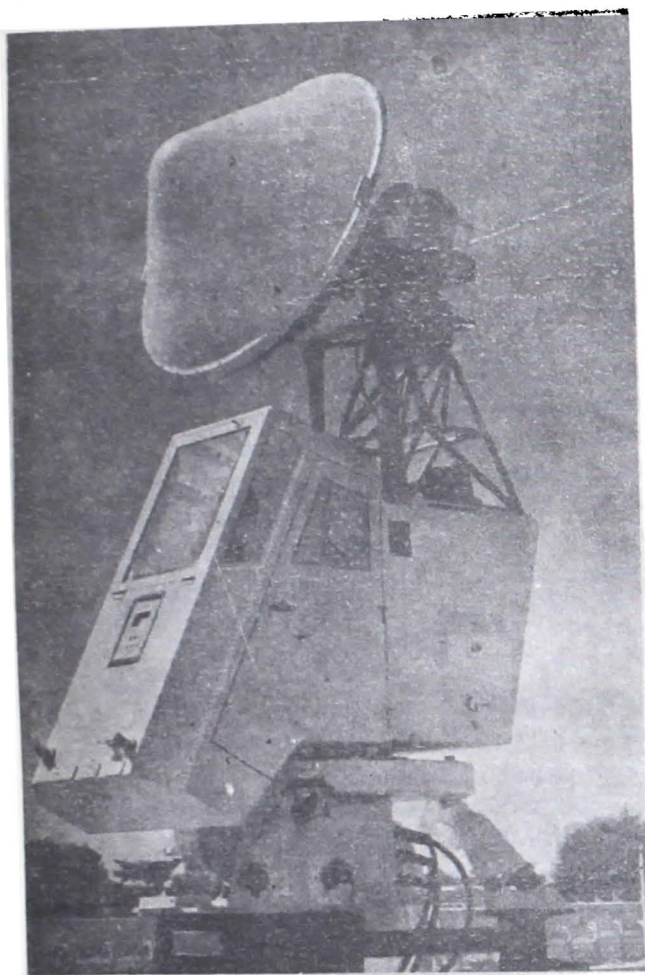
X-band Radars: IMD has been using for the last 20-25 years Metox radio theodolites for upper wind measurements and there are 15 such stations. This equipment has now become obsolete and it is proposed to phase out this equipment and install in its place dual purpose radars with wind computing facilities. It is also proposed to upgrade some of the pilot balloon stations to radar wind stations by installing X-band dual purpose radars. The requirement of dual purpose X-band radar with wind computing facilities would be about ten in the Fifth Plan period.

S-band Radars: IMD has placed orders for 4 S-band radars with BEL. These are expected to be delivered by the end of 1976 in a phased manner. An additional requirement of 5 S-band radars—two for cyclone warning network and 3 for radar hydrological studies—during the Fifth Plan period has been envisaged. The radars for hydrological and precipitation measurements should be equipped with advanced digital data processing techniques compatible with IBM computer 360/44.

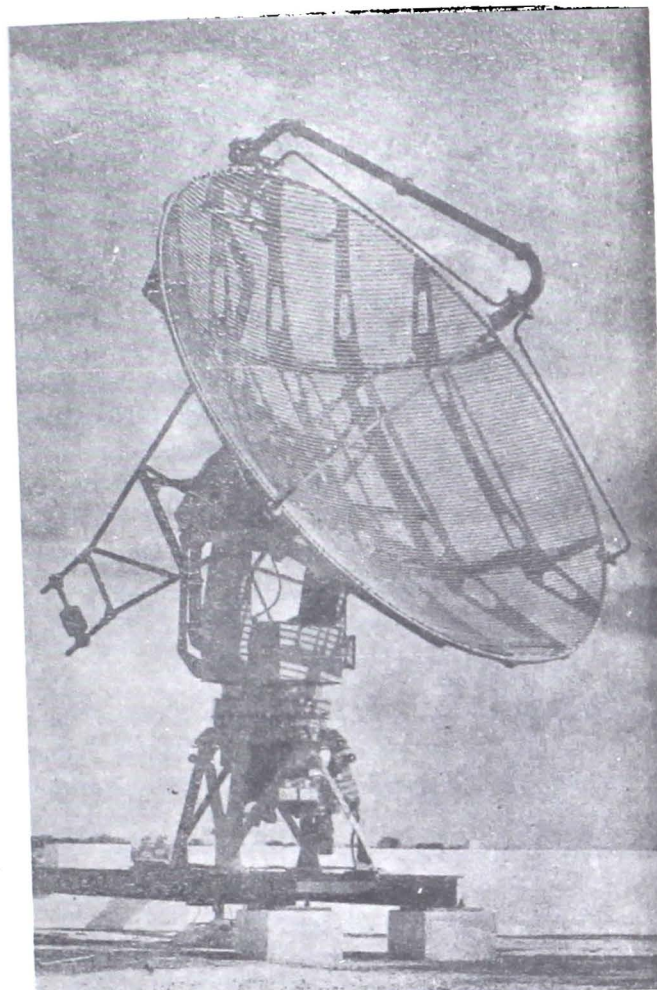
The requirement of meteorological radars during the Fifth Plan period including the equipment for transmitting cyclone warning/storm warning radar pictures (requirement of eight such sets expected during the period) would involve an expenditure of about Rs. 5.5 crores. During Sixth Plan period these may involve an expenditure of about Rs. 8 crores.

5.6.3.2. Development and Production of Meteorological Radars

As regards the indigenous effort to meet the requirements of the IMD is concerned, BEL has already designed and supplied X-band storm detecting radars to the Department. The development of S-band cyclone warning radar system has been completed at BEL. The system is substantially of a solid state design and meets the meteorological specifications for this class of radars. 4 such radars are expected to be delivered by the end of 1976 in a phased manner. Thus, the needs of IMD for X and S-band radars can be met by BEL.



Gun/Missile Control Radar System for Leander Frigate developed and built by BEL.



Antenna of Cyclone Warning Radar fabricated by BEL.

The development of wind finding and weather analysis radar (a surveillance cum tracking X-band radar system with a dedicated digital computer) has been taken up by BEL with the financial support from the Electronics Commission. It is, therefore, hoped that BEL would be able to meet the future requirement of meteorological radars.

It may be useful to integrate meteorological radar requirement of IMD with those of Defence Services not already covered by IMD. This may necessitate the rearrangement of the existing radars and subsequent integration of the future requirements to meet the overall needs of the country.

5.6.4. Radars for the Department of Space

The space programme of seventies envisages the augmentation of facilities for developing and building high power rockets and various kinds of scientific and communication satellites to be launched from the Indian soil. For such purposes, amongst various multiferous activities, the need for precision tracking radars for obtaining the trajectories of various rockets, including the satellite launch vehicle (SLV 3) from Sriharikota Launch Complex (SHAR), was felt as early as 1970. It was also emphasised at that time, that this radar system should be of indigenous design, and expertise available in the various

institutions of the Department of Atomic Energy (DAE) in different disciplines like, microwaves, control systems, etc., should be fully utilised in the development of the subsystems.

After assessing the expertise available at various centres, the final responsibilities for the radar development project and subsystem development were vested as follows:

TERLS, Trivandrum	: Project management, overall system design and integration, test and evaluation, and subsystem development of digital range tracking system, receiver, displays, data processing and power supplies.
TIFR, Bombay	: Modulator and transmitter, microwave transmit receive chains including microwave components and receiver front end.
BARC, Bombay	: Angle servo subsystem for azimuth and elevation.
ECIL, Hyderabad in collaboration with IMD, ISRO	: Antenna subsystem, including feed and pedestal, etc.

Some of the salient features of the radar being jointly developed by these organisations are:

(a) The radar operates in the C-band of frequency range in which most other satellite tracking radars in the world operate. This has the advantage that other earth stations can be used, if required, for tracking our vehicles and satellites and exchange standard techniques available in this band.

(b) It uses a digital range tracking servo system that would track targets at very large slant ranges, without reducing the basic prf in transponder mode. This will increase the precision and reliability of measurement along with the increase in range tracking rate.

(c) It uses a solid state construction, except for the high power transmitter circuit, to enhance compactness and reliability of operation.

(d) It can be used in skin mode, transponder mode or mixed mode of operation.

5.6.4.1. Total ISRO Requirements for the Fifth Plan Period

(i) One C-band tracking radar would be required for TERLS during Fifth Plan period.

(ii) For SHAR complex, two C-band radars of medium range would be required. One is for prediction of SLV-3 launch vehicle trajectories and the second one is for down range requirements of a station located in the Andaman Nicobar area which would give the necessary tracking support for launchings of SLV-3. These are currently being developed at VSSC, Trivandrum.

(iii) A few radars like side looking airborne radar, weather radar, radar scatterometer, etc. will be required by ISRO for various experiments in remote sensing area.

The future programme of ISRO and the national expectations from this organisation have not been crystallised to arrive at any concrete long-term requirements. However, it may be mentioned that significant indigenous capability has been built up in various units of ISRO/DOS in the field of radars and therefore indigenous design, development and fabrication would play a major role in meeting the futuristic requirements of ISRO/DOS.

VI

Computers

6.1 Introduction

In the Bhabha Committee Report, the field of computers had been dealt with in a tentative manner, as at the time the report was prepared the picture of the computer industry in India was very vague. Subsequently, the Electronics Committee took certain positive steps to update the projections and recommendations of the Bhabha Committee. Two of the Working Groups constituted by the Electronics Committee viz., the Rao Committee (1967) and the Narasimhan Committee (1968), have evaluated the computer requirements in the country and have given many suggestions for developing a viable computer industry in India.

The total outlay for computers for the ten years (1967-77) was estimated by the Rao Committee to be Rs. 75 crores. This does not include the Defence sector. The Narasimhan Committee estimated the outlay to be Rs. 161 crores for the entire country for the ten years starting from 1968. The impact of the minicomputers on the computer utilisation pattern, the growth of the computer consciousness to a high level, and the efforts to promote the use of computers in all areas where their use may catalyse development, have completely changed the demand pattern since then.

The current status of production and use of computers in India are discussed in Section 2 of this Chapter. The new technological trends towards minicomputers and minicomputer networks, the technology alternatives available in the development of CPUs and memories, the level of integration, etc., are discussed in Section 3. The class of peripherals which are primarily electronic, rather than electro-mechanical in their operation are likely to play an important role in the future. Specific examples of this type are, non-impact printing devices such as teletypewriters and line printers, optical character readers, plasma, liquid crystal and colour emulsion displays.

A ten year demand profile for computers, taking into consideration the impact of minicomputers and efforts taken to promote the use of these machines in all relevant areas, is given in Section 4.

In the field of computers, gaps exist mainly due to reasons like technological gaps in the component industry, financing and entry costs, size and sophistication of the market, structural changes in the computer industry, role of Government support, management and so on. Some of these aspects are discussed in Section 5.

As one of the major aims of the production programme for computers is to reduce the foreign exchange drain on imported computers, the programme should aim at building a viable indigenous industry. This needs intensive developmental efforts in the initial phase. Such areas requiring immediate attention for development efforts are identified in Section 6 and the know-how acquisition for these development efforts, and the supporting and ancillary facilities needed are discussed.

As the establishment of a healthy and self-dependent computer industry depends on the number of entrepreneurs operating in the field, their technical competence, the production volumes and so on, there is an urgent need for evolving a proper licensing policy. Some of the broad guidelines for this area are also given in Section 6.

The investment required for production to meet the demand projected in Section 2 is given in Section 7. A total production worth of Rs. 560 crores is envisaged for computers, peripheral equipment and related items during the 10 year period.

6.2 Current Status of Production and Use of Computers in India

Computers have been in use in India for more than a decade. Whereas in 1961, there were only two computer installations in the country, by 1965 the number had increased to 32 and by 1967 this number had doubled. From then on, there has been an exponential growth. There are, at present (upto June 1974), 224 computer installations in the country. The cumulative number of computer installations during the period 1961-74 is shown in Table 6.1. In what follows, sectorwise, manufacturerwise and regionwise distribution of computers in India is given. This is followed by the present indigenous production of computers and calculators in the country.

6.2.1. Sectorwise Distribution of Computers

The sectorwise distribution of computer installations is shown in Table 6.1. An analysis of the distribution pattern shows that there is equal distribution of computers in the Government departments and the private sector, each covering about 35 per cent of the total. Research & development and educational institutions cover the remaining 30 per cent. The current status of computerisation in India as a whole, is that the private and public sectors have assumed equal importance. There is a disproportionately large concentration of computer power in the business and administrative data processing area. In this area, again, the concentration of Governmental and public sector agencies would seem to be high. The investment in computers in the educational sector, in scientific and research organisations and in service centres with educational and training facilities, is very poor.

6.2.2. Manufacturerwise Distribution

Most of the computers installed at present in India are of foreign origin. From Table 6.1 it can be seen that IBM covers more than 60 per cent of the total installations in the country. Of these IBM installations, about 75 per cent are of the 1401 type. ICL computers account for 12 per cent of the total installations. TDC and Honeywell computers cover about 16 and 5 per cent, respectively.

6.2.3. Regionwise Distribution

On the basis of the current computational activities, it is possible to demarcate certain regions having well developed computer utilisation. They are, in order, as (i) western region, (ii) eastern region, (iii) northern region, and (iv) southern region. The existing computational facilities in these regions are discussed below.

6.2.3.1. Western Region

Maharashtra and Gujarat are covered in the western region. In this,

VI

Table 6.1. Sectorwise and manufacturerwise distribution of computers in India (as on 1.6.1974)

	Government	Educational institutions	R&D institutions	Private	Total
IBM	52	18	9	62	141
ICL	7	1	—	17	25
Honeywell	7	1	2	—	10
ECIL (TDC)	11	10	13	1	35
Others*	1	3	9	—	13
Total	78	33	33	80	224

* Include CDC, BESAM, HP, PDP, MINSK, VARIAN, FERRANTI, ELLIOT, OLDAP and ISIJU.

the Bombay-Poona area has the maximum computational facility in the country. The CDC 3600-160A computer installation at TIFR is one of the largest in the country and is being operated as a national computation facility. The TIFR computer is used extensively, apart from TIFR, by BARC, PPED, other members of DAE complex, universities and research institutes, and public/private sector organisations. This system is heavily loaded with the utilisation being nearly 700 hours per month.

BARC, the major user of TIFR computer system has installed the Russian Computer BESAM-6. This system having a 64K word (48+2 bits) memory will cater to the computational needs of BARC at present.

Other installations are in small or medium range. The information regarding manufacturers and models of various computers in this region is given in Table 6.2.

6.2.3.2. Eastern Region

Computational facilities in the eastern region are concentrated mainly in Calcutta primarily in the form of small in-house systems. Outside Calcutta city, there are limited facilities at Kharagpur, Durgapur, Ranchi and

Table 6.2. Regionwise distribution of computers in India (as on 1.6.1974)

Region	State	IBM	ICL	TDC	Honeywell	Others	Total
Western region	Maharashtra	41	11	5	3	5	65
	Gujarat	8	3	3	—	1	15
Eastern region	West Bengal	18	1	—	1	1	21
	Orissa	3	—	—	—	—	3
	Assam	1	1	—	—	—	2
	Bihar	8	—	—	—	—	8
Northern region	Delhi	17	2	1	4	1	25
	Punjab	1	—	1	—	—	2
	Rajasthan	1	—	1	—	—	2
	Uttar Pradesh	11	—	4	1	—	16
Southern region	Madhya Pradesh	4	—	—	—	—	4
	Andhra Pradesh	9	—	12	—	—	21
	Karnataka	6	4	5	1	3	19
	Kerala	3	—	1	—	1	5
	Tamil Nadu	10	3	2	—	1	16
Total		141	25	35	10	13	224

Jamshedpur. Details of existing computer installations are shown in Table 6.2. The current level of facilities provided and their utilisation cannot be taken as a guideline for the quantum of loads in this region where use of computers even for justifiable fields of applications has received a set back due to extraneous reasons.

The systems in the educational institutions like Jadavpur University, Indian Statistical Institute, IIT Kharagpur, Utkal University etc., are utilised mainly for research and training. A large number of users in the region make use of installations outside their organisation both within and outside the region.

6.2.3.3. Northern Region

Computational facilities exist in Delhi and Kanpur and to a limited extent at Dehra Dun, Roorkee, Chandigarh and Aligarh, and there is potential for development of commercial applications further at Delhi, Chandigarh, Faridabad, Ghaziabad, Hardwar, Jaipur and Ludhiana, as well as some educational applications in the Universities of Agra, Aligarh, Kurukshetra, Meerut and Roorkee. The details of existing computer installations in the northern region are shown in Table 6.2. One of the largest installations in this region is the one at IIT, Kanpur, having IBM models 1401, 1620, 1800 and 7044. IIT has been the acknowledged vanguard of computer science education in the country offering educational and postgraduate programmes in computer sciences. IIT has in-house load of nearly 80 per cent on its computers. The other major users of the IIT system are Research Design and Standards Organisation, Air Force Station (Kanpur), Defence Research Laboratories, State Electricity Board, Local Self-Government Engineering Department, and Kanpur University. The other installations in this region include Diesel Loco Works (Varanasi), Swadeshi Mills (Kanpur) and FCI (Sindri).

6.2.3.4. Southern Region

Bangalore has 19 computer installations most of which are being used for R&D activities. The IBM 360/44 at Indian Institute of Science, which is one of the major scientific systems, meets the scientific computational needs of the Institute. The Institute provides for advance learning in computer sciences. The systems at HAL, LRDE and NAL are mainly loaded with the in-house requirements of research and development work.

There is no large computer system, except the IBM 370/155 at IIT Madras, available in this region to take care of the scientific computation, planning and decision making, administration, industrial and commercial data-processing requirements of the institutions in and around Madras. The computer centres in Kerala and Andhra Pradesh are mainly used for in-house purposes and therefore, cater to the specific needs of the organisations housing them.

6.2.4. Production of Computers and Calculators

The present indigenous production of computers in India is very limited. ECIL, the major manufacturer of computers, has so far produced and installed about 35 TDC systems. These systems are used for on-line applications, education and scientific purposes, hardware and software development, and business data processing.

ICL has been granted an industrial licence to manufacture 1901 A series in collaboration with BEL (Bangalore). In this joint venture BEL produces only the central processor and electronics for the peripherals. The indigenous effort of BEL is in the fabrication of printed circuit cards, back-panel wiring, mainframe assembly and final testing. The overall indigenisation in this programme is around 40 per cent.

IBM, in their factory at Kurla, Bombay manufactures unit record machines and key punches. They were also engaged in reconditioning and assembling 1401 central processors. IBM has a manufacturing programme for the model 129 key punches on a 100 per cent export basis.

A range of electronic desk calculators (EDC) of indigenous design has already appeared in the Indian market. One of the significant trends is that the prices of the calculators have come down to an average of about Rs. 4000 from the earlier figure of around Rs. 6000. These prices are expected to go down further when the components are made available indigenously.

The capacity so far approved for the manufacture of EDCs in the organised sector, including letters of intent issued, is about 50,000 numbers and in the small scale sector about 44,000 numbers. The manufacture of a variety of electronic devices and peripherals such as display devices, key-boards and printers for the EDCs is already being encouraged. The present import content of ten per cent of the total cost per machine is expected to be brought down further.

6.3 Technology Trends and Alternatives

If a developing country like India adopts a policy to centralise its computing facilities into regional servicing centres planned around only maxicomputers, it will result in a growing foreign exchange drain of the order of 200 million dollars in the next 10 years. A technological alternative, which, while sustaining the natural growth of development catalysing applications, tends to minimise the foreign exchange drain in a phased sequence, is the minicomputer network technology, which is gaining momentum. It is predicted that the present decade will see the dominance of minicomputers in view of the spectacular developments in integrated circuit technology. Intelligently planned minicomputer networks are increasingly substituting maxicomputers.

It is observed that the main difference between the alternatives is that maxicomputers have more hardware—larger words, more instructions, complex I/O controllers, and sophisticated facilities for indexing. It shall be noted that there is a good trade off possibility between hardware and software. Hardware complexity and hence cost can be reduced by increasing software as in minicomputer networks. The speed penalty often encountered in software is avoided by executing it in stacked-up minicomputers. This is a very attractive proposition for a country like India for:

(i) Cheaper intellectual labour in India indicates that software capability can be obtained cheaper than hardware capability. Hence a trade off between the two favours software better in developing countries than in developed countries.

(ii) India has the competence for designing and manufacturing minicomputers but not maxicomputers.

The peak attained by the minicomputer evolution, as it stands now, has gone out of the original concept of a limited-performance, stripped-down version of a maxi which realised a low cost realisation at the cost of speed

VI

and capacity. A contemporary minicomputer designer has now several powerful conceptual tools to play with, namely, mixed memory systems, multiple unibuses, powerful set of instructions, microprogramming, hardware floating point units, memory segmentation, Schotky logic gates and multilayer boards.

An important factor that gave the designer flexibility in system design is the unibus, which is a fast asynchronous system for data transfer between computer system elements. This facilitates mixing memories of different speeds, and the expansion of load capability and line lengths. The contemporary technology has made possible memory units having access times exceeding the bus speed. This has dictated a new design philosophy. According to this, memory is split into two parts, one catering to the slower core bulk storage and conventional peripherals, and the other for the higher speed semiconductor memory units. A fast short dedicated bus connects a bi-port SC-memory to the central processor. The second SC-memory control post is a standard unibus interface. Such a flexibility has given the minicomputer a feature that can make the system performance higher.

A brief summary of the latest technological development in memory and CPUs is given below:

6.3.1. IC Technology and MOS and Bipolar Memories

The latest development in IC technology and the introduction of ROM and MOS memories have reduced the cost of memory units considerably. In minicomputers, as the memory size is limited, semiconductor memories are finding more cost effective and may compete with cores. Though core memories may survive, increasing usage of semiconductor memories is the trend. Bulk of the minicomputer systems available today use MOS and bipolar memories.

Bipolar and MOS memories differ in cost organisation and performance. In general, MOS memories offer lower cost but are slower in performance than bipolar. While bipolar memories use a relatively standard flip-flop as a storage element, different MOS memories (static and dynamic) are available. Dynamic MOS circuits, which make use of the low-leakage current which is associated with the gate circuits and junctions of properly designed MOS, require more elaborate drive signals as compared to the static MOS, which, like bipolar, uses flip-flop as the storage element.

It has been shown that MOS static is price competitive for systems of less than 8K bits when a cycle time of less than 1.5 microseconds is required. Also MOS dynamic is competitive with core up to 128K bits for cycle time requirements of less than 1.5 microseconds. It is, however, not competitive for less than 16K bit applications. The bipolar memory system is cost competitive for applications of upto 16K bit, when cycle time of less than 500 ns is required. At the 250 ns level, it is cost competitive up to 250K bits. The choice of the type of memory, therefore, rests on the type of application and the possible trade-off between the various factors like speed, the cost per bit and the total memory requirement.

6.3.2. Central Processing Units

The developments in the central processing units are almost parallel to those for memory units. The introduction of medium and large scale integrated circuits has increased the efficiency of the central processors and at the same time resulted in substantial cost reductions.

The fabrication techniques used for the logic function of CPU are the same as those used for the semiconductor memories. While the level of integration required for the memory for minisystems is generally accepted as LSI, the level required for the CPU logic has two alternatives, namely MSI or LSI. Both MSI and LSI have their own advantages and disadvantages in the context of CPU logic. This question was discussed in detail by the Mini Computer Panel constituted by the Electronics Commission. Some of their findings and recommendations are given below:

Implications of Large Scale Integration

Other things being equal, it would appear that increasing the level of integration (number of circuits per chip) has advantages. There is, however, a number of considerations which are important. The following is a list of implications of this approach:

- (i) Packaging costs per circuit (not per chip) decrease.
- (ii) Cost per circuit decreases due to smaller unit area utilised per circuit on the chip.
- (iii) Reliability improves, with reduced interconnections.
- (iv) System assembly costs reduce.
- (v) Yields deteriorate with larger chip sizes and smaller device dimensions.
- (vi) Device diversity increases with greater levels of complexity per chip.
- (vii) Demand levels and volumes of production go down as a given function can be performed with fewer chips.
- (viii) Costs of development, manufacture and testing of the devices increase.

All these conflicting considerations, precise quantification being not very easy, merely indicate that there exists an optimum level of integration (where the cost per function to the user is minimal). Precise determination of this level would be difficult. Further, with rapid advances in technology, this optimum point is continually shifting towards increased levels of integration. Added to this is an additional level of uncertainty relating to differences in costs of production, levels of production, labour costs, etc., in India. Today, the maximum packing density possible is around 8000 gates per chip.

L.S.I. Minicomputers—State of the Art and Applications

The field of minicomputers and desk calculators is a case in point. The level of integration today is such as to permit the entire central processing unit of a desk calculator or a minicomputer to be realised practically in a single chip. Programmable calculators and controllers (MM 5700, CK 110, CK 114) are now available from National and AMI. Micro processors for 4 bit and 8 bit operations are being made by Intel (MCS4 and MCS8). American Micro Systems 7200 is an example of a 'minicomputer on a chip' using a single MOS chip for arithmetic, an LSI ROM for control and RAMs for storage; the machine uses only LSI devices. Somewhat loosely, such a machine is called a single chip computer or a computer on a chip.

Availability of single chip processors could revolutionise the traditional approaches to computer system design and usage. Being rugged, reliable and small, it is not surprising that these machines are finding increasing applications. On the one hand are applications like automatic railway signalling, elevator control, automatic broadcast programming, etc., uses never

before visualised for computers. Simple process control and data processing applications for dedicated use, numerical machine tool control and automated testing of various types of systems and equipment are among some of the applications for single chip minicomputers. Defence applications for such systems include field artillery computing systems, meteorological data computers for army meteorological systems, wind finding radars, etc. Use of these machines as dedicated special purpose peripheral controllers is another category which will find application in a variety of areas such as on-line reservation systems, interactive displays, etc. Because of its small size and ruggedness, the computer on a chip will find even more applications in future.

Arguments against Single Chip Processors

All the advantages mentioned earlier for large scale miniaturisation in general are applicable for minicomputers too. There are, however, a number of arguments against this approach:

(i) The main argument against these machines today is their slow speed; in general single chip MOS machines are at least 10 times slower than their bipolar MSI counterparts.

(ii) From the Indian point of view, there is as yet no strong prospect of MOS LSI chips of this type being manufactured locally. Volumes of production, even if production capability should develop, might remain below the level of economic viability.

(iii) With the variety of designs possible, design standardisation becomes very difficult; this, however, is an essential prerequisite to local manufacture.

(iv) Even abroad, these machines are not yet very popular. There are very few suppliers for these devices at present. Major American manufacturers and users (TI and Computer Terminal Corporation, for instance) have decided against these machines.

(v) By their very nature, these machines have certain limitations with regard to adaptability, flexibility and expandability. Design modifications, for instance, are very difficult in general, and impossible after the system is realised. Replacement and repair costs are high, since each component is a significant part of the machine itself. Test facilities required for these components, since they are very complex, may also be very much larger than for MSI systems.

(vi) Existing designs of single chip processors have rather limited interrupt processing facilities. These machines are primarily used in sequencing type of applications, and can never really become a viable alternative which can replace MSI minicomputers.

(vii) Even costwise, components for these machines are not significantly cheaper than for MSI versions. Table 6.3 shows a cost comparison between these. In addition, the costs of MSI circuits are dropping very fast, each year.

(viii) Even assuming that chips have to be imported in India, both for MSI and LSI machines, the LSI approach, by incorporating the computer design into the component, reduces the value added locally, minimises the intellectual challenge in computer design, and reduces it practically to the level of tinsmithy and carpentry.

(ix) The FE content is also likely to be higher.

(x) MOS LSI being a very new technique, sufficient data does not

exist about the long term failure rates of these devices. Doubts have been expressed about the overall life of systems built with MOS LSI as compared to the bipolar MSI counterparts. These arise out of the fact that this is a new technology as well as the small size of individual components.

Arguments in favour of Single Chip Machines

The arguments in favour of LSI single chip computers are also numerous and weighty. They are enumerated below:

(i) The present level of LSI complexity attainable is around 8000 gates per chip. The rate of technological progress is such that this has so far been increasing by a factor of 8 every 2 years. Prices have also been falling at a very fast rate, by a factor of 10 every 5 years. These trends are likely to be steeper for the new LSI technology, than for the more conventional bipolar technology which may be levelling off.

(ii) The cross-over point for the optimum level of integration per chip is already nearer LSI and progressively moving further in that direction. It would be unwise to foreclose this option at this stage and arrest the trend of technology. Beyond a demand of 200 machines annually, manufacture of such machines might be economically viable in India even based on imported components.

(iii) Objections about costs, performance, speed, etc., likewise, may disappear with technological improvements which are sure to come. The cost analysis of Table 6.3 shows only a marginal advantage in favour of the MSI approach, but it does not consider manpower costs which might tilt the balance further in favour of LSI. Also, the difference in memory and additional CPU electronics costs which work against the LSI approach will tend to disappear with time.

(iv) The number of supplies of LSI devices is sure to increase with time.

(v) It is not necessarily true that test equipment for LSI need be much more elaborate and expensive than that for MSI. In fact, such test equipment could be designed and built on the basis of local development effort within a reasonable time.

(vi) Electron optics and ion implantation techniques, being very close to nuclear physics which has a strong base in India, are likely to be easier to develop and establish, leading to MOS LSI facilities, rather than bipolar MSI.

(vii) The reliability and simplicity of these machines are their greatest assets. Mean-time-between-failures and mean-time-to-repair are both likely to be far better than those for MSI machines.

(viii) These machines are likely to find progressively increasing use. Their availability is likely to revolutionise concepts of computer architecture. With hardware procurement and assembly costs plummeting down, efficiency of hardware utilisation need no longer be an important criterion in system design. This might result in shifting a number of software functions to hardware and even otherwise, reducing software overheads. Networks of computer modules might form the basis of the architecture of the next generation of computers.

The foregoing enumeration is enough to convince one that arguments for and against both approaches are so strong as to render too hardy any effort to foreclose either approach in favour of the other. In this connection the Minicomputer Panel has given the following recommen-

VI

Table 6.3. Cost comparison of components used in LSI and MSI minicomputers.

	System using MCS-8 (\$)	System using SSI/MSI (\$)
Cost of CPU chips	200	300 (assuming 1000 ICs at an average cost of .3 dollars/chip)
Additional CPU electronics done outside CPU to take care of demultiplexing from the data bus	240	—
8K/8 bit memory (\$11 1024 bit)	800	650
Interface electronics for memory	250	250
Connector cost	Negligible	60
PCB cost	Negligible	40
Total	1460	1300

dations: "Since LSI minicomputers and MSI machines, at least for some time to come, cater to almost totally different types of applications, there is no immediate need to irrevocably choose between them. At present, it is impractical for various obvious reasons, to eliminate the need for MSI machines by any means. Similarly, with a futuristic outlook, it would be very unwise to lose sight of the present applications and potentialities for LSI machines. It is, therefore, recommended that no restrictions be placed on the level of integration for minicomputers."

6.3.3. Peripherals

Peripheral equipment design has always lagged behind the technological advances in CPUs and memories. Emerging peripheral designs place the emphasis on the electronic parts of these systems rather than the electromechanical parts. Remote terminal development remains one of the most important activities in the minifield. New and faster teletype units, cathode ray tube displays and optical character readers are emerging at an increasing rate.

The conventional off-line card preparation equipment are being replaced by key-to-magnetic tape equipment. Apart from data entry, these equipments provide facilities for data verification, data editing, data search, data merge, etc. Most of these units offer error detection and correction facilities like parity checks, redundancy checks and read after write.

There exists a class of peripherals and devices which, because they are still in the developmental stage abroad and are primarily electronic (rather than electromechanical) in their operation, can be attempted and developed within the country. Specific examples of this type are nonimpact printing devices such as teletypewriters and line printers, optical character readers for handprinted or typewritten documents, plasma, liquid crystal and colour emulsion displays and magnetic bubble memories. Some of these are likely to play an important role in the field of computers in the years to come. With intelligent forecasting of technological trends, and an analysis of expected demand patterns and investment requirements for each of these in depth, it would be possible to determine inter-se priorities between them.

6.4 Ten Year Demand Profile for Computers

A ten-year demand profile for computers (CPU, memory and peripheral interface), peripheral units, system software and electronic desk calculators is given below. The profile for the Fifth Plan is given first. This is followed by the projections for the Sixth Plan period.

6.4.1. Demand Projection for Computers During the Fifth Plan Period

Demand for computers has been projected under various norms and conditions. A committee constituted by the Chairman, Atomic Energy Commission in 1967 under the Chairmanship of Dr. P. V. S. Rao made an estimate of the computers required in the country for the following 10 years. The details of its estimate are given in Table 6.4. It was estimated that 81 major process plants will use, between themselves, 15 process control computers and that other applications such as electrical power, message switching, research, etc., will require 45 such machines, also for real-time applications. In addition, it has estimated, a demand of 1000 desk calculators. Six large systems were proposed as regional computer centres. The total outlay for computers was estimated to be Rs. 75 crores. The requirement for the Defence sector was not included in this estimate.

Table 6.4. Rao Committee* estimate of requirements of computers during the Fifth Plan period.

Sector	Large machines	Medium machines	Small machines
R&D laboratories	—	30	—
Universities	—	25	30
Industry	—	95	60
Banks and insurance	—	20	—
Transport and communications	—	10	—
Defence	No information**		
Others	6	—	—
Total	6	180	90

* Constituted by Department of Atomic Energy, 1967.

** Committee did not cover Defence sector.

A Working Group formed by the Electronics Committee in 1968 with Professor R. Narasimhan as the Chairman revised the estimates given by Rao Committee. It considered the demand for three types of computers, namely, maxisystems, midisystems and minisystems, separately. The following terminology has been adopted, to have some concrete idea of the financial commitments involved.

Very large systems	—	Rs. 200-500 lakhs
Large systems	—	Rs. 100-200 lakhs
Medium large	—	Rs. 50-100 lakhs
Medium	—	Rs. 25-50 lakhs
Small	—	Rs. 10-25 lakhs
Very small	—	Less than Rs. 10 lakhs

According to this analysis systems to be operated as national facilities have to be large or very large. These national centres have to be located in places where the computer utilisation is already well developed at a reasonably high level. It was estimated that there will be a need for 1 very large

Table 6.5. Estimate of computer system requirements in the Fourth and Fifth Plan periods*
(3 tier approach).

Category	Very large	Large	Medium large	Medium	Small
Cost range (Rs. lakhs)	200-500	100-200	50-100	25-50	10-25
Application Area					
1. National and regional centres	1	3	2	—	—
General Purpose					
2. Defence	—	—	4	42	65
3. Public/Private sector and Government departments	—	—	—	100	—
4. National laboratories and educational institutions	—	—	—	10	5
Real Time					
5. Defence	—	—	10	126	35
6. R&D, industry, Government agencies, merchant marines	—	—	—	5	80
Total	300	450	1,200	11,400	2,775
Total cost (average)	1	3	16	283	185

* Estimates of 'Narasimhan Committee'.

system, and 3 to 5 large systems, considering various centres like Bombay, Calcutta, Delhi, Bangalore and Madras.

In estimating the requirements of small to medium-large systems, two classes of usages, namely, general purpose and real time were distinguished. The requirements during the Fourth and Fifth Five Year Plans, for these machines in various sectors like, Defence, public/private sector, Government departments, national laboratories, and educational institutions, etc., have been analysed, a summary of which is given in Table 6.5.

The above approach is quite rational and sound and can meet the computational requirements of the country, in the next Plan period, provided the required foreign exchange is easily available. However, in view of the hard currency scarcity faced by the country, serious attempts have to be made to minimise the foreign exchange drain. It has been estimated that a policy to centralise the computing facilities into regional servicing centres planned around only maxicomputers, will result in a total foreign exchange drain of the order of 200 million dollars by 1981-82. Adopting the view that growth of healthy applications of computers has a development catalysing effect, the minimisation of the foreign exchange drain cannot be carried out by minimising computer utilisation, which unfortunately happens to be the present trend. A positive approach to the problem is to expose technological alternatives which, while sustaining the natural growth of development catalysing applications, tends to minimise the foreign exchange drain in a phased sequence. An important technological development that is gathering momentum, viz. minicomputer network technology, promises to

VI

Table 6.6. Projection of the requirement of computers for a legitimate absorption into the Indian economy during the Fifth Five Year Plan period.

	1974-75			1975-76			1976-77			1977-78			1978-79		
	L	M	S	L	M	S	L	M	S	L	M	S	L	M	S
1. R&D establishments	1	5	25	—	6	32	1	7	40	—	8	46	1	9	50
2. University establishments	—	3	10	1	3	13	—	4	15	1	4	18	—	5	20
3. Industrial establishments	—	8	60	—	10	75	—	12	90	—	14	103	1	16	120
4. Banking and insurance	—	2	20	—	3	25	—	4	30	—	5	35	—	6	40
5. Statistics, planning and Govt. administration	—	2	20	1	3	24	—	4	30	1	5	35	—	6	40
6. Defence	1	10	40	1	12	50	1	14	60	1	16	70	1	18	80
7. Transport and communication	1	1	15	—	1	18	1	2	20	—	2	26	—	3	30
8. Other public utilities	—	1	10	—	1	13	—	1	15	—	2	17	—	2	20
Total	3	32	200	3	39	250	3	48	300	3	56	350	3	65	400

S : Small computer : Less than Rs. 10 lakhs (PDP 11/20 to TDC 16).

M : Medium computer : Rs. 10-50 lakhs (Average system : TDC-32) (or Minicomputer networks).

L : Large computer : More than Rs. 50 lakhs (Average system : ICL 1906A, CDC 6500 or IRIS-80).

Table 6.7. Estimation of the supply position of computers during the Fifth Plan period, taking into consideration the lead time required for the production and promotion of minicomputers in India.

	1974-75			1975-76			1976-77			1977-78			1978-79		
	L	M	S	L	M	S	L	M	S	L	M	S	L	M	S
1. R&D establishments	1	5	8	—	6	16	1	7	24	—	8	30	1	9	38
2. University establishments	—	3	3	1	3	6	—	4	9	1	4	12	—	5	15
3. Industrial establishments	—	8	18	—	10	36	—	12	54	—	14	70	1	16	87
4. Banking and insurance	—	2	6	—	3	12	—	4	18	—	5	23	—	6	30
5. Statistics, planning and Govt. administration	—	2	5	1	3	10	—	4	15	1	5	21	—	6	26
6. Defence	1	10	13	1	12	26	1	14	40	1	16	48	1	18	60
7. Transport and communication	1	1	4	—	1	8	1	2	12	—	2	16	—	3	20
8. Other public utilities	—	1	3	—	1	6	—	1	8	—	2	10	—	2	14
Total	3	32	60	3	39	120	3	48	180	3	56	230	3	65	290

S : Small computer : Less than Rs. 10 lakhs (PDP 11/20 to TDC 16).

M : Medium computer : Rs. 10-50 lakhs (Average system : TDC-32) (or Minicomputer network).

L : Large computer : More than Rs. 50 lakhs (Average system : ICL 1906A, CDC 6500 or IRIS-80).

VI

Table 6.8. Demand estimation for minicomputer peripherals during the Fifth Plan period (Assuming the production of about 900 minicomputer during the period)

Equipment	Percentage of installations which may use the equipment	Total No.	Average price (Rs.)	Total cost (in Rs lakhs)
1. Teletypewriters* (10 ch/sec)	80	1440	10,000	144.0
2. Paper tape readers (300 ch/sec)	70	630	10,000	63.0
3. Paper tape punches (110 ch/sec)	70	630	10,000	63.0
4. (a) Line printers (300 lpm)	50	450	130,000	585.0
(b) Line printers (600 lpm)	10	90	175,000	157.5
5. Card readers (300 cpm)	30	270	20,000	54.0
6. (a) Magnetic tape units* (Transfer rate 28k ch/sec)	50	900	60,000	540.0
(b) Magnetic tape units* (Transfer rate 60k ch/sec)	20	360	80,000	288.0
7. CRT displays	40	360	50,000	180.0
8. Disc (mini)	20	180	60,000	108.0
				2182.5

*On an average 2 equipments per system

Table 6.9. Typical peripheral configuration of midicomputer systems and their requirements during the Fifth Plan period.

Equipment	Number	Percentage of installations which may use the equipment	Total	Average price (Rs.)	Total cost (in Rs. lakhs)
1. Teletypewriter (10 ch/sec)	1	100	240	10,000	24.0
2. Paper tape reader (300 ch/sec)	1	40	96	10,000	9.6
3. Paper tape punch (110 ch, sec)	1	40	96	10,000	9.6
4. Line printer (600 lpm)	1	100	240	175,000	420.0
5. Card reader (60 cpm)	1	60	144	40,000	57.6
6. Magnetic tape units (20k ch/sec)	2	70	168	60,000	100.8
7. Magnetic tape units (60k ch/sec)	2	70	168	80,000	134.4
8. CRT displays	1	30	72	50,000	36.0
9. Disc (fixed head)	1	30	72	120,000	86.4
Total					878.4

provide the basis for planning such a positive approach for the country. Carefully planned minicomputer networks are increasingly substituting maxicomputers. The second approach is based on this technological alternative. The technical feasibility of such a programme and its economic viability are discussed, in detail, in IPAG Analysis Report on 'Economics of Regional Computer Centres for Developing Countries'.

Taking into consideration the potentialities of the minicomputers and, the possibility of their indigenous manufacture and scarcity of the foreign exchange, a demand profile for computer during the Fifth Plan period is given below.

Assuming a linear growth of demand for computers in various sectors of economy, the projection of the requirements of computers for a legitimate absorption into these sectors, during the Fifth Plan period is given in Table 6.6. It can be seen that in the five year period a total of 15 large systems, 240 medium systems and 1500 small systems, will be required. The large systems, with average prices of rupees 90-100 lakhs each, have to be imported. The demand for minicomputers and major portion of the demand for midisystems have to be met by indigenous production. However, considering the lead times for development of the minicomputer industry in India, the anticipated supply position of minisystems during the Plan period may lag behind the demand, as shown in Table 6.7. It can be seen that, starting from a low level, of 60 systems a year, the industry is anticipated to have a linear growth for the first 3 years followed by an exponential growth. Due to the slack in the anticipated supply position, some of the requirements for minicomputers may have to be postponed.

Considering average prices of 90, 15 and 4 lakhs of rupees for large, medium, and small computers, respectively, the total investment on computers (including peripherals and interfaces in the case of maxisystems) will come to Rs. 85.5 crores, approximately, during the Fifth Plan period. Out of this, Rs. 13.5 crores, needed for large systems and part of Rs. 36 crores needed for midisystems have to be paid in foreign currency. Considering the foreign exchange scarcity in the country, some of the very large systems required for the national centres, may have to be funded by international credits.

Peripheral Requirements

The peripheral requirement of mini and midi systems have to be met by indigenous production. Typical configuration of peripherals for the two types of systems are listed in Tables 6.8 and 6.9, respectively. As the peripheral requirements change from one installation to another, the demand for a particular peripheral is computed by taking the approximate percentage of installations which may use that equipment. These percentages are arrived at by taking the factors such as, the minimum I/O requirements, cost of peripherals, possible substitutions, etc. The total number of peripherals required are computed with respect to the anticipated supply position of computers, given in Table 6.7. The price figures are arrived at by taking the average of the prices quoted by various manufacturers. In the case of OEM prices, an increase of 25 per cent is assumed for retail. It can be seen from these tables that, peripherals worth Rs. 30.6 crores have to be manufactured during the Fifth Plan period, to cater to the needs of mini- and midicomputer systems. Interface electronics, including peripheral controllers, worth Rs. 30

crores will be required for the mini- and midicomputer systems, during the period. As the peripherals and the required interface electronics for the maxi systems which may have to be imported, come with them, a break up is not given for them. Thus systems worth totally Rs. 146 crores have to be supplied during the Plan period.

There is a large difference in the number of computers required, between the estimates of Rao Committee (1967), Narasimhan Committee (1968) on one hand and the present estimate on the other hand. One of the reasons for this is that the earlier estimates were made when computer consciousness was low and promotional efforts for computer use were nonexistent. The present estimates assume a high level of computer consciousness and also intensive efforts to promote use of these machines in all areas where their use may catalyse development. Also the earlier estimates were made during a time when only discrete component machines were available, when there was no indigenous computer industry at all and all the machines had to be imported. In the present context of cheap IC machines, an established desk calculator industry in India and very bright prospects for a local mini-computer industry, the outlook is, naturally, far more optimistic. With local availability of inexpensive minicomputers, there will be very major shifts in utilisation towards these machines and away from larger ones.

Electronic Desk Calculators

It is estimated that a minimum of 100,000 calculators will be required during the Fifth Plan period. The Electronics Desk Calculators (EDC) Panel constituted by the Electronics Commission suggested a higher figure but subsequent experience indicated this estimate. This include nonprogrammable calculators for commercial applications nonprogrammable calculators for scientific and statistical applications and programmable calculators. The requirement of the EDC industry should promote the development of a variety of electronic devices, components and peripherals such as large scale integrated circuits (LSI), display devices (nixies, liquid crystal fluorescent displays and light emitting diodes (LEDs)), key boards and printers for hard copy outputs, etc.

Software Requirements

Any country embarking on a computer production programme can ill afford to neglect the system software development as the economics of a computer is as much dependent on its software as on its hardware. Intensive software development activities have to be initiated to support the planned mini- and midicomputer manufacturing programme. The basic system software necessary for the mini systems will include assembler, one of the high level languages such as FORTRAN and COBOL depending upon application areas, loader, and debugging editor. For systems with more core storage and bulk storage in the form of discs or tape, the following additional systems will be required. (a) basic operating systems, (b) real time operating systems, and (c) high level application software. As the minicomputers are expected to have various development catalysing applications in sections like, R&D establishments, universities, industrial establishments, banking and insurance, transport and communications, defence, agriculture and related areas and so on, a variety of application packages have to be developed. Online application packages for data acquisition, control, communications, etc., will need considerable efforts in certain important sectors like steel, power, etc.

Table 6.10. Cost of total computer systems to be supplied during the Fifth Plan period.

System	Total cost (in Rs. crores)
1. Large systems	13.5
2. Midi systems	36.0
3. Mini systems	36.0
4. Peripherals for midis	8.8
5. Interface electronics for midis including peripheral controllers	12.0
6. Peripherals for minis	21.8
7. Interface electronics for minis including peripheral controllers	18.0
Total	146.1

6.4.2. Projections for the Sixth Plan Period

By the end of the Fifth Plan period the country will have a good production base for mini- and midicomputer systems. Due to the availability of the indigenous computers, growing industrialisation and need for optimising scarce resources of the country and the development of application areas like, total management information systems, production planning and control, material management, process control, scientific application and so on, there will be a steady increase in the demand for computers.

During the Fifth Plan period, though a steep rise in the demand for computers is projected, the estimated supply position will result in a forced demand. This is mainly due to the slow take off of the computer industry in the country. In order to minimise the gap between the demand and supply positions, a high rate of growth is necessary in the beginning of the Fifth Plan. However, this growth rate is expected to reduce slowly over the rest of the Fifth Plan period and the Sixth Plan.

Assuming a gradual, uniform decrease in the growth rate of the demand, the projection for mini- and midicomputers during the Sixth Plan period is given in Table 6.11. In the case of minicomputers, starting with a growth rate of 24 per cent and gradually coming down to 16 per cent an yearly demand of 720 systems is estimated by the end of the Sixth Plan. Similarly, in the case of midicomputers, starting with a growth rate of 15 per cent and coming down to 11 per cent an annual demand of about 125 systems is estimated by 1983-84. Total demand for mini- and midicomputers during the Sixth Plan period is about 2700 and 500 systems, respectively. Thus the demand for minicomputers during this period is expected to be three times that of Fifth Plan period whereas the demand for midi systems is expected to double. Demand for large systems during Sixth Plan may be of the same order as that of the Fifth Plan period in view of the possibility of substitution of maxi systems by the minicomputer networks. During the Sixth Plan period complete requirement for mini- and midicomputers are expected to be met by indigenous production.

The peripheral requirement during the Sixth Plan period is estimated on the assumption that the demand for mini and midi systems during the period will increase three and two folds, respectively from the Fifth Plan requirements. The miniperipherals like, cassette tape drives, key-to-tape units, etc., will have an increasing use during this period. Peripherals worth

VI

Table 6.11. Demand projection for mini- and midcomputers during the period 1974-84.

Year	Minicomputers		Midcomputers	
	Expected demand	Rate of growth (percentage)	Expected demand	Rate of growth (percentage)
1974-75	60	—	32	—
1975-76	120	100	39	22
1976-77	180	50	48	23
1977-78	230	28	56	17
1978-79	290	26	65	16
1979-80	360	24	75	15
1980-81	440	22	86	14
1981-82	525	20	98	13
1982-83	620	18	110	12
1983-84	720	16	122	11
Total	3545		731	

Rs. 95 crores will be required for mini- and midcomputers, as shown in Table 6.12.

Assuming that the requirements of maxicomputers will be the same as that during the Fifth Plan, the total cost of computer systems required during the Sixth Plan is given in Table 6.13. It can be seen that systems worth Rs. 375 crores will be required during the period.

6.5 Analysis of Gaps

One of the OECD studies on Gaps in Technology in the field of computers reveals that gaps exist mainly due to reasons like, technological gaps, sophistication of the market, structural changes in the computer industry, the role of Government support, management and so on. Some of these aspects are relevant for India too and these are discussed below.

Table 6.12. Requirement of peripheral for mini- and midcomputer systems during the Sixth Plan period.

Equipment	Total cost in lakhs of rupees
1. Teletypewriters (10 ch/sec)	500
2. Paper tape readers (300 ch/sec)	400
3. Paper tape punches (110 ch/sec)	400
4. Line printers (300 lpm)	1800
5. Line printers (600 lpm)	1300
6. Card readers (300 cpm)	150
7. Card readers (600 cpm)	150
8. Low speed magnetic tape units	1800
9. High speed magnetic tape units	1200
10. CRT displays	600
11. Disc drives	500
12. Cassette tape units, key to tape units, etc	700
Total	9500

Table 6.13. Estimate of the cost of total computer systems to be supplied during the Sixth Plan period.

	Total cost (in Rs. crores)
1. Large systems	15.0
2. Midi systems	75.0
3. Mini systems	110.0
4. Peripherals for mini and midi systems	95.0
5. Interface electronics for minis and midis including peripheral controllers	80.0
Total	375.0

6.5.1. Technological Gaps

Technological gap in the component industry is one of the bottlenecks for a speedy growth of the computer industry in the country. As pointed in the OECD report, this is a problem pertaining to almost every country which is in this field. When the first generation computers (using vacuum tubes) were introduced in United States, the vacuum tube technology was already well established. Therefore, there were no marked technological differences between the two industries. In the second and third generations, the situation was different. There was considerable decrease in time lag between the development of components and that of computers using these components. For example, the transistor developed in 1948, was commercialised around 1954, about six years earlier to the introduction of the second generation computers. But, for the third generation computers, the time lag was much shorter. The integrated circuits were commercialised in 1964-65 and third generation computers were introduced in 1965-66. When the time needed to develop a new computer and the problem of international diffusion of technology are considered, the above time lag for the third generation machines was very critical. The development of a computer takes about 2-4 years of work depending on the type and size. Therefore, the new components which will be going into the central processor should be available at least 1½ to 3 years before the computer is commercialised. When the initial development work of the third generation machines started, for example, in United States around 1962, the IC technology was still in a nascent state and the prices of the then available circuits were prohibitively high. This may be one of the reasons why IBM went for hybrid instead of IC technology for their new 360 series and ICL introduced a transistorised series of computers, namely, the 1900.

This problem is much relevant to the computer industry in India, which is entering the third generation now. In minicomputers, as the memory size is limited, semiconductor memories are proving more cost effective and they may compete with cores. The introduction of ROM and MOS memories has reduced the cost of memory units considerably. But these technologies are yet to be developed in India. In view of these, the Semiconductor Panel constituted by the Electronics Commission has recommended the following: "The rapid growth of MOS LSI memories and its importance to the production of future generation computers suggest that some immediate steps should be taken to establish the technology/production, as gestation time of such projects is of the order of 2 or 3 years". Also, fabrication of the central processing units for the third generation machines requires reliable integrated circuits at the level of MSI or LSI. Already necessary

steps are being taken to start the production of ICs by the middle of the Fifth Plan period.

Peripheral manufacture is the weakest link in the indigenisation programme of the computer industry due to stringent requirements of precision tooling facilities and material and process technology. The requirements of high precision tooling, process technology and components for the indigenous manufacture of the standard peripherals, like paper tape I/O equipments, card readers, line printers and magnetic tape units are discussed below and the gaps are identified.

Paper Tape Readers

Paper tape readers require less sophisticated process methods, have low level of sophistication in terms of number of components, but require a medium degree of manufacturing tolerances for various mechanical parts. Photo cell assembly, which involve silicon photocell, pyrex glass and quartz rods, is a critical item, as their indigenous replacement is not possible, at present. Similarly, integrated circuits and high precision card edge connectors can also be termed 'critical' in the same sense. The capstan pulley and the electromechanical solenoid in the brake assembly require high precision machine tooling facilities.

Paper Tape Punch

Paper tape punches require less sophisticated process methods, but require high precision tooling (though not very high) facilities for the mechanical parts like, punch pin set, punch die and stripper, pick up disk, etc., and have a large number of small mechanical parts.

Drive sprocket and positive drive belt and cable connectors are some of the critical areas, where indigenous replacement is not possible, at present.

Card Readers

The process technology required for card readers is of medium level and is much higher than that of paper tape equipments. Complexity in terms of number of components is also at the medium level. However, many of the assemblies like picker solenoid assembly, picker frame, etc., require very fine machining and casting facilities with a high degree of tolerance.

Fibre optic assembly, fibre optic light carrier, light divider and photo transistors are the major parts in the read station, whose indigenous replacement may not be possible, at present. Similar is the case for items like, picker belt set, and positive drive belts. The timing disk, a high precision mechanical part, needs photo etching process for its manufacture, which is not presently available in the country. Unless immediate development efforts are undertaken for items like, cable connectors, lead connectors, card edge connectors, integrated circuits, push switches, indicators, etc., their indigenous replacement may not be possible in the near future.

Line Printers

Production of line printers is highly complex as it involves a large number of precision and complex mechanical parts. Many of the process technologies like photo etching and those for other high precision machine parts are not, at present, available in the country.

Some of the critical areas, where indigenous replacement seems to be difficult at present, due to reasons like, nonavailability of process and precision technology, etc., are identified below.

Print drum, a machined part with character engraving, requires special process technology and material which are not at present available in the country. Also, toothed rotor disks in character, index and strobe pulse generators and shuttle timing disks require photo etching process for their production, which is not at present available in India. Paper feed clutch and brake assembly and shuttle clutch and brake (for ribbon feed mechanism) assembly require electromagnetic clutches and high precision machined parts and indigenous replacement may not be possible, at present. Similarly, other high precision machined parts, like hammer module and timing belt drive sprockets, also fall in the same category. The other critical items whose indigenous replacement is not possible at present, unless intensive development efforts are put into, include fibre optic unit, card edge and cable connectors, integrated circuits, photo transistors, hammer solenoids and timing belts.

Magnetic Tape Units

High speed magnetic tape transport requires highly sophisticated process technology. However, low speed drives require only less sophisticated technology. Both have medium complexity in terms of number of components. High speed magnetic tape transports require high precision tooling facilities for the fabrication of mechanical parts like, tape drive capstan and tape guide.

Indigenous replacement of the mechanical assemblies like, reel servo motor, capstan motor, tachometer, etc., though they are standard products, may not be possible, at present. Similarly, positive drive belts, timing belt drive sprocket, read/write heads, end-of-tape sensors etc., may be difficult to replace indigenously, at present, without intensive development efforts.

6.5.2. Financing and Cost of Entry into the Industry

Another reason for the existing wide gap in the computer industry in India is the high entry cost and the cost of growth. Entry costs of the industry depend mainly on the type of activities envisaged. The highest entry costs are to be found if a company attempts to enter all the three areas of the industry, namely hardware, software and peripherals simultaneously. For example, the French Plan Calcul, which attempted to enter these three areas simultaneously, estimated an expenditure of the order of \$100 million over a five-year period. A company, which concentrates on the software side alone, can enter the field with a very low initial expenditure. The concept of OEM (Original Equipment Manufacturer) will considerably reduce the initial entry costs. This is one of the reasons of Digital Equipment Corporation's successful entry into the industry.

The concept of system engineering corporations, which buy system hardware, software and peripherals separately on an OEM basis and link them together according to the requirements of the customers, would help the Indian computer industry to have a speedy growth.

6.5.3. The Size of the Market

The limited size of the market for computers in the country initially, is another reason for the slow growth of the industry. This is mainly

because of the reasons like, lack of awareness among the people at the decision making level in the user industries, undue emphasis on job automation instead of decision automation, lack of promotional measures in the other areas like process control, on-line applications, etc. However, this situation is slowly changing and there is a general computer awareness in the country, at present. A wide range of applications of the minicomputers and their low cost have opened a growing market.

6.5.4. Conclusion

From the foregoing, it is clear that bridging the technological gaps is one of the aspects which needs immediate attention for a speedy and healthy growth of the computer industry in the country. Corporations, which also involve themselves in promotional activities, emphasise decentralisation and this will accelerate the growth of the industry and will reduce the initial entry cost of the hardware manufacturers.

6.6 Guidelines for Technology Development and Indigenous Production

It has been already accepted that the production of minicomputers is a viable programme in this country. Such a production programme is being planned mainly to reduce the foreign exchange drain on imported computers. Thus the programme is worthwhile only if we can reduce the foreign exchange requirements considerably. This needs intensive developmental efforts in the initial phase, carefully evolved licensing policies and standardisation of equipment. These aspects are discussed below.

6.6.1. Present Indigenisation Capability

The initial development activities like those in TIFR, Jadavpur University, Indian Statistical Institute at Calcutta, IIT, Kanpur, BARC, etc., are few instances which testify that the necessary talents for the computer system design and development as well as fabrication of production prototype, already exist in the country. Electronics Corporation has made considerable head-way in the design, fabrication and productionisation of the central processing units for TDC machines. The bulk of the manufacturing programme of CPUs and memories will depend on the supply of ICs in the country. Plans are already under way to take up the manufacture of ICs in the country. Development work for the production of ICs is already going on in places like, TIFR, CEERI Pilani, SSPL Delhi, NPL Delhi, BARC, NCL, the five IITs, IISc Bangalore, ECIL, BEL, etc. The production of ICs and other semiconductor devices during the Fifth Plan period has already been planned under a public sector corporation. Assuming the availability of electronic devices and components, the system integration of small general purpose and special purpose computers poses no problem for realising the processor unit of the computer.

Semiconductor memories, now under development in the world, are significant for our computer manufacturing programme. A start may be made straight away on semiconductor memory areas along with the production of ferrite memory cores needed for medium size computers under production. Ferrites have already received attention in many of our national laboratories. If ferrite cores are made available in requisite standards, their fabrication into memory modules—a highly labour intensive activity with low overheads—would be an area that needs attention which, if perfected, would reduce the import content of our medium-type-computer programme.

Limited facilities for development and production of certain peripherals already exist in the country. A brief description of the overall infrastructure is given below.

Teletypewriters

Hindustan Teleprinters Limited (HTL) is currently manufacturing about 6000 units of 5 level teleprinters per annum and spares for nearly 1000 teleprinters. HTL teleprinters stand in comparison with other makes. A comparison of the features of a few makes of page model teleprinters is given in Table 6.14. Keeping in view of the latest trends in the teleprinter field, HTL has already taken up development work in order to meet the anticipated demands. For example, there are two versions of teleprinters currently under development at HTL, namely, the following:

(i) Electro-mechanical teleprinter 5-level convertible to 8-level: The design aims at providing an integrated automatic send-receive printer with built-in tape transmitter and tape perforator units. The design also aims at providing a lighter keyboard touch and optional facilities like, serial/parallel output, built-in memory, automatic case shift and higher speeds of operation giving upto 100 bauds. Other objectives are reduction in transmitter distortion, improving receive margin and reduction in noise.

(ii) Electronic teleprinters: The electronic teleprinter envisages the replacement of the mechanical designs of the keyboard, send unit and receive unit with solid state circuits. The adoption of solid state techniques will enable the incorporation of large number of additional facilities in the teleprinter, such as buffer memory, automatic shifts, higher operational speeds and better reliability.

BEL has developed a mini mosaic (dot matrix) printer and are now working on an input/out typewriter (BELWRITER) using the dot matrix printing head and a stepper motor for driving it. Technical specifications (provisional) of BELWRITER are given in Table 6.15.

Paper Tape Equipments

HTL and BEL have already undertaken (and almost completed) the development of high speed tape readers and punches. At HTL, laboratory models of a medium speed tape reader (100 chs/sec) using a stepper motor and a high speed tape reader (500 chs/sec) using a synchronous motor, have already been fabricated and tested. Development of a medium speed tape punch, having a speed of 32 characters per second, has been completed and is now in production. A laboratory model of a high speed tape punch, having a speed of 110 characters per second, has been fabricated and tests have been completed. A modified version of the same is under development. Technical specifications of the HTL Tape Readers and Punches are given in Tables 6.16 to 6.19.

The technical specifications of the paper tape reader and punch being developed at BEL are given in Tables 6.20 and 6.21, respectively.

Indian Statistical Institute (ISI), Calcutta has developed a high speed paper tape reader, which is capable of reading 350 characters per second, with complete indigenous know-how. Technical specifications of this reader are given in Table 6.22.

Line Printers

Development work of line printers is already in progress in places like IIT Kanpur and BEL. BEL has studied the possibility of taking up the deve-

VI

lopment of a miniprinter, whose specifications are given in Table 6.23. This is expected to be compatible in price with similar imported miniprinters.

From the foregoing discussions, it is clear that the necessary competence for the development of less complex peripherals, like teleprinter, paper tape readers and punches already exists in the country. However, except in the case of teleprinters, these equipments are now at prototype stage. Their suitability for productionisation is yet to be tested and proved. The competence and skill generated by these efforts, however, is worth mentioning and these can be utilised for the development of more complex peripherals.

Table 6.14. Comparison of teleprinter characteristics.

Details	HTL 728-SN	Olivetti Te 315	Teletype ASR 32
1. Telegraph code	5 Unit CCITT, No. 2 code	5 Unit CCITT, No. 2 code	5 Unit CCITT, No. 2 code
2. Signalling speed	50 to 70 bauds	45.5, 50, 75 or 100 bauds	50 bauds (45 and 75 bauds optional)
3. Transmission cycle	7.5 units	7.5 units	7, 7.42 or 7.5 units
4. Mode of operation	Double or single current	Double or single current	Single current, double current with external circuiting
5. Margin	$\pm 40\%$ at 50 bauds $\pm 37.5\%$ at 75 bauds	$\pm 40\%$ at 50 bauds	42%
6. Motor	230 V 50 Hz governed induction motor. 80 W	220 V 50-60 Hz governed induction motor. 140 W	115 V 60 Hz or 50 Hz
7. Distortion	$\pm 4\%$ at 50 bauds $\pm 5\%$ at 75 bauds	$\pm 5\%$ at 50 bauds	$\pm 5\%$ at 50 bauds
8. Remote control of motor	Starts on receipt of first space pulse. Stops about 1 minute after receipt/transmission of last signal. Control exists from keyboard also for full duplex working	Starts on letter key and stops about 1 minute after receipt of last signal	Starts on letter key and stops 1 minute after receipt of last signal.
9. Printing method	Moving type basket	Moving type wheel	Moving type wheel
10. Line length	75 characters	80 characters	72 characters
11. Line spacing	1, 1½ or 2 lines	1, 1½ or 2 lines	1 or 2 lines
12. Key-board	4 row standard 4 row condensed or 3 row	4 row standard or 4 row condensed	4 or 3 row
13. Transmitting and perforating attachments	Fitted outside the main-cover	Fitted inside	Partially projecting out of the main cover
14. Automatic carriage return and line feed	Optional	Optional	Optional
15. Automatic case shift	No	Yes	No
16. Storage	No	10 characters	No
17. Overall dimensions:			
Width	61.5 Cm.	57.4 Cm.	55.9 Cm.
Height	39.0 Cm.	23.7 Cm.	33.5 Cm.
Depth	62.5 Cm.	58.2 Cm.	47.0 Cm.

Table 6.15. Technical specifications (provisional) of the BELWRITER.

Speed	: 10 characters/sec.
Characters	: 64 alphanumeric in 5x7 dot matrix
Feed	: Friction feed, 6 lines per inch using 8.5 inch wide (maximum) roller paper
Carriage return and line feed	: Automatic, with bell warning for end of line and margin
Keyboard	: Closely resembles ASR33
Keys	: 47 for alphanumeric characters and 9 for control
Error detection	: Optional parity generator plug-in for peripheral error detection

Table 6.16. Technical specifications of the medium speed paper tape reader being developed at HTL.

Operating speed	: 100 characters/second
No. of channels	: 5 to 8 channels
Tape width	: 11/16 inch for 5 level, 7/8 inch for 6 or 7 level, 1 inch for 8 level
Feed hole	: In line
Feed hole pitch	: 1/10 inch
Type of tape	: Paper, paper-mylar, metalised mylar, 0.002 to 0.006 inch thick (Butt splices to 0.010 inch) Transparency not to exceed 60 per cent
Tape tolerance	: Width \pm 0.01 inch Lateral \pm 0.01 inch from nominal Longitudinal \pm 1 ch/inch from 10 ch/inch. Thickness 0.002 inch to 0.006 inch
Splice	: Overlap and butt splices will be sensed accurately.
Data amplifier outputs	
Hole	: +5 Volts or -5 Volts
No hole	: +0.4 Volts or -0.4 Volts
Remote control input	: +5 Volts maximum at 1 Amp maximum
Power requirements (external)	: (i) +5 V for drive circuitry at 2 Amp (ii) 8.5 V AC or DC for lamp at 2.5 Amp (iii) +5 V at 200 mA for amplifier circuits (iv) -5 V at 100 mA for control circuits
Ambient temperature	: 0° to 45°C

Table 6.17. Technical specifications for high speed tape reader (500 chrs/second) being developed at HTL.

Speed	: 500 characters/second, synchronous
No. of channels (or levels)	: 5, 6, 7 or 8
Tape width	: 11/16 inch for 5 level, 7/8 inch for 6 or 7 levels, 1 inch for 8 level
Feed hole	: In line
Feed hole pitch	: 1/10 inch
Type of tape	: Paper, paper mylar, aluminised mylar (Transparency not be exceed 60 per cent)

Type tolerance	: Width ± 0.01 inch Lateral ± 0.01 inch from nominal Longitudinal ± 1 ch/inch from 10 ch/inch Thickness 0.002 inch to 0.006 inch
Splice	: Overlap and butt splices will be sensed accurately
Date Amplifier Output	
Hole	: +5 Volts or -5 Volts
No hole	: +0.4 Volts or -0.4 Volts
Code	: CCITT No. 2 for 5 level ASCII or CCITT No. 5 for 8 level
Power supply (external)	: (i) 230 V 50 Hz at 0.5 Amps for motor drive (ii) 8.5 V AC or DC at 2.5 Amp for lamp (iii) +20 V DC through a 200 Ohms 2.8 Amps. Rheostat for clutch and brake magnets at 1 Amp (coil resistance about 1 Ohm). (iv) +5 V DC at 200 mA for amplifier circuits
Ambient temperature range	: 0° to 45°C

Table 6.18. Technical specifications of the medium speed paper tape punch being developed at HTL.

Standard speed	: 32 characters per second
Magnet specifications:	
Magnet coil resistance	: 305 Ohms
External current limiting resistance	: 1000 Ohms
Operating current	: 30-40 mA
Operating voltage	: 48 V DC
Magnetic pick up specifications:	
Speed (operations/sec)	: 32
Voltage generated	: 4 Volts
Feed magnet specifications:	
Voltage (DC)	: 48 Volts
Coil resistance	: 765 Ohms
Tape specifications:	
Level	: 5 (with in line feed hole)
Width	: 11/16 inch
Code combination/inch	: 10
Feed hole diameter	: 0.0465 inch
Code hole diameter	: 0.071 inch
Centre of feed holes to guiding edge	: 0.297 inch
Motor unit:	
Type	: Induction type asynchronous motor
Input voltage	: Single phase 230 V AC +10% to -15%
Frequency	: 50 cycles/sec
Speed	: 2520 RPM governed to $\pm 75%$ of the normal value, by a speed governor
Power consumption	: 40 Watts
Heat	: 45°C over ambient of 45°C
Protection	: Fuse -0.375 Amps
RIS unit	: Radio interference suppressor circuits are provided in motor and speed governor

Weight and dimensions:

Depth	: 400 mm.
Width	: 300 mm.
Height	: 230 mm.
Weight	: (Approx.) 3 Kgs.

Table 6.19. Technical specifications of the high speed paper tape punch being developed at HTL.

Speed	: 110 operations (or characters) per second (1100 words per minute)
Magnet:	
Attract time (milli-seconds to fully attract)	: 4.5 milli seconds
Release time (milli-seconds to fully release)	: 6.8 milli seconds
Magnet coil resistance	: 7.1 Ohms
Current	: 800 mA
Voltage	: 30 Volts
External resistance	: 50 Ohms
Magnetic pick-up:	
Speed (operations per second)	: 110
Voltage	: 6V
Peak to peak	: 450 micro seconds
Tape:	
Levels	: 5 and 8 with in-line feed hole
Width	: 11/16 inch (5 level) 1 inch (8 level)
Code combination per inch	: 10
Feed hole diameter	: 0.0465 inch
Code hole diameter	: 0.071 inch
Motor unit:	
Type	: Asynchronous induction type
Input voltage	: Single phase 220 V AC 50 Hz/sec.
Power consumption	: 60 Watts

Table 6.20. Technical specifications of the paper tape reader being developed at BEL.

Read speed	: 400 ch/sec.
No. of channels	: 5, 6, 8
Tape code	: ASCII
Type of tape	: Paper, paper Mylar, aluminised Mylar or solid Mylar
Tape thickness	: 0.06 to 0.12 mm
Tape loading	: In line
Outputs	: ITL compatible
	Hole : 2.4 to 3.3V
	No-hole : 0.2 to 0.4V
Power source	: 230V, 50 Hz
Power consumption	: 225 W

Table 6.21. Specifications of BEL paper tape punch.

Speed	: 100 char/sec.
No. of channels	: 5 or 8 (not selectable)
Feed	: In-line feed hole
Pick up	: Magnetic pick-up device for synchronisation
Tape mechanism	: Tight tape and tape out mechanism
Tape code	: ASCII
Power source	: 230V, 50 Hz
Power consumption	: 75 W

Table 6.22. Technical specifications of the paper tape reader developed at ISI.

Speed	: 350 char/sec.
No. of channels	: 5, 6, 7, 8
Feed	: Friction feed by pinch rollers
Optical system	: 12V, 45W lamp, without lense
Stopping time from full speed	: Less than 2 ms.
Power supply lines	
(a) For the cards	: \pm 6V dc regulated at 250 ma —20V dc regulated at 100 ma
(b) For clutch and brake coils	: —50V dc with filtering condensers at 4A
(c) For lamp supply	: 7.0 to 12.0 V ac at 4A

Table 6.23. Specifications of a miniprinter being developed at BEL.

Printer speed	: 200 lpm
Character set	: 64 alphanumeric characters
No. of columns	: 132
Column spacing	: 10 col/inch
No. of characters on front belt	: 384 (6 sets of 64 or 24 sets of 16 etc.)
Printing technique	: Impact, on fly continuous loop print belt transports characters horizontally at a constant speed.
Forms feed control	: Tape controlled 12 channel, IBM compatible tape
Paper advance speed	: Single line: 25 lps Multiple line: 10 lps
Copies	: Upto 6
Width of paper	: Upto 14 7/8 inches
Electronics	: Fully solid state, protected against short circuit and over voltage
Interface level	: Logic 0 : 0 to + 0.4 VDC Logic 1 : 2.4 to + 5.0 VDC
Input data rate	: 500 kHz (7 bit data)
Power	: 300 Watts

6.6.2. Know-how Acquisition and the Required Developmental Efforts

In the area of system design, software, logical design, mechanical design, packaging, printed circuit facilities, etc., the level of technology and know-how available within the country are such that minicomputer main-frame manufacture can take place in India without any know-how being imported from abroad. While for special applications, such as air-borne and ship-borne minicomputers,

mechanical and environmental tolerance requirements are specially stringent, there appears to be no need for the import of technology, even in this area. There were many successful attempts at indigenous design of computers, of which some were planned for commercial exploitation which are under way.

As the peripheral manufacture is the weakest link in the indigenisation programme of the computer industry, intensive development efforts have to be initiated in the peripheral equipment area to meet the plan targets. Certain items, whose indigenous development is comparatively time consuming and costly, import of know-how at various levels depending on indigenous augmenting capability may be needed. These aspects are discussed below.

Paper Tape Input/Output Equipments

As the development of paper tape readers and punches has already been completed and are now undergoing laboratory tests at various places, as explained earlier, there is no need for import of know-how in this case. Suitability of these prototypes for productionisation is yet to be tested and proved. However, no major problems are anticipated to start their production.

Card Reader

Mechanical complexity of the card reader lies only in the card feed mechanism. Design of the electronics circuitry is relatively simple. Therefore, a total import of know-how may not be necessary in this case. In the initial phase, a selective import of complex assemblies like, card feed mechanism and fibre optic assembly, augmented by adaptive research to suit the Indian conditions, giving due royalty, wherever required, seems to be reasonable and adequate. Development programmes for import substitution of such assemblies have to be taken up in parallel.

Line Printers

Import of know-how may be beneficial in the case of line printers for the following reasons:

- (i) Tooling, overheads and machinery involved for development are very costly;
- (ii) time-frame for local development is comparatively longer;
- (iii) a very high percentage of the total number of systems planned for indigenous production will require line printer facility;
- (iv) cost of imported line printers is very high; and
- (v) number of systems required fully justifies local production.

From the indigenisation point of view of the standard peripherals, maximum number of critical areas exists in the case of line printers. High precision requirements of these critical items may justify the import of such parts in the initial phase, assuming that local competence will be developed for their fabrication and assembly, in parallel.

Magnetic Tape Drives

Low speed magnetic tape drives require medium level of complexity and precision, but require only a low level of process technology. No technology import may be required in this case. However, to increase the performance level of locally developed prototypes, import of selected subassemblies at the blue print level may be advisable.

However, high speed magnetic tape drives require high precision tooling and the intricacy of know-how involved justifies limited foreign participation.

VI

The type of know-how acquisition discussed above presume initiation of intensive development efforts without delay. Development for indigenous manufacture of peripherals should be taken up with the optimum selection between indigenous development and purchase of know-how.

Electronics/Electrical Items

On the electronics and electrical side the development of integrated circuit technology, high precision card edge, lead and cable connectors, push switches and indicators, photo transistors, special purpose solenoids, magnetic reading and writing heads, etc. is essential.

Mechanical Items

Mechanical assemblies and parts dominate the critical areas requiring development efforts. These include high precision electro-magnetic clutch and brake assembly, high precision timing disks which require photo etching process, timing belts and drive sprockets, sprocket drive wheels, servo motors, capstan motors, tachometers, hammer modules, print drums and character code disks.

Optical Items

Most of the sensing devices require photo cell assemblies. These include, silicon photo diodes, fibre optic assembly units, fibre optic light carriers and photo transistors.

Technologies

A successful indigenisation programme for standard peripherals assume the availability of the precision technologies, like integrated circuit technology, photo etching process, and fibre glass technology. However, these processes and technologies which are general in nature, will be required more intensively in the manufacture of other electronic devices and equipment, as well.

Materials

Technological gaps exist in the production of basic materials like soft iron for relay cores, nickel silver for springs, precision metal contacts and polyester film. Many of the special springs used in mechanical assemblies are made of phosphor bronze. Though, phosphor bronze, as a material, is available in the country in a limited scale, the springs made out of it are not available, at present.

Tooling Facilities

High speed compound or progressive tools of required accuracies are needed for the fabrication of high precision mechanical assemblies required for peripherals. Limited profitable production of peripherals may not call for complete inhouse facilities. They have to depend on central tool room facilities. In the organised sector of electronic industries, facilities exist for tool design and tool manufacture as well as for tool maintenance. However, for achieving high volume production of precision components, the tool room facilities existing today have to be augmented considerably. There are certain centralised institutes for training in tooling, not attached to production units, such as the CSI group of tool rooms at Katpadi, Tellichery and Dharwar as well as the UN aided tool rooms and training centres at Hyderabad and Madras. There are several small units in the country capable of undertaking, tooling projects of a

minor nature. However, these tool rooms are not capable of producing large volume of precision components. The demand for such tools and components is increasing in other areas, as well, in this country and abroad. Therefore, additional training facilities and manufacturing and design strengths are to be built up in the country. As a first step, it may be possible to expand the existing facilities in the public sector units concerned with the electronics production as well as some of the bigger organised industrial units who are prepared to expand.

It may be necessary to import some sophisticated tool making machinery such as jig borers, jig grinders, optical grinders, numerically controlled spark erosion machines, precision milling machines and lathes with digital readouts, and allied mechanical test and measuring equipments.

Facilities are to be set up concurrently for precision investment casting, large volume pressure die casting for special carbide tool for manufacturing fine blanking and progressive functioning

6.6.3. Support Facilities and Ancillary Industries

The minicomputer industry requires a number of supporting facilities like, printed circuit facilities, precision tooling facilities, etc., and ancillary facilities for a number of items like PC and cable connectors, teflon wire, glass epoxy sheets, switches, relays, display systems and so on. These aspects are discussed below in detail.

Printed Circuit Facilities

Good quality printed circuit facilities are a vital link in the establishment of a reliable computer industry. Minicomputers that are being contemplated and that may be required for general applications can be conveniently fabricated using double-layer boards. The only requirement for this industry is the establishment of a reliable plated-through-hole facility on which a number of public and private sector firms like Hegde & Golay, Bangalore, Bharat Electronics, Bangalore, Electronics Corporation of India Ltd., Hyderabad, Micro-electronics Ltd., Bombay are already working.

Multi-layer boards, which dispense with the need for back panel wiring, and reduce sizes very substantially besides considerably improving reliability and tolerance to vibration and shock, are necessary only for very specialised applications such as defence, space, etc. While the need for such rugged machines is not very substantial at the present moment, it nevertheless exists and can be neglected only to a great disadvantage to the country.

Here, the level of investment, level of technology, quality control requirements and the environmental conditions which the board should tolerate dictate that the activity be of very high calibre and essentially rule out the small scale sector. However, large scale houses, both in the public and private sector may also be permitted to enter into this field, provided there is a large enough in-house requirement for these facilities justifying their establishment.

This is an area where there is need for substantial import of equipment and know-how. It would appear, however, that most of the fabrication know-how for multilayer boards is automatically available with the purchase of machinery.

In view of the substantial national investment by way of foreign exchange necessary for establishing such facilities in a particular house, machinery should be evolved to make available to other consumers, excess capacity in any of the plants so established. This should be imposed as a condition

for issuing import licence for the machinery required for establishing the facility.

Ancillary Industries

For an advanced industry, such as that of minicomputers, to be self sufficient in more than a merely nominal way, it is necessary to ensure the availability of a large variety and a number of ancillary facilities. Needless to say, the quality of these ancillary industries will have a direct bearing on the reliability and acceptability of the final product.

While it may be impracticable to make an exhaustive list of all the ancillary facilities required, the following is an indicative list of the more important of these facilities which are vitally important for the establishment and sustenance of a viable minicomputer industry within the country.

- (i) Double-sided copper-clad glass-epoxy laminates.
- (ii) Teflon insulated single-strand and multi-strand wires.
- (iii) Reliable and rugged printed-circuit card-edge connectors and cable connectors which are capable of operation under adverse environmental and mechanical conditions
- (iv) Coaxial and flat cables of various sizes and descriptions.
- (v) Switches, relays, display systems and so on.

Industrial capability in these areas is virtually nonexistent in the country as of today. Concerted effort is required to ensure that indigenous capability is established in these fields to enable the computer industry in this country to exist on its own. While the capability for making many of these devices potentially exists within the country, the main reason for these industries not having been established is lack of demand, coupled with minor gaps in know-how availability in some of these areas

In some cases, attempts by some units to cash in on the market by establishing manufacture with poor technical skills and poorer quality control have given rise to substandard products. These products, while serving no purpose, have actually done a dis-service by lowering the credibility of Indian efforts. In such areas, having no product is better than having a substandard product.

It is reasonable to expect that it would take a few years before these industries can be fairly well established, possibly 3 to 5 years. Since it is necessary to establish the minicomputer industry within the country with a minimum of delay, it is necessary to identify and establish other sources for the intervening time. In view of the wide availability of most of these materials, the USSR and East European countries can be considered as interim sources for these materials. The Computer and Electronics Delegations which visited the USSR and East European countries have had an occasion to look at the wide range and variety of products available there. Positive steps may, therefore, be taken immediately to ensure that requirements are standardised and supply lines maintained as long as is necessary.

Assembly Hardware

A specific set of items, the manufacture of which will be of great convenience to the various R&D groups and will also be a valuable aid to minimise the delay between the bread-board model and production prototype in the field of digital systems, is versatile aluminium hardware for packaging card-holders, modules, racks and other electronic units. Aluminium extruded

sections of various shapes and sizes as well as moulded or cast aluminium parts such as mounting hardware, are available abroad in a wide variety. Local availability of such standardised parts will enable even small R&D laboratories to design their cards and package their subsystems and modules using these standard hardware components into flexible and rugged packages.

It is lack of availability of such products that compels the local R&D units to realise their systems using crude bread-boards, poor interconnections and fixtures and very bad packaging. These reflect directly on the reliability of the products and the ease with which they can be productionised. Demand for such fixtures and products has existed in the country for the last 5 years or more. The only reason why such units have not been fabricated so far is that there has been no effort to study this demand. Also, compared to the cost of these materials, the capital investment involved in fabricating dies and extrusion fixtures for each particular type of design is quite high. Thus, unless demand exists in huge quantities, it will not be feasible to produce these profitably.

6.6.4. Norms for Licensing

As the demand for computers during the next ten years is around 300 to 500 per year, it is necessary to establish a healthy and self-dependent computer industry in the country. As this depends upon the number of entrepreneurs operating in the field, their technical competence, the production volumes, etc., there is an utmost need for evolving a proper licensing policy. The Mini-computer Panel has suggested the following guidelines:

“Two basic criteria are important in evolving a successful licensing policy in any vital field: firstly, that the issue of licences bears an optimum relations to the existing and anticipated demand, and secondly that licences be given to the proper type of applicants. Limiting the issue of licences has the danger that shortages might arise if the production plans are not implemented. Overlicensing, on the other hand, might give rise to other difficulties. In the first place, if all the licencees implement their plans, there would be a sizeable glut and wastage of resources. In the second place, this fear discourages many of the serious licencees from going ahead in a risky field where there is overlicensing. Overlicensing, instead of ensuring adequate production, might thus have the opposite effect.

Instead of initial overlicensing and the creation of a runaway situation, there is thus need to implement and review policy on a continuing basis, preferably annually. During this review, in addition to fresh licensing to cater to the demand, licences of parties who may not have made due progress can even be revoked. This policy will not only minimise uncertainties in establishment of production, but will also take into account other eventualities such as inaccuracies in long term forecasts, changes in pattern of demand, usage and manufacture as a result of technological innovations, etc. Dropouts have been of the order of 75 per cent in the electronics component industry and 50 per cent in TV and other industries. This means that only one in two to four licences fructify. In the minicomputer field, this mortality rate would be disastrous. Instead of excessive overlicensing initially, careful preselection and annual progress review (involving revoking of idle licence and fresh licensing to cover the gaps) are desirable, overlicensing can then be kept to a level of 25 per cent over the demand-supply gap at any time.

Small vs Large Manufacturers

Selection with regard to the type of manufacturer is an important issue. In sophisticated fields, the tendency would normally be to prefer large manufacturing concerns. They are more likely to be able to establish plant and machinery and ensure adequate facilities and quality control required for a high technology industry. Besides, many of the testing assembly and process steps would be common for several related areas of subsystem and system manufacture for allied products. A large firm, which may be involved in the manufacture of a wide range of products might be able to pool such resources and bring down overheads and costs by diversity and increased levels of production. This is not likely for a small manufacturer.

A large manufacturer, with better market survey, sales and follow-up efforts is likely to keep in closer touch with the users of his product and may be expected to be better able to give them a product which is ideally suited to their needs.

There is, however, a strong case for encouraging the medium size firms also. Firstly, it is the accepted policy of the Government to promote the growth of small and medium entrepreneurs rather than big ones. Secondly, in actual fact, the big manufacturer, with large capital investments, turnovers and established product lines, is likely to be reluctant to change his approach either to suit the customers' needs, or to keep in step with technological trends. They, in many instances, have demonstrated that they can tailor both the needs of the customers and technological trends as it suits them. The small manufacturer, on the other hand, is likely to have far less inertia and would have to be in the forefront of technology to give him an edge over larger sector competitors. This is not to imply that all big manufacturers are conservative or that all small manufacturers are progressive. However, surviving on a small fraction of the total demand that exists, the small concerns, provided they are run on progressive lines and under competent management, should be able to manufacture and supply products which are far more contemporary than it might, in general, be possible for their large scale sector counterparts to make.

Very often, the large manufacturer, by sophisticated sales techniques and high pressure promotion, which make up for technical shortcomings and backwardness, veers the customer around to accepting what he intends, for his own reason, to sell, rather than what is best to the interests of the customer. It is the small manufacturers in USA who were the first to come with IC computers while the giants took several years to follow. The advent of minicomputers has itself been spearheaded in USA by the small rather than the big manufacturer.

Finally, it would appear to be a good policy to encourage the large manufacturers to focus attention on only those products which require their special capabilities, resources and technical skill. It would be undesirable for them to be preoccupied with manufacture of smaller and simpler systems, essentially as a soft option. Obviously, the R&D capabilities and special facilities which a large manufacturer is able to deploy can and should be better utilised in more challenging tasks".

Though it may not be necessary to exclusively reserve the manufacture of various machines to the different sectors, viz., small, medium and large, the complexity, competence and financial requirement, etc., will naturally indicate certain guidelines for licensing. A uniform policy may

not be possible for the wide spectrum of machines with programmable desk calculators on one end and the sophisticated machines having major on-line applications on the other. Various types of machines, their application areas and the complexity involved are analysed below, from this point of view.

Programmable Desk Calculators

In the first instance, there are programmable desk calculators which are only marginally more complicated than electronic desk calculators currently being made within the country. Using LSI chips, assembly of these machines does not involve any effort other than following the interconnection instructions given by the device manufacturer. Very often, even the mechanical and engineering design effort is negligible, since usually these machines are essentially screw-to-screw copies of machines made abroad. With this easy option available, it is very unlikely that manufacturers of programmable desk calculators will choose a different course of action. Since this method is likely to provide a usable product which would probably be cheaper to produce than by any other method, it would appear to be acceptable. Capital equipment and other expenses are minimal using this approach.

It is, at least for some time, unrealistic to expect that the peripherals required for this type of machine (the magnetic card or cassette memory and the miniprinter) will be made under the same roof. Actually, these will initially require to be imported, until local capacity is established for their manufacture. Since this is a logical extension of the manufacture of desk calculators, manufacturers of desk calculators may be allowed to enter this field.

Processor-on-a-chip Minicomputers

What applies for programmable desk calculators is also true for the "single-chip" calculators which will also be essentially assembled here for the time being. In case ion-implantation and other MOS techniques are established locally, design of such machines for versatile applications will pose a sizeable challenge.

OEM Applications

There are the real-time applications in specific areas where the machines are required in large numbers. Machines for such applications require to have the following features: small size, good engineering design, ruggedness, reliability and ease of operation. Such machines could be built as intelligent adaptations of machines currently available from other countries. The peripheral complexity for such applications is likely to be minimal. Most of the software required for these systems will be written in the assembly language. Interfacing and development of application software might be done either by the computer manufacturers, a software consultancy firm operating as an intermediary or by the OEM firm itself.

On-line Applications

The processor of the OEM type machine is itself adequate for other small on-line applications as well. The main difference is that there is much greater diversity in the application software. Since most non-OEM

on-line users expect their machines to be available for off-line applications also, there will be additional requirements for peripherals and off-line application software. Sales effort is also likely to be larger in this area.

Major On-line Applications

Total system engineering for major applications involves extensive instrumentation, modelling of control systems, complex software, after sales service and maintenance, etc. Examples are: process control for petroleum, steel, fertiliser, atomic power and other large industries. Machines required to operate in these areas require sophisticated design, high speed, large memory, adequate peripherals and extensive software. Even in these areas, software consultancy and system engineering firms could play a positive role by adapting available machines for each of these uses.

Stand-alone Systems

Stand-alone systems for educational institutions, business and scientific applications as well as other miscellaneous uses also require an integrated approach where main frames, peripherals as well as systems and applications software of a wide ranging nature have to be supplied as total systems to users for each type of requirement. The nature of services required in this area is qualitatively similar to that expected in medium and large scale systems.

Families of Computer Systems

The installed capacity of any given system may soon be saturated due to increased demand. The period for such a saturation of load on the system may typically be around three to five years. Such situations make it mandatory to build systems which are extensible. The directions for such extensions are usually in terms of available backing store, available primary memory and most important, available processors. Normally, it is also possible to reorganise software and give improved service, e.g., batch multiprogramming instead of simple batch processing, etc. The generic term, 'family', is used to characterise computer systems which span a range of capabilities as above, but are compatible in terms of software, peripherals and hardware.

The benefits that accrue from making available such families are many. To the manufacturer, it means (i) a large variety of systems to sell with minimal overheads for production of such a range; (ii) modularity in hardware for easy extension or replacement; (iii) lower software development cost in the overall production of the system due to compatibility; (iv) lower engineering costs as the nature of packaging could be uniform for a wide variety of systems; (v) the freedom to produce large capacity systems without using high capacity processors by building multiprocessor and network systems; and, (vi) lower cost in development of sophisticated software systems as basic machines and software would be available to bootstrap this development. To the user, the biggest advantage is that he can configure his system to suit his needs and his pocket. Also smoothed out is the transition between one system and another. There is no need for extensive changes in user developed software due to the compatibility of different members of the family. Families of computers with minicomputers at one end of the spectrum, moving towards medium, medium-large and

even large computer system at the other end, are very desirable. It is also clear that the only way such manufacturers can meaningfully attempt minicomputer manufacture, is to make it a member of a planned family of computer systems. Another aspect which validated this view point is that the manufacturer may grow his technical know-how from the minicomputer end of the family. The fall-out from such an approach is that, for the succeeding members of the family, one can build upon the existing software to extend its range of applications or use the existing software to produce sophisticated systems.

Number of Manufacturers

In order that demand be met, it is essential that at least 2 to 3 units start production by 1978-79. Assuming that by careful preselection, the mortality of firms is kept at low level, and that overlicensing is made only to the tunes of 25 per cent to 30 per cent, it may be necessary to license upto 12 units for the manufacture of minicomputers during the Fifth Plan period, each with an initial planned capacity of 50 to 60 machines per year.

Computer manufacture by the Component Industry

In the Indian conditions where there are very few manufacturers of active components, nearly all of whom are operating at the subcritical level, allowing the component manufacturer to compete with other computer manufacturers, who have to obtain their component from the former, might put them in a position of unfair disadvantage with respect to the former. If the component manufacturers be allowed to enter the field, there should be some means to ensure that other computer manufacturers are supplied adequate quantities of reliable components at fair prices and with reasonable delivery periods. This condition, obviously, must apply even for peripheral manufacturers who themselves make computers.

This precaution, it may be emphasised, is relevant to manufacturers of components such as LSI and MSI integrated units, where there may be very few manufacturers, and the capital equipment, production technology and turnover requirements are such as to make it difficult for a large number of intending manufacturers to set up the manufacturing facility.

The situation is not so critical in the case of manufacturers of other sub-systems. The manufacturer of core matrices, for instance, will not be able to control the market even if he manufactures minicomputers as well as supplies his core matrices to other manufacturers of minicomputers. The reason is that it is not very difficult to establish alternative facilities where core matrices can be manufactured.

For wholly different reasons, the same argument is valid for manufacture of peripherals. Here the reason is not that it is simple to make these peripherals or even to establish alternative source of peripherals; in fact, the position is the contrary. However, viability of manufacture of peripherals is very critically volume-dependent; the manufacturer of peripherals depends as much on the consumer as the consumer does on him. As a result, even if the peripheral manufacturer enters the minicomputer field, he would, in all probability, not wish to squeeze out others from the minicomputer market because, in doing so, his market for peripherals will get hurt before his market for minicomputer might improve.

The above does not suggest a blanket ban, but advises caution during licensing to assure that control of the market is not given to any one manufacturer exclusively.

Preselection and Continued Monitoring

The importance of preselection is obvious from the fact that in its absence, dropouts may be much higher, necessitating overlicensing to the tune of 100 to 200 per cent above the expected demand, as experience in other electronics industries indicates. This would mean licensing 20 to 30 firms, with consequent wastage of effort, foreign exchange, etc. A careful technical scrutiny of the application is very essential, based on detailed information provided by the applicant. This information will not only enable the Government to weed out the inadequately planned ventures, but also, being required to give this information, will force the intending entrepreneur to appreciate in full the implications of computer manufacture and discourage the ill-informed and frivolous applicants right at that stage.

An additional advantage of this approach is that the information supplied by the manufacturer will also help to monitor his progress and compare achievements with expectations. Progress made by the licencees may be reviewed 2 years after the issue of a letter of intent. Depending on the progress achieved by each licencee, and the number of actual dropouts, a decision can then be taken as to whether additional licensing may be given in the areas which require intensive R&D efforts. The success in the pre-production developmental efforts in the first 1-2 years themselves can be taken as guidelines to issue licences.

It must be emphasised that the initial scrutiny of the applications as well as review of progress must be performed by a group of experts. Mechanical comparison of the time scales, requirements for equipment imports and other data (without a thorough understanding of the underlying technical factors) will, in all probability, help the unrealistic and frivolous applicant, at the expense of the serious and competent one. It is thus very essential that this function be entrusted only to an expert panel.

Promotional efforts are also required to establish a number of software and system consultancy houses to accelerate the growth of the industry and widen its range of applications.

Guidelines for the Import of Computers

The Electronics Commission has always taken the view that imported computers are scarce commodities, because of the heavy demand they make on our foreign exchange resources. It has therefore adopted the policy that import of computers would be permitted only when detailed technical evaluation has shown that indigenously available computers would be inadequate for the computational tasks involved. The evaluation would also cover details of the configuration needed for the purpose. Priority for acquisition for computer systems is to be accorded to organisations which are dealing with priority national tasks.

Based on the assessment of the Technical Panels set up by the Electronics Commission to assess the requirements of different kinds of computers over the Fifth Plan period, production-cum-import plans were prepared to

meet the demand on the basis of maximum self reliance. It was also decided, in the light of the requirement pattern, that the National/Regional Computer Centres would be set up at nodel computing areas like Bombay, Delhi, Calcutta and Madras so as to get maximum computing power from the investments made. The requirements for major computational efforts in the areas of national planning, simulation and various other computer applications directly related to national development are also expected to be met on a planned basis through these centres. As the actual number of such computers required will be of the order of 2-3 systems annually over the next five years, it is felt that large computer needs can be met through imports within the available foreign exchange resources, until such time as the production base for them is built up domestically. Given the time frame needed to build both the R&D and production bases in this area, it is assessed that the country could be in a position to enter the large computer area in the 1980s.

6.6.5. Norms for Standardisation

As the computer industry in the country is expected to cater mainly to the limited indigenous market in the early years, the aspect of standardisation is very significant to have an economically viable production programme. An unrestricted growth of nonstandard items covering a wide spectrum is undesirable especially in the case of CPUs and peripherals.

Level of Integration

The state of art, using silicon MOSFET technology is such that entire desk calculators and even minicomputers have been fabricated essentially on single chips. The manufacture of minicomputers now has a wide choice between SSI, MSI, LSI and ELSI devices. Thus, starting from small scale integration (SSI) where each chip contains 4 to 6 gates, the industry has moved to medium scale integration (MSI) with 15 to 50 gates constituting entire functional modules per chip and large scale and extra large scale integration (LSI and ELSI) where entire subsystems and systems can be realised in a chip. Small and medium scale ICs use bipolar (NPN and PNP transistor) logic, whereas large scale ICs use metal oxide insulated semiconductor field effect transistor (MOSFET or MOS) logic.

Due to conflicting considerations like cost of production, levels of production, labour costs, etc., a precise determination of the level of integration and consequently 'chip' standardisation would be difficult. Unlike in the case of desk calculator industry which is entirely LSI based in the country, whether minicomputers are fabricated out of LSI or MSI is not a vital question that might affect the industry at least for some time to come. However, whether it is LSI or MSI, standardisation of the chips is very important due to various feasibility considerations. Even at the early design stages, the replacement of the imported ICs by a limited variety of indigenously available ICs in the future should be taken into consideration. Enough flexibility has to be provided in the circuitry design in order to switch over to the indigenous components as they become available.

Peripheral Equipment

The standardisation of peripheral equipment which goes with mini- and midcomputers only is discussed here, as the large machines which have

VI

to be imported for at least some time to come, will have their own peripheral configuration supplied by the manufacturer.

Standardisation of the peripheral equipments which go with mini- and midicomputers is done by analysing the peripheral configuration of a representative range of mini- and midicomputers which are popular in terms of rate of sale, price and applications.

Teletypes

Teletypes are the most popular peripheral equipment that go with minicomputers. Almost all mini- and midicomputer manufacturers are going for ASR or ASR 35 models or equivalent teletypes, having a speed of 10 characters per second.

Typewriters, though their speed is limited, can be conveniently used in data terminal systems where only occasional printing is required or for applications requiring preprinted fixed format forms for daily logs or hourly routine information.

Paper Tape Equipments

Increasingly, minicomputers are equipped with paper tape input/output devices because, they are relatively cheap to maintain and the paper tapes are easy to store and resistant to all but tropical conditions. Paper tapes have other important applications in the control of various kinds of machines besides that of computer input.

Paper tape readers are available with a wide range of input speed from 200 to 1000 characters per second. Readers with a speed of 300 characters per second are more popular with minicomputers. Tape punches with a speed of 60 or 110 characters per second go well with the mini systems.

Paper tapes having 5, 6, 7 and 8 levels of punching and 1 inch width are in use. Tapes having 5, 7 and 8 levels are adequate for the use with minicomputers.

Card Readers

Punched cards are also popular as input media because they have the advantages of being unit records and giving compatibility between mini- and maxicomputer systems.

Card readers with various speeds namely 200, 300, 400, 600, 1000, etc., cards per minute are available. A 300 cards per minute (cpm) reader goes well with the minicomputer. Two models, one with a speed of 300 cpm and another with 1000 cpm, will cater to the needs of both small and big computer systems.

Printers

Printers, in general, are of two types—impact and non-impact. Both types come in either serial or line forms. The line printers, of course, have a much greater printing capacity, but are more expensive. The impact printers have a wide range of speed, starting from 10 characters per second, in the case of serial types, upto 2500 lines of 150 characters each, for the line printers.

The impact line printers are either drum type or chain type. Many of the fastest line printers today are of the chain type, but they are costlier than the drum type. Moreover, the controls for the chain printer are more

complex than those for the drum because, they must make many print/no-print decisions for each hammer during the printing of one line.

The performance gap between the serial printers, like the teletypes, having a maximum speed of 30 characters per second and line printers, the slowest of which, having a speed of 100 lines per minute and costing more than \$10,000, is very wide. Even the range of the costs vary widely between the slow and the fast line printers. Therefore, it is necessary to choose the printers with optimum speed for the use with both mini- and maxicomputer systems. A speed of 300 lines per minute is quite an optimum for the line printers associated with minicomputers. Larger computer systems will require faster printers having the speeds of the order of 1000 lines per minute. Thus two models of drum type, impact printers having speeds of 300 and 1000 lines per minute, respectively, will cater to the needs of both mini- and maxicomputers.

Magnetic Tape Drives

The compatibility of the tape drives with the main frame computer and with existing tape drives will be determined mainly by 3 factors, namely, the number of tracks, the packaging density and the method of recording data.

Most of the modern computers require 7 or 9 track tape drives. The choice pattern of the number of tracks indicates that the 7 track drives are associated with word oriented machines, while the nine track ones go with the byte machines. The exceptions are there, like the ICL 1900 series and certain Honeywell machines which, although use 7 track drives, can handle 9 track devices as well.

The packing densities are almost standardised, at least for some time to come, on 200, 556, 800 and 1600 bits per inch. Continuous efforts are being made to increase the density for tape economy and faster access. There are two methods of recording data on to tapes. For recording in densities 200, 556 and 800 bits per inch (bpi) the NRZI (Non-Return to Zero) technique is used. But in the case of higher densities, like 1600 bpi, the phase encoded method is generally used. The electronic circuitry needed to handle the phase encoded method is much more expensive than that for NRZI.

The ICL 1900 series and Univac invariably employ 7 track drives capable of handling 200, 556 and 800 bpi. IBM 360 and ICL System 4 use 9 track, 800 bpi in most cases. However, IBM 360/370 installations are tending to switch over to 1600 bpi drives. Honeywell computers usually employ 7 track tapes with densities 200 and 500 bpi.

As most of the minicomputers are word oriented machines, the tape drives which can handle 7 level track tapes are more suitable. As the phase encoding equipments are more expensive, tape drives which can handle tapes with densities 200, 556 and 800 bpi and using NRZI recording techniques are adequate.

An important aspect to be considered in the case of tape drive is the data transfer rate or tape speed. Various models, having wide ranges of speeds starting from 25 inches per second to 200 inches per second, are available. Drives having the speed of 45 and 75 inches per second, respectively, are more popular with minicomputers.

These specifications of the standard set of peripherals are summarised in Table 6.24.

Table 6.24. Specifications of a standard set of peripherals.

Equipment	Speed	Other characteristics
Teleprinter	10 ch/sec	Standard ASR 33, ASR 35
Paper tape reader	300 ch/sec	5, 6, 7 level tape
Paper tape punch	110 ch/sec	5, 6, 7 level tape
Card reader	300 cpm	
High speed card reader	1000 cpm	
Line printer	300 lpm	Impact, drum type
High speed line printer	600/1000 lpm	Impact, drum type
Tape drive	45 ips	Transfer rate 20 K ch/sec, 7 or 9 tracks.
High speed tape drive	75 ips	Transfer rate 60 K ch/sec, 7 or 9 tracks.

Magnetic Disc

One of the serious limitations of minicomputers, namely, limited storage capacity, is overcome by the use of disc units which provide bulk random access storage. The early units were fixed discs, which were permanently fastened to rotating shafts with fixed or movable heads.

A storage device which combines the random access operation of the disc with the removability of the tape unit is the disc pack. Although fixed disc units are still in wide use, disc pack devices with one or more discs are the most rapidly developing peripheral storage medium today. Single disc cartridges are used with systems which need only limited bulk storage.

Fixed head, fixed disc units have short access times but low capacities. With typical speeds of 1500 revolutions per minute, their average access time is 20 milliseconds. Average access time for movable head, fixed disc units may be 50 to 100 milliseconds or higher, including head positioning time. Industry standard is disc packs with 11 discs (20 surfaces).

In the field of minicomputers, very few systems use multiple disc packs. Cartridge and fixed head types are more popular. Cartridges having a storage capacity of 3 million bytes and fixed discs with a capacity of 256K bytes and access times of 10 to 20 milliseconds are suitable for use with minicomputers. Inexpensive minidisks, suitable for use with minicomputers, are becoming available (256K bytes, 60 ms access time at \$2000) and are likely to replace tape cassettes, with which they are becoming comparable in price.

For very large files, disc pack drives are popular. The drives can be used to provide very large data bases for minicomputers. It is not uncommon to have minis with nearly a billion bits on-line. With the disc pack, the cost per bit drops to the 0.015 cent-per-bit range. But in spite of this very low cost, the enormous capacity of these drives put the typical cost to the user at more than \$35,000. Applications include inventory systems, reservation systems, space allocation systems and even small business information systems. This is specially important in view of the intention to eliminate unit record equipment very soon.

The manufacture of disc drives and disc packs involve high technology. Foreign participation, with a predominant (80 to 90 per cent) export commitment, is one possible solution.

Visual Display Units

Visual display units provide for fast through-put in an interactive way

and can display large amounts of fast changing information. They are thus suitable for many diverse applications.

Alphanumeric displays with refresh memories and screen capacity varying from 480 to 2000 characters are available today. Units having screen capacity between 1000 and 1280 characters and a character set composed of 64 characters are adequate for use with minicomputers.

Graphic display units have a much smaller market than alphanumeric ones and often are custom designed. Major application areas for these are military command and control, process control and engineering design.

Plotters

Minicomputer systems generally use standard plotters. These have a typical operating speed of 300 increments per second. The maximum head movement speed is 3 inches per second in the horizontal or vertical axes and 4.2 inches along the diagonal.

Keyboard-to-Magnetic Tape Conversion Equipment

Keyboard-to-magnetic tape equipment includes devices designed to transfer data from keyboard directly on to magnetic tape, thus eliminating conventional off-line card preparation equipment. Because of its importance, this system is being considered here, even though it does not strictly belong to the area of peripherals.

A typical stand alone key-to-tape data recording unit would include a keyboard, a tape/cassette transport, a display device and the necessary control electronics. Though the keyboard unit itself is about twice as expensive as the average card punch, it is claimed that these costs are more than offset by 30 to 50 per cent improvement in operator efficiency and through-put. Apart from data entry, other available functions include data editing facilities such as data verify, data search, data merge, etc. Most available units offer error detection and correction facilities, parity checks, redundancy checks and read after write. Many provide hard copy through typewriter. The more popular recording densities are 556 bpi and 800 bpi, though lower and higher densities are also available.

A key-to-cassette recorder having the following characteristics may be adequate for use with minicomputers:

- (i) A standard alphanumeric keyboard
- (ii) A typewriter for hard copy
- (iii) Data entry, data verify, data correction and merge facilities
- (iv) Parity check for error detection (optional)
- (v) CRT display—This may be an option to the typewriter in item (ii).
- (vi) Two level program select
- (vii) Program entry through key-board
- (viii) Cassette tape with recording densities of 500 and 800 bpi
- (ix) Variable record size
- (x) Communication capability

Key-to-tape data preparation can be done in a minicomputer system, using a small processor with an 8K to 16K memory, a magnetic disc drive, a tape drive, a supervisory station and 6 to 64 key entry stations. As this is an application of minicomputers rather than an independent peripheral equipment, it has not been considered in detail here.

Document Readers and Character Reading Devices

Peripherals such as document readers and character sensing devices are generally used in applications connected with banking and insurance. The demand distribution for minicomputers in various subsectors of the national economy indicates that banking and insurance cover only a small fraction of the total demand.

Even in technologically advanced countries, where character and mark reading devices have been in existence for nearly twenty years, these machines are being used in only one in every 80 computer installations. Optical mark readers which are at present available, are not suitable for applications involving mixed alphanumeric input and complex variable data. These machines are very expensive and are not expected to be popular in the Indian context.

6.7 Investment and Production Profile

Investment and production profile of computers and calculators for the ten year period, 1974-84, is given below. The requirements during the Fifth Plan period and the Sixth Plan period are given separately.

6.7.1. Investment and Production During the Fifth Plan

A total production of Rs. 186 crores is envisaged during the Fifth Plan period for computers, computer accessories and calculators. A break up of this and a brief description of the production and investment plan are given below.

Computers

CPU and the peripheral interfaces would amount to about Rs. 102 crores, during the period. A total investment of Rs. 8.5 crores may be required for this.

Peripherals

The basic peripherals like teletypes, paper tape readers and punches would require an investment of Rs. 0.90 crores. Sophisticated peripherals which include card readers, medium/high speed line printers and magnetic tape drives worth Rs. 25 crores have to be produced during the period. An investment of Rs. 5 crores is required for this. Import of know-how is economical for the manufacture of many of the sophisticated peripherals. Magnetic disc drives worth Rs. 2 crores have to be imported during the Plan period. The manufacture of disc drives and disc packs belong to the category of high technology. Foreign participation, with a predominant (80 to 90 per cent) export commitment, is one possible solution for providing domestic supply of the peripherals.

National/Regional Computer Centres

During the Fifth Plan, national/regional computer centres are proposed to be established at Bombay, Delhi, Bangalore, Calcutta, Kanpur and Hyderabad. In this, the national centre at Bombay has already been set up with UNDP assistance and the national centres at Delhi and Bangalore are also expected to receive UNDP assistance. The two centres, viz., Calcutta and Kanpur require the commitment of national resources to cover the cost of the computer. A total investment of Rs. 3.6 crores is planned for this.

Software Development

The National Centre for Software Development and Computing Techniques (NCSDDCT) has been established in Bombay with UNDP assistance with the primary objective of developing software and computing techniques to support the growth of a major self-reliant indigenous computer and semiconductor industry. An investment of Rs. 2.3 crores is estimated for this.

Computer Networks

The hardware and software required for computer networks are being developed in the country. However, a number of development problems have to be

solved in the meantime to make the network a commercial success. For this a total investment of Rs. 3 crores would be needed. As the project would be partly funded by UNDP as a contribution towards NCS DCT, a complementary investment of Rs. 1.4 crores is estimated towards data transmission equipment, terminals, locally made computers, etc.

Computer Maintenance Corporation

A Computer Maintenance Corporation of the Department of Electronics has been approved by Government and is expected to start operations in the next few months. An investment of Rs 1.0 crore was estimated initially. However, this has been updated to Rs. 2.0 crores subsequently. Apart from the maintenance and servicing of all non-indigenous computers, the Corporation is expected to assist in technology, system engineering, training and other problems associated with computerisation, and to develop the capability and assist in designing sophisticated computer configurations for special purposes.

Computer Tapes

Considering the fact that a large local production has been estimated for computers and peripherals during the Plan, the Task Force estimated that the demand for computer tapes during the period will be about 170 million running feet. Know-how may have to be purchased on a one-time basis for the manufacture of computer tapes. Separate units should be set up in the private sector for films and coating materials. An investment of the order of Rs. 2.6 crores is estimated mainly in the private sector.

Manufacture of Punch Cards

In order to meet the demand for punch cards and introduce healthy competition, more units need to be set up during the Plan period. Three more new units, each with a production capacity of 300 million cards annually may be adequate. Since investment and running expenses are low, they may be set up in the small scale sector. A total investment of Rs. 0.3 crore is estimated for this.

Desk Calculators

A turn over of Rs. 20 crores worth of electronic desk calculators is estimated during the period. As the field is already licensed to take care of the above demand, even assuming a high mortality rate of licensed firms, no new units may be required during the Plan period.

6.7.2. Investment and Production During the Sixth Plan

CPU and Peripheral controllers

The growth rates of the mini- and midicomputer industries during the Sixth Plan period have already been given earlier. By the end of the Sixth Plan, the annual demand for minicomputers is expected to be about 750. This is roughly 2½ times the demand expected by the end of the Fifth Plan. To meet this demand 5 to 6 new manufacturing units may have to be started during the Plan period. The annual demand for midicomputers is expected to be around 125 a year by the end of Sixth Plan. This is roughly 2 times the demand expected by the end of the Fifth Plan. To meet this demand 3 to 4 new manufacturing units may have to be started during the Sixth Plan period. The total investment required for this may be Rs. 12 to 14 crores during the Sixth Plan period. Requirement for large computers, which necessarily have to be imported, is not included here.

VI

Peripherals

An average five fold increase in demand for the basic peripherals, like teletypes, paper tape readers and punches is expected during the Sixth Plan period. An additional investment of Rs. 4 to 5 crores may be necessary for this.

A production worth Rs. 80-85 crores is expected for sophisticated peripherals like card readers, line printers, magnetic tape drives, disk drives, display units and other desk top peripherals. An investment of Rs. 20-25 crores may be required for this.

System Engineering and Software Houses

A number of system engineering corporations and software houses are expected to come up during this period. A two fold increase in the production of system and application software is expected during the period. An investment of Rs. 3 to 4 crores may be required for this.

Miscellaneous

The demand for miscellaneous items, like magnetic tapes, punch cards, etc., will have a corresponding increase. The availability of key-to-tape units is expected to bring down the demand for punch cards considerably. However, substantial expansion of the manufacturing facilities may be required over the five-year period. An investment of the order of Rs. 6 to 8 crores may be required for such items.

Thus, a total investment of Rs. 45 to 55 crores may be required in the computer industry during the Sixth Plan period. This excludes the cost of large computers which may have to be imported during the period.

VII

Control Components and Systems

7.1 Introduction

With the accelerating progress in technology, industrial processes have become increasingly complex. It is vital to run them with adequate and sophisticated instrumentation and control systems, so that operational cost, efficiency and quality are optimised. Control and instrumentation is, therefore, regarded as one of the important parts of the total manufacturing activity of any economy.

In early stages of industrial development in India, industrial plants were imported as package units, of which control systems formed an integral component. The Bhabha Committee estimated that over Rs. 100 crores were invested on instrumentation and control systems as part of the imported process plants. Initially the requirement of instrumentation and control systems in the country was, therefore, confined to replacement of unserviceable systems and components. Difficulties and delays in importing these for replacement in the original plant compelled plant operators to discard the use of automatic control systems and replace them by manual controls. Even when design and fabrication of process plants for some of the industries began in the country, emphasis was placed in the initial stages on manual control.

With the growth of industrialisation in the last decade, particularly in the last five years, higher pressures and temperatures at which plants had to be operated and the dangerous fluids that had to be handled rendered measurement and control by instruments inevitable. Design engineers and operators, therefore, had to accept instrumentation and control systems as an integral part of the manufacturing systems. Also, the national policy of import substitution and development of indigenous capacities for industrial plants gave a further fillup to the requirement of various types of control systems in the country.

In recent years, automatic control systems have found wide applications in the country, not only in the new industries such as fertilisers, petrochemicals, heavy chemicals, plastics and synthetic fibres, but also in the traditional industries like steel, textiles, sugar, paper and pulp. With both the horizontal and vertical growth of various engineering industries as proposed in Fifth Five Year Plan, the application areas are expected to grow rapidly.

Although the control components and systems industry has nucleated recently in the country, the performance shown by the units, both in terms of volume of production as well as production pattern, is significant. In a short span of time the country has achieved considerable self-reliance in this field. As far as essential technological services, system engineering installation and commissioning are concerned, the country has the necessary expertise. Also, a suitable nucleus exists for undertaking various R&D

activities. Nevertheless, there still exists a number of gaps which need attention. These gaps are related to technological base, general facilities, manpower and standardisation. Considering the anticipated requirements in the next ten years, for the attainment of self-reliance, present technology development efforts will have to be considerably augmented and reoriented.

It is difficult to define the generic terms "control components" and "control systems" in precise words. Broadly, the term control components is used to cover devices involved at various stages of the information flow in the control system; and control systems are physical systems in which one or more variables are controlled. Control components can be divided into four major groups, namely, (i) the components giving information of the control systems (sensing elements, transducers, etc.), (ii) the components transmitting information, (iii) the components designed to process information, and (iv) the final control elements (actuators, etc.).

Each of the groups above embraces a large number of component types differing in operating principle and construction. Furthermore, the components of each group manifest into a variety of characters: electronic, electromechanical, hydraulic, pneumatic, optical, nuclear, to mention a few. Due to this reason, as well as the different operating power levels, it is difficult to define the industrial sector of the national economy which covers all the control components and systems. Control technology, as it stands today, is one of the most heterogeneous of the technologies, principally centred around electronics, involving various scientific disciplines and covering numerous industrial applications.

In this chapter, the terms control components and control systems are used in a restricted sense. Only those components and systems, which are relevant in the present context, are considered. Thus the term control components is used here to denote only low-power electromechanical devices used in servo systems and the term control systems is used to cover only the process control instruments and instrumentation systems. Because of the different technologies and areas of application involved, the chapter is divided into two different sections, namely, (i) the instrument servo components and (ii) the process control instrumentation.

It may be noted that the connotations of the terms "control components" and "control equipment" used earlier in Chapter II are somewhat different from the meanings of the same terms employed here. The investment and production profiles presented in Chapter II are therefore different from those given in this chapter.

7.2 Instrument Servo Components

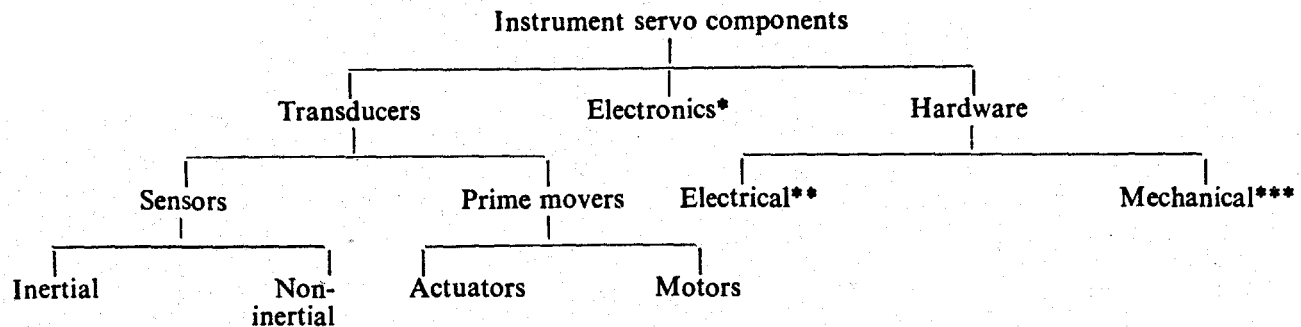
7.2.1. Definitions and Classification

The generic term servo system is used to denote the control system in which the controlled quantity is of the nature of a linear or angular position, speed or acceleration of an object. Components used in servo systems are called servo components.

The power level of the final actuating element in a servo system may range from a fraction of a watt to several kilowatts. Only upto 10W power electrical actuating elements are relevant to the electronics industry. High power electrical hydraulic and pneumatic actuating elements and associated power sources fall under the purview of process control instrumentation and other industries.

The class of servo components dealt with here is generally known as instrument servo components. A general classification of instrument servo components is shown in Figures 7.1, 7.2 and 7.3.

Figure 7.1. Classification of instrument servo components.

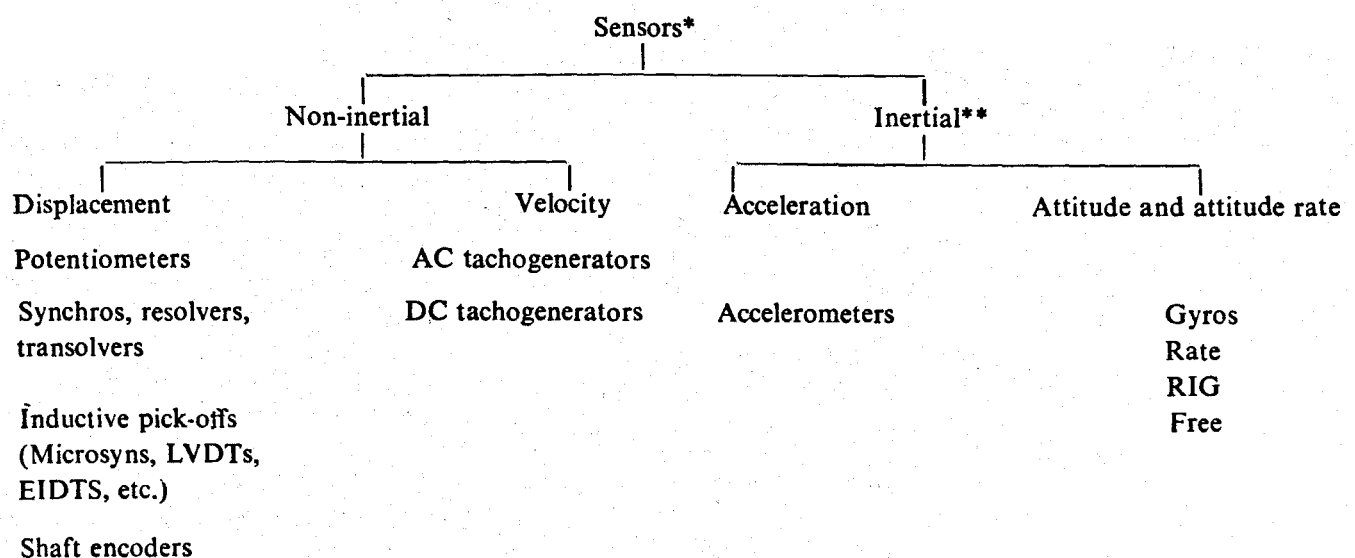


* The term "Electronics" is used here to denote electronic subassemblies such as amplifiers for control, modulators and demodulators, compensating and filter networks, power supplies, A—D and D—A converters, etc.

** This includes components such as cables, connectors, switches, contactors, relays, timers etc.

*** This includes mechanical components such as gears, shafts, couplings, clutches, brakes, heatsinks, blowers, cams, limit switches etc.

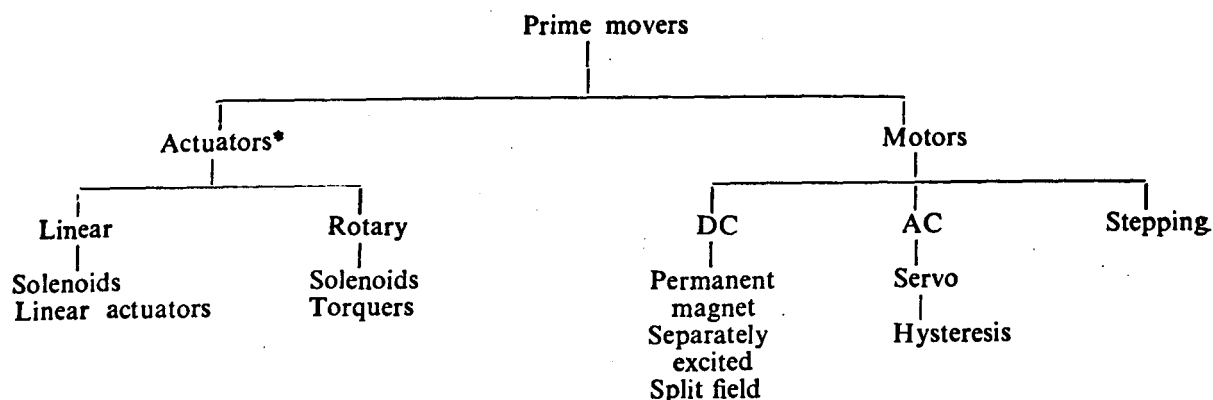
Figure 7.2. Classification of sensors.



*The generic term "sensor" is used here in a restricted sense. It is used here to denote low-power level transducers which function through the modulation of an electrical signal by the mechanical input.

**Inertial components such as vertical gyro, gyro compass, etc., which fall into the category of navigational instruments, are not included.

Figure 7.3. Classification of prime movers.



*Devices with limited movement at output.

7.2.2. Demand Profile

Approximately 80 per cent of the total demand for instrument servo components is expected to arise from defence and aerospace applications. Defence and aerospace applications include (i) guidance and navigation systems for rockets, aircrafts, ships and submarines, and, (ii) various types of radar and gunfire control systems used in land, sea and air. Industrial applications are mainly in the fields of process control instrumentation, numerically controlled machine tools and computer peripherals.

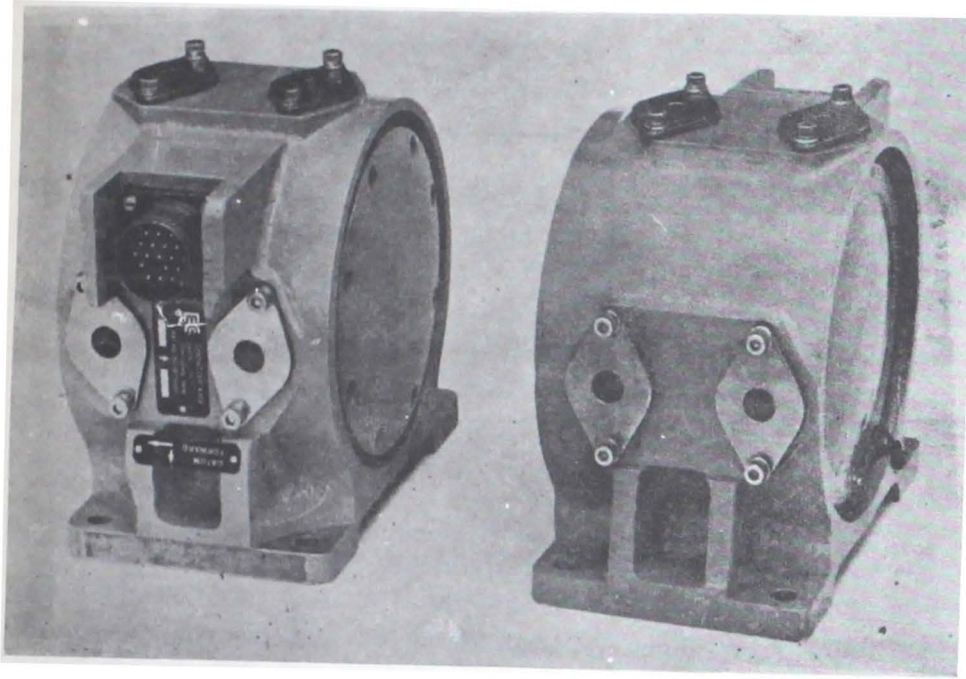
An estimate of the demand during 1973-74 for instrument servo components, based on the known OEM requirements in the Defence sector, is given in Table 7.1. The total requirement, including that of aerospace and industrial sectors, has been projected from this figure, and is placed at Rs. 2 crores in 1974-75. Table 7.3 gives the ten year demand profile of instrument servo components beginning from 1974-75. A growth rate of 25 per cent per annum has been assumed for the first five years, and 15 per cent per annum for the subsequent five years. The growth rate assumptions are based on the study of US and Europe servo components production statistics over the last six years.

While working out the ten year profile, the demand arising from replacement or maintenance requirements of imported equipment has been ignored. There are two reasons for this: Firstly, the great diversity in the types of components that are likely to be met with in such equipment, makes it difficult to meet this requirement through indigenous production. Secondly, with progressive indigenisation of such equipment, a production plan based on OEM requirements will itself cater to replacement or maintenance requirements.

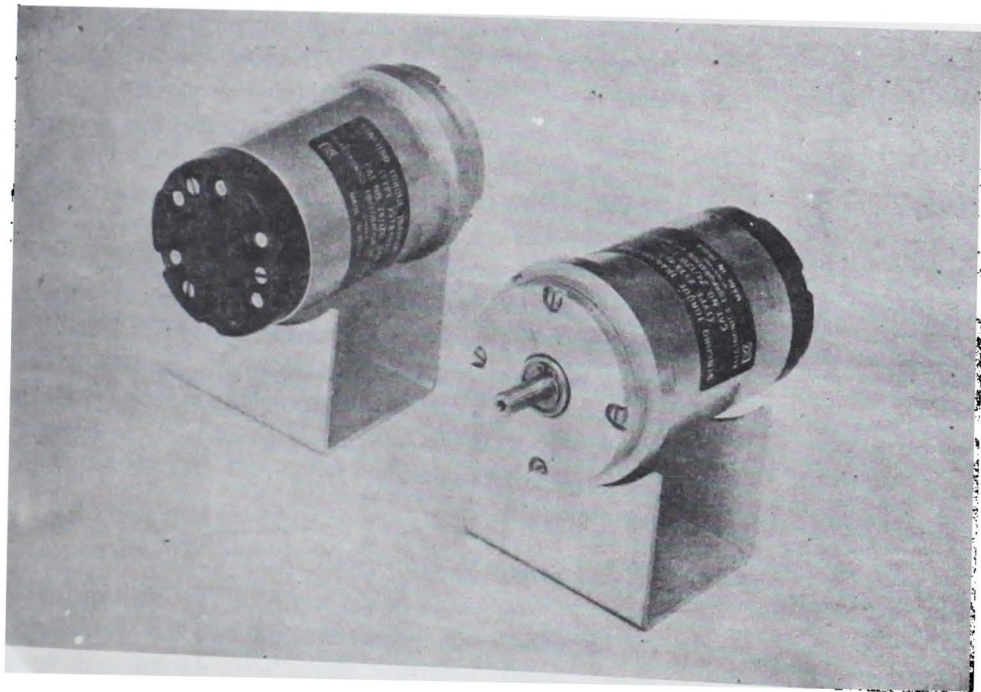
7.2.3. Current Status

A few years back, most of the instrument servo components required for defence and industrial applications were imported from various countries. Today, requisite skills from design and development of servo components exist in the country. Several R&D groups have been working in this area, the most prominent being the Servo Control Division of ECIL and the Control Guidance and Instrumentation Division of SSTC.

VII



Two-axis Rate Gyro Unit developed by ECIL.



Size 23 Synchros developed and productionised by ECIL.

Table 7.1. Estimated demand for instrument servo components during 1973-75 (Rupees in crores).

	1973-74	1974-75
Requirement of Defence and aerospace	1.4	1.8
Requirement of industrial sector	0.2	0.2
Total	1.6	2.0

The Servo Control Division of ECIL was built around a nucleus group drawn from BARC. This group had been engaged in the development of certain instrument servo components for a period of almost 10 years, at BARC, before moving over to ECIL in 1967. At BARC, the group had built and tested prototypes of a variety of such components as servo-motors, synchros, microsins, LVDTs, stepping motors, linear motors, and rate gyros. But these were essentially laboratory models. After moving over to ECIL, the group has concentrated on the commercial exploitation of the expertise and know-how it had developed at BARC.

The Control, Guidance and Instrumentation Division of VSSC has done a great deal of work in the design, fabrication and testing techniques of gyroscopes, accelerometers, and other servo components such as, hysteresis synchronous motors, microsins, torquers and servomotors. This Division has also made working units of a complete rate gyroscope, milli 'g' accelerometer and free gyroscope using in-house developed and fabricated subassemblies.

Some R&D work in this area has also been done at CSIO, IL, HMT, IITs, IISc, and other institutions. But it can be generally said that the output of many of these R&D groups, in terms of production worthy models, has so far been rather meagre on account of (i) non-orientation of R&D effort towards any end use or application, (ii) lack of facilities for and experience in high precision mechanical fabrication, (iii) indigenous non-availability of and inadequate familiarity with the primary materials used in the construction of servo components, and, (iv) lack of facilities for the testing of servo components.

Indigenous production of servo components has been recently established at the Servo Controls Division of ECIL. Components already in production are : (i) a range of 50 Hz geared servo and hysteresis motors, (ii) size 23, 400 Hz synchros of type CX, CDX, CT and TX, and, (iii) two-axis rate gyro packages. A significant feature of ECIL's venture is that it is based entirely on indigenous know-how and technology.

ECIL is presently the dominant production agency in the country for servo components. Its production capacity is expected to reach about Rs. 50 lakhs per annum by 1976. This could, however, cater to not more than 20 per cent of country's total estimated demand during that year.

7.2.4. Analysis of Gaps

Materials

Estimates of primary materials required for a production of Rs. 3 crores worth of instrument servo components, are presented in Table 7.2. Total value of these materials comes to about Rs. 25 lakhs which represents only about 8 per cent of the value of finished product. It may be noted that values of materials not

presently available indigenously, are based on the prevailing c. i. f. prices of these items. Actual cost of these items will go up quite substantially on account of stiff import duties. Even so, the total value of primary materials is not likely to exceed 15 per cent of the value of finished product.

Table 7.2. Primary materials required for instrument servo component manufacture.

Material	Applications	Form	Qty.	Rate	Value (in Rs. lakhs)	Indigenous availability
1	2	3	4	5	6	7
1. Magnetic						
1.1 Soft						
1.1.1 CRGD Silicon steel	Laminations	Sheets, strips	5 tons	Rs. 4/kg	0.20	Not available
1.1.2 Nickel iron alloys	Laminations, magnetic cores, shields, etc.	Sheets, strips	10 tons	Rs. 25/kg	2.50	Not available
1.2 Hard						
1.2.1 PM alloys	Magnets, hyst. rings	Castings, bars	500 kg	Rs. 40/kg	0.20	Partially available
1.2.2 Ferrites	Magnets	Mouldings	100 kg	Rs. 40/kg	0.04	Available
2. Electrical						
2.1 Conducting materials						
2.1.1 Enamelled copper wires	Windings	26-47 SWG polyester/silicon en.	1.5 tons	Rs. 80/kg	1.20	Partially available
2.1.2 Lead wires	Leads	PTFE cov., multistrand tinned copper wire	—	—	0.20	Partially available
2.1.3 Resistance wires	Pot. windings	36-50 SWG	30 kg	Rs. 200/kg	0.06	Not available
2.2 Insulating materials					0.20	Partially available
2.2.1 Mylar	Winding insulation	Sheets, tapes sleeves, etc.	—	—		
2.2.2 Teflon (PTFE)						
2.2.3 Fibre glass						
2.2.4 Presspahn						
2.2.5 Silicon rubber						

1	2	3	4	5	6	7
2.3 Contact materials						
2.3.1 Noble metals and alloys	Sliprings, brushes, contacts	Rods, tubes, sheets and strips	40 kg	Rs. 10,000/kg	4.00	Partially available
2.3.2 Graphite (Cu&Ag)	Brushes	Mouldings and extrusions	—	—	0.20	Partially available
2.3.3 Beryllium copper and phosphor bronze	Contact springs	Sheets, strips	40 kg	Rs.60/kg	0.03	Partially available
3. Mechanical						
3.1 Fasteners and springs (mostly SS)	Mechanical assembly	Screw, nuts, washers, rool pins circlips, etc.	—	—	4.00	Not available
3.2 Bearings						
3.2.1 Ball bearings		Miniature, precision BB	40,000 nos.	Rs. 15 each	6.00	Not available
3.2.2 Pivots and jewels			2,000 nos	Rs. 3 each	0.06	Not available
3.2.3 Porous metal			10,000 nos.	Rs. 0.30 each	0.03	Available
4. Structural materials						
4.1 Metals and alloys						
4.1.1 Stainless steel	Housing, shaft, gears, springs and other mechanical hardware	Bars, tubes, sheets, strips (free machining)	15 tons	Rs. 20/kg	3.00	Not available
4.1.2 Aluminium and alloys	Housing, die cast rotors, drag-cups, gears	Die castings, bars, tubes forgings, etc.	5 tons	Rs. 15/kg	0.75	Partially available
4.1.3 Misc. non-ferrous	Gyro gimbals, torsion bars, wheels, etc.	Die castings, bars	—	—	0.20	Not available

1	2	3	4	5	6	7
4.2 Plastics (PF, MF, DAP, epoxy, PTFE nylon, polycarb)	Terminal blocks, slip ring assemblies, covers, spacers, washers, coil forms, c	Mouldings, laminates, sheets, rods, tubes	—	—	0.30	Partially available
5. Process materials					0.50	Partially available
5.1 Adhesives						
5.2 Impregnants						
5.3 Encapsulants and pottants						
5.4 Lubricants						
5.5 Floatants						
5.6 Cleansing agents						
5.7 Soldering brazing alloys and fluxes						
5.8 Plating, anodising and passivating chemicals						
Total					24.67	

- Note :*
1. Costs of imported materials are shown on FOB basis.
 2. Materials are estimated for a production level of 20,000 instrument servo components. Allowances for process wastages and rejects are included.

In Table 7.2 referred above, materials are broadly classified under the five categories, namely (i) magnetic, (ii) electrical, (iii) mechanical, (iv) structural, and, (v) process.

A priority analysis of these reveals the following priority items:

- | | |
|--------------------------|---------------|
| 1. Ball bearings | Rs. 6.0 lakhs |
| 2. Noble metals/alloys | Rs. 4.0 lakhs |
| 3. Fasteners and springs | Rs. 4.0 lakhs |
| 4. Stainless steel | Rs. 3.0 lakhs |
| 5. Nickel-iron alloys | Rs. 2.5 lakhs |
| 6. Winding wires | Rs. 1.2 lakhs |

It may be noted that these 6 items account for nearly 80 per cent of the total value of primary materials listed in the Table.

In the present technological status of the country, the bulk of these materials have to be imported. In view of the strategic importance of instrument servo components, there is a definite need to progressively indigenise the primary materials base for their production. Otherwise, at emergency times, indigenous production of these components could be crippled by an embargo placed by the exporting country on critical primary materials like, nickel iron alloys in the form of laminations/bonded stacks or precision miniature ball bearings. Stock-piling of critical primary materials for tiding over emergencies could be considered as an alternative, until indigenous base is established for these.

A further incentive for indigenisation of primary materials for instrument servo components, is the fact that, perhaps with the exception of precision miniature ball bearings, these items have definite applications in other

sectors of electronics and light electrical component industries. Thus, the total demand in the country for these materials would be several times the instrument servo components industry alone.

Technology

A very important technological requirement in the production of instrument servo components is the extremely high precision and very tight tolerances (2 to 10 microns) to which their parts have to be produced. Development of precision mechanical technology is, therefore, sine qua non for this industry. Mechanical processes commonly encountered in parts fabrication are die casting, plastic moulding, pressing, machining (turning, drilling, boring, milling, shaping, broaching and hobbing), grinding, honing and lapping, metal finishing (plating, anodising, passivating), dynamic balancing, bonding and cementing, spot welding, mechanical assembly, and hermetic sealing. All of these are characterised by the requirement of very high quality and precision. To obtain this, it becomes necessary to employ (i) costly machines/equipment, jigs and tools, (ii) highly skilled labour, and (iii) close environmental control (as regards cleanliness, temperature and humidity) of process areas.

Electrical fabrication work involved in the production of instrument servo components consists primarily of insulating and winding small bore (5 to 50 mm) stators and rotors. Machinery required is relatively simple and inexpensive, as it is necessary only for winding coils and cutting insulation to size. However, the processes have to be carried out in a controlled environment and by employing highly skilled labour and special jigs, fixtures and tools. Stators and rotors are generally subjected to impregnation after winding.

The exacting quality standards which have to be maintained in the production of instrument servo components necessitate very extensive inspection and testing, frequently amounting to 100 per cent, of materials, parts and assemblies at all stages. Components which are intended for military and aerospace applications are generally required to be tested for performance and life, when subjected to extremely severe temperature, humidity and shock environments. For conducting such tests sophisticated test equipment and skilled labour have to be employed. On the whole, quality is a very important factor in this industry and accounts for a substantial part of the production cost.

7.2.5. Proposed Guidelines

Although the total demand for instrument servo components has been estimated at only Rs. 50 crores during the next ten years, in view of the strategic importance, attainment of self-sufficiency in these should receive a much higher priority than would be warranted by mere considerations of volume of requirements, economics of production or savings in foreign exchange. Dependence on foreign sources for even the primary materials required in the production of these components, is undesirable and should be minimised.

Indigenous production of servo components should be progressively set up during the next ten years so as to reduce ultimately the level of imports to less than 5 per cent of the total demand. No foreign collaboration is necessary or desirable for this purpose.

As the development of instrument servo components is a highly technology-intensive effort requiring a lot of expensive machinery and test equipment, it is not practicable to proliferate this activity over too many centres. It should be initially entrusted to ECIL and SSTC, who have already equipped themselves for and gained some experience in such work. During the Fifth Plan, ECIL should be allowed and encouraged to expand the existing production facilities.

A new unit should be set up, during the Fifth Plan, for indigenous production of instrument servo components. The investment in plant, machinery and test equipment at this unit would be between Rs. 1.5 and 2.5 crores.

Attainment of ultimate self-sufficiency in instrument servo components can be a meaningful goal only if there is a concerted effort to attain self-sufficiency in those equipment wherein these components find use. Considerable volume of such equipment is being imported at present, particularly, for Navy and Air Force. Steps should be taken to set up indigenous production of such equipment. Particularly, high priority should be accorded to the indigenisation of (1) various types of radar, (2) gunfire control systems, and, (3) guidance and navigation systems. This work should be entrusted to (i) laboratories under DRDO, (ii) IITs, IISc, and similar institutions, and, (iii) agencies like BEL, ECIL and HAL.

Further, it will be necessary to develop indigenous capability to design future requirements of such equipment from QR's generated by Defence forces, using indigenously produced servo components, as far as possible.

A systematic effort, aimed at the indigenisation of primary materials base for instrument servo components should be initiated. HMT may be asked to set up a factory for precision miniature ball bearings, and DMRL may be asked to look into the indigenisation of special magnetic materials.

Finally, it is both necessary and important to examine the technology advances in the developed countries and keep these in mind before planning the future production programmes. Specifically, the following recent technological trends in this area should be taken into account.

Miniaturisation: Space, weight and power consumption are vital factors in aerospace applications. In order to economise on these, it has been necessary to progressively miniaturise the servo components intended for these. The current common sizes of components for these applications are 08 and 11 (size numbers indicate the outside diameter of a device in tenths of an inch. Thus, size 08 indicates a device with outside diameter between 0.7 and 0.8 inches). However, a full range of the still smaller size (05) components are already in use in USA.

Enhanced Environmental Capability: Defence and aerospace applications have given rise to the demand for extremely tough and reliable components capable of withstanding and performing in very adverse temperature and acceleration/shock environments. By a careful choice of materials, which in some cases had to be specially developed for these applications, and special design/constructional feature, it has been possible to substantially widen the operating temperature limits and enhance the capability for withstanding accelerations and shocks. Present day components are typically capable of performing within the following environmental limits:

- (i) Ambient temperature lower limit ... -40°C to -70°C

(ii) Ambient temperature upper limit	...	+90°C to 130°C
(iii) Accelerations	...	10 to 50 g
(iv) Shocks (5 millisecond duration)	...	20 to 100 g

Improved Performance: By employing better materials, designs and manufacturing processes, the performance of instrument servo components has been steadily upgraded in the past two decades, as regards accuracy, sensitivity and resolution in the case of sensors, and speed of response and power-to-weight ratio in the case of prime movers. Demand for improved performance coupled with miniaturisation poses difficult technological problems which had to be solved for the simultaneous achievement of these two objectives.

Digital Devices: The increasing use of digital computers in control systems has given rise to a demand for transducers directly capable of giving digital outputs. Typical examples of these are shaft encoders and stepping motors. Such devices already account for a significant part of the total instrument servo component production in advanced countries like USA. In our country, the relative demand for these devices is expected to grow to a significant level in the next decade or so.

7.2.6. Investment Forecast

Estimates of resource inputs required to establish a production capacity of Rs. 5 crores worth of instrument servo components per annum are given below:

	Cost in Rs. crores	
	Total	FE content
Plant, machinery and test equipment	5.00	3.50
Research and development	1.20	0.12
Production engineering and tooling	1.60	0.16

The total 10-year investment and production profile is shown in Table 7.3.

The turnover-to-investment ratio would appear to be rather low, but it will be unrealistic to assume a higher ratio because, (i) overall production volume is quite low and (ii) in order to meet peak demands during emergencies, production capacity is intentionally under-utilised by working on a single shift in normal times.

The R&D expense and production engineering cost for a particular type of servo component may each be assumed to range from 200 to 500 times the normal (international) price of that component. Requisite inputs have been calculated using an average multiplier of 250 for development and 330 for tooling and on the supposition that, at a level of Rs. 5 crores (35,000 nos.) per annum, production will encompass 35 different types of components, each priced on the average at Rs. 1,500.

The minimum level of investment recommended for an individual production unit is Rs. 1 crore, if only non-inertial components are to be produced in it, and Rs. 2 crores, if inertial as well as non-inertial components are to be produced. It follows that the total investment of Rs. 5 crores in the Fifth Plan, should therefore be not divided between more than 2 or 3 production units.

Table 7.3. Ten year profile for instrument servo components.

		1974-75	1975-76	1976-77	1977-78	1978-79	1983-84
1. Demand	(Rs. lakhs)	200	250	310	390	500	1100
2. Production	(Rs. lakhs)	50	90	150	260	450	1010
	(Numbers)	3,500	6,000	10,000	17,000	30,000	70,000
	(No. of types)	3	6	10	17	30	70
3. Incremental investment ¹	(Rs. lakhs)	40	60	110	190	50	150
	(FE in Rs. lakhs)	28	42	77	133	35	80
4. Cumulative investment	(Rs. lakhs)	90	150	260	450	500	950
	(FE in Rs. lakhs)	63	105	182	315	350	685
5. R&D expenditure	(Rs. lakhs)	40	40	40	40 ²	40 ²	80
	(FE in Rs. lakhs)	4	4	4	4	4	8
6. Tooling cost	(Rs. lakhs)	20	40	50	50	40 ²	90
	(FE in Rs. lakhs)	2	4	5	5	4	9
7. Primary materials ³	(Rs. lakhs)	8	14	23	41	45	100
	(FE in Rs. lakhs)	6	11	18	33	36	10
8. Manpower	(Numbers)	300	420	600	840	1,200	2,500
9. Total FE required	(Rs. lakhs)	40	61	104	175	79	107

- Notes : 1. Initial investment at the beginning of Fifth Plan estimated as Rs. 50 lakhs (FE 35 lakhs).
 2. The expenses are related to R&D/tooling for production subsequent to the Fifth Plan period.
 3. As most primary materials are imported, it is assumed that they are procured one year ahead of the year in which they are consumed.

7.3 Process Control Instrumentation

7.3.1. Definition and Classification

Process control is one of the fast changing technologies of today. Technology obsolescences and advancements in sensors, transmitters, controllers and final control elements have been both rapid and significant in the past decade, particularly in the last five years. It is, therefore, necessary to arrive at a comprehensive definition and classification of the process control instruments, keeping in view their current as well as futuristic applications in process industries.

In the modern context, the term process means a method of carrying out certain operations in series of changes, in order to attain the desired results. Whatever may be the process, it is essential to control it from the point of view of safety and achieving maximum quality control and output in proportion to the inputs. In other words, a process consists of maintaining within the desired results or altering in a predetermined manner, the energy and the material balance of the matter undergoing treatment in the process. Process control could, therefore, be defined as a correction action rendered to a process to achieve the desired results.

The instruments employed for measurement and control of process variables are called process control instruments. The most important variables measured and controlled in the process industries are temperature, pressure, flow, liquid level, bulk-solids level, density and specific gravity and chemical composition. In process industries, process control instruments are used for a number of reasons such as product quality control, material savings, production inspection and testing, plant safety and cost accounting.

Table 7.4 gives a comprehensive classification of process control instruments based on the process variables as used in modern industrial applications.

Table 7.4. Classification of process control instruments.

- | | |
|----------------------|---|
| I Temperature | <ul style="list-style-type: none"> (a) Differential expansion <ul style="list-style-type: none"> 1. High expansion metal strip 2. Bimetallic thermostat 3. Bimetallic contact making thermostat (b) Fluid expansion <ul style="list-style-type: none"> 1. Liquid filled thermal thermometer 2. Filled system thermometer (c) Resistance thermometers <ul style="list-style-type: none"> 1. Fine wire resistance thermometer 2. Thermistor 3. Temperature type (d) Thermoelectric pyrometers <ul style="list-style-type: none"> 1. Noble metal couples 2. Base metal couples 3. Special thermocouples (e) Radiation pyrometers <ul style="list-style-type: none"> 1. Fixed focus type 2. Focusing type 3. Thermopile radiation pyrometer 4. Two colour (ratio) pyrometer 5. Infrared two colour pyrometer (f) Optical pyrometers <ul style="list-style-type: none"> 1. Disappearing filament type 2. Optical wedge type (g) Change of state <ul style="list-style-type: none"> 1. Melting point method 2. Pyrometric cones 3. Fusible crayon (h) Other <ul style="list-style-type: none"> Ultrasonic thin wire thermometer |
| II Pressure | <ul style="list-style-type: none"> (a) Absolute pressure <ul style="list-style-type: none"> 1. Liquid column barometer 2. Mcleod gauge 3. Single bellows absolute pressure gauge 4. Double bellows absolute pressure gauge 5. Thermocouple gauge 6. Hot filament ionisation gauge 7. Cartesian-diver absolute pressure gauge 8. Aneroid manostat (b) Gauge pressure or vacuum (liquid type) <ul style="list-style-type: none"> 1. Liquid filled glass columns of well or U tube design 2. Inclined draft gauge |

-
- (c) Gauge pressure or vacuum (spring-balanced type)
 - 1. Bourdon type pressure deflecting unit
 - 2. Slack diaphragm gauge
 - 3. Bellows type gauge
 - 4. Piston gauge
 - 5. Liquid sealed bell
 - 6. Force balance gauge seal
 - 7. Strain gauge load cell
 - 8. Resistance pressure detector
 - 9. Capacitive pressure sensor
 - (d) Differential pressure (manometer type)
 - 1. Glass liquid column manometer
 - 2. Metal manometer, plain tube
 - 3. Tilting manometer
 - 4. Ring-balance manometer
 - (e) Differential pressure (sealed-bell type)
 - 1. Floating bell
 - 2. Formed bell
 - (f) Other
 - 1. Slack diaphragm, square-root compensated
 - 2. Single bellows differential gauge
 - 3. Double bellows differential gauge
 - 4. Differential pressure transmitter
 - 5. Pressure transmitter
 - 6. Differential air pressure switch
-
- III Force, tension, compression
 - 1. Fluid pressure spring system
 - 2. Pneumatic force balance
 - 3. Bonded strain gauge
 - 4. Unbonded strain gauge
-
- IV Radio-activity measurements
 - 1. Geiger-Mueller counter
 - 2. Ionisation chamber
 - 3. Scintillation counter
 - 4. Proton detector
 - 5. Neutron flux detector
 - 6. Atomic battery
 - 7. Scalers and pulse counters
-
- V Fluid flow
 - (a) Volumetric meters
 - 1. Piston meter
 - 2. Lobed rotar meter
 - 3. Nutating disc meter
 - 4. Rotary vane meter
 - 5. Rotary abutment meter
 - 6. Liquid sealed gas meter
 - (b) Variable head meters (closed channel)
 - 1. Orifices
 - 2. Flow nozzle and venturi nozzle
 - 3. Flow tube
 - 4. Venturi tube
-

-
- 5. Pitot tube
 - 6. Primary flow device
 - (c) Variable head meters (open channel)
 - 1. Weirs
 - 2. Flumes
 - 3. Open flow nozzle
 - (d) Variable area meters
 - 1. Plugged and ported cylinder
 - 2. Tapered plug orifice
 - 3. Plug flow indicator
 - 4. Flow switch
 - 5. Tapered tube rotameter, free bob
 - 6. Tapered tube rotameter, center guide
 - 7. Tapered tube rotameter, beaded tube
 - 8. Tapered tube rotameter, metallic
 - (e) Velocity and current meters
 - 1. Cup anemometer
 - 2. Vane type velocity meter
 - 3. Shunt type current meter
 - 4. Vortex meter
 - 5. Turbine meter
 - 6. Induced voltage electromagnetic flow meter
 - 7. Hot wire anemometer
 - 8. Swirlmeter
 - 9. Magnetic resonance flow meter
 - (f) Mass meters
 - 1. Heat-addition flow meter
 - 2. Angular momentum meter

VI Liquid level

- (a) Float methods
 - 1. Tank float
 - 2. Float controlled valve
 - 3. Magnetic position converter
 - 4. Magnetic gauge
 - 5. Buoyancy displacer
- (b) Hydrostatic pressure methods
 - 1. Direct hydrostatic type
 - 2. Air bubbler
 - 3. Differential pressure bubbler
- (c) Other methods
 - 1. Liquid conduction type
 - 2. Gauge glass automatic detector
 - 3. Ultra sonic probe
 - 4. Electronic level gauge
 - 5. Liquid level gauge
 - 6. Continuous capacitance gauge
 - 7. Diaphragm actuated liquid level switch

VII Solids level

- 1. Gamma ray gauge
 - 2. Flexible diaphragm type
 - 3. Rotating paddle type
-

VII

4. Pendant cone type
5. Balance paddle type
6. Slack detector
7. Weighing vessel
8. Ultrasonic solid level gauge

VIII Weight and weight rate of flow

- (a) Fixed load weighing
 1. Unevenly balanced scale
 2. Spring balanced scale
 3. Hydraulic scale
 4. Pneumatic weight transmitter
 5. Strain gauge or tension gauge
 6. Hydraulic load cell weigher
 7. Continuous belt conveyor weigher
 8. Continuous automatic nuclear weigher
 9. Load cell cable suspension
- (b) Moving load weighing
 1. Semi continuous feed belt weigher
 2. Scale mounted feed tank
 3. Continuous conveyor scale
 4. Radio active transmission gauge, absorption type
 5. Radio active transmission gauge, back scattering type
 6. Volumetric solids meter
 7. Solids flow meter
- (c) Weigh feeders
 1. Weight rate meter
 2. Scale balanced belt feeder
 3. Balanced weigh belt, mechanical feeder
 4. Loss in weight star feeder
 5. Balanced belt, electric vibrating feeder
 6. Loss in weight vibrating feeder
 7. Mass rate meter

IX Thickness and displacement

1. Ultrasonic resonance gauge
2. Caliper roll
3. Infrared width gauge
4. Continuous photo metric film gauge

X Velocity (linear and auglar)

1. Air speed indicators
2. DC magneto tachometer
3. AC generator techometer
4. Magnetic drag tachometer
5. Centrifugal governor
6. Differential speed recorder
7. Stroboscope

XI Fluid density and specific gravity

- (a) Weight methods
 - Hand hydrometer

-
- | | |
|------|---|
| | (b) Weight methods, fixed volume |
| | 1. Balanced flow vessel |
| | 2. Gas specific gravity balance |
| | 3. Buoyancy gas balance |
| | 4. Gas density balance |
| | 5. Chain balanced float density recorder |
| | 6. Balanced pipe loop |
| | 7. Automatic hydrometer |
| | (c) Other methods |
| | 1. Differential air bubbler |
| | 2. Gamma-ray density gauge |
| | 3. Boiling point elevation |
| | 4. Viscous drag gas densitometer |
| | 5. Gas densitometer |
| | 6. Gas density detector |
| XII | Viscosity and consistency |
| | 1. Pressure drop through friction tube |
| | 2. Continuous consistency meter |
| | 3. Ultra viscoson continuous viscometer |
| | 4. Piston viscometer |
| | 5. Drag torque on stationary element in rotated cup |
| | 6. Rotating torque type |
| | 7. Viscosity sensitive rotameter |
| | 8. Cone and plate viscometer |
| | 9. Haake rotovisco |
| | 10. Pour point analyser |
| XIII | pH concentration and oxidation-reduction potential |
| | 1. Electrometric method |
| | 2. Colorimetric method |
| | 3. Oxidation-reduction potential |
| XIV | Electrical conductivity |
| | 1. Conductivity cells in AC bridge |
| | 2. Electrodeless conductivity measurement |
| XV | Thermal conductivity |
| | 1. Double cell, single pass type |
| | 2. Double cell, double pass type |
| | 3. Four cell, conductivity convection type |
| | 4. Four cell, single or double pass type |
| XVI | Caloric value, combustible control, and explosibility |
| | 1. Continuous gas calorimeter |
| | 2. Combustible gas detector |
| | 3. Explosive gas recorder, thermocouple type |
| | 4. Heat-flux radiometer |
| XVII | Humidity of gases |
| | (a) Wet-bulb depression |
| | 1. Sling psychrometer |
| | 2. Recording psychrometer |
| | 3. Direct recording psychrometer |
| | (b) Hygrometers |
| | 1. Dimensional change hygrometer |
-

-
- 2. Electrical resistance hygrometer
 - 3. Aluminum oxide hygrometer
 - (c) Dew point
 - 1. Dew point hygrometer
 - 2. Electric hygrometer type dew point meter
 - (d) Other
 - 1. Water vapour recorder
 - 2. Electrolytic water analyser
 - 3. Moisture analyser
- XVIII Moisture content of solids**
- 1. Resistance meter
 - 2. Dielectric constant meter
 - 3. Dielectric constant moving web meter
 - 4. Solids moisture analyser
 - 5. Continuous granular moisture meter
 - 6. Infrared moisture analyser
 - 7. Infrared moisture gauge
 - 8. Microwave moisture gauge
- XIX Optical properties**
- (a) Colour
 - 1. Colour comparators
 - 2. Photo electric colorimeters
 - 3. Recording spectrophotometer
 - 4. Diffraction grating spectrophotometer
 - 5. Photometric analyser
 - (b) Turbidity, opacity
 - 1. Smoke and dust density meter
 - 2. Turbidimeter
 - 3. Photo-electric turbidimeter
 - (c) Other
 - Pour point tester
- XX Composition by chemical properties**
- 1. Orsat gas analyser
 - 2. Gas analysis by pressure drop
 - 3. Oxygen analyser
 - 4. Colorimetric differential photometer
 - 5. Electrolytic oxygen analyser
 - 6. Potentiometric titration
 - 7. Process oxygen monitor
 - 8. Dissolved oxygen analyser
 - 9. Polarising cell oxygen analyser
 - 10. Bromine titration for sulphur gases
 - 11. Sulphur dioxide by electrical conductivity
 - 12. Automatic titrator
 - 13. Hydrogen sulphide content by colour change
 - 14. Water hardness analyser
- XXI Composition by spectroscopy**
- (a) Emission
 - 1. Arc or spark spectroscope
 - 2. Flame photometer
-

-
- (b) Infrared absorption (dispersive types)
 1. Infrared absorption spectrometer
 2. Infrared absorption plant stream analyser
 3. Infrared absorption spectrometer, double beam
 - (c) Infrared absorption (non-dispersive type)
 1. Infrared analyser, nonselective or negative type
 2. Infrared analyser, selective or positive (luft) type
 3. Three beam infrared analyser, positive type
 - (d) Ultraviolet and X-ray absorption
 1. Ultraviolet spectrometer
 2. Non-dispersive ultraviolet analyser
 3. X-ray photometer
 - (e) Fluorescence and diffraction
 1. X-ray fluorescence continuous analyser
 2. X-ray diffraction spectrometer
 3. Electron diffraction
 4. X-ray fluorescence spectrometer
 - (f) Mass spectrometry
 - Mass spectrometer
 - (g) Radio frequency spectrometry
 1. Nuclear magnetic resonance
 2. Electron paramagnetic resonance
- XXII Composition by other physical properties
- (a) Oxygen by magnetic susceptibility
 1. Magnetic susceptibility, non-uniform-field type
 2. Low range oxygen analyser
 - (b) Electrochemical cell
 - Electrochemical oxygen analyser
 - (c) Index of refraction
 1. Automatic refractometer
 2. Process refractometer
 - (d) Dielectric constant
 - (e) Gas chromatography
 - Gas chromatography distillation analyser
 - (f) Radiological methods
 - Trace gas analyser
 - (g) Other methods
 1. Ionisation detector
 2. Gaseous conduction
 3. Hydrogen by diffusion
 4. Boiling point analyser
 5. Distillation analyser
 6. Freezing point analyser
 7. Light-ends recorder
-

-
- 8. Btu-units meter
 - 9. Boiling point and melting point unit
 - 10. Vapour pressure analyser
- XXIII Electrical quantities
- (a) DC voltage
 - 1. Permanent magnet, moving coil voltmeter (or ammeter)
 - 2. Electrodynamic voltmeter
 - (b) AC voltage and frequency
 - 1. Electrostatic voltmeter
 - 2. Electromagnetic moving iron voltmeter
 - 3. Rectifier bridge
 - (c) Current
 - Thermocouple ammeter
 - (d) Power and energy
 - Dynamometer type meter
 - (e) Other
 - Solidstate operational amplifiers
- XXIV Measuring methods
- (a) Circuits
 - Capacitance bridge
 - (b) Balancing methods
 - 1. Microsyn system
 - 2. Dynamaster thermocouple
 - 3. Electronic
 - 4. Dynalog
 - 5. Electrosyn system
 - 6. Speedomax
 - (c) Monitoring and data logging
 - 1. Magnetic tape recorder
 - 2. Transducer
 - 3. Digital converter
 - 4. Cloud point analyser
- XXV Transmitters and telemeters
- (a) Hydraulic and magnetic
 - 1. Hydraulic transmission
 - 2. Magnetic follower
 - (b) Pneumatic
 - 1. Positioning non-balance transmitter
 - 2. Force-balance transmitter, beam type
 - 3. Force-balance transmitter, null balance-vector type
 - 4. Force-balance transmitter stack type
 - 5. Air-relay slack type force balance transmitter
 - 6. Target flow transmitter
 - (c) Electric and electronic
 - 1. Wheatstone bridge transmitter
 - 2. Self synchronous motor
 - 3. Inductance bridge
 - 4. Differential transformer
-

-
- 5. Impedance bridge
 - 6. Force balance transmitter
 - 7. Pressure transmitter
 - (d) Impulse and timed signal
 - 1. Time signal telemeter
 - 2. Pulse counter flowmeter
- XXVI Controllers
- (a) Self operated
 - 1. Self operated pressure regulator
 - 2. Hot chamber regulator
 - 3. Self pilot pressure regulator
 - 4. Adjustable orifice flow regulator
 - (b) Pilots and relays
 - 1. Non-relay pilot
 - 2. Electro-hydraulic relay
 - 3. Electro-pneumatic relay
 - 4. Digital pneumatic transducer
 - 5. Electro-hydraulic operator
 - 6. Electro-hydraulic actuator
 - 7. Electro-optical relay
 - 8. Fluidic digital controller
 - (c) Pneumatic controllers
 - 1. Stack type force balance controller
 - 2. Beam type force balance controller
 - (d) Electric controllers
 - 1. Oscillating coil control pick-up
 - 2. Electric heat control duration adjusting type
 - 3. Proportional electric control
 - 4. Electronic-pneumatic control
 - 5. Syncro process control station
 - 6. Optimising controller
 - 7. Computer control station
 - 8. Electronic control amplifier
 - 9. Direct digital controller
 - (e) Ratio control
 - 1. Ratio totaliser
 - 2. Ratio control mechanism
 - 3. Proportioning pump, paced by meter
 - 4. Continuous flow proportioning
 - 5. Continuous flow porportioning with feedback control
 - 6. Flow (pressure) ratio control
 - (f) Time relations
 - 1. Blending systems
 - 2. Combined variable control
 - 3. Feed-forward control
- XXVII Final control elements
- (a) Pneumatic operators
 - 1. Diaphragm-top valve
 - 2. Valve positioners
-

3. Pneumatically operated piston
4. Piston-top valve
- (b) Electric and hydraulic operators
 1. Electric valve operator
 2. Hydraulic valve operator
 3. Integral operator and valve
 4. Diverting valve
 5. Dual-range diaphragm valve

7.3.2. Demand Profile

Process control instruments have now found wide applications in the country, not only in the relatively new process industries such as, fertilisers, chemicals, petrochemicals, plastics, synthetic fibres, etc., but also in the traditional industries like steel, textiles and sugar. With both the vertical and horizontal growth of industrialisation, the demand of these instruments is expected to grow steadily in future.

It may not be practicable to work out a detailed productwise or even groupwise demand for process control instruments. The problem is further aggravated due to varying industrial applications of these instruments. Besides, the requirement of a particular industry depends upon the processes and technologies followed by individual manufacturers.

Present Demand

A reasonably good picture of the structure of the present demand of process control instruments could be obtained from the indigenous production and imports data. However, this method of assessing the demand would not be precise as a sizeable quantity of instruments are imported in the country as integral parts of packaged units for various industrial applications and there is no method to compute the volume of such imports. In the absence of an alternative reliable method, the indigenous production plus imports give a fairly good indication of the present local consumption.

Table 7.5 gives the import figures of process control instruments for the period 1969-72. The indigenous production of these instruments in 1971-72 was of the order of Rs. 13.20 crores. On the basis of this figure and the import figure of Rs. 5.74 crores, the local consumption of process control instruments in 1971-72 can be placed at Rs. 19 crores. With the growth rate of 10 per cent per annum, the consumption is expected to reach Rs. 23 crores in 1974-75.

Future Demand

The problem of analysing the future potential demand is even more difficult. The demand for instrumentation is a derived one and is dependent on the investments envisaged for establishment of new process industries and expansion of existing units. Future requirements can be approximately worked out by relating the instrumentation cost to the physical plant cost for the future industrial development programmes of the economy.

Based on the investment in process industries originally indicated in Fourth Plan period, and on the assumption that this magnitude of investment will be met, if not exceeded, for Fifth Plan period, it has been estimated that Rs. 4000 crores will be invested in Fifth Plan for the expansion of existing

Table 7.5. Import statistics of process control instruments
(Figures in Rs. lakhs).

Items	1969-70	1970-71	1971-72
Controlling apparatus	119.74	188.40	407.03
Apparatus for measuring liquid and gas flow	37.86	62.77	44.97
Heat, light, etc., measuring apparatus	24.59	36.90	36.54
Pyrometers	2.08	3.98	15.53
Porosity, etc., measuring apparatus	5.59	10.85	13.53
Photometers	4.52	12.75	10.74
Physical and chemical analysis apparatus	5.29	7.26	10.55
Pressure gauges	15.88	8.83	9.54
Thermostats	3.96	3.49	6.09
Gas analysis apparatus	2.44	0.90	5.29
Colorimeters	3.44	4.84	5.23
Automatic temperature controlling apparatus	4.92	3.10	3.89
Refractometers	1.59	1.84	2.34
Flow meters-gas	2.12	2.59	2.19
Polarimeters	1.27	6.84	0.55
Heatmeters and automatic draught regulators	0.12	1.15	—
Total	235.41	356.49	574.01

process industries and setting up of new units. There is likely to be spill-over from Fourth Plan period, and this has not been taken into consideration for computing the demand.

The investment pattern related to the anticipated additional capacities during the Fifth Plan is given in Table 7.6. The instrumentation demand as worked out using the ratios of instrumentations cost to the total plant cost in different industries is placed at Rs. 133 crores. The ratios given in Table 7.6 were determined from (a) actual experience on work connected with major steel plants, thermal power plants, fertiliser and chemical plants, (b) data from published papers and (c) actual verifications with process plants.

The demand estimate of Rs. 133 crores is a conservative one, since the percentages assumed are likely to increase in the future years with greater automation consequent on provision of data loggers, computers and other sophisticated control equipment.

The total instrumentation demand of Rs. 133 crores does not include the demand for data loggers and on-line process control computers. There is no prior usage of such equipment in the country by which the demand can be derived. However, it is estimated that the demand of data loggers and process computers in Fifth Plan would be around Rs. 7 crores.

The ten year demand profile for process control instruments including data loggers and process computers is worked out and shown in Table 7.21. The average growth rate of 15 per cent per annum has been assumed.

Instrumentation for process industries involves:

- (i) System design and engineering
- (ii) Supply of indigenous as well as imported investment
- (iii) Fabrication of special assemblies
- (iv) System installation
- (v) System commissioning
- (vi) Maintenance and services

VII

This can be broadly grouped under three headings namely, engineering and project services, indigenously produced instruments and imported completing items.

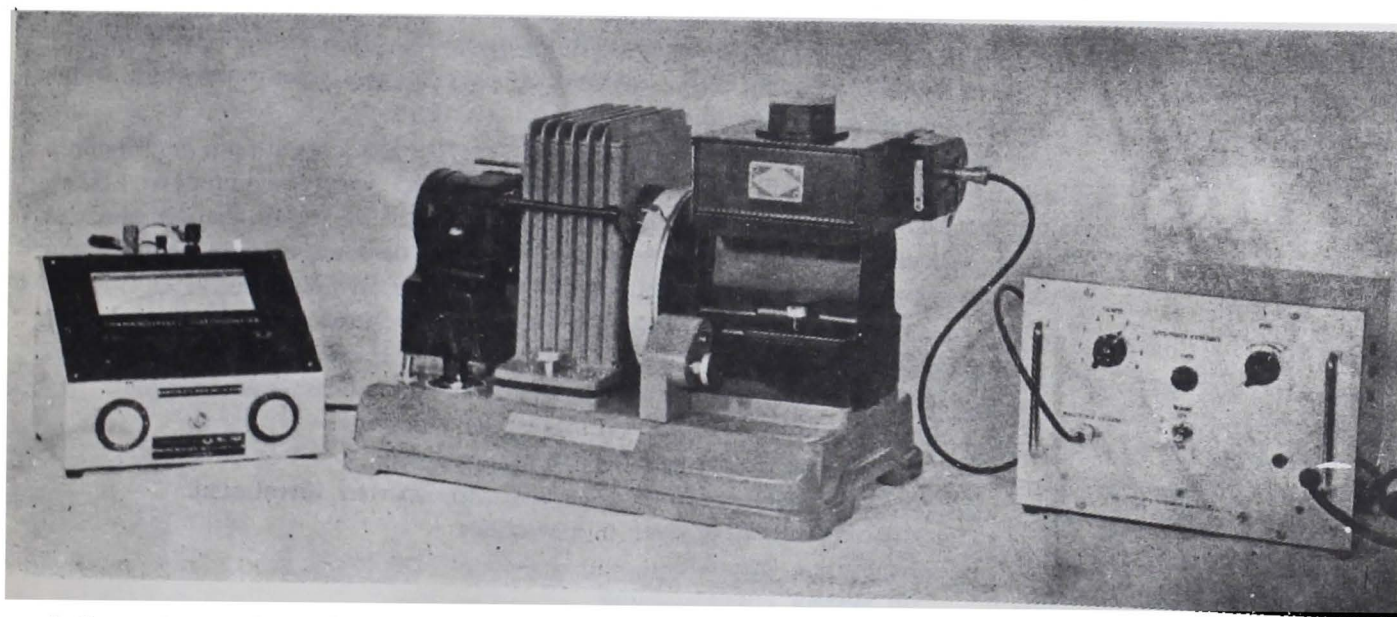
Table 7.6. Demand of process control instrumentation based on planned investment on process industries in Fifth Plan*

Industry	Additional capacity in Fifth Plan	Overall investment (Rs. crores) A	Percentage investment on instrumentation** B	Demand of instrumentation in Fifth Plan** C=A × B/100 (Rs. crores)
Steel	6M tonnes	1,500	2	30
Thermal power	11M kW	1,500	3	45
Fertilisers	2M tonnes	400	4	16
Refineries	13M tonnes	300	4	12
Chemical, petrochemical and miscellaneous		1,000	3	30
Total		4,700		133

* Based on the following data:

1. Anticipated growth rate as given in Fourth Plan documents.
2. References from Annual Eastern Economist 1971, Chemical Age of India, December, 1970, etc.
3. Announcements for establishment of steel plants, thermal power plants.

- **
1. Instrumentation includes cost towards installation, commission, import of completing item, etc.
 2. Percentage investment on instrumentation is based on actual experience and typical analysis of instrument needs for various industries, but excludes provision of computers and data loggers.



Indigenously manufactured dual cell colorimeter.

The break-up of demand under these three groups is given in Table 7.7. Engineering and project services, which are completely indigenous, account for about 15 per cent of the total demand, while 60 per cent is contributed by indigenously available instruments and special assemblies. The remaining 25 per cent constitutes the imported completing items.

Table 7.7. Break-up of instrumentation demand.

	Rs. crores	Percentage contribution
Engineering, project and services	21	15
Indigenous production	84	60
Import of completing items	35	25
Total	140	100

7.3.3. Current Status

In the early stages of industrial development in the country, process plants were imported on a turn-key basis. The initial lag in the production of process control instruments is therefore due to the fact that the instrumentation was designed and supplied along with the plant. The Bhabha Committee estimated that over Rs. 100 crores were invested on instruments as part of the imported plants.

It would appear that the indigenous production of process control instruments started during the second half of 1950's. But till 1960 little progress was made and the bulk of the country's requirements were met by imports only. Since 2 to 10 per cent of the investment on plant goes on investments, depending upon the nature of industry and the level of technology employed, the need for import substitution was felt necessary. Bearing this in mind, a number of licences were granted to both public and private sector manufacturers.

Present Structure

Today, there are about 80 units in the industry, 14 in the large scale and 66 in the small scale. The industry is fairly decentralised, the units in the small scale being distributed throughout the country. Though the share of the large scale sector works out to only 16 per cent, in terms of production it commands 62 per cent of the output and the remaining 38 per cent is that of the small scale sector.

Most of the production units in the industry are of composite nature and produce a variety of instruments. In view of the heterogenous types of instruments produced by the industry and their flexibility of taking up production of new instruments, it is difficult to present precise data on annual installed capacity of the industry. However, as a first approximation, it can be said that the total annual installed capacity of the industry was around Rs. 17 crores in 1971-72. On an average, the industry utilises about 75 per cent of this capacity.

Table 7.8 gives the State-wise number of units and their actual production during 1972. It will be observed that the total output of the industry during 1971-72 was Rs. 13.20 crores. Nearly 60 per cent of the total production in the large scale sector is from the public sector units. On an average, over the last five years, the growth rate of the industry is around 15 per cent and is on the increase. This trend compares with the growth rate of process control instruments in the developed countries.

Table 7.8. State-wise number of units and their production in 1971-72.

State	Number of Units			Production Rs. lakhs
	Large Scale	Small Scale	Total	
Rajasthan	2	—	2	350
West Bengal	3	9	12	325
Maharashtra	5	34	39	300
Haryana and Delhi	2	5	7	230
Andhra Pradesh	1	4	5	50
Tamil Nadu	—	4	4	30
Mysore	—	6	6	20
Uttar Pradesh, Kerala, Gujarat and Madhya Pradesh	1	4	5	15
Total	14	66	80	1320

Production Pattern

Although the process control instruments industry has nucleated very recently in the country, the production activity shown by the units, both in terms of volume of production, as well as, the production pattern, is remarkable. The manufacturing units are producing a variety of instruments and catering to the need of many a process industry. Table 7.9 provides a picture of process control instruments manufactured in the country. Though the range of instruments produced may appear quite narrow as compared to the range of instruments being produced in the highly industrialised countries (Table 7.21), the achievement is by no means small, looking at the short span of time in which the industry has acquired this progress.

R&D Base

The R&D base in the country today comprises of the programmes and activities being carried out in R&D departments in the public and private sector units, CSIR laboratories, BARC, universities and other institutions.

IL has to its credit the development of a variety of thermocouples, thermometers and electronic and moving coil instruments. It has improved many of its products and has undertaken comprehensive import substitution activities. Apart from this, it has already undertaken feasibility studies on evolution of product range for the post 1975 period. The investment on R&D at IL for 1972-73 was about Rs. 20 lakhs.

ECIL has been responsible for developing solid-state annunciators, logic systems and time-delay relays. Also, ECIL is presently developing nuclear weigh feeders. The digital computers and data-logging systems, for which ECIL has development programme, have wide fields of application in power generation and process control. The R&D investment of ECIL in 1972-73 in the field of process control instrumentation excluding computers was about Rs. 4 lakhs.

Table 7.9. Types of process control instruments presently produced in India.

Process variable	Type of instruments
I Temperature	(a) Differential expansion Bimetallic thermostats (b) Fluid expansion 1. Mercury-in-steel thermometers

II Pressure

- 2. Filled system thermometers
(vapour pressure thermometers)
- (c) Resistance thermometers
 - 1. Fine wire resistance thermometers
 - 2. Thermistors
- (d) Thermo-electric pyrometer
 - 1. Noble metal couples
 - 2. Base metal couples
 - 3. Special thermocouples
- (e) Optical pyrometer
 - Disappearing filament type
- (a) Absolute pressure
 - McLeod gauges
- (b) Gauge pressure or vacuum (spring-balanced type)
 - 1. Bourdon type pressure deflecting units
(hydraulic gauge, draught gauge, low pressure gauge)
 - 2. Diaphragm gauge
 - 3. Bellows gauge
 - 4. Strain gauge load cell
- (c) Differential pressure (manometer type)
 - 1. Glass liquid column manometers
 - 2. Mercury-in-steel manometer
(recording type)

III Force, tension, compression

- (a) Bonded strain gauges
- (b) Unbonded strain gauges

IV Fluid flow

- (a) Variable head meters (closed channel)
 - 1. Orifices
 - 2. Flow nozzle and venturi nozzle
 - 3. Venturi tube
 - 4. Pitot tube
 - 5. Plane and intake cones
- (b) Area flow meter
 - Rotameters
- (c) Variable head meters (open channel)
 - 1. Weirs
 - 2. Flumes

V Liquid level

- (a) Float methods
 - 1. Tank float (level switches)
 - 2. Displacement buoyancy
- (b) Hydrostatic pressure methods
 - 1. Air bubblers
 - 2. Differential pressure bubblers
 - 3. Slack diaphragm type
- (c) Other methods
 - Liquid conduction type

-
- | | |
|--|---|
| VI Weight | (a) Strain gauge
(b) Tension balanced load cell |
| VII pH concentration | Electronic method (pH meters) (direct method, potentiometric method). |
| VIII Electrical conductivity | 1. Conductivity cells in AC bridge
(conductivity meter, conductivity bridge)
2. Moisture meters |
| IX Optical properties | (a) Colour
1. Photoelectric colorimeter
2. Spectrophotometer
(b) Turbidity
Turbidity meter

Gas chromatography |
| X Composition by other physical properties | |
| XI Transmitters | (a) Pneumatic
Force-balance transmitters
(b) Electric and electronic
Pressure transmitters, temperature transmitters, differential transmitters, flow transmitters |
| XII Controllers | (a) Self operated
Self-operated pneumatic regulators
(b) Pneumatic controllers
Force-balance three-term (PID) controllers
(c) Ratio-control
Ratio totalisers |
| XIII Final control elements | (a) Pneumatic control
1. Diaphragm operated valves
(diaphragm control valves)
2. Valve positioners
3. Pneumatically operated pistons
4. Piston operated valves
5. Butterfly valves
(b) Electric and hydraulic control
Solenoid valve (electric) |
| XIV Others | 1. On-off temperature controllers
2. CO ₂ meter
3. Pressure regulators
4. Gas regulators
5. Thermo hygrometers
6. (a) Galvanometric and potentiometric temperature and pressure recorders |
-

- (b) Ferrodynamic recorders
- (c) Pneumatic recorders
- 7. Dead weight testers
- 8. Pressure switches
- 9. Motorised valves
- 10. Air filters
- 11. Alarm annunciating system
- 12. Bomb calorimeter
- 13. Baby calorimeter
- 14. Flash point tester
- 15. Charts and graphs
- 16. High vacuum equipment

The Planning and Development Division of FCI has developed a number of products like solid state annunciator, capacitance level probe, level indicator, etc. These have been undertaken for productionisation by industries. CSIO has developed a number of instruments and devices some of which have been entrusted to industries. Similarly, BARC has developed nuclear level gauges and gas chromatographs.

Tables 7.10 through 7.17 give the completed and on-going R&D projects undertaken by IL, ECIL, FCI and CSIO. Similar details were not available for the various private sector manufacturing units. It is, however, recognised that some R&D activity does exist, particularly in the small scale units.

It can be seen from Tables 7.10 through 7.17 that the R&D activities resulted in the following contributions:

- (i) import substitution resulting in FE savings
- (ii) standardisation and rationalisation resulting in enhanced productivity
- (iii) product improvement
- (iv) cost reduction
- (v) new product development
- (vi) techniques for speedy progress through the innovative chain.

Table 7.10. Completed R&D projects at IL, Kota.

Equipment	Remarks
1. Pyrometric indicator with controller	New product. Completed March 1969. Now in use. Development based on initial design of CSIO. Production 1970-71—200 nos., 1971-72—520 nos. Net FE saving has been \$ 72,000.
2. Orifice plates, flow nozzle	Import substitute. Completed March 1969. Now in use. FE saving \$ 300,000 per annum.
3. Built-in power supply for cross coil indicator	Import substitute. Completed July 1969. Now in use. Production 1970-71—100 nos., 1971-72—250 nos. Net FE savings \$ 2,800.
4. Cross coil indicator with controller	New product. Completed July 1969. Now in use. Production 1970-71—50 nos., 1971-72—120 nos. Net FE saving \$ 17,000.

Equipment	Remarks
5. Throw-away tips	Import substitute. Completed March 1970. Now in use. Production 1970-71—16,000 and 1971-72—60,000. Net FF saving has been \$76,000. FE saving in 1972-73 is \$0.2 million.
6. Dynamic breaking device	Import substitute. Completed May 1971. Now in use. Production 1971-72—600 nos. Net FE saving \$16,800.
7. Position indicator	Import substitute. Completed May 1971. Now in use. Expected FE saving \$17,000 per annum.
8. Relay-based annunciator	New product. Completed June 1971. Now in use.
9. Auto compensator	Import substitute with improved characteristics. Completed July 1971. Now in use. Expected FE saving \$3,200 per annum.
10. Receptacles for throw-away tips	Import substitute. Completed October 1971. Now in use. Production in 1971-72—100 nos. Thereby FE saved \$350.
11. Ferrodynamic pressure transducer	New product. Completed October 1971. Now in use. Production in 1971-72—40 nos. Thereby FE saved \$6,600.
12. Stabilised power supply	Import substitute. Completed October 1971. Now in use.
13. Lance for throw-away tips	Import substitute. Completed February 1971. Now in use.
14. Solid state digital signaliser for water meters	New product. Completed March 1972.
15. Solid state amplifier for ferrodynamic recorder	Import substitute. Completed May 1972. Now in use.
16. Single pen and two pen recorders with control station	New product. Completed June 1972. 35 nos. of instrument produced in 1971-72.
17. RTD for MAPP—1&2	Import substitute. Completed June 1972. Now in use. About \$0.3 million FE expected to be saved during 1973-74.
18. Electronic differentiator	Import substitute. Completed June 1972. Now in use. Expected FE saving is about \$25,000 per annum.
19. Solid state chopper	New product. Completed June 1972. Now in use. Expected FE saving is about \$32,000 per annum.

Equipment	Remarks
20. Electronic controller	Import substitute. Completed August 1972. Now in use. Expected FE saving is about \$ 1.7 lakhs per annum.
21. Silos thermometer	Import substitute. Completed August 1972. Now in use.
22. Fast response recorder for throw-away tips	New product. Completed September 1972. Now in use.

Table 7.11. Completed R&D projects at ECIL.

Equipment	Remarks
1. Solid state logic system, mark I	Import substitute. Completed in 1968. Now in use. Complex logic system utilising a total of 5000 logic elements has been produced.
2. Relay logic annunciation system, mark I	Import substitute. Completed in 1969. Now in use. Complex schemes totalling to about 700 points have been produced for RAPP-1 project.
3. Indicator controller with two adjustable set points	Import substitute. Completed in 1969. Now in use. A total of 700 units have been produced for RAPP-1.
4. Sensitive electronic relays	Import substitute. Completed in 1969. Now in use. About 50 units were produced for detecting heavy water leaks.
5. High performance DC power supplies	Import substitute. Completed in 1970. Now in use. A number of high performance reliable power supplies have been produced. Capabilities exist upto 1000 amperes and upto 250 V DC.
6. Nucleonics level gauges	Import substitute. Completed in 1970. Now in use. A total of 40 units has been produced and 100 units are under production for 1973-74.
7. Gear head motors	Import substitute. Completed in 1971. Now in use. Total of 1200 motors has been produced to date.
8. Digital on-line computer	New product. Completed in 1971. Now in use. TDC-12 is available in the market.
9. Relay logic annunciation system, mark II	Redesigned product, with better performance and higher indigenous content. Completed in 1972. Now in use.

Equipment	Remarks
10. Solid state logic system, mark II	Redesigned product, with better performance and higher indigenous content. Completed in 1972. Now in use. A total of 10,000 logic elements designed for Indian conditions has been produced for incorporation into complex fuel handling control systems for RAPP-2 and test systems.
11. Solid state time delay elements, plug in type	Import substitute. Completed in 1972. Now in use. Approximately 200 units have been produced with ON delays and OFF delays, capable of precision operation over wide range of ambient temperature.
12. Solid state annunciation systems	Import substitute. Completed in 1972. Now in use. Capability exists for many non-standard options including first out, ring back, weather proof cabinet, intrinsically safe circuits, etc.
13. Solid state high performance power supplies	Import substitute. Completed in 1972. Now in use. A total of 80 power supplies is under manufacture.
14. Excitation system for railways	Import substitute. Completed in 1972. Now in use. A total of 85 systems is being manufactured.

Table 7.12. Completed R&D projects at P&D Division, FCI.

Equipment	Remarks
1. Level alarm for solid storage bunkers	Import substitute. Completed in 1971. Now in use. Being manufactured by Bestobell.
2. Level indicator for acid tanks/HP vessels	Import substitute. Completed in 1971. Now in use. Manufactured by M/s. Eskay Electrochemical Industries, Calcutta.
3. Solid state alarm annunciator	New product. Completed in 1971. Now in use. Manufactured by IL.

Table 7.13. Completed R&D projects at CSIO.

Equipment	Remarks
1. EMF current converter	Import substitute. Completed in 1965. Not in use. Only laboratory model has been produced so far.
2. Two point indicator controller	Import substitute. Completed in 1966. Now in use.
3. Linear displacement including transducer	Import substitute. Completed in 1967. Not in use. Only laboratory model has been produced so far.

Equipment	Remarks
4. Servomotor	Import substitute. Completed in 1968. Not in use. Only laboratory model has been produced so far.
5. On-off controller	Import substitute. Completed in 1969. Not in use. Only laboratory model has been produced so far.
6. Temperature probe	New technique. Completed in 1970. Not in use. Only laboratory model has been produced so far.
7. Non-contacting speed probe	Import substitute. Completed in 1970. Not in use. Only laboratory model has been produced so far.
8. Non-contacting electronic tachometer (portable)	Import substitute. Completed in 1970. Not in use. Only laboratory model has been produced so far.
9. Precision potentiometer	Import substitute. Completed in 1970. Only laboratory model has been produced so far.
10. Electronic temperature control	New technique. Completed in 1971. Now in use.
11. Torque motor	Import substitute. Completed in 1972. Mahindra & Mahindra propose to manufacture it.

Table 7.14. On-going R&D project at IL, Kota (1972-73).

Equipment	Remarks
1. Resistance thermometer for bearing temperature measurement	Import substitute. Major users are, Fertilizer, Petrochemical and other industries.
2. Pneumatic indicator with electric alarm contacts	New Product. Major users, Fertilizers, Petrochemical and other industries.
3. Pneumatic three pen recorder	New Product. Major users, Fertilizers, Petrochemical and other industries.
4. Pneumatic manual loader	New Product. Major users, Fertilizers, Petrochemical and other industries.
5. Pneumatic two pen recorder	New Product. Major users, Fertilizers, Petrochemical and other industries.
6. Solid state annunciator	New Product. Major users, Fertilizers, Petrochemical and other industries.
7. Slot type resistance thermometers for winding temperature measurement in motors	Import substitute. Major users motor manufacturers.
8. Multizone thermocouples	Import substitute. Main user, Fertilizer industries.
9. Mark II version of potentiometric recorders	New development with enhanced characteristics Major users, all process control industries.

VII

Equipment	Remarks
10. Miniature potentiometric indicator	New product. Major users, all process control industries.
11. Zenner barriers	Import substitute. Major users, all process control industries.
12. (a) Voltage to current connector for thermocouples and resistance bulbs (b) Diff. pressure to current converter (c) Pressure to current converter (d) Electro-pneumatic converter (e) Pneumo-electric converter (f) Current indicator and controller (g) Current recorder and controller (h) Flow totaliser (i) Square root extractor (j) Other miscellaneous items required for current system	The development goal is, feasibility studies on 'current system of instrumentation for induction in production in period 1975-80. The total system injection is expected in period 1977-78.

Table 7.15. On-going R&D projects at P&D Division, FCI (1972-73).

Equipment	Remarks
1. Continuous level measurement of solid in bunkers	Import substitute
2. Constant flow purge meter for level measurement	Import substitute
3. Level transmitter for liquids	Import substitute
4. Intrinsically safe circuits for hazardous locations	Import substitute
5. First trip indicator	New product
6. Pneumatic actuators for sounders valves	New product

Table 7.16. On-going R&D tasks at CSIO (1972-73).

Equipment	Remarks
1. Line printers	Import substitute
2. Thyristor controlled variable speed driver	Import substitute
3. Electromagnetic flowmeter	Import substitute
4. Linear DC servomotor	Import substitute
5. Fluidic devices and systems	New product

Table 7.17. On-going R&D project at ECIL (1972-73).

Equipment	Remarks
1. X-Ray gauging equipment	Import substitute, units for on-line gauging of density are being manufactured.
2. Synchro transmitters and receivers	Import substitute
3. Intrinsically safe circuits for hazardous location	Import substitute
4. High performance DC power supplies Mark III	Import substitute
5. Digital on-line computers TDC-16	Import substitute
6. Nuclear weigh feeder	Import substitute
7. Solid state DC motor drive system	Import substitute
8. Industrial solid state logic system	Import substitute
9. Turbine supervisory equipment	Import substitute
10. E/C connectors	Import substitute
11. Automatic tube welding machines	Import substitute
12. Advanced data logging and annunciation systems	Import substitute
13. Digital blending systems	Import substitute

7.3.4. Analysis of Gaps

From the review of the present production base, it can be seen that in a short span of time, the country has achieved considerable self-reliance in the field of process control instruments. As far as essential technological services, system engineering, installation and commissioning are concerned, the country has the necessary expertise and is self-reliant. Also, a suitable nucleus exists in the country for undertaking R&D activities. With proper augmentation, this base can execute a comprehensive indigenisation plan.

Nevertheless, there are still a number of gaps which need attention. These gaps are related to:

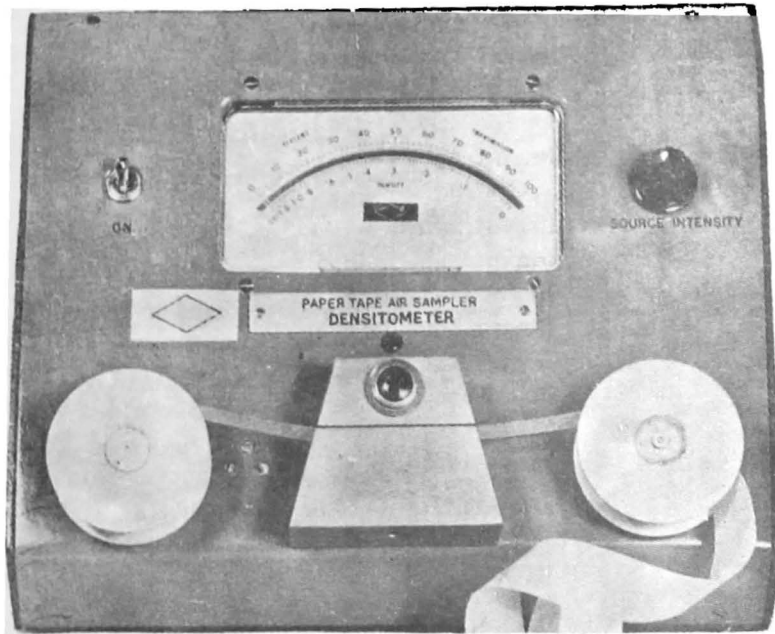
- (i) Technological base
- (ii) General facilities such as designing, workshop and tooling and testing and calibration
- (iii) Manpower for R&D, production, maintenance and testing
- (iv) Standardisation.

7.3.4.1. Technological Base

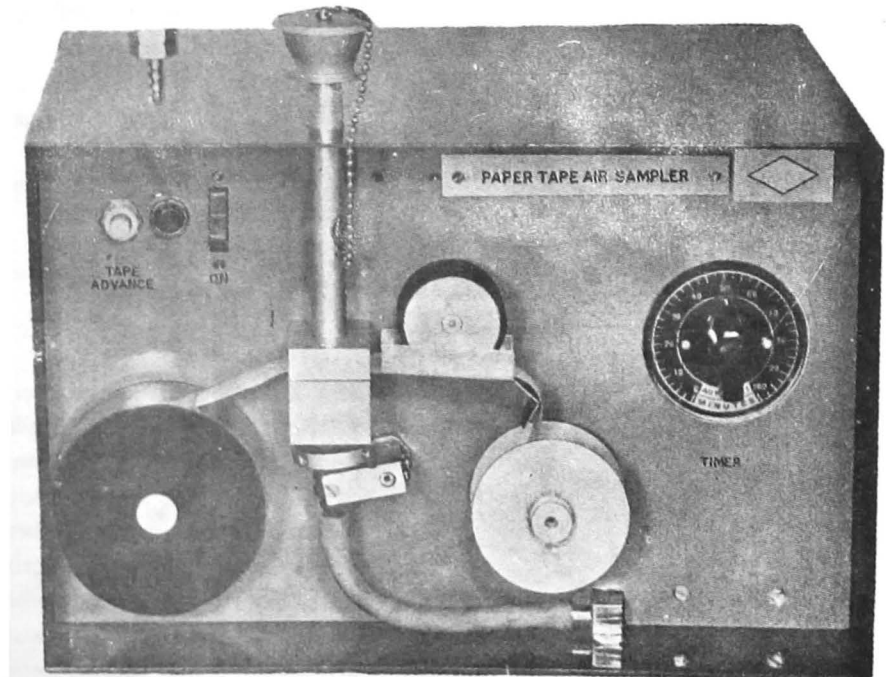
Equipment

Process control instrumentation is a field where there is a good scope for diversification and hence specialisation. The small scale units have therefore an opportunity to progress along various specialised directions and yet have an advantage of the limited though distinctly growing demand for different sophisticated instruments. However, a peculiar tendency can be noticed in the manufacturing units. Presently, a number of units are directing their efforts towards development and production of a few general-purpose simple equipment like, thermocouples, resistance thermometers, bi-metallic thermometers, vapour pressure thermometers, mercury-in-steel thermometers, temperature controllers, temperature recorders, pressure gauges, flow meters, level indicators, conductivity meters, solenoid valves and control valves.

VII



Paper tape air sampler manufactured in the country.



Looking to the growth in production of individual units making these instruments and the wide range in qualities of instruments being produced by some units, it appears that this tendency of the manufacturers to concentrate on a few items is because of unsatisfied demand for certain instruments. This is a natural phenomenon, especially for the instruments having wide applications in process industries, in view of the trend to catch up with modern technology.

The tendency to concentrate on a few equipment for R&D and production is not conducive to the future growth of the industry as considerable efforts and resources are involved in R&D. It seems that there is a lack of co-ordination in the R&D programmes among the units. Coordination to organise R&D among the production units cannot be achieved in the absence of a central body.

Materials and Components

The import content of process control instruments, on an average is about 7 per cent. The scheduled production programmes are currently adversely affected because of the delays involved in the supply of imported materials and components. Main causes for such delays are long and tedious procedures involving a number of departments to issue import licences, and difficulty in locating foreign suppliers for the items having low demand. Moreover, stock-piling of materials and components creates inventory problems for individual units.

Quite apart from the problems related to the procurement of these items from abroad, a sizeable amount of FE drain is involved. One of the factors acting as a deterrent to the indigenisation programme is the low volume of demand for individual items. But with the expected growth of the industry, the demand will grow to the extent of justifying local production. In the interim period, the difficulties in procuring can be ironed out by setting a central agency which would locate proper sources, stock-pile such items and evolve efficient distribution networks.

The major raw materials and components which presently form part of the problem-area are listed below:

Materials:

1. Aluminium
2. Steel and alloy steels (stainless steel, invar, spring steel, hardenable steel, etc.)
3. Copper and copper alloys (beryllium copper, phosphor bronze, constantan, manganin, etc.)
4. Brass
5. Nickel and nickel alloys (nickel brass, nickel iron, monel, inconel, chromel, alumel)
6. Cadmium metals
7. Cadmium sulphate
8. Noble metals (platinum, rhodium)
9. Thermocouple wires (chromel-copel, chromel-alumel, copper-constantan, iron-constantan, platinum-rhodium-platinum.
10. Manganin wires
11. Nichrome wires
12. Compensating wires

13. Microresistance wires
14. Bimetallic strips
15. Plastics
16. Organic liquids

Components:

1. Ceramic-to-metal seals
2. Instrument springs
3. Pivots
4. Hobbings
5. Precision gears and gear trains
6. Precision mechanical hardware
7. PVC sheathed copper tubes (single and multi case),
8. Quartz tubes
9. Bellows, capsules
10. Bourdon tubes
11. Sensors
12. Subassemblies for transmitters

7.3.4.2. General Facilities

Designing

Designing requirements of the industry can be classified into two major groups: design of instruments and components and design of necessary tools, jigs and fixtures.

Most of the problems regarding designing of components and instruments are oriented towards import substitution. Some of the design problems presently faced by the industry relate to the following components and instruments:

1. Resistance thermometers
2. Vapour pressure thermometers
3. Temperature controller using thermocouple sensing elements
4. Temperature controller using SCRs
5. Amplifiers for thermocouple circuits
6. Low pressure gauge with digital readouts
7. Liquid level indicators and controllers
8. Capacitance type liquid level controllers
9. Magnetic liquid level switches
10. Magnetic level detectors and controllers
11. Turbine flowmeter
12. pH meter incorporating proportional control
13. pH electrode boot for high pressure
14. Electrodynamometers
15. High pressure solenoid valves
16. Proportional controllers

The designing problems for tools, jigs, fixtures, and subassemblies encountered by the industry are of complicated nature and cannot be handled by the existing resources of the industry in terms of both men and machines. Some of the problems faced by the industry are:

- (i) Design and fabrication of a suitable equipment for filling vapour pressure thermometer bulbs

- (ii) Development of diaphragm stacks, metal bellows, range springs, bourdon tubes, capillary tubing, etc.
- (iii) Design of press tubes
- (iv) Design of jigs and fixtures for assembly

Workshop and Tooling

A majority of the units in the industry have to depend today on outside sources to get their tools, jigs and fixtures designed and fabricated. The workshops and toolrooms through which the design and fabrication work is done do not necessarily specialise in precision tooling for instrument industry, with the result that the close mechanical tolerances of the products are not generally met.

Some large units have their own toolroom and workshop facilities, but these are not available to smaller units. Smaller units can hardly afford the high investment necessary for a toolroom of their own. The investment per worker in the industry is around Rs. 11,500. This is just sufficient to carry out day to day production activities. Moreover, the product range and volume of demand do not justify the maintenance of a full-fledged toolroom. This entails the need for a centralised workshop and toolroom facility, which will cater to the basic needs of the industry. The major investment for setting up such a workshop would be in the capital equipment. Most of these will have to be imported.

A good workshop and toolroom facility exists at IDEMI. This institute has provided development facilities for a variety of jobs to the industry, such as:

1. Fabrication of housing of instruments
2. Tools and fixtures for moving coil assembly
3. Moulds for pressure die casting
4. Press tools and fixtures for assembly of pressure gauge mechanisms
5. Jigs and fixtures for variable air flow needle valves

Testing and Calibration

Production of process control instruments involves extensive inspection, calibration and testing of materials, components, subassemblies and completed products at all stages of manufacture. It is necessary that all products of the industry are designed and manufactured to certain definite specifications covering both quality and performance aspects. It is further necessary that the products are tested to ensure compliance to the specifications. The availability of products which are designed, manufactured, tested and certified for compliance to specifications will permit their wide usage in instrumentation schemes within the country. It will also facilitate export of total instrumentation schemes as well as products themselves.

Some large units such as IL and ECIL have the commonly required testing facilities as a part of their production programmes. Also, reasonably good testing facilities are available at IDEMI, CSIO, BARC, CMERI and IISc. These are not, however, on a scale adequate for testing a very large number of products.

Most of the small units do not have such facilities due to high capital investment involved in testing apparatus. The contribution of these units to total production, however, is quite significant and many of them manufacture special purpose instruments not made in the large units. These factors

show there is a need for a centralised test and calibration facility in the country.

Some of the problems in testing and calibration faced by the industry are, (a) testing of solenoid valves for high temperature (300°C) and pressure applications (600 psi), (b) testing and accurate calibration of thermometers for low temperature (0-10°C), (c) calibration of thermometers at 600°C, (d) calibration of pressure gauges at high ranges of 2,500 kg/cm², (e) calibration of rotameters for fluid flow, (f) testing and evaluation of gas analysers, and (g) calibration of moisture meters for different applications.

7.3.5. Guidelines for Technology Development and Production

For the attainment of self-reliance in the field of process control instrumentation, efforts should be made in the following directions:

- (i) Integrated approach to planning and promotion of automation and control technology
- (ii) Creation of R&D environment in academic institutions
- (iii) Augmentation of the present technology base for (a) development and production of items which are presently imported in the country, (b) diversification of existing product range, and (c) continuous updating of product range bearing in mind the rapid obsolescence in this field
- (iv) Establishment of centralised facilities for design and development, workshop and tooling, and test and maintenance.
- (v) Forward-looking investigations on rapidly evolving technologies such as computer control, data-logging, digital sensors and fluidics which will enable rapid evolution of advanced products and systems in Sixth Plan period

7.3.5.1. Promotion and Planning of Automation and Control Technology

Automation and control technology is one of the mainsprings of economic and technological progress. In the developed socialistic economies, it has led to an unprecedented increase of productivity of labour. Since Indian process industry, by and large, is unaware of the benefit that automation offers, it is necessary to launch an organised campaign as in USSR and other countries for introducing the right kind of productive automation in India.

It must be noted that the core technology on which automation rests—the control technology—is one of the most heterogeneous of technologies, encompassing numerous scientific disciplines principally centred around electronics and covering many industrial applications. For example, the design of pneumatic chromatographic controller calls upon the integration of electronics with hydraulics, pneumatics, chemical engineering, mechanical engineering, and finally system engineering—because the device is a system comprised of an instrument, a computer, a process and a controller all condensed into a package. Thus, the development of control hardware represents one of the most challenging and rewarding tasks.

Due to the interdisciplinarian nature of control technology, there is an urgent need for integrating electronics industry with other sectors of the national economy, such as power generation, steel and nonferrous metals, fertilisers, petrochemicals, machine tool, etc.

7.3.5.2. Creation of R&D Environment

R&D activity in academic institutions in the process control area has been sporadic in nature so far and has revolved around individuals or small

groups with little liaison with industry. Consequently, neither interest nor opportunity was evident for translation of R&D into production. The funding for such work had also been insignificant. To remedy this situation, following steps should be taken:

- (i) Identification of five institutions as centres for technology development activity in process control instrumentation
- (ii) Setting up of two central automation and control laboratories in two such institutions
- (iii) Allotment of adequately funded sponsored research projects to such centres with freedom to operate within an agreed framework
- (iv) Involvement of instrument production units in the organisation and implementation of post-graduate programmes in process control instrumentation through project works jointly supervised by the faculty and staff in the industry
- (v) Organisation of short-term exchange programmes, seminars and workshops with participants drawn from industry and academic institutions

7.3.5.3. Augmentation of Technology Base

Equipment

As indicated earlier, the total imported completing item content for the Fifth Plan period, based on the present status of manufacturing is Rs. 35 crores. In addition, Rs. 8 crores worth of instrumentation is tentatively assumed to be imported during this period as part of turn-key projects funded by World Bank loans and similar aids.

Broad plans for the indigenous development and production of process control instruments are given in Table 7.18. Out of the import of Rs. 35 crores, control valves and allied items contribute the major share. IL, Kota has recently entered a collaboration with Honeywell for the manufacture of these sophisticated products. With the implementation of the control valve manufacturing programme as well as the other technology development and production activity, the import of completing items will be significantly reduced.

Table 7.18. Development and production plan for indigenisation.

Equipment	Remarks
1. Control valves, hydraulic, pneumatic and electric actuators, positioners and associated equipment	IL will commence production from 1974 under collaboration.
2. Liquid level transmitter and controllers	IL will commence production from 1974 under collaboration.
3. Analytical instruments for gases (infrared, paramagnetic, thermal conductivity types)	Private unit licensed for production of certain oxygen analysers. For other types, development should be done at BARC and production in either private or public sector.
(a) Conductivity meters	Production base exists. This base has to be enlarged by support of quality assurance measures.
(b) Gas chromatographs for hydrogen, nitrogen, chlorine, oxygen, etc.	BARC and CSIO should help in further development and production on a pilot plant basis.
4. Intrinsically safe circuitry and equipment	ECIL, IL, IITs and other institutions should take up this task.

Equipment	Remarks
5. Magnetic, target and turbine flowmeter	CSIO and IDEMI should be entrusted with development in coordination with IL. IL should take up production.
6. Variable area flowmeters	Units in small scale sector are making basic types. This base has to be activated to diversify and meet all requirements.
7. Electropneumatic and pneumo-electric converters	IL has plans to develop and diversify. Some private units also have plans to manufacture.
8. Pyrometers for on-line applications	CSIO and IITs should develop the prototypes. National Instruments should productionise.
9. Level gauger glasses	IIT, Bombay should play a leading role in improving the standard. CSIO should offer help.
10. Level switches	Existing units should be asked to improve the quality, and cover high pressure, high temperature applications.
11. Storage tank level indicators	Units in small scale sector should take the development and production work under the guidance of FCI.
12. Local flow indicators, diaphragm and bellow type	Existing manufacturers of pneumatic instruments should diversify.
13. Special temperature elements	IL should develop and produce as required.
14. Solenoid valves	IL should direct its efforts on DC operated, multi-port, explosion proof and pilot operated valves.
15. Miscellaneous items	No specific indigenisation plan envisaged presently.

Materials and Components

In addition to the equipment-oriented and technology-oriented R&D programmes, there is a need to undertake time-targeted R&D programmes for ensuring material and component availability in the country.

Materials

Important imported materials needed for the manufacture of process control instruments are listed in Table 7.19. Many of the materials needed are special alloys. The base metals for some of these alloys are available in the country, but the requirement of the process control instruments industry is not enough to warrant immediate commercial production.

The special alloys mentioned in Table 7.19 are also required for other electronics industries. Hence, the situation requires a coordinated action of various planning groups in assessing the needs in totality. After considering standardisation and unification, a plan should be prepared for:

- (i) manufacture of these on a pilot plant scale in the National Metallurgical Laboratories, and,
- (ii) stock-piling of these so that in case of emergencies or other conditions, the industry may not suffer because of the nonavailability of raw materials.

DMRL has recently proposed the establishment of facilities tuned to the Defence requirements. These facilities could be used for the production of the specialised raw materials (Table 7.19) on a pilot plant scale. This activity will have to be supported by adequate funds (about Rs. 1 crore) during Fifth Plan period.

Table 7.19. Materials needing R&D work prior to pilot production.

Materials	Suggested agency for R&D and production
1. Duraluminium	Many venues exist, the most likely ones not identified (for items 1—6)
2. Alloy steels	
3. Beryllium copper	
4. Copper alloys	
5. Phosphor bronze	
6. Nickel brass	
7. Bimetallic strips	DMRL
8. Thermocouple wires (chromel-copel, chromel-alumel, chromel-constantan, platinum-rhodium, platinum, etc.)	NML, DMRL
9. Manganin wires	NML, DMRL
10. Microresistance wires	Ravindra and Heraeris, Aurora Mathey
11. Compensating wires and tubes	NML, P&T, Cable manufacturers
12. Hi-permeability transformer laminations	GKW, DMRL
13. Bourdon tubes	NIL, IL, Private
14. Special flexible plastic tubes	Private

Components

A variety of basic electrical, mechanical, electromechanical and electronic components are available indigenously to fairly acceptable standards. These components should be improved to meet the increasingly stringent requirements of the industry.

However, there are some components which are not indigenously available. A list of such components is given in Table 7.20. Table 7.20 also indicates the venues where technology development and production activities could be undertaken.

Table 7.20. Components needing R&D prior to production.

Components	Suggested agency for R&D and production
1. Ceramic to metal seals	CGCRI
2. Quartz tubes	CGCRI/Private
3. Sapphire tips	Private
4. Miniature steel balls	Private
5. Moment springs and taut band suspensions	IDEMI, HMT (Watch factory)
6. Pivots	IDEMI, HMT (Watch factory)
7. Stainless steel capillary tubes	Private, HSI
8. PVC Sheathed copper tubes, single and multicore	Private
9. Miniature bulbs	Private
10. Neon lamps	ECIL, Private
11. Trim pots (printed card type)	ECIL, Private
12. Microswitches	Private
13. Miniature fuses and fuse holders	Private
14. FET	BEL, Private
15. Thyristors	BEL, Private
16. Miniature resistance elements	NPL
17. Capsules, bellows and membranes	IL

Capsules, bellows and membranes are important components required for the development and production of process control instruments. Proposals for production of those vital components should be encouraged to attain self-reliance.

7.3.5.4. Establishment of General Facilities

It was pointed out earlier that, to help small scale units, there is a need for establishing centralised facilities for design and development, workshop and tooling, and test and calibration. At least six such facilities should be provided in Fifth Plan period. Four of these should be established by augmenting the present facilities at IDEMI, CSIO, CMERI and IISc.

Electronics Commission has approved the setting up of centralised Test and Development centres in all States, as and when the growth of the electronics industry in small scale becomes substantial. The main function of such centres will be testing, calibration and product development. Twelve such centres are envisaged in Fifth Plan period in which the total capital cost would be Rs. 3 crores—Rs. 2 crores to be given as a grant by Department of Electronics and the remaining Rs. 1 crore as an outlay by the State Governments. While setting up these facilities, the specific needs of the process control instruments industry should be kept in mind.

7.3.5.5. Technology Development

Considering the anticipated instrumentation requirements in the next ten years, for the attainment of self-reliance and self-sufficiency, the present technology development efforts will have to be considerably augmented and reoriented.

Modifications of the present development programme are necessary to : (i) have an innovation chain which is geared to continually up-date the present products, (ii) ensure speedy and economic development of new equipment capable of commercial production, (iii) acquire adequate experience in the application of on-line digital computers, and, (iv) adequately examine technology advancements for possible exploitation in the post 1980 period.

The likely technology trends during the Fifth and Sixth Plan periods and modifications that would be necessary to the development and production programme are given below.

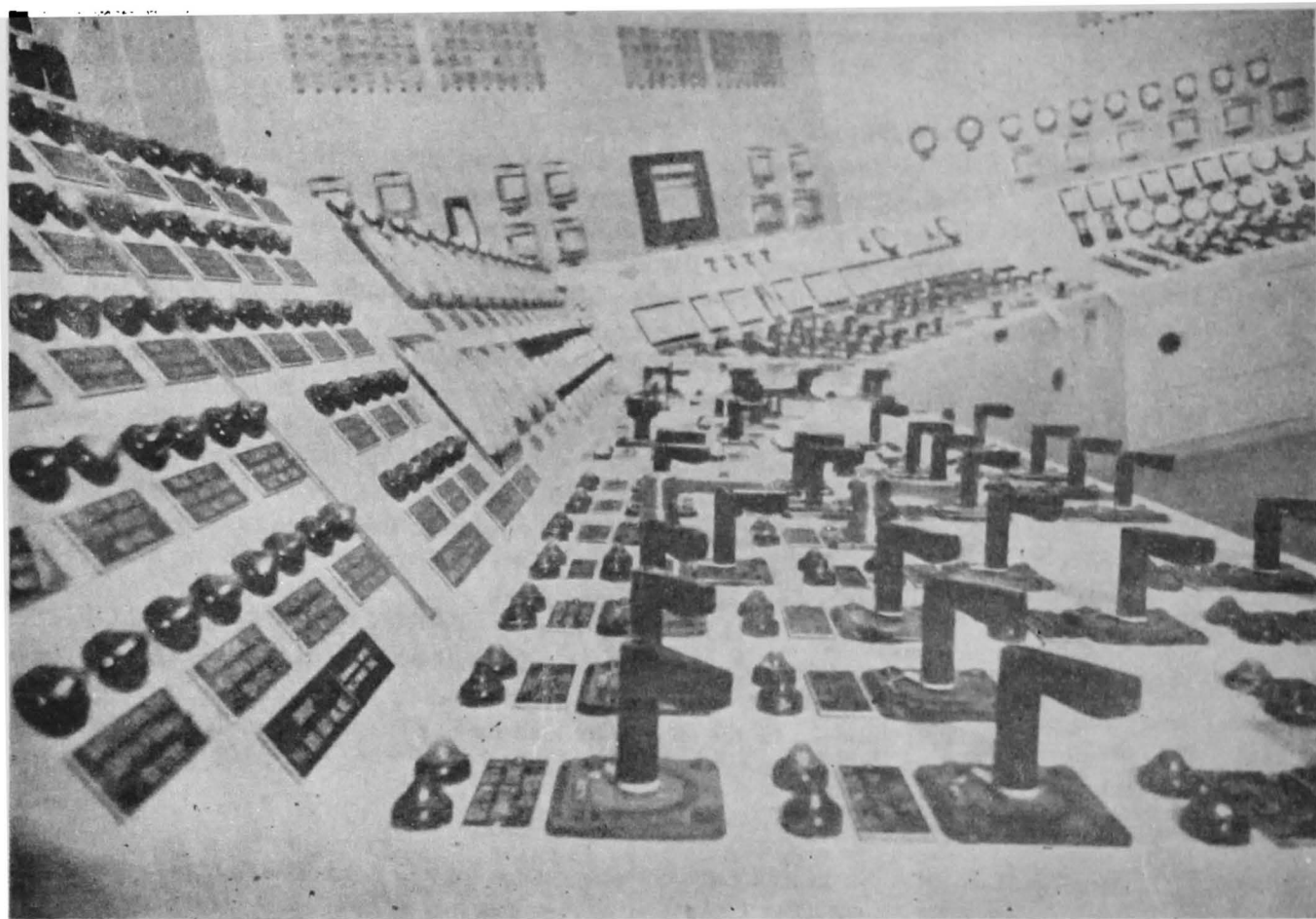
Electronics and pneumatics

It is visualised that although both electronic and pneumatic systems will concurrently be in usage, the electronic systems will predominate over pneumatic systems.

Instrument designs may be either modular or unitised. The exact construction for each instrument will depend on complexity, use requirement, economies of production and other such factors. However, it is expected that progressively greater accent will be placed on modular approach.

Building blocks for both electronic and pneumatic systems are presently manufactured in the country. However, the electronic building blocks need to be designed afresh, based on the adoption of unified current system.

For the various building blocks that are required in the electronic and pneumatic product range as well as for items like annunciators, it is considered desirable to have at least two sources in the country so as to ensure constancy of supply despite manufacturing and labour problems.



Control Panel of the Rajasthan Atomic Power Plant.

Computers, Data Loggers and Digital Blending Systems

In the Fifth and Sixth Plan period a number of Indian process plants will require the use of computers and data loggers. Even for export of instrumentation systems, the need has already been felt for on-line computers which are now being provided through imports. ECIL has plans to manufacture small and medium sized third generation computers. ECIL has already started marketing its minicomputers TDC 12 and TDC 16 for on-line process control and data logging applications, and the development of TDC 32, the third generation computer, for real time and general purpose applications is nearing completion.

Many countries have now introduced digital blending systems. They were originally developed for the oil refineries and are capable of high accuracy. In recent years, these systems have been utilised in chemical, synthetic fibre, cement and other process industries.

ECIL is presently working on digital blending and on-line computer fields and has plans to have some operational systems by 1975 covering computerised guidance, set point control and possibly direct digital control.

ECIL has assumed the responsibility of developing and producing digital computers for several process control applications. In this process, various development work packages have been released to IITs and other similar institutions, whose activities ECIL is now coordinating. Digital computers

for on-line process control and data logging will be one of the regular products of ECIL.

Miniaturisation

Since instruments will take a larger share of the plant investment, it is natural to assume that they will consume larger share of the space in the plant equipment. In order to maintain their accuracy, instruments need controlled environment. Hence, there will be an increased demand to reduce the size of the instrument. Miniature and graphic display units will soon replace the large-sized units used presently.

The prime factor which will contribute to the reduction of size will be the use of integrated circuits. In the coming years, it is certain that integrated circuits will be widely used in the electronic subassemblies required in process control instruments. Once prices come down, new electronic subassemblies design and development will make use, almost exclusively, of integrated circuits. The advantage in reliability, size, speed and eventually, cost are such that if compared to discrete components, there is no doubt that these components will be widely used.

Indigenous manufacture of integrated circuits can be expected shortly. The progress of such manufacture has to be critically monitored such that availability in large numbers of a variety of products is certain in the near future. In the alternative, adequate provisions must be made for the import of integrated circuits.

Fluidics

Large sums are currently being spent abroad in R&D activity pertaining to fluidics. Fluidics is a new tool for control, barely ten years old. In this short span of time its impact has been substantial in a large number of application areas including process control, aerospace, machine tool control and materials controls. The great promise of fluidics is high reliability at low cost in normal, hazardous or extreme environments, due to the absence of moving parts.

Fluidics is still a very young technology in comparison with electronics. It is now accepted that fluidics will not replace electronics, as was predicted earlier, but that it will find its own place, side by side, with other tools of control.

It will be worthwhile for India to conduct feasibility studies and closely follow the development abroad, to enable us to assess possible application in the post 1980 period.

Preliminary studies of fluidics should be entrusted to a suitable agency. It is understood that some work in this area is already, underway at IIT Bombay, IISc, BARC, NAL and CMTI. Coordination of work in this field should be entrusted to CSIO, who may, in turn, form out some tasks of basic nature to academic institutions, under appropriate grant-in-aid schemes.

System Engineering, Simulation and Synthesis

With the accent on the development of complex and large process systems indigenously, the need would arise to develop the optimum control and surveillance system configurations to suit their specific needs. As an example, if indigenous design and manufacture of large thermal power plants are contemplated, it would be necessary to design suitable control systems for

them. Such systems would have to be proven out and refined through simulation and test-bed studies.

Other Areas

R&D efforts should also be directed towards the human and presentational aspects of control panels and instruments to examine the manner in which the information should be presented to the plant operator, design of instrument scales and operation controls, and clustering and layout of instruments on a panel for optimum panel-operator interface.

Efforts should also be put in with respect to the development of diagnosing and self-diagnosing instrumentation systems so that maintenance can be carried out with minimum down-time and cost. This work can be entrusted with IITs and IISc., for ultimate production by ECIL.

7.3.5.6. National Automation and Control Agency

Keeping in view the various problems and gaps in technology identified earlier, the Electronics Commission has proposed to launch an independent authority called the National Automation and Control Agency (NACA), involving various sectors of the national economy not only to plan and guide the growth of the instrumentation and control technology, but also to promote the right kind of productive-automation in the country.

The National Automation and Control Agency will initially act as a central focus for automation information, planning and promotion and eventually act as an apex body for planning and monitoring the entire field of automation and control with regard to technology development, industrial activities and manpower problems; for formulating plans for introducing the right kind of automation and control technology in various sectors of the economy and for directing the implementation programmes in coordination with other implementation organisations. The ultimate objectives of this agency will be as follows:

(i) To review the present status of automation and control technology with regard to research, development and industrial operation, and to formulate policies in this field, to direct implementation, in coordination with various implementation bodies, on sound economic and technical principles, that are necessary for the country to attain higher productivity and sound economy.

(ii) To evaluate continuously the socio-economic impact of automation on different sectors of the national economy with particular reference to productivity gains, employment, labour and management problems and to work out programmes for the promotion of an 'active manpower policy'.

(iii) To coordinate the existing system engineering consultancy services and augment them adequately, particularly keeping in view the minicomputer process control applications, in order to help and guide the on-going and proposed plant-installation projects and also the turn-key projects undertaken outside the country.

(iv) To draw up and organise comprehensive education and manpower training programmes at various levels, including courses at educational institutions, research projects, in-plant training programmes in both production units as well as process industries.

(v) To install and maintain a continuously updated information system on all aspects of automation and to promote the industry by setting up a technology exhibition centre of automation techniques and practices on a classified basis to include all aspects of industrial electronics and control technology.

(vi) To organise workshops, seminars, conferences, short-term training courses, audiovisual programmes, etc., to create automation consciousness wherever beneficial.

(vii) To liaise with concerned ministries, Government departments, development and production agencies, process and other industries, educational institutions, labour organisations and international centres on automation and control, and to coordinate the activities of these agencies related to this field.

Based on the above objectives, the National Automation and Control Agency will have the following four groups for carrying out different activities:

1. Planning and Promotion Group
2. Socio-economic Impact Evaluation Group
3. System Engineering Coordination Group
4. Education, Information and Exhibition Group

7.3.6. Investment and Production Profile

7.3.6.1. Production

It is expected that the industry would produce equipment worth Rs. 122 crores during Fifth Plan. This also includes system engineering and project services that would be covered in this period. The total imported equipment content for Fifth Plan, based on the present status of manufacturing, is Rs. 35 crores. It is envisaged that the indigenisation plan suggested in the earlier section would bring down the import content to at least Rs. 22 crores. This is a conservative estimate and a much more import reduction is expected if the import reduction plan is fully implemented. The export through local production in Fifth Plan period is expected to be about Rs. 5.5 crores. In view of this, the total local production would be of the order of Rs. 122 crores. The ten year production profile for process control instruments industry is shown in Table 7.21. It is assumed that the production will reach Rs. 72 crores by the end of Sixth Plan.

Table 7.21. Ten year profile for process control instrumentation
(All figures in Rs. Crores. Figures in bracket indicate FE content).

	1974-75	1975-76	1976-77	1977-78	1978-79	—	1983-84
1. Total local demand	23.0	25.0	27.5	30.5	34.0	—	70.0
2. Total direct import of parts and products*	5.0	5.0	4.5	4.0	3.5	—	5.0
3. Export through local production	0.5	0.5	1.0	1.5	2.0	—	7.0
4. Export through free-trade-zones	—	—	—	0.5	1.0	—	3.0
5. Total local production**	18.5	20.5	24.0	27.0	32.5	—	72.0
6. Investment for local production	4.0	4.5	5.0	5.5	5.0	—	20.0
	(0.4)	(0.5)	(0.5)	(0.5)	(0.5)	—	(2.0)
7. Investment for technology development, manpower training and coordination	0.75	0.75	1.0	1.0	1.0	—	2.0
	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	—	(0.2)

* Excluding instrumentation imported as integral parts of the process plants.

** Including engineering and project services.

The ratio of capital investment in machinery to annual output of this industry varies from 0.5 to 1. This means that in order to produce Rs. 32 crores of equipment in 1978-79, an investment of about Rs. 24 crores will be necessary. Approximately 10 per cent of this will be required in FE. Table 7.21 gives the ten year investment profile.

7.3.6.2. Technology Development

The present R&D investment in process control instrumentation is about Rs. 40 lakhs, with about 40 scientists and engineers committed to this activity.

For carrying out the multi-faceted R & D activity required to sustain the production programme (including system engineering, project services, manpower training and coordination) of Rs. 122 crores during the Fifth Plan, and to build up the infrastructure for further expansion in the Sixth Plan period, an R&D investment of Rs. 4.5 crores (about 4 per cent of the total expected value of production) will be needed for the Fifth Plan period.

The R&D investment profile is shown in Table 7.21. Optimum results are likely to be secured by investing 80 per cent of the expenditure on R&D activities carried out at production units and 20 per cent on R&D carried at academic institutions, existing R&D laboratories active in the area, and the proposed automation and control laboratories.

The above level of funding implies that the R&D investment, at the production units will be about Rs. 3.6 crores with 100 scientists and engineers dedicated to this activity. The major part of this amount should be spent at IL and ECIL. R&D departments of both units should be augmented and provided with the necessary capital equipment, manpower, buildings and other facilities.

The total quantum of R&D investment in the academic institutions and national laboratories will be about Rs. 0.9 crores (20 per cent of total R&D investment) during the Fifth Plan with a commitment of about 50 scientists and engineers.

In addition to CSIO, academic institutions and research laboratories should be identified for R & D activity in the field of process control instrumentation. For each of these institutions sustained funds should be provided for at least five years. Each institution will have freedom to operate within an agreed framework, but towards well-defined goals. Coordination of all activities in this connection should be done by the Department of Electronics.

7.3.6.3. Manpower Training

It is necessary to orient the faculty members in academic institutions as well as R&D personnel from automation and control laboratories towards the needs of the process control instrumentation industry. It is equally necessary however, to expose industry-based R&D personnel to the academic environment. For this purpose, exchange programmes, seminars, short-term courses and workshops are needed on a continuing basis during the Fifth Plan period. In some specialised areas, it may be required to send personnel, abroad or to have foreign experts visit the country. The investment on this programme may be about Rs. 20 lakhs. The investment needed during the Fifth Plan to train the required addition manpower would be about Rs. 30 lakhs.

7.3.6.4. Investment Programme for NACA

The National Automation and Control Agency is proposed to be an independent organisation under the Electronics Commission. Under the approved programme of the Planning Commission, the proposed investment on this project is Rs. 1.8 crores during the Fifth Plan period. It is anticipated that NACA will launch several sponsored projects including central automation and control laboratories, a centre for system engineering activities and also the manpower training and retraining programmes.

VIII

Industrial Electronics

8.1 Introduction

Automation is universally recognised as a new branch of Science and Technology which is one of the mainsprings of technological progress. As such, it ranks in importance with such new areas as atomic energy, space and electronics. In the highly industrial countries automation has accelerated at a rapid rate leading to an unprecedented increase in the productivity of labour, a buoyant economy, and a sharp rise in the standard of living. The core technology on which automation rests is the 'industrial electronics and controls', which is one of the most heterogeneous technologies. It encompasses numerous scientific and engineering disciplines principally centred around electronics but covering many industrial applications.

In spite of its large techno-economic and social implications, the development of industrial electronics and control technology has not received sufficient attention in the country until recently. There was no mention of this field in the Bhabha Committee Report or in the Proceedings of the National Conference on Electronics. Also, although industrial electronics and control technology has continued to evolve without respite for the last several years, Indian industry has been slow to utilise its benefits. This must be attributed in part to the fact that both our electronics engineers and planners have devoted their attention mainly to low-power applications of electronics such as entertainment, communications, instrumentation and computers, while power and process engineers, wedded to conventional electrical, mechanical and pneumatic equipment, lacked the necessary background and training for the speedy introduction of the new technology in the industry. As a result, development efforts have suffered and it is only relatively recently that planning organisations, R&D institutions and industrial establishments have begun work in this field.

It is important that in the coming years adequate inputs are provided for the development of this area so that development abroad, both in design and fabrication as well as in the application of industrial electronics and control equipment, are applied to our own industrial structure at the most appropriate pace and manner. This chapter presents a first approximation strategy for this purpose, and complements and supplements the previous chapter which concerned itself with two important control areas, namely, (a) instrument servo components and (b) process control instrumentation. The chapter is divided into the following six sections :

- (i) Industrial drive control
- (ii) Numerical control
- (iii) Induction and dielectric heating
- (iv) Mining electronics
- (v) Pollution monitoring
- (vi) Agri-electronics

8.2 Industrial Drive Control

One of the most significant facts that has to be appreciated in the matter of industrial drive control equipment is the new 'power electronic' technology, which has emerged in recent years as a discipline by itself. This has brought together two types of people namely electrical engineers and electronics engineers/physicists, who are trained in two different ways. The electrical engineer, for example, acquires skills mostly mechanical engineering in nature and handles mate-

rials like copper and steel in weights of pounds and kilograms and works in ordinary clean rooms. The electronic engineer/physicist, on the other hand acquires skills of experimental physics and circuitry and uses materials like germanium and silicon of purities of the order of 99.99 per cent and handles weights in ounces and grams and works in dust free atmosphere and clean rooms. The marriage of these two disciplines has yielded remarkable results. The electrical engineer who was working with noisy and bulky equipment can now work with compact and noiseless ones, thus bringing about a 'silent' revolution in electrical engineering. The replacement of the motor generator set in the Ward-Leonard system of control by a compact power electronic equipment using thyristors is notable example of this. On the other hand, the electronic engineer/physicist can now work with circuits of kilowatts of power along with those of milliwatts and watts. Power electronics is steadily replacing conventional methods by static semiconductor equipment for practically every type of motor drive. The impetus for this major trend arises from the progress in silicon power devices of which the thyristor is the outstanding example. Individual thyristors with current ratings exceeding 500 amperes are now available from existing production. Forward and reverse voltage ratings exceeding 3,000 volts are available in thyristors. As a result, static power converter modules, capable of controlling large motor drives, are now possible without the need to have series and/or parallel combinations of thyristors. With multiple thyristor elements (parallel and/or series connected) very large units are presently being designed and constructed for large drives of several thousand horsepower ratings such as are needed for steel and other metallurgical industries. Parallel progress in integrated circuits, both linear and digital has considerably simplified both the design and fabrication of fully static electronic control cards for the reliable and accurate performance of thyristor equipment. The future requirements will be mainly for drive control equipment using the new technology because of better efficiency, limited requirements of space, absence of noise and vibrations and easier servicing and maintenance.

Recent progress in circuit techniques for 'forced commutation' has improved the speed and respective switching capability of thyristors. From this point of view considerable attention is being devoted to improving the performance specifications of 'fast turn off' (inverter grade) thyristors. As a result of the progress in forced commutation techniques and 'fast turn off' thyristors, drive control equipment using the 'chopper' and 'inverter' techniques are gaining prominence. Currently thyristor 'chopper' converters are being used for DC motor drives from battery trucks to electric motor coaches in railway traction. Regenerative braking is easily incorporated in chopper systems, thereby achieving economy in energy consumption. In each case planning should be directed towards objectives in both R&D and manufacture.

8.2.1. Scope and Classification

A drive is a means of converting power (electric, hydraulic, pneumatic or other) to mechanical form. An industrial drive here is identified as a drive used for industrial applications. The term 'industrial drives and control' is used here to mean a combination of an industrial drive and the associated control equipment to provide the required performance. Motors without any kind of control system are not considered in detail and the switchgear for these are mentioned in passing.

The types of industrial drives and controls will include all categories of drive systems—electrical, electronic, electromechanical, electrohydraulic, pneumatic or fluidic. Motors used for instrumentation, measurement and display are not considered as industrial drives. Drives based on fossil fuel combustion are also not dealt with.

VIII

A list of typical industries covered in this report is given in Table 8.1. Broad classification of drives is given in Table 8.2 and detailed classification in Table 8.3.

Table 8.1. List of typical industries covered.

1. Iron and steel manufacture
2. Textile manufacture
3. Paper and pulp manufacture
4. Machine tool manufacture
5. Mining industries
6. Cement manufacture
7. Railway traction (electric)
8. Petrochemical industries
9. Sugar manufacture
10. Fertiliser manufacture
11. Heavy engineering

Table 8.2. Classification of industrial drives (energy).

1. Electrical	AC Special DC
2. Hydraulic	Rotary Linear
3. Pneumatic	Rotary Linear
4. Fossil Fuel *	Petrol Diesel Natural gas Coal

* This is outside the purview of this report.

Table 8.3. Classifications of industrial drives (actuator).

- | |
|----------------------------------|
| A. AC Motors |
| 1. Squirrel cage induction motor |
| 2. Wound rotor induction motor |
| 3. Synchronous motor |
| 4. Schrage motor |
| 5. Single phase motor |
| 6. AC Servomotor |
| B. DC Motors |
| 1. Shunt motor |
| 2. Series motor |
| 3. Separately excited motor |
| 4. Compound motor |
| 5. Brushless DC motor |
| 6. DC servomotor |
| C. Special Motors |
| 1. Stepper motor |

VIII

2. Linear motor
3. Universal motor
4. Hollow rotor motor
5. Printed circuit motor

D. Hydraulic Actuators

1. Gear rotary motor
2. Vane type rotary motor
3. Radial piston motor
4. Radial cam motor
5. Axial swash plate motor
6. Radial vane motor
7. Ram linear jack
8. Axial piston motor

E. Pneumatic Actuators

1. Motor
2. Linear actuator

-
- Notes:* (i) Gear motor, clutch and brake motor may belong to any one of the above three categories.
- (ii) Torque motors are specially designed for prolonged stall or for certain special running characteristics.
- (iii) Multispeed motors are special AC motors with tap changing provision.

The drives mentioned in Tables 8.2 and 8.3 are all controlled in respect of their speed, torque, horsepower and overall performance. Overall performance is an important factor governed by the duty cycle of operation, acceleration, deceleration, response time, starting torque, breakdown torque and heat dissipated in the motor for a given industrial application. The control system that is needed for the drive, for a specific performance, therefore, occupies an important role. Methods available for control of speed of industrial drives are listed in Table 8.4.

Table 8.4. Adjustable speed drives.

-
1. Electrical
 - 1.1 Adjustable DC voltage drive
 - 1.1.1 Motor generator drive
 - 1.1.2 Electronic tube drive
 - 1.1.3 Magnetic amplifier drive
 - 1.1.4 Controlled rectifier drive
 - 1.1.5 Amplidyne control drive
 - 1.1.6 Chopper system (a version of controlled rectifier drive)
 - 1.2 Adjustable frequency AC drive
 - 1.2.1 Motor alternator drive
 - 1.2.2 Rectifier inverter drive
 - 1.2.3 Cycloconverter (wave converter drive)
 - 1.3 Wound rotor drive (AC)
 - 1.3.1 Resistance controlled drive
-

VIII

- 1.3.2 Phase controlled drive
 - 1.3.3 Power controlled drive
 - 1.4 Eddy current clutch drive
 - 1.4.1 Aircooled drive
 - 1.4.2 Water cooled drive
 - 1.5 Special motors
 - 1.5.1 Bipolar stepper motor drive
 - 2. Mechanical
 - 2.1 Gear drive
 - 2.2 Belt drive
 - 2.3 Pulley drive
 - 3. Electrohydraulic
 - 3.1 Hydraulic rotary drive (valve controlled)
 - 3.2 Linear actuator drive (valve controlled)
 - 4. Electropneumatic
-

Table 8.5 provides the typical control systems that are used normally, in the various industries listed in Table 8.1. It is observed from Table 8.5 that essentially most industries need DC motors in addition to AC motors. From the control system point of view for these motors, by and large, thyristor drives (also called SCR drives) occupy an important role. In many industries, such as cement and mining, control system (resistant control drive) continues to be used. The other types of control systems listed in Table 8.5, (a) either have no future, or (b) need only spares to be provided for, or (c) are currently under development and will be definitely needed in another five years. Motor generator/alternator systems, magnetic amplifiers and amplidyne control systems come under (a) above. Spares for these are also not recommendable.

In respect of electronic tube drives (including thyratron type controls) spares are to be provided, as presently industries are facing difficulty in keeping these systems working. Stepper motor drives, wave converter drives, eddy current clutch drives, etc., are presently in developmental stage and full scale exploitation of these systems may not materialise before 1978-79.

8.2.2. Demand Profile

In the following sections the requirements of various industrial sectors are assessed based on the present investments, the present production rates and capacities, and the projected growth rates as given by various Government, and public documents (references). In the absence of published/communicated information, the growth rate is tacitly assumed to be 10 to 15 per cent per year.

The industries listed in Table 8.1 are taken for a detailed study and projection of demand for a Five Year period. These industries are chosen in view of their large capital investment in respect of industrial drives and control and complexities in control. The drives needed in general for small scale industrial workshops, R&D establishments, agricultural sectors and the like are not considered.

VIII

Table 8.5. Control systems used in industries.

No.	Nature of industry	Types of motors used*	Types of control systems used**
1.	Iron and steel	A and B	(1.2.1), (1.2.2), (1.1.1), (1.1.4)
2.	Textiles	A and B	(1.2.2), (1.1.4), (1.4.1), (3.2)
3.	Paper and pulp	B	(1.1.4), (1.4.1), (1.1.5)
4.	Machine tools	A, B, C and D	(1.1.4), (1.2.2), (1.5.1), (3.1), (3.2)
5.	Mining industry	A	(1.2.1), (1.3.1)
6.	Cement manufacture	A and B	(1.3.1), (1.1.4)
7.	Railway traction (electric)	B	(1.1.4), (1.1.6)
8.	Petrochemicals	A	(1.3.1)
9.	Sugar manufacture	A	(1.3.1), (1.2.2)
10.	Fertiliser	A	Switchgear control is adequate for all the drives.

* Alphabets designate the type of motors indicated in Table 8.3.

** Number in brackets designates the control system indicated in Table 8.4.

Notes: (i) It is observed that presently drives (1.1.5), (1.1.3), (1.1.2) are in use in some industries. However, these are gradually becoming obsolete and will be replaced by (1.1.4).

(ii) No speed control of drive appears to be necessary for Nos. 5, 8, 9 and 10. However, systems (1.3.1) and (1.1.1) are considered quite adequate. Industries Nos. 5 and 9 are in need of vibrators (electromagnetic type) which is outside the purview of this Report.

Iron and Steel

Production of finished steel in 1970-71 has been 4.48 million tons (MT). The Fifth Five Year Plan envisages production of 8.9 MT of finished steel requiring a doubling of existing production. Based on the above, and the information provided by the Ministry of Heavy Industries, Mysore Iron and Steel Ltd. Bhadravati and BHEL, the following estimates have been arrived at.

A projected total motor capacity will be 1,600,000 kW with the individual capacities as indicated in Table 8.6. Of these, nearly 60 per cent would be in DC machines and the rest in AC machines. The total estimated values of the drives and control are Rs. 108.6 crores and Rs. 31.6 crores, respectively.

Table 8.6. Drives and controls for iron and steel industry.

Motors (quantity)		Quantity and type of control system						
AC	DC	Motor alternator (1.2.1)*	Rectifier inverter (1.2.2)	Motor generator (1.1.1)	Controlled rectifier (1.1.4)	Switchgear controlled (SGC)	Estimated cost (excluding SGC) (Rs. crores)	
							Motors	Control
50(a)	60(a)	—	10	45	15	49(AC)	33.4(AC)	0.6(AC)
800(b)	1000(b)	—	—	—	1000	800(AC)	42.8(DC)	29.4(DC)
16,000(c)	20,000(c)	—	—	—	2000	16000(AC) 18000(DC)	14.4(AC) 18.0(DC)	1.6(DC)
Total cost							108.6	31.6

*Number in brackets designates the control system indicated in Table 8.4

Notes: (i) 'a' stands for motors 1000 kW and above (averaged at 1500 kW).

(ii) 'b' stands for motors between 100-1000 kW (averaged at 500 kW).

(iii) 'c' stands for motors upto 100 kW (averaged at 20 kW).

(iv) Only 20 per cent of AC motors of 100 kW and above are speed controlled. The rest are switchgear controlled.

(v) 75 per cent of DC motors of 1000 kW and above are motor-generator driven. Rest are SCR controlled.

VIII

- (vi) 100 per cent of DC machines between 100-1000 kW are SCR controlled.
- (vii) 10 per cent of DC machines below 100 kW are SCR controlled. Rest are switchgear controlled.
- (viii) 25 per cent of AC motors above 1000 kW are taken for inverter-rectifier drive. Rest are switchgear controlled.
- (ix) Table 8.17 details the unit costs assumed to arrive at cost estimates.

Textiles

At present, there are about 300 composite textile mills in the country. The value of textile machinery produced in 1969-70 was to the tune of Rs. 6 crores. On the assumption of 5 per cent growth rate, the present production (1974-75) is estimated at Rs. 7.5 crores. Assuming the same growth rate during the Fifth Plan period, the terminal year production would be nearly Rs. 9 crores, and the total Plan period production about Rs. 40 crores. The cost of drives and control expressed as the percentage of the total cost of textile machinery is found to vary between 12 and 15 per cent. Thus on an average the total Fifth Plan demand for industrial drives and controls works to be about Rs. 5.5 crores.

On this basis and considering typical textile mill drive constituent, Table 8.7 has been arrived at. Of the Rs. 5.5 crores requirement, nearly 20 per cent is expected to be for control systems.

Paper and Pulp

The existing capital investment in paper and pulp product manufacture amounting to 10 lakh tonnes installed capacity, is about Rs. 132 crores. Assuming a growth rate of 15 per cent per annum during next five years, an additional Rs. 70 crores would be required to produce about 16 lakh tonnes of paper and pulp products.

Of the new investments in paper and pulp product manufacture, about 2 per cent is likely to be for industrial drives and 2 per cent for controls. The latter is a necessity in view of extreme complexities in sectional drive requirements. Rs. 1.25 crores worth of drives and Rs. 1.2 crores worth of control equipment would be required during the Plan period. The breakup of this is indicated in Table 8.8.

Machine Tool

The present production capacity of machine tool manufacturing firms is about Rs. 45 crores per year at the current prices. It is envisaged that a production of Rs. 100 crores per year will be achieved by the end of the Fifth Plan period. The total production of machine tools during the Fifth Plan period is likely to be about Rs. 300 crores. Typically 10 per cent of this is likely to be on the drives and their control. Thus a sum of Rs. 30 crores will be required for drives and their control components for the machine tool manufacturing industry. Table 8.9 provides the breakup of motor and control requirements.

Mining

Major mining activities are for coal, iron ore and lime stones. Coal is mined in about 750 coal mines to produce nearly 90 MT annually. Limestone produced in the country is about 2 MT annually. Other minerals like bauxite, manganese, dolomite, gypsum, etc., have a production of about 1 MT annually.

Mining activities require industrial drives for ventilation fans, winch motors, coal washeries, conveyors and crushers. Table 8.10 provides a breakup of motor requirements, and controls. The cost of motors is estimated at Rs. 9.6 crores and controls at Rs. 12 lakhs.

Cement

At present, there are about 60 cement producing units in the country. So far as the growth rate of cement production is concerned, it is observed that production of cement has gone up from 6 lakh tonnes in 1930 to 16 million tonnes in 1972-73, the actual installed capacity being even more. Presently, cement machinery of the order of Rs. 7 crores is being manufactured annually in the country. On this basis, the total production of cement machinery during the Plan period is expected to be around Rs. 40 crores. About 7 per cent of this is assumed to be the cost of drives and controls. Table 8.11 provides a breakup of drives and controls required for the industry.

Railway Traction (Electric)

The Indian Railways are going in for additional thyristor controlled locomotives for main line AC traction and thyristor chopper controlled motor coaches for DC suburban traction system. The demand for drives and controls for traction has been assessed and presented in Table 8.12. Rs. 4.5 crores worth of DC motors and Rs. 4.5 crores worth of SCR control gears are needed during the Plan period.

Petroleum

There are at present, 9 refineries in operation and 2 under construction. At the end of 1972, the total capacity of 9 refineries was 20 million tonnes and the crude processed during 1972 was about 19.7 million tonnes. Data obtained from these refineries indicate a substantial requirement of AC motors. In petroleum industry, most of the motors are switchgear controlled. Table 8.13 provides a breakup of drives requirement.

Sugar

Annual production of sugar in the country is about 35 lakh tonnes which is likely to be enhanced to above 50 lakh tonnes at the end of the Fifth Plan. The cost of sugar machinery manufactured per year amounts to about Rs. 7 crores. During next five years about Rs. 40 crores worth of sugar machinery may be manufactured out of which 5 per cent is likely to be for industrial drives. Thus about Rs. 2 crores worth of motors, with a total capacity of 40,000 kW as detailed in Table 8.14, are required.

Fertiliser

The present production of nitrogenous and phosphoric fertilisers is about 7,000 tonnes per day (tpd). The Fifth Plan target of 17,000 tpd requires additional capital investment to produce the extra 10,000 tpd fertilisers. Based on the data (for a typical 2,000 tpd plant) given by FACT engineering and design organisation, Table 8.15 has been arrived at. Because of the chemical environment, all the motors are AC and switchgear controlled.

Total Demand Forecast

Based on the detailed individual estimates for the various industries, the overall drives requirements of the country are stated in Table 8.16 under various categories. The total demand of drives works out to be about Rs. 200 crores during 1974-79. The attendant demand and electronic control equipment during this period would be about Rs. 60 crores.

VIII

Table 8.7. Drives and controls for textile industry.

Motors (quantity)		Quantity and type of control system				Estimated cost (Rs. crores)	
AC	DC	Rectifier (1.2.2)*	Eddy current (1.4.1)	Controlled rectifier (1.1.4)	Switchgear controlled (SGC)	Motors	Control
400(a)	100(a)	40	40	100	320(AC)	4.05(AC)	0.48(AC)
1000(b)					1000(AC)	0.40(DC)	0.60(DC)
6000(c)					6000(AC)		
Total cost						4.45	1.08

Notes : *Number in brackets designate control systems indicated in Table 8.4.

- (i) 'a' stands for motors of 100 kW.
- (ii) 'b' stands for motors with an average capacity of 20 kW.
- (iii) 'c' stands for motors with an average capacity of 5 kW.
- (iv) 10 per cent of AC motors of 100 kW capacity are controlled by rectifier-inverters, 10 per cent of the same are clutch controlled and the rest are switchgear controlled.
- (v) Table 8.17 details the unit costs assumed to arrive at cost estimates.

Table 8.8. Drives and controls for paper and pulp industry.

Motors (quantity)		Quantity and type of control system		Estimated cost (Rs. crores)	
AC	DC	Controlled rectifier	Eddy current clutch (1.4.1)*	Motors	Control
Nil	150(a)	150	—	1.25(DC)	1.20(DC)
	750(b)	675	75		
Total cost				1.25	1.20

Notes : *Numbers in brackets designate control systems indicated in Table 8.4.

- (i) 'a' stands for motors with an average capacity of 100 kW.
- (ii) 'b' stands for motors with an average capacity of 20 kW.
- (iii) 10 per cent of DC motors with average capacity of 20 kW are clutch controlled and the rest are rectifier controlled.
- (iv) Table 8.17 gives the details of the unit costs assumed to arrive at cost estimates.

Table 8.9. Drives and controls for machine tool manufacturing industries.

Motors and actuators		Type and quantity of control system					Estimated cost (excluding SGC) (Rs. crores)	
Electric	Hydraulic	Rectifier-inverter (1.2.2)*	Controlled rectifier (1.1.4)	Stepper motor (1.5.1)	Servo/Solenoid drive motors	SGC	Motors	Controls
150000(a)		5000	—	—	—	145000	20.00	0.90
1000(b)		—	1000	—	—	—	0.12	0.18
500(c)		—	—	500	—	—	0.15	0.60
	5000(d)	—	—	—	5000	—	1.50	0.40
	10000(e)	—	—	—	10000	—	1.50	4.50
Total cost							23.27	6.58

Notes : *Numbers in brackets designate control systems indicated in Table 8.8.

- (i) 'a' stands for motors of 3 kW capacity (AC machines).
- (ii) 'b' stands for motors of 5 kW capacity (DC machines).

VIII

- (iii) 'c' stands for stepper motors of all capacities.
 (iv) 'd' stands for hydraulic motors of all capacities.
 (v) 'e' stands for hydraulic linear actuators.
 (vi) Table 8.17 gives the details of unit costs assumed to arrive at cost estimates.

Table 8.10. Drives and controls for mining industry.

Motors (quantity)		Quantity and type of control system		Estimated cost (excluding SGC) (Rs. crores)	
AC	DC	Motor alternator	Switchgear control	Motors	Control
200(a)			200		
200(b)	Nil	20	180	9.60(AC)	0.12(AC)
1000(c)			1000		
Total cost				9.60	0.12

- Notes : (i) 'a' represents motors with an average capacity of 500 kW.
 (ii) 'b' represents motors with an average capacity of 200 kW.
 (iii) 'c' represents motors with an average capacity of 100 kW.
 (iv) 10 per cent of AC motors with an average capacity of 200 kW are motor alternator controlled, the rest are switchgear controlled.
 (v) Table 8.17 details the unit costs assumed to arrive at cost estimates.

Table 8.11. Controls and drives for cement industry.

Motors (quantity)		Type and quantity of control systems		Estimated cost (excluding SGC) (Rs. crores)	
AC	DC	Switchgear control	Controlled rectifier	Motors	Control
—	50(a)	—	50	0.708(AC)	—
75(b)	—	75	—	1.000(DC)	1.000(DC)
480(c)	—	480	—		
Total cost				1.708	1.000

- Notes : (i) 'a' represents motors with an average capacity of 500 kW.
 (ii) 'b' represents motors with an average capacity of 200 kW.
 (iii) 'c' represents motors with an average capacity of 5 kW.
 (iv) All the DC motors are rectifier controlled.
 (v) Table 8.17 details the unit costs listed on which cost estimates have been prepared.

Table 8.12. Control and drives for railway traction (electric).

Motor (quantity)		Type and quantity of control systems		Estimated cost (Rs. crores)	
AC	DC	Controlled rectifier (1.1.4)*	Chopper system	Motor	Control
Nil	150(a)	120	30	4.5(DC)	4.5(DC)
Total cost				4.5	4.5

VIII

Notes: * Numbers in bracket designate control systems initiated on Table 8.4.
 (i) 'a' represents motors with an average capacity of 750 kW.
 (ii) 20 per cent of the motors are controlled by chopper system.
 (iii) Table 8.17 details the unit costs based on which estimates have been prepared.

Table 8.13. Controls and drives for petrochemical industry.

AC motors with average capacity (in kW)	Quantity	Estimated cost (Rs. crores)
500	7	0.14
100	700	2.80
5	700	0.28
Total cost		3.22

Notes: (i) All motors are assumed to be controlled only by switchgear.
 (ii) Table 8.17 details the unit costs assumed in the cost estimates.

Table 8.14. Controls and drives for sugar industry.

AC motors with average capacity (in kW)	Quantity	Estimated cost of motors (Rs. crores)
50	600	1.35
5	2000	0.45
Total		1.80

Notes: (i) All the AC motors are assumed to be switchgear controlled.
 (ii) Table 8.17 details the unit costs based on which cost estimates have been made.

Table 8.15. Drives and controls for fertiliser industry.

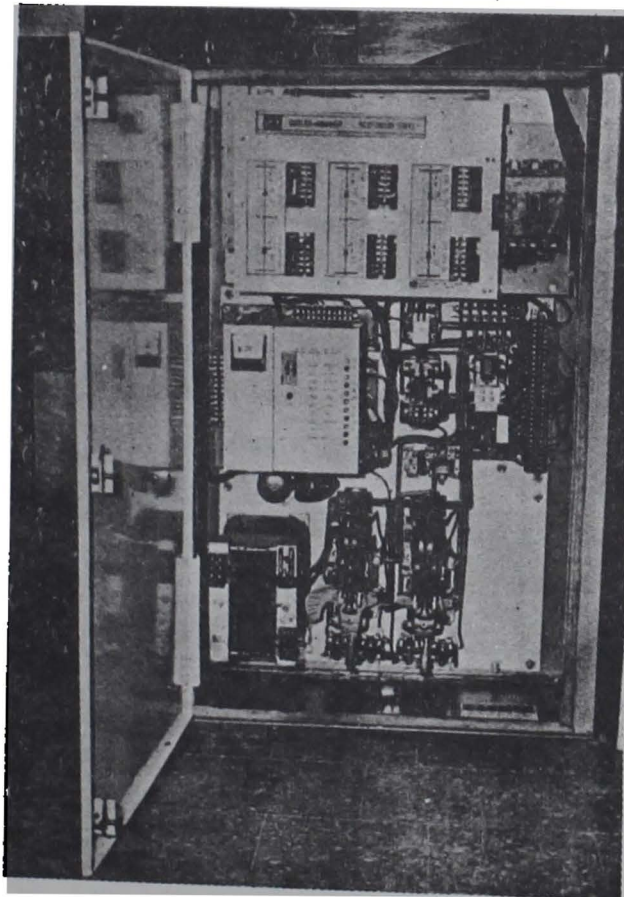
Motors		Types and quantities of control systems	Estimated cost of motors (excluding SGC) (Rs. crores)
AC	DC	SGC	Motors
30 (a)	—	30	1.35
200 (b)	—	200	4.00
1000 (c)	—	1000	1.00
Total			6.35

Notes: (i) 'a' stands for motors of 100 kW capacity and above.
 (ii) 'b' stands for motors of capacity 100 to 1000 kW.
 (iii) 'c' stands for motors of capacity less than 100 kW.
 (iv) All motors are assumed to be controlled only by switchgear.
 (v) Table 8.17 details the unit cost assumed.

VIII

Table 8.16. Total demand forecast for industrial drives.

No.	Item	Less than 10 kW (Average 5 kW)	10 to 100 kW (Average 50 kW)	100 to 1000 kW (Average 500 kW)	More than 1000 kW (Average 15000 kW)	Cost (Rs. crores)
1.	AC motors	100,000	13,700	1,300	80	84.10
2.	DC motors	44,700	4,500	1,275	60	49.30
3.	Stepper motors	500	—	—	—	0.75
4.	Hydraulic motors	5,000	—	—	—	3.75
5.	Motor alternator drives	—	—	20	—	0.16
6.	Rectifier-inverter drives	3,000	80	—	10	2.04
7.	Motor generator drives	—	—	—	45	2.70
8.	Controlled rectifier drives	3,700	500	1,230	15	27.24
9.	Eddy current clutch drives (aircooled)	—	—	40	—	0.20
10.	Bipolar stepper motor drives	—	80	—	—	0.75
11.	Hydraulic rotary & linear drives	500	—	—	—	11.25
12.	Chopper controlled drives	15,000	—	30	—	0.60
						182.84
13.	Drives for industries not considered above (10 per cent of the above)					18.28
Total cost						201.12



Indigenously manufactured static DC adjustable speed drive control equipment.

Table 8.17. Typical unit costs for industrial drives and control.

Type of industrial drives and controls	Assumed unit cost (Rs.)
(1) AC motors per kW for capacities exceeding 1000 kW	300
(2) AC motors per kW for capacities between 100 to 1000 kW	400
(3) AC motor per kW for capacities below 100 kW	450
(4) DC motors per kW for capacities exceeding 100 kW	400
(5) DC motors per kW for capacities below 100 kW	450
(6) SCR control per kW	400
(7) SCR control in rectifier-inverter model per kW	600
(8) Eddy current clutch drive per kW	500
(9) Chopper system of controlled rectifier per kW	400
(10) Stepper motor per kW for capacities upto 5 kW	3,000
(11) Stepper motor control electronics per kW	3,000
(12) Hydraulic motors per kW for capacities upto 30 kW	1,500
(13) Linear actuator and control (typical combination)	6,000

8.2.3. Current Status

Drive Control Equipment

At present, static drive control equipment using semiconductor power elements are indigenously manufactured only for relatively low power ranges (tens of kilowatts). These are, by and large, for variable voltage DC motor drives without very stringent performance requirements, and also generally for isolated drives and not for coordinated drive systems such as are needed for rolling mills or paper mill drives, where the requirements are of a more sophisticated nature.

Where sophisticated drive control equipment, or a static thyristor unit of very large capacity, has been installed by an Indian manufacturing industry, only the motor and switchgear part are of Indian manufacture while the entire thyristor equipment and all the associated electronic control modules are imported to match the indigenous machine. In the field of static drive control equipment, the production levels, power ratings and technical refinements indigenously achieved so far are negligible compared to the volume and types of requirements.

Thyristors

Thyristors and high power silicon diodes constitute main power handling elements in static drive control equipment and therefore the position regarding their indigenous development and manufacture deserves special considerations. For the requirements of industrial drive control equipment the most important devices are conventional reverse blocking thyristors and silicon power diodes. In decreasing order of importance are bi-directional thyristors (power triacs), high power transistors and the reverse conducting thyristors.

Silicon power diodes with ratings in the range of tens of amperes and above are presently produced in the country by a few manufacturers. Each of these manufacturers has collaboration with either a British, or American or German industrial organisation. The highest diode ratings presently in

production in the country are 240 amperes for current (full cycle average rating, 180° conduction angle) and 3,000 volts peak inverse. An individual diode with higher ratings has recently been announced by one firm. These ratings are below the ratings of similar devices available with leading manufacturers abroad.

Thyristors are currently supplied by two manufacturers, both with foreign collaboration. The highest device ratings, that have been listed under current production, are 125 amperes (full cycle average 180° conduction angle) and 1,200 volts peak forward and reverse. These again are far below the ratings available with most thyristor manufacturers abroad. The indigenous production is presently restricted to converter grade thyristors. Other specifications such as dv/dt and dI/dt are also below the levels available in imported devices. Inverter grade (fast turn off) thyristors are not currently produced in the country.

In the case of power transistors, the highest ratings currently made in the country are 15 amperes (Type 3055, 15A and 60V). This must be viewed against current ratings of 250 amperes and voltage VCE ratings of 600 volts available abroad. Bi-directional thyristors (triacs) have good application potential and have been produced upto ratings of several hundred amperes and maximum voltage ratings in the region of 1,000 volts. These devices are not made in the country. A relatively newcomer in the power thyristor family is the reverse conducting thyristor. These are particularly useful for chopper converters. Reverse conducting thyristors produced in Japan have achieved high current and voltage ratings for individual devices (400 amperes forward, 150 amperes reverse and 2,500 volts peak forward blocking). These are being used in railway application in Japan, for chopper controlled DC motor coaches with regenerative braking, in rapid transit systems. These devices are particularly suited for this application. Not only are such devices not made in the country, but the existing R&D activity in the power devices field is limited even for the development of indigenous thyristors of the conventional and well established types.

8.2.4. Analysis of Gaps and Proposed Guidelines

An assessment of the present position and a realistic estimate of the requirement in the next five years, make it imperative, in view of the large industrial implications, both direct and indirect, to have clearly defined objectives and effective programme of efforts to achieve self-sufficiency in the matter of (i) thyristor and other power electronic devices, and (ii) static power control equipment. The policy guidelines in this regard are stated below.

Devices Technology

This concerns the development of semiconductor power elements. The power devices of interest are the following:

- (i) Silicon power diodes
- (ii) Thyristors, reverse blocking converter grade
- (iii) Thyristors, reverse blocking inverter grade
- (iv) Bidirectional thyristors (Triacs)
- (v) Thyristors, reverse conducting
- (vi) High power transistors

The position as regards the production of these devices in the country is reviewed. An important aspect of the situation that needs

VIII

consideration is that presently the production of silicon power devices, both power diodes and thyristors, is not only undertaken solely by industrial enterprises having foreign collaboration, but despite such access to foreign technology, the ratings of the devices produced are far below those achieved abroad. At the same time, the voltage and current ratings of the silicon diodes produced completely indigenously cannot even be classified as power elements. Under these circumstances, unless immediate steps are taken regarding the production plans, a very large gap will continue to exist between the ratings and specifications of devices available in the international market and those in the country. In suggesting a policy for the indigenously production of power semiconductor devices, such as thyristors, the following considerations need to be kept in view.

While there are basic similarities in the technologies of high power semiconductor devices and low power devices such as transistors and integrated circuits, there are basic differences also. Mass production techniques which are suitable for the latter are not so readily applicable to high power elements. Much greater individual treatment of devices at different stages of manufacture and testing is involved in the case of the latter. One major difference centres around the amount of heat generated in the device as a result of large current ratings. This poses special heat dissipation problems which have to be taken care of during the manufacturing stage itself. For these reasons high power device manufacture cannot be considered as an extension or enlargement of low power device manufacture.

The advances in power electronics field have been quite considerable and have brought about a conceptual change in power engineering. It has opened up new avenues of activity in speed control of AC and DC machines, high frequency lighting, battery operated vehicles, static excitation systems, high voltage DC transmission, etc., besides providing for qualitative improvements in a number of control systems.

In India, R&D efforts in this field have been undertaken in a number of organisations like, academic institutions, industrial establishments, scientific laboratories, etc. Power electronic equipment in the range below 250 kW have been designed, manufactured and commissioned by industrial establishments in the country. A representative list of such equipment and also power semiconductor devices available indigenously is given below for illustration.

(a) Silicon power diodes

Max. peak repetitive reverse voltage (in volts)	Average value of forward current (in amp)	Max. value of forward current (in amp)
3400-4300	420	532
2400-3600	520	675
1500-2200	535	650
800-1800	700	850
100-1500	70	110
100-1500	35	55
100-1200	40	63
100- 500	830	960
80-1200	200	235
40-1440	370	425
40-1440	290	320

VIII

(b) Thyristors	
Peak inverse voltage (in volts)	rms current (in amp)
(i) Converter grade	
100-1200	15-30
100- 800	35
200-1200	55
200-1200	110
200-1200	140
200-1000	175
200-1200	175
200-1200	250
200-1200	300
200-1200	325
(ii) Inverter grade	
100- 500	15-30
100- 800	25
100- 800	35
200-1200	35
200- 800	110

Power electronic equipment of the lower end of the power spectrum have been made and are under various stages of production. A representative list of industries for which the work has been undertaken is given below for illustrative purpose.

- (a) Thyristor converter drives
 - (i) Steel mills
 - (ii) Metal working industry
 - (iii) Paper industry
 - (iv) Cement industry
 - (v) Textile industry
 - (vi) Chemical and synthetic fibre industry
 - (vii) Machine tool industry
 - (viii) Rubber and plastic industry
- (b) Thyristor inverters
 - (i) Oil refineries
 - (ii) Petrochemical industry
 - (iii) Power plants
 - (iv) No break power supply units
 - (v) Chemical industry
- (c) Rectifier equipment
 - (i) Electroplating
 - (ii) Battery charging

VIII

- (iii) Electrostatic precipitators
- (iv) Traction
- (v) Power supplies for electrochemical plants
- (vi) Mobile rectifiers for shore-to-ship supplies

In power electronic equipment in the high power ranges, i. e. upto and above 5000 kW, the country is still to acquire the necessary competence to undertake production activities. One of the main reasons for not developing the know-how for the high power equipment indigenously is due to the fact that high power semiconductor devices, specially the thyristors, are not being manufactured in India. The equipment and devices of this power range have already been commercially tested and proven elsewhere and have yielded beneficial results.

Further, the electrical power industry is firmly established in the country with most of the requirements of the country being met from indigenous sources. It has also exported a number of products individually and is able to undertake the execution of turn key projects as a whole.

The electrical power industry is poised for a considerable expansion which is indicated by the fact that, in the Fifth Plan period the generating capacity is expected to be almost doubled from 18M kW in 1974 to about 35M kW by 1979. From the point of view of the user, the industries in general are expected to have access to this increased power; consequently the demand for electrical equipment in general and power electronic equipment in particular, is expected to increase.

Further, the Railways have programme for substantial electrification of its suburban services requiring considerable power electronic equipment. Another new field of activity which has gained considerable importance is the development of battery operated vehicles. The interest in this has arisen from the increasing cost of petroleum products as well as minimisation of pollution.

The above indicate the involvement of power electronics in the growth of the electrical industry. In order to keep up the tempo of progress and to enable the electrical industry to grow to the full extent it is capable of, it is necessary to have a sound base in power electronics.

In view of these and from the fact that the lead time necessary to develop know-how both in regard to high power equipment and high power semiconductor devices indigenously is considerably long, it is felt necessary to acquire the know-how through foreign collaboration.

With this in view, the Department of Electronics has approved the manufacturing programme of these high power semi-conductor devices and high power equipment in the two public sector organisations viz., Bharat Heavy Electricals Ltd., and New Government Electrical Factory, with foreign collaboration. Besides these two, a few more firms have already got their letters of intent and are likely to come up with their manufacturing programmes, mainly in the lower range of high power equipment and devices, in the course of the next few years. With the above mentioned units setting up their manufacturing facilities, it is expected that a substantial portion of the needs of power electronics in the country will be met indigenously.

Drive Control Equipment

This aspect of power electronics technology relates to the development and manufacture of static drive control equipment utilising the power elements. This is the industrial application aspect of semiconductor device technology. The existing activity in the country is very small compared to the estimated industrial needs.

In the matter of equipment development it should be emphasised that

developmental work should not be tied to, or restricted by, the progress in device development. This is important not only for achieving speed in indigenous development, but also from consideration of immediate savings in foreign exchange. This statement may be illustrated as follows. In the typical case of a large industrial drive equipment supplied by an Indian manufacturer, say for the metallurgical industry, only the motor and switchgear part are manufactured indigenously. The entire thyristor equipment and all associated electronic modules are imported from abroad to match the indigenous motor drive at a cost of the order of several lakhs of rupees for a single equipment depending on the rating and the degree of sophistication stated in the performance specifications. If the same equipment is designed and built in the country using imported components, the total foreign exchange requirements will be only a small fraction of what is presently being spent.

The need to invest in the required R&D efforts and also production facilities in the matter of industrial drive control equipment must be emphasised. High power thyristor equipment are to a large extent custom built. But if certain basic categories of prototype equipment are designed and developed, it will be possible to achieve a certain degree of standardisation as well as adaptability, to suit drives of different horse power ranges and degree of sophistication in the performance requirements. Some suggestions, regarding prototype equipment to be developed, are given below. These constitute the important categories of equipment on the basis of which planning of prototype development can be done.

Thyristor Drive Control Equipment : Basic Prototype to be Developed

(a) Direct Thyristor Drive Control Equipment (Static Ward-Leonard Drive) for a Rolling Mill

A reversible DC motor drive system is envisaged constituting an electronically coordinated set of 3 drives for (i) the main stand motor, (ii) the wind reel motor, and, (iii) the unwind reel motor. Dual thyristor bridge units will be provided for direct supply to each motor armature and a smaller unidirectional thyristor converter for each field. Besides the thyristor modules, all the necessary electronic control cards for achieving accurate control in the matter of tension, strip speed, inertia compensation, diameter compensation, etc., should be developed. The suggested horsepower for the basic unit is 500. The basic thyristor unit as well as the control cards should permit standardisation for adaptation to suit various drive ratings and usual modifications in drive specifications.

(b) Rectifier-Inverter Drives for AC Motors

Here also a rating of 500 hp is suggested for the prototype equipment. The rectifier-inverter unit should provide for variation of both output voltage and frequency independently to meet the requirements in the matter of V/f for motor speed control. The prototype should be adaptable for both cage type induction motors and synchronous motors with design changes. In the case of synchronous motors the necessary field converter also should be incorporated in the drive control equipment.

(c) Thyristor Controller for Slip-ring Induction Motor Based on Slip Energy Control

This will be a basically different type of thyristor equipment consisting of a rectifier-inverter sequence in the rotor circuit for slip energy control to achieve speed variation. A power rating of 500 hp is suggested for the basic prototype.

(d) Direct Frequency Converter Equipment of the Cyclo-converter Type for AC Motor Control

This type of direct frequency converter, using thyristor phase controlled converter configurations, has applications particularly for squirrel

VIII

cage type of AC induction motor drives. Suggested prototype equipment is a 3 phase to 3 phase converter with output frequency variation up to a maximum of 20 Hz from a 50 Hz input. A power rating of 100 hp is suggested.

(e) Thyristor Chopper Equipment

This equipment will be for the control of DC motor from DC supply systems. The suggested power rating is 100 hp for the prototype. In view of the immediate application potential for this type of equipment in the Indian Railways, a larger horsepower rating may also be considered for the prototype. The prototype equipment should have facility for regeneration (operation in two quadrants). A fixed frequency chopper equipment, with a chopper frequency of approximately 200 Hz, is suggested with pulse width control for both driving and regenerative braking.

While the above are some of the basic types of prototype equipment proposed for development, it will also be advisable to keep in view the thyristor power equipment for applications other than industrial drives such as for static converters for traction converter installations, industrial lighting and heating, power transmission, etc. In all cases, full specifications and detailed time schedules with assigned responsibility for project leaders and the R&D establishment should be drawn up in the manner suggested for device development.

Pilot Facilities and Production Unit

The R&D groups should be requested to install pilot production facilities, so that some of the industrial drive control equipment needed can be initially produced at the pilot plant. This should facilitate the planning and establishment of a manufacturing unit for static semiconductor power equipment of all types, the major output of which will be in industrial drive control equipment. The manufacturing units for power devices and power equipment should be planned as two wings of a single undertaking for achieving coordinated development in both areas.

8.3 Numerical Control

Modern economies require industries where output per man is high, where wastage of material, time and human effort is kept low, and where there is an intrinsic capacity to adopt the changing needs of both technology and the market. This calls for a radically new approach to the process of manufacturing in which the entire operation, from the provision of materials or stock right through to inspection and packaging, is viewed as a continuous flow process. With this, there must be the ability to change the style or content of the product, or alternatively the mixture of products, in harmony with fluctuations of demand. This involves the introduction of numerical control (NC) machine tools, which imposes an essential discipline throughout the manufacturing process.

8.3.1. Relevance to India

The advantages of NC are wellknown like reduced scrap, reduced leadtime, design changes at low cost, accuracy and interchangeability at no extra cost, better inspection, better machine utilisation, reduced inventory, reduced tool room load, less fixture handling and storage, extended tool life, automatic tool changes, etc. In spite of these well known advantages, many

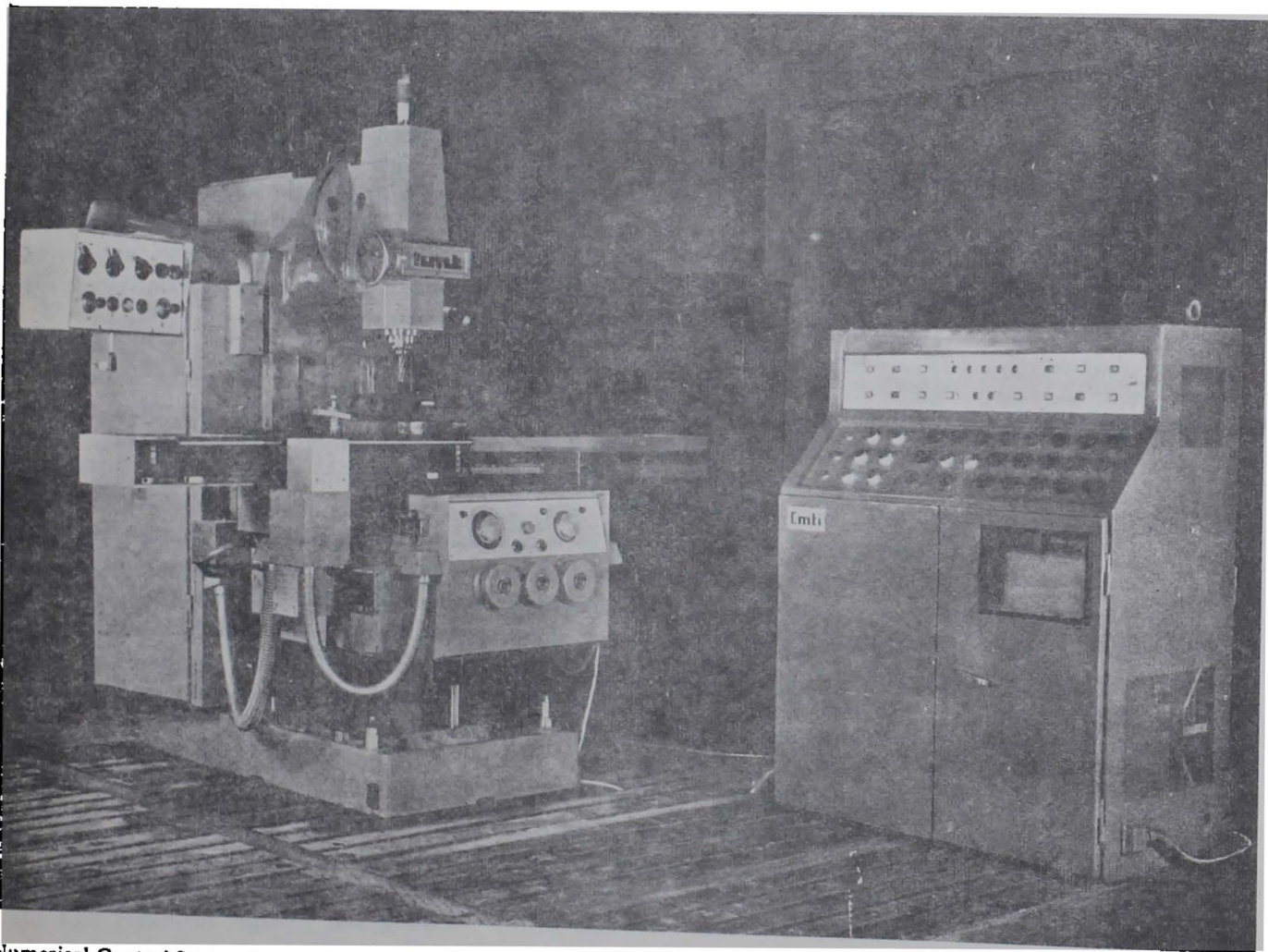
VIII

workshops in India consider NC as a means to take only impossible jobs. The standpoint has often been reinforced by foreign manufacturers of NC equipment, whose advertising campaigns show the wonders of NC for dream workpieces that most workshops will never have to make. The fact is that NC is highly advantageous even in the most routine machine tool operations.

Numerical control technology has a special relevance to India where skill in mechanical technology is still a rare commodity. The training needed, to transform the mammoth manpower into a dedicated army of skilled workers, would demand a very high price in terms of time, money and effort. NC technology offers a tool of achieving better quality production without the prerequisites of high skill and experience needed in conventional production techniques.

8.3.2. Demand and Current Status

The volume of demand of NC equipment in the country has been small in the past. From small and hesitant beginning in the 1960-s, the engineering industry in India is slowly realising the potentials and applications of NC in manufacture. Factors like relatively high capital investments,



Numerical Control System for precision drilling developed by CMTI.

VIII

lack of skilled manpower for operation and maintenance, and absence of software expertise have been responsible for the low volume of demand of NC machines. However, there has been a significant increase in demand for these equipment in recent years, due to the modernisation and diversification programmes in the engineering industry on the one hand and the emphasis on indigenisation on the other. It is estimated that by the end of Sixth Plan period NC machines worth Rs. 10 crores would be installed in the country.

Although development of NC has just nucleated in the country, the work done by various agencies like CMTI, HMT, BEL, etc., is noteworthy. CMTI has already demonstrated their open-loop NC system engineered to HMT E2 milling machine. Since then, various investigations have been carried out by CMTI, HMT and BEL, both independently and jointly, on various aspects of NC. These investigations have resulted in development of NC knee type Turret milling machine, collaborative development of NC centre Lathe-A24NC, vertical machinery centre, and the development of closed-loop NC systems.

HMT has an expansion programme to design and manufacture some NC machine tools indigenously. Also efforts are underway to develop multi-axis machine tools to make full use of computer NC machines.

Recently an NC Centre has been set up at CMTI for introducing, promoting and developing the NC technology in the country. This Centre has an installation of a PDP 11/40 minicomputer, which is expected to aid the promotion of NC machine tool technology in preparing both post programmes and executive application programmes for computerised numerical control (CNC), and act as a computer facility behind tape reader for hard wired NC systems.

UNIAPT, a version of automatically programmed tool (APT) language, is being implemented at CMTI on this computer. In addition to UNIAPT, the computer also has an operating system RSX-11 D which is a multi-user/multi-programming system which can support upto 16 user terminals. The operating system has ANSI FORTRAN compiler, macro assembler, file control services, batch capability and many utility programmes. In addition to part programming, the CMTI computer has been equipped with the special software for the generation of post processors for special machine tool and control system combination for the generation of control tapes for NC machines.

Summarily it can be said that the necessary infrastructure exists in the country to undertake both hardware and software development for the planned introduction of NC technology in the country.

8.3.3. Analysis of Gaps and Proposed Guidelines

The main hindrance to the growth of NC in the country is the insular nature of our engineering industry. The industry is unaware of the potentials and benefits of NC. Only a few industries like HMT, HAL and L&T have introduced NC machines into the production lines. The prime emphasis should, therefore, be on the promotion of NC in a planned manner. Also there is a need for spelling out the national policy for NC over the next ten years. The proposed National Automation and Control Agency (NACA) should take up this task in close association with the NC Centre at CMTI.

To shorten the gap between development of NC and CNC machine

VIII

tools and their adoption by users, a 'pre-production order' scheme should be instituted, under which a suitably set up Government Body is prepared to buy advanced models and place them out on free loan for initial evaluation and trial by potential purchasers. The maker is thus assured of a market for NC machines, and the user is encouraged to try them without having to bear undue risk.

To enable potential but inexperienced user to establish the advantage of NC, a 'trial period scheme' should be introduced which will permit users to purchase systems in the knowledge that they can be returned for a guaranteed re-purchase price, if the user wishes so.

The adoption of NC should be encouraged, by advisory and demonstration facilities and by promoting undertaking work on contract or otherwise in order to demonstrate the advantage of NC on potential user's production. This programme should include short-term courses for members of user firms.

The indigenous development of NC technology can be promoted only if the import of NC machines is strictly restricted. But before restriction is imposed on certain machines, it is necessary to develop enough competence and expertise in developing and building them at competitive costs. In order to do this, it is necessary to augment the present design and development efforts significantly.

Simultaneously, it is necessary that the components for building NC machines are progressively developed and productionised indigenously. An important area is measuring system transducers. Among these, the more important ones are encoders, resolvers, noise fringers, etc. Expertise exists in the country for the development of most of the control components required in NC applications.

A variety of drive systems are in use today for NC, but the recent trends are SCR control motors and stepper motors. It is necessary to institute appropriate technology development projects in this area.

The design of NC machine is a departure from the conventional type as the machine is expected to guarantee a repeated performance within the defined parameters over its life of operation. The systems approach to the complete design concepts of the NC machine has to be evolved and perfected. NC systems consist of electronic, mechanical, hydraulic and electrical hardware.

Another important aspect is the development of software for various applications. There are a number of alternatives in the area of facilities for preparation of NC tapes using computer. All of these alternatives involve access to computer. Owning or renting computer by individual user is ruled out since it requires very high investment and a certain minimum workload before it can be economically justified. Computer sharing is also not feasible, at least at present. The only feasible solution is the establishment of centralised facilities for software development. One such facility has been established at the NC Centre of CMTI, which is expected to meet the needs of the Southern region. At least two more such facilities should be established during the Sixth Plan period, one in Bombay and another in Calcutta.

Finally, the technology trends in the NC area must be carefully considered before planning the future development activities. Recent years have witnessed the introduction of microprocessors in NC systems. While the advent of computer technology in NC systems has brought to the forefront

many advantages and flexibilities over the conventional NC systems, the introduction of microprocessor is throwing a challenge to hard-wired and minicomputer control systems. A recent report estimated that microprocessors ranked fourth in usage after hard-wired logic, programmable controllers and minicomputers, respectively. The micro-base systems, being comparatively low-priced, are claiming an advantage over the other systems. Controllers using these processors have already become popular and are used by machine tool manufacturers.

8.4 Induction and Dielectric Heating

In several industrial heating applications, HF heating equipment have assumed growing significance in recent years, as sharpening competition has necessitated increasing efficiency in manufacturing processes allied to improvements in quality. After more than twenty years of practical use, the HF heating process has achieved a high degree of technical perfection, and has made considerable contributions to the rationalisation and to the far reaching automation of many operational processes in mass production. In India, both the application and the production of HF heating equipment are of recent origin and have not gained the importance they merit in the industrial heating applications.

8.4.1. Application Areas

In HF heating, two methods are distinguished in principle: (a) induction heating and (b) dielectric heating. The principle of induction heating, in which a metallic material is heated in an electromagnetic alternating field, is most successfully applied in practice to surface hardening, forging, annealing, tempering, soldering, sintering and melting. The special advantage of the process lies in the possibility of transmitting high power outputs into the work pieces and, in this way, achieving short operating periods. Table 8.18 gives typical applications of induction heating.

Dielectric heating is employed with insulating materials or bad conductors such as plastics, wood, textiles, tobacco, foodstuffs and so on. Heating is achieved by inserting such materials in a capacitor to which HF voltage is applied. Dielectric HF heating has established itself in the manufacture of synthetics, since the conventional methods substantially reduce the durability of material during seaming, and a welding process is thus preferable. Dielectric heating has found a very important application in the wood processing industry, particularly in glueing multi-layer wooden sheets and in the manufacture of curved wooden sections. Other application areas in the food industry are, chocolate melting, thawing frozen foodstuffs, separating the germ in wheat products, as well as the drying processes in the textile and tobacco industries. Table 8.19 gives typical applications of dielectric heating.

8.4.2. Demand, Current Status and Proposed Guidelines

The volume of demand of HF heating equipment is mainly determined by the level of automation prevalent in various heating process of the engineering industry. Indeed, the future of induction and dielectric heating lies in the field of semi-automated and fully-automated heating processes, which can be fitted directly into the production lines. The present demand for these equipment can be placed at Rs. 1.5 crores per annum. However, in view of present energy crisis and the growing trend of introducing more and more automated processes in the industry, the demand is expected to grow significantly in the next decade.

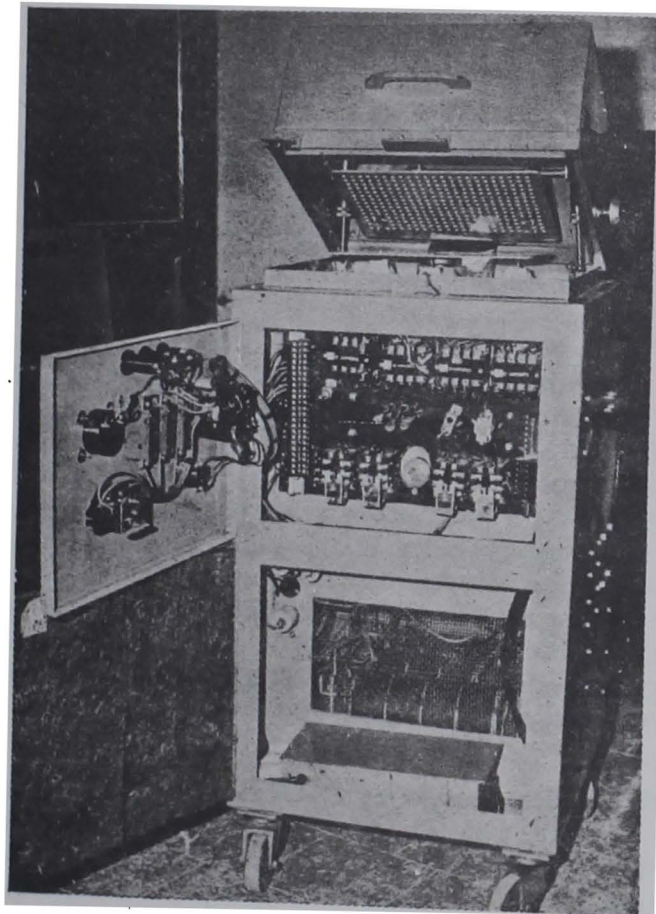
Both induction and dielectric heating equipment are presently manufactured in the country. The available heaters are designed for continuous operation and

VIII

incorporate some recent design techniques. The induction heaters manufactured in the country are of medium impedance output suitable for general purpose heating applications. The dielectric heating equipment manufactured are of high impedance output suitable for heavy duty work, and the rapid curing of synthetic resin and adhesives in the woodworking industry. The import content of the equipment includes oscillator valves, HF capacitors, DC relays, timers, etc. The present production of HF equipment in the country would be approximately Rs. 60 lakhs per annum.

In order to realise the potential demand of HF heat generators, promotional efforts will have to be initiated. The future of these equipment lies in the field automated heating processes which can be directly placed in the production lines.

Present manufacturing base has to be expanded to meet the future demand in this area. Diversification of the system range should be undertaken either by developing new systems indigenously or by allowing limited foreign collaboration for certain sophisticated systems. The former alternative would necessitate the import of certain vital components. Simul-



Indigenously developed preheater

VIII

taneously, it is necessary to build up the capability in the custom manufacture of automatic feeding mechanisms required for different applications. Development of these mechanical handling systems could be undertaken at CMERI, CMTI and HMT.

Table 8.18. Typical applications of induction heating.

Annealing

Bolt heads, screw threads, blanks for pressings, tube ends for swaging, pipe fittings, welds, shaft ends for drilling, tangs of pocket knife blades, bright annealing continuous strip for edge rolling.

Brazing

Thermostat parts, perambulator components, tool tips, jet assemblies shaft to chain sprocket, waveguide flanges, soldering-iron components, twist drills to shanks, manifold assemblies, immersion heaters, television tube components, yokes to cuff links, studs to cover plates, pressure gauge and gauge components, stainless steel brazing in aircraft industry.

Melting

Rare metals, metals in atmosphere or vacuum, steel for precision casting.

Soldering

Braid to lugs, fuse cartridge ends, thermostat assemblies, components of stoves, ferrules to flexible shafts, electric torch cases and reflectors, transformer cans and seams of tins.

Hardening

Gear teeth, shafts, faces of tools and gauges, punches, cams, push rods, shackle pins, sprockets, tappet screws, valve stems, crank shafts, edge tools, hobbing cutters, mower blades, grinding wheel dressers, typewriter and calculator components, collect hardening and tempering.

Forging, Upsetting and Blending

Billets for forging, local heating for bending tubes, bar stock for upsetting heads or flanges, straightening twist drills, taps and shafts, etc.

Special Processes

Glass to metal sealing, exciting discharge tubes, sintering, seam welding of pipes, making diamond tools, rubber to metal bonding and debonding, shrink fitting of rotors, etc., on shaft, heating carbon for heat transfer test rigs, heating metals in controlled atmosphere or vacuum, outgassing and getter firing of electronic valves, igniting oil samples for sulphur determination, fusion of silicon, germanium, etc., in semiconductor industry, crystal growing, zone refining of finished crystal and metals.

Table 8.19. Typical applications of dielectric heating.

Woodworking Industry

Making laminated shapes, edge jointing of timber, fixing of plywood tops, etc., gluing, drying and curing of wood, setting of synthetic resin glues, making plywood, particle boards, etc., lipping of flush doors chipboards, etc., assembly of wooden cabinets and furniture.

VIII

Industrial Applications

Sputtering flying of metal for ICs, welding of plastics such as PVC, curing of sand cores in foundry.

Vacuum Coating

Drying and processing of chemicals, cooking and warming of foods, killing of moulds in bread, diathermy applications, treatment of dairy products, setting of synthetic resin glues, thawing of frozen foods (raw or precooked), drying and heat treatment of rayon yarn, etc., sterilisation of foods and medical supplies, processing of rubber and synthetic materials, preheating and curing of bakelite, urea, melamine, preheating and processing of rubber or plastic footwear.

8.5 Mining Electronics

Mining industry plays an important role in Indian economy. Its contribution to the total industrial GNP is about 5 per cent, and it shares about 10 per cent of India's foreign trade. This industry is highly labour-intensive and total manpower engaged in this activity exceeds 6 lakhs covering over 8100 coal and non-coal mines. This reveals an interesting feature that although mining products make only 5 per cent of the industrial GNP, manpower employed exceeds 14 per cent of the total manpower of the industrial sector.

However, India has one of the lowest labour-productivity in mining industry, measured in terms of tons of materials produced per man-shift. For coal mines, o.m.s. in tons per man-shift figures are shown in Table 8.20. Recent emphasis on higher production of coal and other minerals demands mechanisation of Indian mines. Indeed, in order to achieve the Fifth Plan targets for essential minerals like coal, iron and copper as shown in Table 8.21, it is necessary to introduce productive-automation techniques in selected mining operations coupled with labour-intensive production methods. This calls for the indigenous development and production of several electronic monitoring, control and safety equipment on a priority basis.

8.5.1. Current Status and Demand Profile

Recent surveys, conducted by IPAG and CMRS Dhanbad on the

Table 8.20. Labour productivity in coal mining industry for selected countries.

Country	o.m.s. in tons per man-shift
India	0.65
UK	2.30
USA	16.00
Australia	25.00

Table 8.21. Fifth Plan production targets for coal, iron and copper.

Mineral	Production in 1973 (million tons)	Production targets in 1978-79 (million tons)
Coal	77.03	135.00
Iron	34.90	66.50
Copper	1.09	6.32

VIII

mining activities in the country, indicate that except for a few gold mines, the application of the entire field of automation and control is generally absent in Indian mines. Specifically, the following observations have been made:

- (i) Communication in underground areas in mines is very poor and it is believed that proper communication may increase the production by at least 5 per cent.
- (ii) Continuous monitoring of flammable and poisonous gases such as methane, carbon monoxide, etc., is absent. Davy's safety lamp continues to be used in most coal mines. Methanometers and carbon monoxide detectors have been introduced only recently in some mines.
- (iii) Environmental conditions such as dust content, temperature, humidity, air velocity, air pressure, etc., are measured only as and when required.
- (iv) Most of the survey instruments used are still mechanical in nature.
- (v) All the control equipment used in mine working need modernisation.

In general it may be remarked that in comparison to the industrially advanced countries, Indian mines have very few electronic equipment. Mining, in many cases, is what may be termed as 'pickaxe mining'. With the exception of some simple instruments like methanometers and similar other instruments developed at CMRS, all the electronic equipment are presently imported in the country, many of them as an integral part of the imported capital equipment for various mining operations.

The demand for mining electronic equipment are widely varied in nature as shown in Table 8.22. The demand of individual equipment is often low, some of them even less than 100 in quantity. There are only a few equipment which are required above 1000. Although the demand for each category in terms of quantity is less, that in terms of value is sizeable, exceeding Rs. 5 lakhs for certain categories. The types of electronic equipment required in mining can be broadly classified as follows:

- (i) Prospecting geology and geophysics instruments
- (ii) Instruments for rock mechanics studies
- (iii) Survey and correlation equipment
- (iv) Mine working equipment
- (v) Transport equipment
- (vi) Safety equipment
- (vii) Communication equipment
- (viii) NDT instruments
- (ix) Metallurgical instruments
- (x) Miner's health equipment

Table 8.22. Demand for some electronic equipment used in mining.

Equipment	Approximate total annual demand (in Rs. lakhs)
Prospecting Geology & Geophysics Instrument	
Electrical and electronic logging devices, instruments for measuring porosity, permeability, hydrogeology of rock formation, etc.	2.50

VIII

Rock Mechanics Instruments	
Load cells	1.00
Shear strips	0.25
Bore hole extensimeter, convergence indicator	1.00
Instruments for rock noise measurement	1.00
Survey & Correlation Equipment	
Microwave survey equipment	2.50
Laser beam devices	4.50
Mine Working Equipment	
Remote control units for mine transportable substation, underground coal winning and other equipment	5.00
Exploders	10.00
Transport Equipment	
Sensing devices for ascertaining the position of cages/skips in shafts and creep adjustment of koope winders	10.00
Control equipment for automatic loading, and unloading of skips including automatic operation of winders	10.00
Control and monitoring equipment for overwinding, speed, slackness, failure of rope	5.00
Level sensing devices for bins, bunkers, measuring hoppers, etc.	5.00
Automatic counting devices for various mining operations	1.50
Magnetic coding equipment for mine cars	2.50
Central despatcher systems for locomotive traffic control in mine	5.00
Automatic track changers	2.00
Safety Equipment	
Monitoring systems for methane, carbon monoxide, carbon dioxide, oxygen and also temperature, air velocity, humidity, dust concentration, etc.	20.00
Booster fan control, sequence control of other fans, control of conveyor belts, etc.	5.00
Control and monitoring equipment for mine ventilation, fan installation, etc.	5.00
Temperature indicators, fire detectors and alarms	2.50
Monitoring and protecting equipment for cable faults	3.00
Communication Equipment	
Intrinsically safe magneto-telephones, sound powered telephones	1.00
Automatic telephone systems for underground use, signalling systems	10.00
Radio communication equipment for underground use	30.00
CCTV	2.00

VIII

NDT Equipment	10.00
Metallurgical Instruments	5.00
Miner's Health Instruments	4.00

Although the equipment covered by the above classes are numerous, the electronic modules required for different equipments have several common features.

8.5.2. Proposed Guidelines

In order to achieve the Fifth Plan targets for coal, copper, iron and other essential minerals, it is necessary to introduce, in conjunction with labour-intensive production techniques, automation and control techniques in selected mining operations. Any introduction of automation without undue social hardships will involve some promotional effort and preparatory manpower planning work. This activity should be undertaken by NACA.

Simultaneously, it is necessary to develop indigenously, monitoring, control and safety equipment required in various mining operations. There are many electronic modules as well as transducers that are common to these equipment and the development work essentially involves modification of existing systems to suit mining environment. All the electronic equipment designed for mining applications have to be intrinsically safe. The environmental conditions that must be withstood are high humidity, corrosive atmosphere, high temperatures and depths varying from 3,000 ft. in coal mines to 10,000 ft. in deep gold mines. Fine coal dust in coal mines is another factor that affects the packaging of electronic equipment.

There are over forty different electronic subsystems that need development. Some priority areas are listed in Table 8.23. Any plan for the indigenous development of these subsystems would be meaningful only if the

Table 8.23. Some priority areas for indigenous development.

-
1. Logging devices for finding out the thickness of various types of rocks in bore holes, water tables, and for the measurement of strata temperature, density and radioactivity
 2. Instruments for measuring the verticality of bore holes
 3. Load cells and shear strips
 4. Convergence indication
 5. Level sensing devices for bins, bunkers, measuring hoppers, etc., using isotopes
 6. Exploders for underground use for gassy mines
 7. Control of over-winding, speed, slackness of rope incorporating safety devices for rope failure
 8. Monitoring systems for methane, carbon monoxide, carbon dioxide, oxygen and also for temperature, pressure, air velocity, humidity, dust concentration, etc.
 9. Booster fan control, sequence fan control for belt conveyors
 10. Temperature indicators, fire alarms, detectors for spontaneous heating in mines
 11. Intrinsically safe dialling type automatic telephone system
-

development of total systems is progressively undertaken in the country. The necessary expertise for the development activities exists in the country but requires considerable augmentation both in terms of technological infrastructure and financial resources. Since it is likely that private units may not immediately take up the production of these equipment, it would be worthwhile to consider setting up of a public sector unit in close association with the development agency like CMRS.

8.6 Environmental Pollution Monitoring

The present decade is witnessing mounting dangers to the integrity of the ecosystems as a life support to man due to the rampant growth of pollution. The problem of environmental pollution is no longer a problem restricted only to the developed countries. It is likely to be even more serious in the developing countries, where rates of population growth are higher, where the industry must not only provide for an increasing population but also simultaneously raise the standard of living and where financial resources are slender and committed to what may seem at first sight to be more urgent demands.

The problem of pollution of natural environment has been no less serious in India too. The strides of industrialisation during post-independence period, brought in its wake the first symptoms of air pollution; the water pollution, on the other hand, dates far back. Water pollution by sewage has, for decades, been singularly responsible for the high incidence of gastro intestinal diseases in the community, particularly amongst the rural folk. Later due to industrialisation, the effluents and wastes discharged into the rivers made the water pollution widespread. Also the less known forms of pollution such as noise and radiation hazards are bound to appear before long as the process of industrialisation steps up. Hence it is very important that a country like India should look ahead and plan for pollution control now, when it is not too late.

8.6.1. Need for Environmental Monitoring

The effective, efficient and economic control of variables affecting environmental quality, requires the use of reliable and timely information. Thus one of the keys to environmental quality management lies in the ability to monitor environmental characteristics continually and provide reliable, accurate and timely interpolation of the data obtained. Such data are essential throughout the pollution abatement efforts, right from initially identifying the problem and providing direct evidence in enforcement actions, to the day-to-day operation of pollution control equipment and programmes.

Pollutants must be monitored not only in the environment but also as they are discharged from the multitudes of stacks, outfalls, and exhaust pipes. The pollutants, that must be measured, number in hundreds and the types of sources in thousands. Further, each situation presents an utmost unique problem in terms of the combination of instrumentation to be employed, sampling point locations, sampling duration and the like. Pollution monitoring is thus a complex and difficult task.

Environmental monitoring has been defined as the systematic collection and evaluation of physical, chemical, biological and related information pertaining to environmental quality and wastage discharges into all media.

VIII

Its main elements are:

- (i) Field sampling and measurement of environmental quality, emission and effluents
- (ii) Laboratory analysis of field samples
- (iii) Operation of technical information systems and data analysis
- (iv) Measurement, sensor and technique development and testing
- (v) Instrumentation and methodology standardisation and quality control.

Each of the above elements is of importance, all requiring concurrent and considerable effort.

The monitoring equipments are employed for a variety of specific purposes. The most important of these are:

- (i) Establishment and enforcement of ambient environmental quality and emission/effluent standards
- (ii) Evaluation of the effectiveness of adopted abatement strategy
- (iii) Determination of trends and the study of pollutant interactions, baselineness and patterns
- (iv) Assessment of pollution effects on man and his environment.

In many instances, data gathered for a specific purpose may also be used for others, for example, trend data are often useful in effects research studies

8.6.2. Demand Profile

The demand for pollution monitoring equipment is directly linked with the national programme for ecosystem management. In India, the environmental programme is expected to begin with the setting up of a monitoring network. Out of the different types of pollution monitoring efforts, it is expected that maximum attention will be required by the air and water quality programmes.

Air quality programmes are of two types, namely, the ambient air and the stationary source monitoring. The ambient air monitoring network will consist of stations, the location of which will depend on the density of population, proximity of the industrial belts and the meteorological conditions. The stationary source monitoring station is expected to monitor only 2 or 3 parameters relevant to the particular source. The number of stationary source monitoring stations will depend on the standards laid down under the national pollution control programme. Table 8.24 gives a typical set of parameters to be monitored in each type of station.

The total number of stations of each type will depend on the distribution planned according to nationwide network of monitoring stations. It is assumed for the estimation of macrolevel demand that each State will have one central Type B air monitoring and one central Type C water quality monitoring station. These stations will also coordinate the activities of the district level ambient environment monitoring stations. Each district in the State is expected to have one Type A air monitoring and one Type B water monitoring station.

The number of source monitoring stations will depend on the concentration of industrial units, the types of effluents discharged, etc. At present, a few industries have monitoring stations of their own. The future number of stations will depend on the timing of legislation, steps taken to implement these and severity of penalties imposed.

The overall demand will be almost completely determined by the

Table 8.24. Representative list of parameters to be measured in different types of stations.

Air monitoring station		Water monitoring station		
Type A	Type B	Type A	Type B	Type C
Particulate density	Dust fall out rate	Dissolved oxygen	Dissolved oxygen	Hydrological and meteorological (e.g. flow rate, wind direction, solar radiation, etc.) Physical (e.g. turbidity, conductivity pH, solids, etc.) Inorganic chemical (e.g. dissolved oxygen, minerals, trace elements, etc.) Organic chemicals (e.g. BOD, COD, cyanides, pesticides, etc.) Nutrients (e.g. organic nitrogen, organic phosphorous, polyphosphates, etc.) Microbiological (e.g. viruses, coliform, etc.) Biological (e.g. plankton, fish, etc.)
Particulate composition	Particulate composition	Conductivity	Conductivity	
Sulphur dioxide	SO ₂ , NO ₂ , N ₂ O, CO concentration	pH	pH	
Carbon monoxide	Condensation Nuclei	Temperature	Temperature	
Photochemical oxidants	Radioactivity		Turbidity	
Hydrocarbons	Meteorological parameters		Colour	
	Chemical parameter (pH, etc.)		Total solids	
	Hydrocarbons		sediment flow rate	
			Wind direction, speed	
			Air temperature	
			humidity	
			Solar radiation	

availability of resources for the State and Central Government programmes. It can be broadly estimated that the requirement of instrumentation for the source monitoring programme will be about Rs. 10 crores and for State and district level monitoring about Rs. 25 crores. The demand is expected to be spread over the period of next ten to fifteen years, the phasing being essentially dependent on the timing of the nationwide implementation programme.

It is expected that the above macrolevel analysis will have to be carried out in greater details and supplemented by an in-depth analysis for each type of industry. Such an exercise relating to the cost-benefit analysis, the level of monitoring and control to be introduced, is already underway.

8.6.3. Current Status

Monitoring and Control

Efforts to study the effects of pollution, and to monitor and control pollutants, although by no means comprehensive or sufficient, had already begun in the country. It is now a recognised fact at all levels that industrial pollution has assumed a major significance in some industrial belts and will unquestionably have to be brought under control as soon as possible.

The establishment of the National Committee on Environmental planning and Coordination (NCEPC) by the Government of India is indicative of the fact that our country is aware of the importance of environmental planning. The Fifth Plan document has recognised the importance of NCEPC to advise the Government on institutional, legislative and technological changes needed to preserve the quality of environment. The Fifth Plan envisages that NCEPC will be closely associated with all the major investment decisions, so that the environmental aspects of such

VIII

projects are fully taken into consideration. Moreover, NCEPC shall be able to coordinate efforts to develop standards for the emissions of pollutants and monitor them. It would also promote, in coordination with the National Committee on Science and Technology (NCST), the areas of research and development within the field of environmental studies. The legal and administrative measures will be instituted during the Fifth Plan period to prevent environment disruption.

The proposed plan of the Office of Environmental Planning and Coordination (OEPC) includes funds for promoting R&D in the field of pollution abatement. In particular, the OEPC is working with the appropriate ministries and departments as well as with several consultancy firms to ensure the proper use of pollution control equipment when future plants are set up. In the field of pollution from domestic, agricultural and other wastes, it is encouraging work in national laboratories to develop techniques for such treatment and disposal of sewage and solid waste. Many such techniques have, in fact, already been developed indigenously, and the problem is, in part, one of the resource constraints which have hindered the utilisation of these techniques on a wider scale.

Pollution control technology, which usually is not a large fraction of the total capital investment of a plant, can sometimes be quite expensive. It appears also to be susceptible to more than its share of breakdowns. For this reason, in addition to encouraging the evolution of technological solution, the OEPC is actively promoting work on other possible options such as proper setting and location of pollution generating activities and the development of alternative methods for the disposal and reuse of wastes.

The OEPC has undertaken surveys of the pollution generated by industry and thermal power stations. Surveys of this kind will help formulate future strategy in this area. Following the enactment of the Prevention and Control of Water Pollution Bill in March, 1974, the OEPC is encouraging those States which have not done so, to adopt this Act and to set up the Water Pollution Boards and laboratories required by it. Guidelines are being prepared and will be provided by the OEPC to the States, to aid in setting up of these agencies. Similar action is envisaged in the case of the Air Pollution Bill which is in the process of enactment.

The OEPC has also taken work in hand to develop policies regarding the environmental problems caused by pesticides and noise. Preliminary work has been done to define the needs for the production, distribution and use of pesticidal chemicals. Shortly, it will start a broad programme to explore the possibility of using integrated ecological methods of pest control.

In these ventures, as in the R&D projects to be funded by the OEPC, it has been attempted, where necessary with outside help, not only to develop the basic ideas and concepts, but also to take the responsibility to make sure of the implementation of these concepts.

Several projects have been undertaken on a longer term nature with a view to protect the environment of the future. In cooperation with UNESCO, they have undertaken to coordinate the national Man and the Biosphere Programme of ecological research. This programme, to be carried out by research and academic institutions, will study the effects of man's activities on the natural environment. It is a broad-based endeavour and the projects are being designed to be multidisciplinary.

As mentioned earlier, a good deal of future environmental protection can

be gained at minimal cost by rational and systematic use of resources and by proper choice of techniques, design and equipment and location of activities. This involves a complex study of the technological and economic options available. The OEPC is attempting to work out guidelines to aid in this kind of analysis, and given a little time, the office will work out methods by which pollution can be minimised at little or no loss to the economy.

National Environmental Engineering Research Institute (NEERI), formerly known as the Central Public Health Engineering Research Institute (CPHERI) under the Council of Scientific and Industrial Research, is one of the few organisations involved in a variety of research problems and investigations in all aspects of pollution.

In addition to conducting research in areas such as water treatment and distribution, sewage treatment and disposal, industrial waste treatment and solid waste management, NEERI has developed considerable expertise in developing instruments for monitoring purposes. It also renders advice to industrial and municipal corporations and public bodies on the control of water and air pollution. The institute has 8 zonal and field centres spread all over the country to study the problems in-situ. It has also undertaken survey of river basins in various parts of the country to study the extent of pollution in these rivers. It has also consistently helped the Indian Standards Institutions (ISI) in the formulation of standards for water quality and discharge of industrial wastes, and in the preparation of codes of practice. NEERI has been designated as a 'collaborating institute' with the World Health Organisation for study of wastes disposal and community water supplies.

There have been few private associations in India, which carry out promotional activities spreading the importance of pollution control. One of these organisations is the Society for Clean Environment (SOCLEEN) which was formed in 1969. It has established five committees to look after the various aspects of the environment.

Development and Production

At present, the electronic instrument manufacturing industry is largely concentrated in the small scale private sector. Some of the manufacturers have embarked on programmes for the manufacture of pollution monitoring instruments. In general, many of the analytical instruments manufactured can be used for monitoring applications with some modifications; the modification mainly being in the sample handling and data transmission modules of the instruments.

The R&D work is already underway in a few institutions in the country for some instruments which can be used for pollution monitoring. Table 8.25 gives a representative list of such instruments, alongwith the development agency. It indicates that considerable expertise exists in the country for the development of many of the monitoring instruments. In addition to this, a variety of meteorological instruments have also been developed in the country.

8.6.4. Proposed Guidelines

Implementation

In order to protect nature and enhance the environment against pollution of any kind, or more realistically, to keep the natural environment within acceptable limits of pollution, two elements are fundamental: (i) A set of

VIII

Table 8.25. A representative list of instruments under development or developed.

-
- (a) Bhabha Atomic Research Centre, Bombay
 - (i) Dissolved oxygen analyser
 - (ii) Automatic preparative gas chromatograph
 - (iii) Portable hydrogen monitors
 - (iv) Atomic absorption spectrophotometer
 - (v) Beta gamma continuous air monitors
 - (vi) Non dispersive X-ray fluorescence analyser
 - (vii) Sulphur analyser
 - (viii) Mass spectrometer
 - (ix) High resolution solid state detectors
 - (b) National Chemical Laboratory, Poona
 - (i) Vapour phase gas chromatograph
 - (ii) Potentiometric strip chart recorders
 - (iii) Direct reading spectrophotometer
 - (iv) DC recording polarograph
 - (v) Infrared spectrophotometer
 - (c) CSIO, Chandigarh
 - (i) Digital pH meter
 - (ii) Gas chromatograph
 - (iii) UV, IR spectrophotometers
 - (iv) On-line gas analyser
-

laws, bye-laws or regulations, and (ii) an authority or an agency, empowered with statutory powers to enforce them. Realisation of these two factors is important as large scale pollution can be controlled only legally and not by voluntary actions. Some industrialised countries are already seized with this problem of minimising pollution and have set up enforcement authorities to enforce strictly the acts passed by their countries to curb pollution.

It is, therefore, imperative that a national environmental programme should begin with the establishment of central agency with powers and resources to plan and implement. Some of the functions of such an agency are visualised to be as follows:

- (i) To work out the various legislations and acts to be maintained at the national level
- (ii) To maintain the overall supervision of all the activities such as setting up standards, their revision, etc.
- (iii) To coordinate the activities of the State Governments and other related departments and ministries
- (iv) To identify the high priority development projects, assign and see through the successful completion at the competent laboratories and agencies
- (v) To act as an intermediatory in the transfer of technology for monitoring and control techniques from R&D base to the production stage

Development and Production

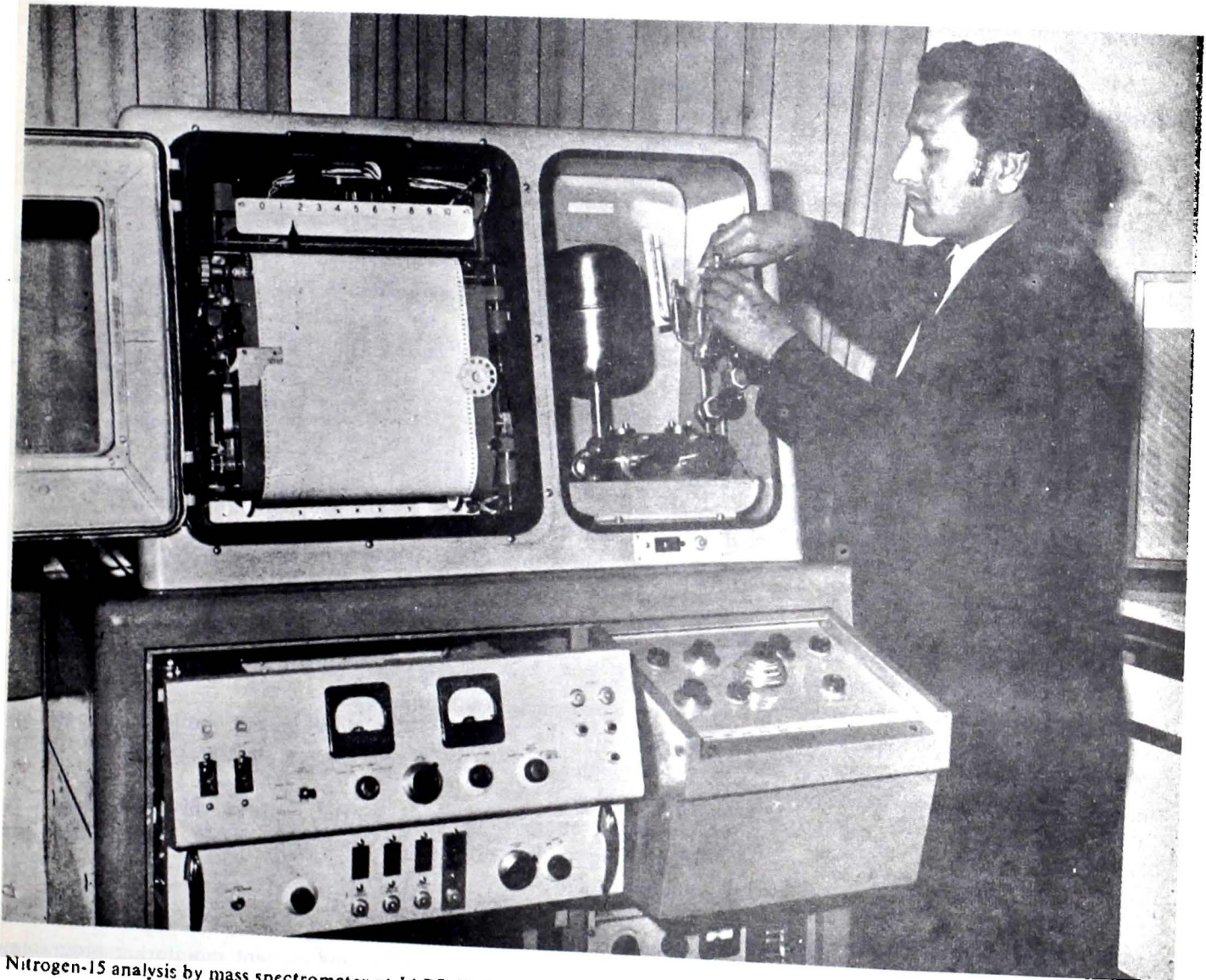
In order to support the nation-wide environment monitoring programme,

VIII

an able support from the instrument and equipment manufacturers is required. An extensive upgrading of the present manufacturing facilities is required to meet the demand for such equipment. In many cases of the pollution monitoring equipment, required techniques for the manufacture are not available in the country. In some cases, it may be necessary to obtain the manufacturing know-how from foreign manufacturers. This can either be obtained through one time purchase of know-how or through limited foreign technical collaboration. The choice will depend on the transfer terms as well as the specifications of a particular type of instrument range.

The following are some of the instruments which will have large demand for the ambient and source monitoring programmes. They may be considered for high priority development and production.

- (a) Air Pollution Monitoring Instruments
 - (i) Non-dispersive IR monitors
 - (ii) Particulate concentration monitors



Nitrogen-15 analysis by mass spectrometer at IARI, Delhi.

VIII

- (iii) High and low volume samplers
- (iv) Gas analysers
- (b) Water Quality Monitoring Instruments
 - (i) Turbidity meters
 - (ii) Dissolved oxygen analysers
 - (iii) Organic material analysers
 - (iv) Trace elements analysers (X-ray fluorescence technique)
 - (v) BOD monitors
- (c) Transducers
 - (i) Temperature (water and air)
 - (ii) Flowrate
 - (iii) Specific ion electrodes (e.g. for cyanides, chlorides, etc.)

It is not expected that all the pollution monitoring equipment will be produced by a single unit. The low-cost, high-volume equipment manufacture may be confined with the small scale private sector whereas high-cost, low-volume equipment may be manufactured by large scale units in private and public sectors. This will be necessary for considering the substantial R&D back up required to undertake the production of sophisticated systems.

A feasibility study is also required to be conducted to examine the commercial viability of a new public sector unit to undertake the manufacture of high-technology instruments covering the pollution monitoring, analytical and geoscientific fields.

8.7 Agri-electronics

Many developing countries have now realised that the need of the hour is to achieve maximum productivity from the available resources. This has set pace for a balanced growth of mechanisation in the agricultural sector. The increasing stress on mechanisation of agricultural operation frequently requires the use of instrumentation for investigating and controlling a wide range of activities. Electronic instrumentation is an effective tool for the immediate adjustments of many operations. Agriculture offers many outlets for standard industrial instrumentation and for many specialised devices to measure and control quantities associated with soil, aerial environment, climate, crop rearing, animal husbandry, product quality assessment and storage. The range and complexity of instrumentation for agriculture are increasing steadily under economic pressures towards greater efficiency through improved gathering of farm data and better utilisation of costly machines, equipment and manpower.

8.7.1. Review of Application Fields

A review of the potential fields of application for electronic instruments in this field would be useful at this stage. The entire agricultural operations may be grouped into two, namely, pre-harvest and post-harvest operations.

The study of soil, as it affects the plant growth and the performance of various agricultural implements, provides application for instrumentation of many kinds. Measurements related to physical, chemical and biological analysis of the soil and its constituents, both liquid and gaseous, which contribute to the root environment, constitute the major area calling for the

VIII

use of a wide range of instruments. Most of these are required mainly for laboratory testing and research. However, some have more immediate application to commercial crop, soil and water management.

There are a number of properties of the atmosphere at and near ground level which influence the farming operations involving crops and livestock. The radiation which provides ambient light and heat energy also comes under this. Other parameters are basically air temperature, humidity, air flow, meteorological parameters and gas and dust concentrations of the air. The influence of these factors extends to farming operations under natural and artificially created environments. Quite often it is required to exert a little control over these environmental parameters. Electronic instruments play a key role in providing such critical information and then help to control manually or automatically the environmental conditions.

The influence of water on plant growth, harvesting, storage and marketing of crops, is quite substantial. The measurement and control of water in plant and plant tissues are equally important as those in the media in which the plant grows. The information on the water content in herbage, crops and seed material is vital especially during harvesting and post-harvest seasons.

Another most important area, where electronic techniques would be of potential use, is the protection of plants and animals from disease pathogens, pests and insects. This is of special significance in view of the stress to protect our living environment from exorbitant use of chemical pesticides.

Advances in electronic instrumentation have played an important role in quality evaluation and control of agricultural products. Electronic instruments have replaced most of the conventional subjective assessment of external features of a product, as they are capable of performing non-destructive internal inspection of the product which in most other cases cannot be done. Reflectance and transmittance spectrophotometry, detection using X-ray and other radiations and ultrasonics provide most effective tools for quality evaluation.

Although all the agricultural products are brought or sold either by weight or volume, purely mechanical methods of measurement of these two parameters impose quite severe physical limitations on the arrangement of a perfect weighing system in many cases. Most accurate weighing systems are now built on electronic devices which can provide remote indication of these parameters.

Even today automatic control techniques are relatively new in the agricultural sector. In the last five years there has been a significant trend to the application of automatic control in agriculture—both static and field operations. Examples of automation in static installations are environmental control of green-houses, crop stores and livestock farms, automatic sorting of agricultural products, automatic control of product handling and product processing, control of grain drying operations, livestock feeding control and so on. Automation of field operations cover automatic control of irrigation and drainage of farms, control systems for field harvest machines, automatic guidance of farm tractors, etc. The introduction of automatic control systems has made possible, new advances in its associated instrumentation.

8.7.2. Effectiveness of Mechanisation in India

Agriculture is the mainstay of the Indian economy. Our experience through the last twenty years brings out the fact that the overall develop-

ment of the Indian economy is dependent on, and sensitive to, changes in the agricultural sector.

The need for large scale mechanisation programme was recognised during the Third Five Year Plan. During the past few years there has been a rise in the demand for all types of farm equipment. Farmers, more than ever before, are eager to buy well-designed tools and equipments for maximising production. Mechanisation of agricultural operations, that has taken place in India, is still of a partial nature, confined mainly to a few operations. Since mechanisation has been accompanied by a number of other developments in the agricultural front, it is difficult to judge the effectiveness of mechanisation. However, it appears to have significantly helped in raising the output in some areas in the country. As for employment, mechanisation as such does not result in any significant displacement of the labour force. Rather, it creates demand for more permanent farm workers. These factors are quite significant when we consider the planned introduction of electronic equipment in Indian agriculture to augment the mechanisation efforts.

8.7.3. Demand Profile

In order to work out the approximate demand for agri-electronic equipment, it is useful to group these equipment into three main categories according to their techno-economic position, viz., (a) high-volume low-cost, (b) high-volume medium-cost and (c) low-volume high-cost (see Table 8.26).

Table 8.26. Techno-economic classification of agri-electronic equipment.

High-volume low-cost	High-volume medium-cost	Low-volume high-cost
1. pH Meter	1. Relative humidity meter	1. UV spectrophotometer
2. Colorimeter	2. Gas analysers	2. IR spectrophotometer
3. Soil moisture meter	3. Polarograph	3. X-ray defraction instrument
4. Grain/crop moisture meter	4. Thermal analyser	4. NMR spectroscope
5. Flame photometer	5. Soil densitometer with neutron probe	5. Photo flurimeter
6. Conductivity meter	6. Tensiometer	6. Gas chromatograph
7. Light intensity meter	7. Tintometer	7. Electron microscope
8. Viscometer	8. Physiograph	8. Evenness tester
9. Respirometer	9. Radiation detector	9. Auto analyser
10. Temperature indicator	10. Radiation monitor	10. Smoke detector
11. Conductivity bridge	11. Turbidity meter	11. Amino acid analyser
12. Strain gauge meter	12. Fraction collector	12. Guiger-Muller counter
	13. Densitometer	13. Scintillation counter
	14. Decade counters	14. Lyophilisers
	15. Water evaporation detector	15. Leaf area meter
	16. Anemometers	16. Acre meter
	17. Electronic balance	17. Titrimeter
	18. Recorders	18. Recorders
	19. Integrators	
	20. Ultrasonic detectors	

The major user of the agri-electronic equipment in the country is the chain of agricultural and animal science research organisations. There are 23 major research organisations and 20 agricultural universities under the Indian Council of Agricultural Research (ICAR), besides other regional institutions spread over the country.

VIII

For agricultural and animal science research, the ten year demand profile is worked out in Table 8.27. It is estimated that during the Fifth Plan period, equipment worth Rs. 4.75 crores would be required for this purpose. In order to support the agricultural production programme, research programmes would be further intensified during the Sixth Plan period, with consequent increase in the demand by at least 50 per cent. The total demand during the ten year period thus can be placed at Rs. 12.25 crores.

Table 8.27. Ten year demand profile for agricultural and animal science research (in Rs. crores).

Equipment type	Fifth Plan period	Sixth Plan period
High-volume low-cost equipment	1.00	1.75
High-volume medium-cost equipment	1.50	2.25
Low-volume high-cost equipment	2.25	3.50
Total	4.75	7.50

A recent survey shows that over 30 per cent of the total electronic equipment available in the research organisation are inoperative due to lack of maintenance. In order to remedy this situation some institutions have already established test and maintenance centres. Implementation of comprehensive maintenance and servicing programme will require a host of general purpose equipment, the demand for which would be of the order of Rs. 1.5 crores during the ten year period.

The prevention of loss and wastage of foodgrains and food crops assumes critical importance in our country. It is indicated that during the Fifth Plan period there will be about 55 per cent increase in the storage and warehousing capacity involving an overall investment of Rs. 100 crores. shared by various Central and State organisations. It is likely that during the Sixth Plan period also the same growth rate in storage capacity will continue. It is reasonable to assume that about 3 per cent of the overall investment would be required to equip the storage houses with specialised electronic equipment to keep the losses to a minimum. The demand for electronic equipment for this purpose would be of the order of Rs. 3 crores during the Fifth Plan and Rs. 4.5 crores during the Sixth Plan.

Furthermore, if the scheme for introducing electronic equipment in direct farming is envisaged, the demand will rise by about Rs. 7.6 crores, making the total volume of demand as high as Rs. 27.35 crores during the ten year period. This is, of course, subject to the introduction of intensive research programmes during the Sixth Plan period, establishment of testing and maintenance centres, modernisation and expansion of warehousing facilities, and the nation-wide programme introducing electronics in direct farming.

8.7.4. Current Status

Some of the electronic equipment required in agri-research and agri-mechanisation are those which find extensive applications in other industries, particularly in the process industries. These equipments include process control instruments such as pH meters, conductivity meters, temperature indicators, colorimeters, etc., and are indigenously available. While some of the process monitoring instruments can be directly used in agri-operations, some require further modification to suit the specific requirements. A case in

VIII

example is moisture meter. A general purpose moisture meter is not suitable for the measurement of moisture content in grains and crops, and requires altogether different design for soil measurement purposes.

For assessing the indigenous capability further, the agri-electronic instruments could be grouped into the following four categories:

- (i) Low-priced, portable, rugged and direct-reading instruments for field use
- (ii) Reliable, vibration-proof equipment suitable for mobile units
- (iii) General purpose instruments for laboratory use
- (iv) Sophisticated instrumentation system for agriculture and animal science research

While some of the instruments falling under category (ii) and (iii) are made in the country, those under category (i) and (iv) are not indigenously available. Category (iv) covers the electronic equipment mentioned under the head low-volume high-cost equipment in Table 8.26. Recording instruments are required for laboratory use. Integration of the available instruments with recorders, poses several problems. Also instruments with remote indicators are presently not made in the country. As a whole, it can be said that the indigenous production base of agri-electronic equipment is still in an embryonic stage.

As far as R&D is concerned, recently a few agricultural organisations have set up instrument design and development centres. These centres are currently engaged in the development work which is mostly related to the modification of the existing instruments to suit the needs of agricultural scientists and workers.

The Instruments Development and Service Centre attached to the Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, has developed prototype types of instruments like solid state galvanometer for flame photometric applications, temperature indicator for rectal temperature measurements and light intensity meter. Laboratory models of soil moisture probe, differential temperature indicator, controlled irrigation system, setups for studies on acoustical energies on plants, etc., have also been developed. Work is in progress in this centre on instrumentation systems for micro-climatic studies on crop growth.

The Central Institute of Fisheries Technology, Cochin has developed instruments like thermister thermometer for temperature measurement of fish, brineometer for measurement of salt content of dry fish, etc. Also some development work is underway at IARI, IIT Kharagpur, and some other places, but exact details of their development projects are not available.

8.7.5. Proposed Guidelines

An important factor, while deciding the optimum level of instrumentation and control that can go into our agricultural sector, is the size and fragmentation of land holdings. Out of the 50.7 million land holdings operating over an area of 134 million hectares, more than 85 per cent are holdings with less than 5 hectares, and the average size of holdings in the country works out to be around 2.63 hectares. Farmers in this size category do not have the potential to support even an intermediate level of instrumentation. Small and medium farmers could join together to bring into existence sizeable farm units which would facilitate the application of a medium level of instrumentation and control techniques.

VIII

Though in the First Five Year Plan the concept of cooperative farming was introduced, it appears that this did not bring in the results envisaged at that time. Although more than 5000 cooperative farming societies are said to exist in India, most of them have been established on Government lands with Government capital under various socio-economic considerations. Only about 30 per cent of this constitute cooperative farming in the real sense of the term, wherein the land owning peasants or tenants have pooled their existing holdings for joint cultivation. Thus, the present set up should create a sufficiently large network of medium-sized farms if agrionic techniques are to be introduced in direct farming.

At present, there is no evidence of the use of such techniques in direct farming operations in India. The essential requirements of the farmer would be in testing of the soil for its density, moisture content, evaporation rate, nutrient level, etc., measurement of some of the atmospheric parameters and testing of grains and seeds. It would be advantageous and more beneficial to the farmers if these facilities are made available directly in the villages. Hence organising mobile facilities would be an ideal practice to promote the use of agri-electronic equipment in direct farming operations. It appears that mobile agrionic service units, pressed into operation at the Community Development Block level, can meet the requirements of the rural agricultural sector. Agri-electronic equipments required for such mobile units are shown in Table 8.28.

At present, there are over 5000 Community Development Blocks existing in the country. It would be possible to introduce, in a phased manner, such mobile units at block level in a ten year period. In view of the limited availability of resources, it may not be possible to provide one mobile unit to each block, but one unit can cover about 3 blocks. If such a scheme is considered, there would be a sizeable demand for the types of agri-electronic instruments to be equipped in the mobile unit. Each mobile unit would involve a capital investment of Rs. 45,000 for instruments alone. Considering the scheme that 3 blocks could be covered by one mobile unit, there would be about 1700 such units in operation at the end of the Sixth Plan.

Also, it is essential to have an effective storage and distribution system of foodgrains to avoid any wastage due to improper storage and processing. This is, in fact, one of the areas wherein the country has to introduce electronic instrumentation to a substantial level so as to ensure optimum use of the available agricultural products. Food Corporation of India with its large storage and distribution system would be better equipped if some of instrumentation techniques are introduced.

Another major area for instrumentation techniques, which is of importance to us, is the protection of plants and stored crops from insects. Much efforts have not gone into this aspect even at a global level. However, a developing country like India should take lessons from what happened elsewhere because of excessive use of chemicals and other pesticides. Hence, due consideration must be given not only to the development of pesticides pollution monitoring instruments, but also for evolving new electronic techniques for pest and virus control itself.

A review of the development and production activities in agrionics shows that the present base has to be strengthened significantly, in order to meet the demand that is likely to arise, if the promotional efforts are undertaken in the manner indicated earlier. Many low-cost high-volume equip-

VIII

Table 8.28. Agri-electronic equipment required for a Mobile Agrionic Service Unit.

Sl. No.	Instrument	Purpose	Qty. reqd.	Availability	Cost in Rs.
1.	Soil moisture meter	Measurement of moisture content of soil	1	Imported	7,500
2.	Grain/crop moisture meter	Measurement of moisture content of grains/crops	1	Indigenous	2,500
3.	pH meter	Measurement of soil pH	1	Indigenous	3,000
4.	Soil densitometer with neutron probe	Measurement of soil density	1	Indigenous	7,500
5.	Conductivity analyser	Measurement of soil nutrient levels	1	Indigenous	3,500
6.	Water evaporation detector	Measurement of evaporation rate of water from soil	1	Imported	3,500
7.	Thermister probe thermometer	Measurement of aerial, soil and grain temperatures	1	Indigenous	1,000
8.	Light traps	Study arrival of pests & insects	3	Indigenous	1,000
9.	Relative humidity meter	Measurement of RH of aerial environment	1	Imported	5,000
10.	Ultrasonic detection	Evaluation of parameters associated with agricultural and livestock	1	Indigenous	6,000
11.	Milk analyser	Analysis of milk	1	Imported	3,000
12.	Accessories			Indigenous	1,500
Total					45,000
FE content					19,000

ment can be easily manufactured in the country with some modifications of the existing equipment. What is necessary would be to bring together agriculture scientists and instrumentation development and production engineers.

In the development and production effort, priority must be assigned to low-cost simple instruments required in direct farming operations. Such instruments would include portable type moisture meter, capacitance type relative humidity meter, water evaporation detector, milk analyser, etc.

In agricultural research, recorders which respond to inputs of the order of microvolts are extensively required. Other instruments which need to be developed on a priority basis are anemometer for low velocity measurements, leaf-area meter, and soil cycrometer for measurement of plant water status. These are only indicative areas; an in-depth study is needed to identify exact priority areas, and to specify the strategy for development and production of agri-electronic equipment.

Medical Electronics

9.1 Introduction

One of the spin-offs due to increasing sophistication in electronics is the emergence of a new area called biomedical engineering or medical electronics. A wide spectrum of disciplines such as engineering, mathematics, biology and medicine has contributed to the growth of this field. Such an interdisciplinary approach has helped in the development of a host of medical electronic equipment for the use of physician as an aid for achieving better diagnosis and therapy. Be it in detecting tumours in the brain, diagnosing heart disorders, or using computers for various purposes, medical electronics is playing a significant role in modern medicine and has been one of the forces that has, in fact, changed the conventional medical practice to what it is today.

In India, though the field of medical electronics is still in its infancy, it has made a significant start in the right direction. New equipment in increasing numbers are currently used in hospitals in the country. The industry is gearing itself to meet the exacting demands posed by this sophisticated area, and products developed in research and development organisations are being commercially exploited. On the educational front, colleges and institutions have already included medical electronics in their curricula. The initial inevitable gap that normally exists between members of different disciplines committed to the development of a new area has considerably narrowed down.

It has been predicted that medical electronics will have an important role to play in the coming decade. In addition to catering to the needs of urban hospitals, medical electronics can aid considerably in improving the health services in the rural areas. The various facets of medical electronics are detailed in the following sections keeping in view the challenging task of planning the growth of this area.

9.1.1. Classification of Medical Electronic Equipment

The product-mix of medical electronic equipment (MEE) is wide and diversified and hence it becomes necessary to evolve a classification encompassing all the items that would broadly fit into medical electronics. In addition to the inclusion of conventional diagnostic and therapeutic equipment, items such as computer systems, paging systems, medical lasers and closed circuit television systems, which are finding increasing application in modern hospital environment, are also listed under MEE. MEE may be classified as follows:

- (i) Ophthalmic, Ear, Nose, Throat and Artificial Equipment
 - Clinical audiometer
 - Acoustical impedance meter
 - Artificial ear
 - Artificial kidney

IX

Artificial heart
Artificial limbs
Hearing aids
Tonometer
Nystagmus recorder

(ii) Pathology Equipment

Spectrophotometer
Absorptionmeter
pH meter
Flame photometer
Chart recorder
Auto analyser
Blood grouping machine
Electrophoresis
Fluorimeter
Colorimeter
Gas chromatograph
Densitometer
Ionisation amplifier
Oximeter
Oxygen analyser
Electronic timer
Galvanometer
Automatic tissue processor
Absorption spectrophotometer
Constant temperature bath
IR gas analyser

(iii) Patient Care Equipment

Pacemaker, implantable, internal and external
Defibrillator
Defibrillator, DC
Respirator
Electro-convulsive therapy unit (ECT)
Humidifier
Incubator
Chiller-thermo-circulator
Renal dialyser
Respirometer
Spirometer
Cardiograph
Anaesthetic machine

(iv) Patient Monitoring Equipment

Electrocardioscope
Electrocardiograph (ECG)
Electroencephalograph (EEG)
Electromyograph (EMG)
Pulse rate monitor
Blood pressure monitor

IX

Temperature monitor
Apnea monitor
Insufflation pressure recorder
Chart recorder
Respiratory gas analyser
Pulmotor
Blood gas analyser
Phonocardiograph
Low frequency oscillator
Multi-channel display oscilloscope
Foetal heart monitor
ECG simulator
Plethysmograph
Multi-channel thermometer
Photic stimulator
Blood-loss meter
Lung compliance unit
Patient monitoring console

(v) Physiotherapy Equipment

Short wave diathermy unit
Radiation lamp (UV and IR)
Microwave source
Muscle stimulator
Ultrasonic therapy unit

(vi) Radiography Equipment

X-ray diagnostic machine, fixed and mobile
X-ray machine, scanning
Automatic film processor
Image Intensifier
Video-monitor, camera, tape recorder

(vii) Radiotherapy Unit

Radiation source, X-ray and gamma ray
Radiation monitors
Scaler
Counter
Dosimeter
Ratemeter
Cobalt unit
Cesium unit
Linear accelerator
Infrared scanner

(viii) Screening and Nuclear Medicine Equipment

Gamma camera
Radioisotope scanner
Storage oscilloscope
Cell counter
Spectrum analyser
Data processor

IX

- (ix) Surgical Equipment
 - Diathermy set
 - Electrocautery
 - Cryosurgical unit
 - Laser, ophthalmic
 - Fibre optic light source
 - Endoscope

 - (x) Transducers
 - Cable, patient-ECG/EEG
 - Pressure, direct and indirect
 - Respiration
 - Temperature probe
 - Displacement
 - Flow
 - Ear plethysmograph
 - Finger plethysmograph
 - Pulse wave pickup

 - (xi) Electrodes
 - Disc
 - Needle
 - ECG, EEG patient cables
 - Probes

 - (xii) Teaching Aids
 - Video camera
 - Video monitor
 - Video recorder
 - Video mixer/fader
 - Audio power amplifier
 - Tape recorder
 - Microphone/headphone/loudspeaker
 - Cine projector
 - Slide projector
 - Tape-slide synchroniser

 - (xiii) Computer Systems
 - Computerised intensive care unit
 - Computerised cardiac catheterisation system
 - Information system, hospital management, patient data
 - ECG interpretive system

 - (xiv) Others
 - Closed circuit television system (CCTV)
 - Medical laser
 - Paging system
 - Fire alarm system
 - Standby generation control
 - Standby power supply
 - Intercommunication system
-

Air conditioning system
Central clock system

9.2 Current Status

9.2.1. Health Programme in India

Health programme in India is primarily the responsibility of the State Governments. The Union Government has, however, sponsored and supported major schemes for improving the standard of health of the people, under the Five Year Plans. The broad objectives of the health programmes during the last decade have been (i) to control and eradicate communicable diseases, (ii) to provide curative and preventive health services in rural areas through the establishment of primary health centres in each community development block, and (iii) to augment the training programmes of medical and para medical personnel. The programmes were formulated on the basis of the report of the Health Survey and Planning Committee of 1961.

Table 9.1 indicates the outlay for health in each of the Five Year Plans, and the percentages of outlay for health in terms of total public sector and total plan outlays. It is seen that although the investment has been on the increase in the successive Plans, the percentage in terms of total plan outlay has decreased from 3.8 in the First Plan to 1.7 in the Fourth Plan. Considering the outlay for health as a percentage of total public sector outlay, the figure drops from 7.2 to as low as 2.7. This trend is disturbing particularly when India is ranked the second lowest country as regards the number of physicians and hospital beds per thousand of population. Table 9.2 indicates the outlay for medical and public health programmes during the Fourth Plan.

Table 9.3 indicates the achievements and targets from 1960 to 1974, in terms of practising doctors and available hospital beds.

From Table 9.4, it is seen that for the year 1970-71, the outlay for training programmes was of the order of 21.60 crores to train nurses and non-medical personnel. Table 9.5 gives the current and proposed target in manpower requirement for health services.

Table 9.1. Outlay for health in Five Year Plans (in Rs. crores).

Five year plan	Period	Outlay for health	Total public sector outlay	Total private sector outlay	Total plan outlay	Percentage of public sector outlay to health	Percentage of plan outlay
First Plan	1951-56	140	1960	1800	3760	7.2	3.8
Second Plan	1956-61	225	4600	2400	7000	4.9	3.2
Third Plan	1961-66	303	7500	4100	11600	4.0	2.6
Fourth Plan	1969-74	435	15902	8980	24882	2.7	1.7
Fifth Plan	1974-79	816	37250	16161	53411	2.2	1.5

Table 9.2. Outlay on medical and public health programmes during Fourth Five Year Plan (in Rs. crores).

Particulars	Central	Centrally sponsored States	Union territories	Total
Fourth Five Year Plan	53.50	176.50	185.75	435.03
1969-70	6.35	22.75	24.65	56.15
1970-71	7.40	25.38	27.14	63.40

IX

Table 9.3. Achievement and targets as to number of hospital beds and doctors practising (in thousands).

Year	Hospital beds	Doctors practising
1960-61	185.6	70.0
1965-66	240.1	86.0
1968-69	255.7	102.5
1973-74	281.6	137.9

Table 9.4. Distribution of outlay for the Fourth Plan (in Rs. crores).

Programme	Fourth Plan outlay	Outlay for 1969-70	Outlay for 1970-71
Medical education research	85.29	11.50	14.65
Training programme	12.93	1.54	21.60
Control of communicable diseases	127.01	20.27	0.15
Hospitals and dispensaries	89.29	9.38	12.50
Primary health centres	76.49	8.19	7.30
Indigenous system of medicine (ISM)	15.83	1.70	2.50
Other programmes	28.10	3.57	4.70
Total	434.94	56.15	63.40

Table 9.5. Manpower requirement.

Upto the year	Hospital beds	Doctors	Nurses	Non medical personnel
1969-70	2,61,200	1,09,000	66,000	52,000
Proposed total target at the end of Fourth Plan (1973-74)	2,81,600	1,37,000	88,000	70,000

9.2.2. Sophistication Level of MEE in India

A sample survey conducted recently of MEE used in hospitals in the country, indicates that from a city hospital down to a taluk hospital, MEE of varying sophistication levels are being used. The findings of a statistical analysis of the answers received from 150 out of the 650 hospitals that were contacted, are indicated in Table 9.6. The equipment listed under each class of hospital indicates the minimum sophistication level prevailing currently.

9.2.3. Production

The base for production of MEE comprises mainly of small and medium scale manufacturers both in public and private sectors. Of the equipment manufactured, X-ray equipment constitutes the major share of the overall production of MEE. Some of the other equipment currently manufactured and marketed are electrocardiograph, cardiac pacemaker and defibrillator, respirator, foetal heart detector, hearing aid and stimulator. Also, for testing purposes, analytical instruments such as pH meter, medical spectrophotometer, colorimeter, electrophoresis unit, etc., are manufactured. Table 9.7 indicates the production of MEE in the country during 1968-74. MEE forms roughly 2 per cent of the total electronics equipment production

IX

for the year 1972-73. The corresponding figure for the European countries is around 3 per cent.

Table 9.6. Prevailing level of sophistication of MEE used in India.

No.	MEE	Taluk hospital	District hospital	City hospital
1.	Electrocardiograph	x	x	x
2.	X-ray, diagnostic	x	x	x
3.	X-ray, therapeutic	x	x	x
4.	Colorimeter	x	x	x
5.	Centrifuge	x	x	x
6.	Incubator	x	x	x
7.	Electroconvulsive therapy unit		x	x
8.	Diathermy (surgical and physiotherapy)		x	x
9.	Audiometer		x	x
10.	Stimulator (muscle and nerve)		x	x
11.	Defibrillator-pacemaker		x	x
12.	Cardiac monitor		x	x
13.	Electroencephalograph			x
14.	Electromyograph			x
15.	pH meter			x
16.	Flame photometer			x
17.	Ultrasonic foetus monitor			x

Table 9.7. MEE production in India.
(in Rs. crores)

Year	Total MEE production	Total electronics equipment production
1968-69	1.0	85
1969-70	1.2	110
1970-71	1.5	138
1971-72	2.5	152
1972-73	3.6	175
1973-74	4.0	187

9.2.4. Inspection, Testing and Maintenance Facilities

Although a variety of MEE are manufactured, the quantum of equipment manufactured is much below that the hospitals in the country can absorb. Even the equipment currently manufactured are not completely utilised due to inadequate inspection, test and maintenance facilities.

There are a few organisations which are catering to this important aspect. The Central Scientific and Instruments Organisation (CSIO) offers test and maintenance facilities to hospitals and industry alike. It has set up service and maintenance centres at New Delhi, Bombay, Calcutta, Madras and Chandigarh. Facilities have been created for undertaking repairs and servicing of electrical, electronic, medical and electromechanical equipment at these centres. The Controllerate Inspection of Electronics (CIL) has good test and maintenance facilities at different locations in the

country. These facilities mainly cater to servicing MEE used by Defence and allied services.

9.2.5. Research and Development

Starting as a subject of the electrical engineering curricula in the early sixties, bio-medical engineering is now offered at Masters and Doctoral level programmes in various educational institutions.

The educational and research institutions, where R&D activity is being pursued, are the IITs, IISc, TIFR, BARC, ICRC, PCI (Delhi), HBTI (Kanpur), All India Medical Institutes at Bangalore, Delhi and Bombay, medical colleges and institutions at Bangalore, Vellore, Madras, Pondicherry and Chandigarh, hospitals at Delhi and Bombay and also in Roorkee and Jadavapur Universities.

The organisations involved in R&D in bio-medical engineering presently in the country are the national laboratories including Defence laboratories and academic institutions.

A summary of the R&D activities completed/in progress at various laboratories is given below.

A. Laboratories under CSIR

1. National Physical Laboratory (NPL), New Delhi

Development project in progress: A Strain gauge instrumentation for physiological measurements.

2. National Aeronautical Laboratory (NAL), Bangalore

Development of transducers: Linear variable differential type, pressure and displacement transducers, bonded strain gauge type, capacitance type pressure transducers and their associated amplifiers for different ranges.

3. Central Scientific Instruments Organisation (CSIO), Chandigarh

Projects that were successfully completed are listed below:

- (i) Stimulators (three different types with RF isolation units)
- (ii) Blood drop chamber and counter
- (iii) Cardiac pacemaker
- (iv) Cardioscope
- (v) AC defibrillator
- (vi) Therapeutic/diagnostic unit
- (vii) ECG stimulator
- (viii) Respiration monitor for babies
- (ix) Foetus monitor
- (x) Stimulator for research and clinical use
- (xi) Medical oscilloscope

Of these, development know-how of the following equipment have been released for commercial production:

- (i) Stimulators (3 models)
- (ii) Cardiac pacemaker
- (iii) Cardioscope
- (iv) AC defibrillator
- (v) Diagnostic/therapeutic unit

Development projects in progress:

- (i) Electromagnetic flow meter
- (ii) Echo-encephalograph
- (iii) Physiological monitor (Multimeter and digital displays)
- (iv) Cardioscope with tape recording
- (v) Oximeter
- (vi) ECG machine
- (vii) Ultrasonic Doppler's technique
 - (a) Foetus heart-rate monitor
 - (b) Blood flow meter
- (viii) Cardiotachograph

B. Laboratories under Department of Atomic Energy

1. Bhabha Atomic Research Centre (BARC), Bombay

- (i) Diagnostic stimulator
- (ii) Multiwaveform treatment stimulator
- (iii) Electromyograph
- (iv) Laser photocoagulator
- (v) Muscle activity monitor
- (vi) Applications of muscle activity monitor
- (vii) Measurement of eye movements using an experimental electronic system
- (viii) 'On-line' spectral analyser and recorder for the investigation of cardiac dynamics

C. Laboratories under Indian Space Research Organisation (ISRO)

1. Space Science and Technology Centre (SSTC), Trivandrum

- (i) Digital panel meter for patient monitoring

D. Laboratories under Ministry of Defence

1. Institute of Aviation Medicine, Bangalore

Development Projects:

- (i) Recording of indirect blood pressure from the thumb by phase shift method

2. Electronics & Radar Development Establishment (LRDE), Bangalore

Projects completed:

- (i) Patient monitor
 - (ii) Cardiac care system
 - (iii) Cardiac pacemaker
 - (iv) Phonocardiograph
 - (v) DC defibrillator
 - (vi) Electro anaesthesia
 - (vii) Electro sleep
 - (viii) Anaesthesia monitor
 - (ix) Electronic thermometer
 - (x) Electronic stimulator
 - (xi) Plethysmograph
-

- (xii) Ballistocardiograph
- (xiii) Phonocardiograph
- (xiv) BP recording system (MK II)
- (xv) BP graph recorder
- (xvi) Pacemaker
- (xvii) DC defibrillator
- (xviii) Implantable pacemaker
- (xix) Implantable demand pacemaker
- (xx) ECG telemetry system
- (xxi) Arrhythmia monitor
- (xxii) Foetal ECG
- (xxiii) Drop rate meter
- (xxiv) Valveless compressor for BP system
- (xxv) ECG recorder

E. IITs and Other Institutions

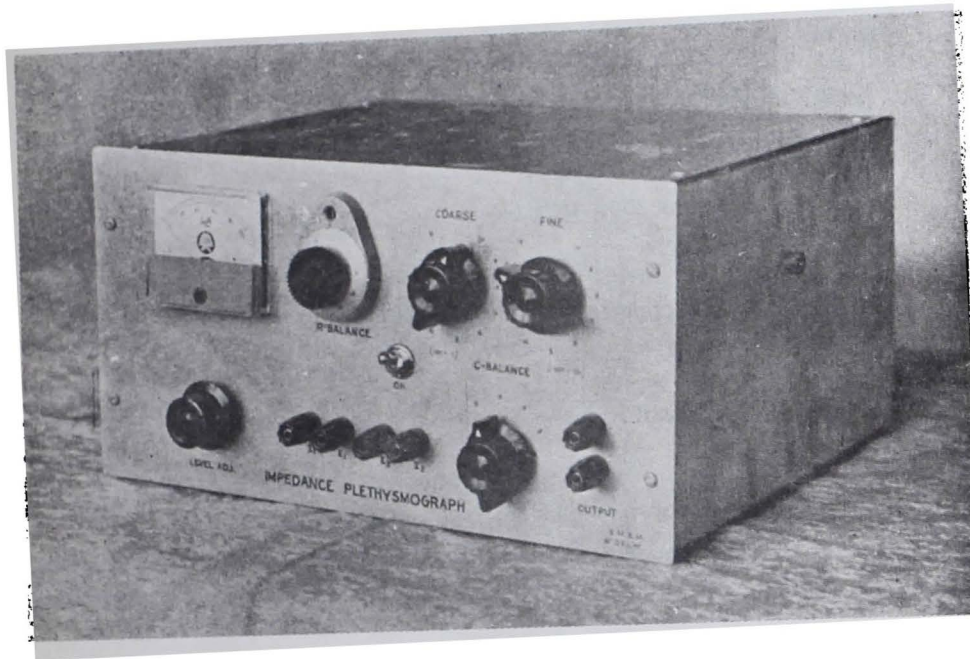
1. IIT, Delhi and All India Institute of Medical Sciences Instrument Design and Development Centre (IDDC)

Activities of this unit are mainly concentrated in areas like fluidics, controllers, instrumentation for power regulator systems, etc.

Projects under way:

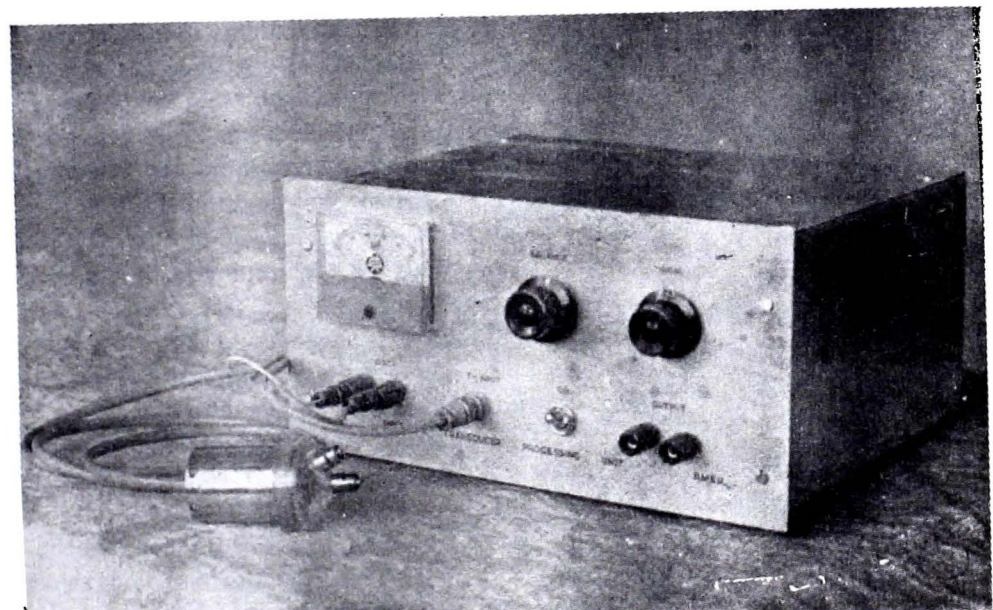
- (i) Electrical field plethysmography
- (ii) Electrical impedance plethysmography
- (iii) Electromagnetic flowmeter
- (iv) Mathematical model for the electromechanical dynamics of muscles
- (v) Study of movement of erythrocytes (red blood cells) in capillaries under the influence of steady and time varying electromagnetic fields
- (vi) Cervix stimulation to reduce time duration of administration of prostaglandins used for abortification
- (vii) Development of male contraceptive device
- (viii) Hand operated small size jet ejectors
- (ix) Ultrasonic techniques for tumour detection
- (x) Artificial control of micturition
- (xi) Enzymatic removal of urea in artificial kidney systems
- (xii) Study of the response of the eye to low frequency mechanical vibrations
- (xiii) Early detection of coronary artery disease from the ECG by computerised mathematical transformations
- (xiv) Design of mobile hospitals
- (xv) Design and fabrication of instruments
 - (a) Telemetry of electrocardiogram, electromyogram and electroencephalogram
 - (b) Premature heart beat detector
 - (c) Apnea monitor for infant incubators
 - (d) External pacemakers
 - (e) Device to record low frequency signals on magnetic tape

The Biomedical Engineering Unit has given advice and assistance to on-going programmes in (i) Artificial Kidney Unit, (ii) Repro-



Electrical impedance plethysmograph developed by IIT, Delhi.

Pressure transducer and signal processing unit developed by IIT, Delhi.



duction Biology Unit, (iii) Department of Physiology, (iv) Department of Medicine and (v) Central Workshop.

2. IIT, Kanpur

- (i) Computer application in medical information processing

3. IIT, Madras

- (i) Organ assist and replacement systems
- (ii) Cardiac pacemaker
- (iii) Cardioscope (3-channel display of ECG output)
- (iv) Low level DC amplifiers
- (v) Digital instruments for parameters like temperature, pulse rate, heart beat, blood pressure
- (vi) Instantaneous rate meter
- (vii) Instruments for cardiovascular surgery
- (viii) Electronic device in neuro-surgery
- (ix) Instrument to measure microwave field intensity in human environment
- (x) Artificial kidney
- (xi) Electro-anaesthesia

The following problems under study represent an important need in vital area of medical treatment:

- (a) the study of locomotion in normal and handicapped human beings, and the design and fabrication of force-plates, strain gauges, etc.,
- (b) the study of electrical potential changes in the muscle,
- (c) the study of forces transmitted by the human hip joints, knee joints and other joints of the extremities and the design of implant prosthesis,
- (d) the study of various types of materials in the provision of prosthetic replacement of joints as well as the internal fixation of fractures,
- (e) the study of the weight-strength characteristics and related properties of indigenous materials used in the fabrication of prostheses and orthoses (artificial limbs and orthopaedic appliances),
- (f) the use of modern principles of mechanics in the fabrication of artificial limbs and orthopaedic appliances,
- (g) the study of externally powered systems for the working of artificial limbs, with internal control (myo-electric control) as well as external control,
- (h) the study of applied bio-cybernetics and the working of the lower extremity prostheses (artificial lower limb),
- (i) the development of feeders and other self-help devices for disabled patients, and
- (j) the design and construction of wheeled platforms and other ambulatory equipments for physically handicapped patients.

University of Delhi has taken up a development project on the positron annihilation in biological samples. A development project on the analysis of ventricular systolic pressure of human aorta and computer model of arterial circulatory system is underway at the Institute of Radiophysics and Electronics, Calcutta.

9.2.6. Imports and Exports

Compared to the production of MEE over the period 1960-72, the imports have been substantial. The import for the year 1971-72 was worth around Rs. 1.70 crores compared to the production worth Rs. 2.5 crores. Electrocardiographs, electroencephalographs, defibrillators and pacemakers, X-ray diagnostic and therapeutic apparatus and their spare parts and hearing aids are some of the items that have been imported. Major countries from where the items are imported include USA, UK, East and West Germany, Japan, USSR and Hungary.

The volume of exports is considerably small compared to production and imports. X-ray equipment forms the main component of exports. There is however, a growing export market for defibrillators, pacemakers and hearing aids.

9.3 Demand Profile

Several inputs, such as the requirements of the country, the present and anticipated growth-trends of the industry, the anticipated global growth trends, etc., are necessary to arrive at a reasonable forecast. New technological innovations and developments, applicable to a particular area in electronics may tend to off-set the forecasts estimated earlier. In spite of such a possibility, demand profile helps in estimating the probable production and imports and exports over the periods envisaged. Based on estimated production capabilities, factors such as reduction of imports leading to import-substitution, possibility of increasing the exports, etc., can be approximately worked out.

The field of medical electronics is essentially interdisciplinary in nature, in the sense that electronic equipment is used in medicine. As such, the demand for these equipment necessarily depends on the requirement of the users, namely the hospitals in the country, and on the manufacturing capabilities of the supplier, namely the industry. In estimating the demand profile for the ten year period 1974-84, the following factors have been taken into consideration.

(i) The requirements of hospitals under Central and State Governments, hospitals under essential services such as the Railways, Defence and public sector undertakings, private hospitals, nursing homes and clinics, medical colleges, laboratories and research institutions

(ii) The demand pattern for the overall electronics and communications industry, as estimated by the Task Force VII set up by the Planning Commission

(iii) The growth trends of MEE in other countries

Table 9.8 gives the estimated demand of MEE for the years 1974 through 1984. Out of a total of Rs. 163 crores, the demand during the Fifth Five Year Plan is expected to be Rs. 50 crores and around Rs. 113 crores in the Sixth Plan. The break-up of requirements of hospitals in the Fifth Plan is given in Table 9.9.

Based on the plans of Health Ministry for introduction of MEE into hospitals at various levels as indicated in Table 9.9 and the break-up of demand profile as indicated in Table 9.8, the requirement of MEE in the country during the Fifth Five Year Plan is estimated. MEE can be broadly classified into high volume, low and medium cost equipment, volume and low, how cost equipment. Equipment such as electrocardiograph, defibrillator

IX

Table 9.8. A ten year demand profile for medical electronic equipment (1974-84) (in Rs. crores).

Year	Fifth Plan period					Sixth Plan period					Total 1974-84
	1974- 75	1975- 76	1976- 77	1977- 78	1978- 79	1979- 80	1980- 81	1981- 82	1982- 83	1983- 84	
Demand	6.0	7.2	9.6	12.2	15.0	17.5	20.2	22.5	25.3	27.5	163.0

Table 9.9. Expected requirement of medical electronic equipment in the Fifth Plan period.

Sector	Rs. crores
Health Ministry:	
Hospitals of Central and State Governments, medical colleges, laboratories and research institutions.	25
Defence, Railway, P&T, Central Government undertaking hospitals	15
Private hospitals, nursing homes and clinics and others	10
Total	50

Table 9.10. Breakup of high volume MEE.

No.	High volume MEE	Estimated requirement (numbers)	Appropriate cost per unit (Rs.)	Total (Rs. crores)
1.	Portable intensive care equipment for mobile van (including defibrillator, electrocardiograph, respirator monitor)	100	50,000	0.50
2.	Electrocardiograph	3000	10,000	3.00
3.	Centrifuge	8000	1,000	0.80
4.	Respirator	1000	8,500	0.85
5.	Colorimeter	5000	3,000	1.50
6.	Incubator	8000	1,500	1.20
7.	pH meter	5000	2,000	1.00
8.	Electrophoresis	5000	2,000	1.00
9.	Flame Photometer	500	12,000	0.60
10.	Diathermy (surgical and physiotherapy)	2000	5,000	1.00
11.	Defibrillator (DC)	1000	10,000	1.00
12.	Audiometer	2000	4,000	0.80
13.	Pacemaker (external and internal)	5000	2,500	1.25
14.	Pacemaker (implantable)	1000	5,000	0.50
15.	Tonometer	1000	3,000	0.30
16.	Foetal heart detector	2000	2,000	0.40
17.	Stimulator (muscle and nerve)	2000	2,500	0.50
18.	Electro convulsive therapy unit	2000	2,500	0.50
19.	Cardiac monitor	8000	10,000	0.80
20.	Hearing aids	2000	250	0.50
21.	X-ray equipment (diagnostic and therapeutic)	—	—	27.00
Total				45.00

IX

Table 9.11. Breakup of low volume MEE.

No.	Low volume MEE	Estimated requirement (in numbers)	Approximate cost per unit (Rs.)	Total cost Rs. crores
1.	Intensive care unit equipment	50	2,00,000	1.000
2.	Electroencephalograph	50	1,20,000	0.600
3.	Electromyograph	80	35,000	0.280
4.	Echoencephaloscope	80	25,000	0.200
5.	Cardiotachograph	100	25,000	0.250
6.	Echocardiograph	50	50,000	0.250
7.	Cell counter	30	25,000	0.075
8.	Nuclear medical scanner	30	75,000	0.220
9.	Renograph (kidney)	25	1,00,000	0.250
10.	Electronystagmograph	30	50,000	0.150
11.	Laser photocoagulator	20	1,00,000	0.200
12.	Medical spectrophotometer	100	25,000	0.250
13.	Polygraph (4 channel)	50	60,000	0.300
14.	Electronic paging system	100	1,00,000	1.000
Total				5.025

Table 9.12. A proposed five-level hierarchy for health plan.

No.	Type	Size (no. of beds)	Present number	Target at end of Fifth Plan	New hospitals
1.	Regional hospitals (city)	1000	200	225	25
2.	District hospitals	250	250	350	100
3.	Taluk hospitals	50	2000	3000	1000
4.	Rural hospitals (upgraded primary health centres)	30	—	1000	1000
5.	Mobile portable intensive care units	—	—	100	100

country during the Fifth Plan is estimated. MEE can be broadly classified into high volume, low and medium cost equipment, low volume, high cost equipment. Equipment such as electrocardiograph, defibrillator and pacemaker, respirator, hearing aids, heart rate meter, etc., are essentially low-cost items which are required in large numbers. Patient monitoring systems, intensive and cardiac care units, electro-encephalographs, etc., are high cost items with a lower demand because of their cost and sophistication. The requirements are indicated in Tables 9.10 and 9.11. The tables also indicate the cost of each equipment and the probable number required upto the end of the Fifth Plan. It is estimated that requirement of high-volume equipment, including X-ray diagnostic and therapeutic machines, would be around Rs. 45 crores and that of low-volume, high cost around Rs. 5 crores. Dental cones and image intensifiers have been included in the projected estimates for X-ray machines. Table 9.12 indicates a proposed five-level hierarchy for the health plan. Table 9.13 gives the equipment necessary for each of the category shown in Table 9.12. It is proposed that the new centres to be started in the Fifth Plan under each hierarchy be equipped with the requirements indicated under its category and the existing centres be replenished gradually with the proposed MEE. An outlay should be provided separately for such replacements. It is proposed that the primary health centres be provided with

IX

minimum requirements as described in Table 9.13. Essential items of MEE are planned at lower levels of hierarchy of hospitals and the degree of sophistication is gradually increased for district and regional hospitals

Table 9.13. MEE for various hospital-levels/health centres.

No.	MEE	Approximate cost (Rs.)	Portable ICU for mobile van	Rural hospitals PHC	Taluk hospitals	District hospitals	Regional hospitals
1.	X-ray equipment 50 mA, 200 mA and 500 mA with image intensifier	6,50,000					x
2.	X-ray equipment 50 mA and 500 mA with dental cone	2,00,000				x	
3.	(a) X-ray equipment 200 mA	75,000			x		
	(b) X-ray equipment 100 mA	50,000		x			
4.	Portable ICU for mobile van	50,000	x				
5.	Electrocardiograph	10,000		x	x	x	x(2)*
6.	Centrifuge	1,000		x	x	x	x(12)
7.	Colorimeter	3,000		x	x	x	x(4)
8.	Incubator	1,500		x	x	x	x(4)
9.	Respirator	8,500			x	x	x(3)
10.	pH meter	2,000			x	x	x(2)
11.	Electrophoresis	2,000			x	x	x
12.	Diathermy	5,000			x	x	x
13.	Flame photometer				x	x	x
14.	Defibrillator (DC)	10,000			x	x	x
15.	Audiometer	4,000			x	x	x
16.	Pacemaker (external and internal)	2,500		x	x	x	x
17.	Tonometer	3,000				x	x
18.	Foetal heart detector	2,000				x	x
19.	Electroconvulsive therapy unit	2,500				x	x
20.	Stimulator (muscle and nerve)	2,500				x	x
21.	Cardiac monitor	10,000				x	x
22.	Intensive care unit	2,00,000				x	x
23.	Electroencephalograph	1,20,000					x
24.	Electromyograph	35,000					x
25.	Echoencephaloscope	25,000					x
26.	Cardiotachograph	25,000					x

*Figures in brackets indicate numbers required.

9.4 Analysis of Gaps

As indicated earlier, the demand for MEE during the next ten years would be of the order of Rs. 163 crores. To meet this demand, it is expected that a host of activities, which are presently inadequate or non-existent, would have to be initiated gradually. The existing lacunae in several areas have to be identified before setting up guidelines to achieve the demand target.

9.4.1. MEE for Better Rural Health Services

The existing production of MEE is mainly catered to the requirement of urban hospitals in the country. Both simple and sophisticated equipment are provided in all city hospitals, whereas facilities at rural hospitals are generally inadequate. There are at present about 360 district hospitals, 2000 taluk hospitals and 4500 primary health centres which need many of the simple equipment for diagnostic and therapeutic purposes. X-ray machines, both portable and mobile, can be effectively used for mass-health check ups. Detection of symptoms of diseases using MEE reduces the time delay in diagnosis of many complicated diseases. Proper therapeutic measures such as, use of pacemaker to counter heart block and boost up the failing heart rate, defibrillator to arrest the otherwise fatal ventricular fibrillation following shock or heart attack, at the right time will be extremely useful at a rural health centre. These MEE are extremely useful as they could keep the patient alive in an emergency before the patient is moved to a larger hospital equipped with intensive care unit.

Promotional effort, in order to reduce the prevailing awareness-gap with doctors and the masses of rural areas regarding MEE, would be necessary.

9.4.2. Inspection, Test and Maintenance

The introduction of many sophisticated equipment into hospitals have increasingly highlighted the need for maintenance of highest order. The fundamental philosophy that inspection, test and maintenance of an equipment forms the life-blood link, from the time the equipment is manufactured to the complete utilisation of the equipment to its designed life-time, should be recognised.

Inadequate maintenance mainly due to lack of skilled personnel and lack of facilities, inevitably degrades the quality and quantity of medical services and indirectly affects the production economy.

The existing maintenance facilities have been reviewed under Section 9.2. Though the CSIO centres are catering to the needs of the industry and hospitals in a commendable way, the load on these centres is heavy and they are too few in number to handle the exacting demands placed on them. Many hospitals in various geographical locations in the country still do not have any test and maintenance facility for an optimum utilisation of their equipment.

In rural areas comprising of district, taluk and primary health centres test and maintenance centres are virtually non-existent. In a survey conducted recently, it was estimated that, on an average, nearly 60 per cent of the equipment in hospitals in these areas are out of order due to one reason or other. Lack of skilled personnel and maintenance facilities has been identified as the primary reason for this state of affairs. Thus the underlying importance of inspection, test and maintenance facilities should be recognised for better maintenance of equipment at hospitals in both rural and urban areas.

9.4.3. Training Personnel

In any patient-care system, it is ultimately the nurse or a supporting staff who should operate the equipment in hospital. Although a doctor would be required to have a complete knowledge of the equipment used for either diagnosis or therapy, it is the supporting staff who is expected to switch-on the equipment, take readings and help the doctor in the diagnosis of a parti-

cular disease. In order to use the equipment intelligently, the operator should be well conversant with various factors such as safety hazards, electronics, physiology and a general knowledge of trouble shooting. It has been observed that lack of trained personnel has come in the way of full utilisation of the available equipment in most of the hospitals in the country. This factor seems to be true for all countries in general. In fact, the United Nations Industrial Development Organisation in its report 'Training of National Personnel for Industrial Development' released in 1972 points out: "At present there is lack of adequate training facilities in developing countries. Further, the training potential in, and by, industry is not being utilised to the best advantage by the governments of either developing or industrialised countries".

9.4.4. Need for a Public Sector Manufacturing Facility

The present manufacturing base available for MEE mostly comprises of small and medium scale companies. In order to cope with the demand target, the existing production base will have to be widened. This can be achieved by allowing for expansion of the existing units and by starting new manufacturing units.

At present, there is no public sector manufacturing unit wholly devoted to the manufacture of these life-saving equipment. ECIL, apart from manufacturing computers, television, nuclear instruments, and components, manufactures some of the MEE. In view of the appreciable growth planned for the next ten years, this area needs a public sector manufacturing unit wholly committed to this particular field. Health being primarily a Government responsibility, be it of State or Central, a unified Government approach is very necessary to give the much needed boost to the medical electronics field. Given the plans to introduce these life-saving equipment from urban hospitals down to primary health centres, and a demand of Rs. 163 crores worth of equipment as a target to be met by the end of next ten years, the setting up of a separate public sector organisation for the manufacture of these equipment becomes imperative.

9.5 Technological Trends

Long term production planning envisages taking into consideration the recent technological trends in medical electronics that may play an important role in the equipment to come in the next decade. The pace of growth of medical electronics can only stand on a strong R&D, dedicated to undertake adaptive and frontier research. New innovations and developments, leading to a breakthrough in technology or harnessing the available know-how for better utilisation, are the main areas wherein concerted efforts will be necessary. The available resources should be optimally utilised, so as to strike a compromise between adaptive and frontier research, keeping the overall equipment requirement in purview. Some of the areas which will find increasing application in medicine in future are discussed below.

9.5.1. Medical Ultrasonics

One of the priority areas wherein new investments for technological development are being made is medical ultrasonics. While in some applications, ultrasonics performs as well as other techniques with an added advantage of safety and precision, in some other applications, it is the only known technique available. The development of any new and relatively complex

modality in medicine requires time, patience and some measure of willingness on the part of the clinician to try something new. That this is a slow process in the case of ultrasonics, can readily be understood from the fact that this field is new to medicine, and that its safety must be rigorously proved before it can be widely accepted.

The application of ultrasonics in medicine can be divided into two categories, viz., (i) those that use infinitesimal amounts of power such as pulse-echo techniques for diagnostic work, and (ii) those in which a finite amount of power is used for the treatment of diseases. Ultrasonics have been applied to detect echoes from various types of tumors and other abnormalities, to reveal lesions in human breast, to determine mid-line structures in the skull, etc. As a therapeutic application, ultrasonics is used as a medium for healing swollen tissues. As a surgical application, ultrasonics has been used to cure Meniere's disease and Parkinson's disease.

9.5.2. Computer Applications

Computer finds a variety of applications in modern hospitals, from effective hospital management system to being used as a tool in scientific research. Apart from regular applications such as hospital payroll and inventory it can be specifically used for keeping patient-data in a large hospital. Once the in-coming patient history is stored in the computer memory, it can be updated from time to time as the need arises. This saves time for the physician, as all the previous data of the patient will be available to him in the form of a computer output-sheet. It also saves needless efforts and money for the hospital staff to maintain files on the history of the patient.

Computer could also be used for automatic multi-phasic check-up for patients conducted on a mass scale. Using operations research techniques, wastage of time and money can be minimised.

Computers have also been extensively used for interpretation of ECG and EEG data in aiding the physician for a faster and better diagnosis. Where enormous data of various parameters is required to be sorted out, it has been found that usage of computer is invaluable. Analysis of blood flow characteristic in the abdominal aorta, planning radio therapy unit by using graphic input-output devices, and graphic presentation of clinical measurement and monitoring are some of the specific areas wherein computers have been extensively used.

Research and development for computer applications is being aimed at developing suitable algorithms and software needed for different types of applications envisaged.

9.5.3. Medical Prosthetics

Medical prosthetics is one of the recent developments of medical electronics. Prosthetics is the art of technologically replacing a natural organ of a body with an artificial organ, where the natural organ has failed to perform its function. The ingenuity of substitution lies in making the replaced part function as close to that of the natural original part.

Although a considerable variety of equipment is developed in recent years, the products are still in large measures experimental. Devices for the blind, artificial limbs such as electronically controlled muscles are some of the prosthetic devices presently productionised in addition to the well-established product, viz., the hearing aid. One of the reasons why this particular area

has not grown appreciably is, that it calls for a high order of competence requiring integration of physiological and psychological factors with electronics technology to tackle problems that are unique. Thus, it is a peculiarity of this type of product that, although one may seem to meet all the required technical criteria, it may still not be a successful commercial product. For example, an artificial limb may meet all the required criteria, but because it requires a great deal of custom fitting in order to fit each individual, it may not be possible to produce artificial arms on a production-line basis. Therefore, the manufacture of the arm, itself, becomes a limited operation, although the electronic devices which power and control the arm could be mass produced profitably. The complexity of fitting is obviously a factor that affects economical production. Distribution and servicing of these equipment are also other factors that should be considered.

The components chosen in making prosthetic devices, apart from meeting the stringent specifications for reliability, should be nontoxic, nonallergic, nonflammable, nonexplosive and spark free. The devices should also be rugged, as they will mainly be used by handicapped and afflicted people. Training for the users should be imparted by well trained staff.

Medical prosthetics, though in its infancy, is bound to grow as more and more sophisticated and miniaturised components are developed. Its market in the next decade will increase as these devices will increasingly substitute the natural organ for a handicapped in a better way and will ultimately become part of the personality of the afflicted human being.

9.6 Guide Lines for Production 9.6.1. Interim Production

The items listed in Tables 9.10 and 9.11 should be taken for production immediately so as to meet the demand target at the end of the Fifth units, by setting up new public sector manufacturing units and encouraging new potential entrepreneurs, the demand targets can be met towards the end of the Plan. It should be mentioned that sufficient indigenous expertise is available in the country to meet the entire demand target. Import of know-how or collaboration with any foreign firm may not be necessary.

Portable equipment that can be fitted in a van, such as electro-cardiograph, colorimeter, centrifuge, pacemaker, defibrillator, etc., should be manufactured with a view to cater to the needs of a taluk hospital and primary health centre. Since the Ministry of Health has ambitious plans to introduce MEE in rural areas for promoting health services, manufacture of miniature, portable equipment should be undertaken immediately.

9.6.2. Long-term Production

Long-term production plan should aim at the following requirements:

(i) A complete indigenisation of medical electronic equipment in the shortest span of time based on the know-how developed at R&D centres is essential.

(ii) Production should be aimed at increasing the sophistication of equipment, distribution of these to rural hospitals according to their requirement. Long term plan should aim at atleast equipping district-level hospitals with patient-monitoring systems by the end of the next decade.

(iii) For large urban hospitals, it is predicted that computers would be

used for effective hospital management and automatic multiphasic mass-screening purposes. Also, computers might form a tool for diagnostic purposes. Equipment such as CCTV, medical laser, etc., could be used for display and therapeutic purposes. The manufacture of these sophisticated equipment would have to be undertaken to meet the growing demand based on adaptive research conducted at R&D centres.

(iv) Digital instruments based on development of digital transducers would be invaluable in read-out displays and might replace the analog systems currently used.

(v) Medical telemetry for transmitting ECG, EEG signals, would be in vogue by the end of next decade. Development and production of these systems should be undertaken in the coming years.

9.7 Investment and Production Profile

Table 9.14 indicates the investment and production profile for the Fifth Plan. To achieve the expected production worth Rs. 45 crores during the period, a direct capital investment of Rs. 7 crores is envisaged. The investment for R&D which will ultimately lead to production, would be around Rs. 1.30 crores. Thus, the total investment leading to production would be Rs. 8.30 crores. Apart from this, an investment of Rs. 2.20 crores would be required for setting up test and maintenance centres for MEE.

Table 9.15 indicates the year by year investment and production profile during the Fifth Plan. The investment profile is in decreasing order, with higher investments planned in the beginning of the Plan to accelerate the growth rate. In the latter half of the Plan period, with a lead-time of two to three years, the investment to production ratio would increase due to the self-sustaining nature of the industry. An average ratio of nearly 1:7 is estimated as the investment to production ratio.

During the Sixth Plan period, a total production of MEE worth Rs. 170 crores is envisaged. A total investment of the order of Rs. 19 crores would be required during the period, of which Rs. 12 crores would account for direct capital investment for production.

Thus the production of MEE during 1974-84 is expected to be around Rs. 215 crores. Out of a total direct investment of Rs. 19 crores estimated for production during this period, around Rs. 7 crores would be utilised for manufacture of X-ray machines. The remaining Rs. 12 crores would be required for manufacture of high volume and low volume equipment. It is estimated that Rs. 9 crores would be required for the former and Rs. 3 crores for the latter. Around Rs. 10.5 crores would be required for test and maintenance facilities, training manpower and R&D during the ten year period.

At present, MEE is mostly manufactured by small and medium scale manufacturers in both public and private sector organisations. MEE, excluding X-ray equipment, can be broadly classified into high volume low cost equipment and low volume high cost equipment. At present, most of the small and medium scale companies manufacture mainly the former category. Since the work involved is basically of assembly type and does not necessitate high capital investment, most of the manufacturers opt for manufacturing high volume equipment. Also, this class of equipment is commercially attractive for the manufacturer as the requirement of these in hospitals is comparatively large. Development and production of these equipment do not require

IX

high sophistication technology. Thus with minimal R&D efforts, entrepreneurs can develop, manufacture and market these equipment.

Table 9.14. Investment and production profile for MEE during the Fifth Plan period.

Sr. No.	Particulars	Rs. crores
1.	Production of medical electronic equipment	45.00
2.	Investment for local production	7.00
3.	Investment for setting up test and maintenance centres	2.20*
4.	Investment for R&D	1.30
Total investment		10.50

* As this activity does not directly lead to production, it is not added in the investment-production profile for the Fifth Plan.

Table 9.15. Breakup of the investment-production profile for MEE during Fifth Plan period.

	1974-75	1975-76	1976-77	1977-78	1978-79	1974-79
Production of MEE	5.0	6.5	8.5	11.0	14.0	45.0
Direct investment for production	1.5	2.0	1.5	1.0	1.0	7.0

Equipment such as EEG, patient-monitoring systems, etc., which need sophisticated technology, can be manufactured by companies which possess or can develop the know-how required and which have the necessary infrastructure to undertake the manufacture of these. As in developed countries, generally such equipment can be taken up for manufacture by companies with in-house R&D facilities.

Regarding the pattern of investment, it is suggested that roughly 70 per cent of the total investment be made in the private sector and the remaining 30 per cent in the public sector.

Large companies which are established in their areas can manufacture intricate, highly sophisticated equipment. Small and medium scale companies deserve encouragement in the form of testing facilities.

9.8 Test and Maintenance

9.8.1. Need for Evolving an Effective Policy for Maintenance of MEE in the Country

As indicated earlier, at present, there are around 50 small and medium scale manufacturers in the country, engaged in the production of medical electronic equipment. Equipment worth Rs. 4 crores was manufactured and marketed in the year 1973-74. These constituted around 2.2 per cent of the total equipment production of Rs. 187 crores for that year. X-ray equipment continued to enjoy a share of nearly 60 per cent of the total MEE market. However, sophisticated equipment like, coronary and intensive care units, patient monitoring equipment, multichannel recorders and ultrasonic therapy apparatus were manufactured showing that the local industry is now well geared to take up indigenous development and manufacture of equipment which were imported till recently.

Considering the quantum of consumption of these equipment in various hospitals of the country, the existing test and maintenance facilities are

woefully inadequate. Although CSIO offers service facilities to various hospitals and other user organisations through its service and maintenance centres, there exists a yawning gap between the equipment that lie out of order and the equipment which are in working condition. This has been the single most important factor affecting the quality of medical care rendered to patients in various hospitals. It was estimated in a survey in 1972-73 that, on an average, nearly 60 per cent of the equipment in a hospital lie unutilised for a variety of reasons. Lack of adequate test and maintenance facilities, lack of trained manpower, lack of spare parts, lack of funds, gross negligence by the user, poor aftersales service by the supplier and a general apathy towards maintenance itself have largely contributed to the nonutilisation of the equipment in hospitals.

This problem of overcoming inadequate maintenance should be given the highest priority in a developing country like India where the quantum of production is none too high and the population to be treated is in teeming millions. Where most of the hospitals have only one equipment like X-ray or an electrocardiograph, a breakdown of these brings the diagnostic activity to a grinding halt. A majority of the hospitals are ill-equipped with regard to spare parts or do not have a stand-by equipment to be put into use; here the situation becomes critical.

Nearly 80 per cent of the total population reside in rural areas and they depend for treatment on primary health centres which are few and far between. Here breakdowns of equipment are frequent, and due to lack of transport and communication facilities, it takes months before an equipment is repaired and put back to use. The problem of rural areas with regard to maintenance facilities should perhaps be considered in a different perspective.

9.8.2. Setting up of Unified Regional Test and Maintenance Centres

The need for organising proper and unified maintenance service for medical electronic equipment has been discussed earlier. It is, by far, one of the most crucial aspects in a life-saving area like medical electronics. Hence it becomes all the more important and imperative to evolve an effective policy considering all the available resources to tackle this particular aspect.

A befitting methodology becomes necessary as to how best a maintenance policy can be evolved. A probable solution is setting up of unified regional test and maintenance centres by the Electronics Commission involving State Governments and the CSIO. Three distinct approaches are mentioned below, which could involve the Electronics Commission, various State Governments and the CSIO which has already set up service and maintenance centres in some parts of the country.

(i) Involving State Governments

Health care in India is a subject of the State Governments, although the Central Government has, from time to time, sponsored and supported major schemes for improving the standard of health of the community under the Five Year Plans. Hence it would be practical to involve the State Governments while formulating plans for setting up test and maintenance centres.

Some of the States in the country, like Kerala, Maharashtra, Gujarat and West Bengal have already set up Electronics Development Corporations and others are in the process of doing so. These States are not only conscious of the growing electronics activity in their area through the manufacture of

electronic equipment and components, but are also keen on setting up test and development facilities for the benefit of local entrepreneurs. Given such an infrastructure, it will be optimal to pool the resources of a State Government and that of the Electronics Commission/Department of Electronics to start a test and maintenance centre for MEE to cater to the needs of the hospitals in that area. Such a joint venture would, by far, result in a proper utilisation of the funds and also give a sense of participation to the concerned State. A suitable mechanism should be worked out with regard to financial participation from both sides and other management aspects. Where a State has already set up a test and development centre for the benefit of local entrepreneurs, the existing infrastructure could be expanded or suitably modified to make it into a test and maintenance centre for MEE. This can be done with minimum effort and money and also saves the time required to set up a separate infrastructure.

(ii) Involving the CSIO

The CSIO has set up service and maintenance centres at Bombay, Calcutta, Delhi, Madras and Chandigarh. These centres offer repair, servicing and preventive maintenance facilities to electronic, electrical, electro-mechanical, optical and medical instruments of different nature and specifications for hospitals and other user organisations. These centres also take up development of MEE as part of their import substitution programme. The CSIO has also plans to set up similar service centres in other parts of the country during the Fifth Plan.

Although these centres are rendering commendable service to the user organisations, they are not able to cope with the exacting demands imposed on them in metropolitan areas. Hence, if possible, wherever CSIO centres already exist, it may be practical to expand these so as to cater to a larger section of the community in that region. Since the CSIO centres are located at major cities of the country, expansion of these centres using the combined resources of the CSIO and the Electronics Commission, in addition to catering to the needs of increasing load faced by urban hospitals, would also eliminate unnecessary duplication.

(iii) Involving the CSIO and the State Governments

Wherever possible, a trident organisation can be set up by involving the CSIO, the State Government and the Electronics Commission. The combined resources of the trio can be pooled together to set up a most modern test and maintenance centre in that region. At a later stage, such centres can also initiate mobile maintenance units and offer periodic preventive maintenance and calibration services to hospitals in nearby areas.

9.8.3. Technical Aspects

Before drawing up plans for setting up new centres, it is necessary to discuss the various technical aspects involved in inspection, testing and maintenance.

Inspection and Testing

1. Reliability, Ruggedness and Usability: The new instruments should be checked for reliability, ruggedness and usability. This applies to instruments that are in the market and to instruments which have been ordered for

use by hospitals within the region. Testing of the former can be done in collaboration with a 'standards body' and nominated clinical groups and the regional maintenance centre; the purpose being to aid the manufacturer and to protect potential users.

2. **Safety Testing:** The instruments tested must meet standards on leakage currents, explosion risk, humidity and heat. However, the hospital environment should also be taken into account where the instrument is likely to be used.

3. **Calibration:** The instruments require periodic calibration in order to give meaningful results.

4. **Equipment Purchase Advisory:** This would enable medical officers to buy wisely and also would permit a degree of equipment standardisation.

5. **Installation:** The equipment should be correctly installed and checked so that its operation should be free from extraneous interferences and incompatibilities.

6. **Education:** Recruited technicians and engineers should be trained with regard to testing, maintenance and safety.

Maintenance of Equipment

1. **Repair Work:** This is straightforward for the trained technician who works under the supervision of an engineer. Recalibration and safety checks may be required after repair in some cases.

2. **Preventive Maintenance:** Schedules must be planned and put into effect for visual inspection and simple operation tests. Routine periodic checks should be conducted for preventive maintenance.

Documentation and Stores

1. **Description of Equipment Malfunctioning:** Requisitions for testing and maintenance must require the user to fully describe the symptoms of equipment malfunctioning. This may be accomplished by asking for description of the fault on a requisition form supplied to the user.

2. **Equipment Records:** Each equipment must have a record, akin to a patient's medical record, in which details of purchase, initial testing, maintenance and calibration are entered. Also any accidents, like electric shocks associated with the instrument must be entered. As with medical records, such a data base proves to be invaluable.

3. **Spare Parts:** Procurement or manufacture of spare parts must be periodically looked into, to maintain the minimum spare part level envisaged.

Requirements for Safety Checks

1. Electrical Safety

Current leakage detector 10, 100, 1,000, and 10,000 micro ampere scales.
Ohmmeter, 1 ohm to 100 megohms range.

Ground resistance meter.

Power supply DC stabilised 1 mV to 1 V.

Frequency generator, Sinewave 0.01 Hz to 1000 Hz.

Digital voltmeter AC and DC 0.001 V to 1 V.

Oscilloscope, hand-portable, accuracy 1 ppm, DC to 50 kHz.

2. Radiation Safety (optional)

Radiation monitors as required for radiology, nuclear medicine equipment in use.

IX

- 3. Explosion Safety
 - Humidity meter
 - Conductivity meter

9.8.4. Organisational Aspects

Keeping these points in view, while drawing up the plans for electronics and telecommunication for the Fifth Plan, it was proposed that a chain of inspection, test and maintenance centres should be set up in the country to cater to the needs of hospitals in various parts of the country. The various cities, provisionally selected to set up test and maintenance centres in the Fifth Plan is indicated in Table 9.17.

Structure and Personnel

The organisational framework for technological services in a health care system must be planned with two purposes in mind. The facility must be patient-oriented and it must offer a satisfactory environment which will attract and retain competent staff.

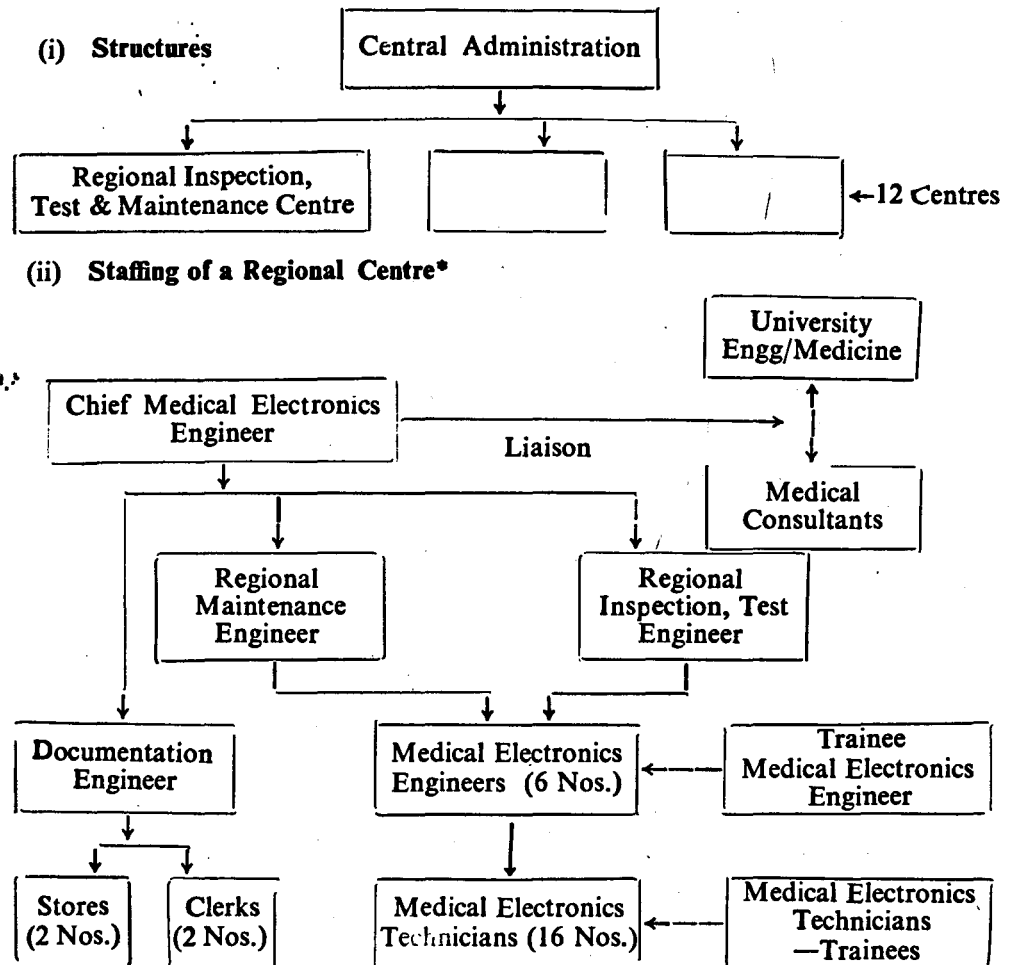


Figure 9.1. Structure and staffing of a regional inspection, test and maintenance centre for medical electronic equipment.

* When the regional test and maintenance centre is linked with an existing test and development centre set up by a State, some of the personnel will be common for the entire set-up.

The structure of the regional centre proposed, is indicated in Figure 9.1. The chief medical electronics engineer heading the organisation should have the status of a department head of any Government hierarchy. In addition to heading the organisation with regard to administrative and technical matters, he should maintain liaison with medical consultants and a university closely attached with the centre. The regional test engineer and regional maintenance engineer should have the overall authority in their respective areas. Six medical electronics engineers and sixteen technicians would be required for the centre which would form the nucleus of test and maintenance activity for that State. A post of documentation engineer is proposed to look after the stores, procurement of spare parts, repurchasing, etc. There should be a provision to train raw hands, both for posts of technicians and medical electronics engineers. Two clerks and a secretary would be required for the office work.

It is estimated that a building with a floor space of 10,000 sq. ft. (920 sq. metres) would be needed to house the staff and the capital equipment. It is preferable to have the entire centre or part of it air conditioned for special tests to be performed. Two vans would be required either for the transport of heavy equipment such as X-ray units from hospital to the centre or for the transport of technicians when the job is to be done in-site. Stationery, office equipment, furniture, staff car, etc., would form part of the initial budget allocation.

A detailed list of the capital equipment needed for the centre is given in Table 9.16. Spare parts worth 5 per cent of the capital equipment should be provided initially and should be repurchased as and when these are used for repairs.

9.8.5. Financial Aspects

Given that any medical care facility that uses equipment for instrumentation in the course of responding to the needs of its patients will need maintenance and repair service, it is necessary to plan as to how best such a service could be provided maximising the end-result with the available resources. The founding of a regional test and maintenance centre helps the economy directly and indirectly. Irrespective of the fact whether such a centre should be a non-profit making body or not, it has very important functions to perform. First, it can create an awareness in hospital circles regarding the need for subjecting their equipment to preventive maintenance, thereby reducing the percentage of equipment that may go out of order. Second, by attending to calls from hospitals in the event of an equipment breakdown, such a centre can quickly restore the equipment to working condition. Most important, the regional centre will indirectly contribute to the production by reducing the percentage of equipment that go out of order every year out of the total equipment manufactured in the country. For instance, even though the present annual production of medical electronic equipment is around Rs. 4 crores, it has been estimated that nearly 60 per cent of equipment used in hospitals are out of order, mainly due to lack of maintenance facilities, lack of skilled personnel and lack of organised effort to tackle such a crucial problem. The need for regional test and maintenance centres to implement the technical aspects enumerated earlier in the best possible manner, therefore, presents itself. It is estimated that 12 regional centres at important locations in the country will be required by the end of the Fifth Plan period to cater to the

IX

needs of hospitals and the industry.

The total cost proposed for (1) expansion of existing CSIO centres at Delhi, Bombay, Calcutta, Madras and Chandigarh and (2) setting up new centres at Ahmedabad, Allahabad, Bangalore, Nagpur, Srinagar, Trivandrum and Kanpur is about Rs. 2.2 crores. Table 9.17 gives a break-up of the contribution from Electronics Commission in terms of Rupees and foreign exchange.

9.8.6. Test and Maintenance Facility during the Sixth Plan

By the end of 1978-79, it is estimated that 12 regional centres set up at various locations as discussed earlier will be catering to the needs of hospitals and industry in and around these places. In the Sixth Plan, in effecting utilisation of the demand target of Rs. 113 crores, at least 20 more centres would be required at different geographical locations hitherto not considered. Also it is envisaged that fully equipped in-house maintenance facilities would be required at large hospitals.

Table 9.16. Facilities and equipment needed for a regional inspection,* test and maintenance centre for medical electronic equipment.

A. Building

A floor space of at least 10,000 sq. ft. is required.

Air conditioning should be provided for certain test rooms.

B. Equipment per Technician

Portable cathode-ray oscilloscope

Multirange test meter: with micro ampere AC and DC current ranges.

Battery operated 500 megger

ECC test set

Earth test set

SWR test set

C. Equipment for a Regional Centre

Portable cathode-ray oscilloscopes

General purpose oscilloscopes

Special purpose oscilloscopes

Wheeled cart for oscilloscope

Megger

Earth test set

Leakage current meter

Multimeter

Digital voltmeter (AC/DC)

Vacuum tube voltmeter

Frequency meter

Voltage standard

Temperature standard

Pressure standard

Transistor tester (portable)

Valve tester

Transistor curve tracer

Variable transformer

Isolation transformer
 Audio function generator
 R-F oscillator
 Low voltage regulated power supply
 High voltage regulated power supply
 Resistor substitution box
 L-C-R impedance bridge
 Attenuator
 X-Y recorder
 Portable single channel recorder
 4-Channel chart recorder
 MAS meter
 Spinning top
 Step wedge
 30 kV multiplier
 Defibrillator tester
 Voltage regulator
 Transistor tester manuals
 Fluorescent screen
 Q meter
 Signal generator
 R-F power output meter
 Universal bridge
 Drill press
 Portable electric drill
 Programmable calculator
 Filing cabinet, furniture
 Storage boxes, card trays, etc.

*Some of the facilities listed will be common for both State test and development centre and test and maintenance centre for medical electronic equipment.

Table 9.17. A proposed financial contribution from Electronics Commission for test and maintenance centres during the Fifth Five Year Plan (in Rs. lakhs).

No.		Rs.	FE	Total
1.	For establishing new centres	42	28	70
2.	For expanding existing CSIO centres at major cities	60	15	75
	Grand total	102	43	145

It is expected that mobile medical vans equipped with portable medical electronic equipment for diagnosis and therapy would be operating in rural areas.

At district hospital levels mobile vans equipped with test and maintenance facilities should be started to facilitate taluk and primary health centres.

9.9 Manpower

Manpower requirement for medical electronics area is of varied and diverse nature. An interdisciplinary faculty like medical electronics needs engineers proficient in electronics and medicine and, equipment operators who have a basic knowledge of both the areas. Coherent relationship between these two faculties of education must be established so that they can complement each other in the total process of providing better health facilities for the people. An integrated system between these two sciences should be developed so that the available manpower can be optimally utilised. A whole new cadre of systems engineers should be trained in such a way that they could grasp the nuances of both the sciences and put their newly acquired skill for the overall growth of this rapidly expanding field. As indicated in an earlier section, many technical institutions have been offering courses in medical electronics at post-graduate level for M. Tech. and Ph.D. programmes. Since the country would need medical electronics engineers in large numbers for various areas, a policy should be evolved as to the type of education given in these institutions. An approximate phasing of training content proposed for medical electronics engineers and senior and junior technicians is given in Table 9.18.

Manufacturers of MEE can play an important role in technical training. Universities, manufacturers and hospitals could mutually interact and help in developing training programmes both in production-line and in hospital floor during installation and testing of these equipment. This on-line training is one of the important facets of technical training for engineers and technicians alike.

Table 9.18. An approximate phasing of training content proposed for biomedical engineers and technicians.

The following indicates the approximate emphases to be given in the training of biomedical engineers and technicians.

	Percentage
(a) Biomedical engineers (B.E., M.Tech., Ph.D., Programmes)	
Anatomy, physiology, biochemistry	15
Physics and electronic engineering	50
Applications of medical equipment	20
Safety	8
Management	5
Medical ethics	2
(b) Biomedical senior technicians (Diploma programmes in electrical engineering, electronics)	
Anatomy, physiology, biochemistry	5
Physics and electronics	20
Electromedical equipment troubleshooting	35
Applications of medical equipment	15
Safety	10
Test equipment	15
(c) Junior technicians (High school education)	
Operation of equipment	80
Minor repairs	10
Any other routine chores	10

State-of-the-art seminars by well established specialists from industry, hospitals and universities aided by practical demonstrations would add importance to the training programmes.

The trainees should be exposed to newer trends in this developing field. The modern outlook is to link the training of technical staff more closely to the clinical environment. The medical electronics student technician should be exposed to hospital procedures and encouraged to consider himself as a part of the health care delivery team rather than a 'serviceman'. Similarly, the medical electronics engineer may serve a term of internship in a hospital as part of his qualification. During this term, he may be associated with a surgical team, assess patients in a pulmonary laboratory, get to know operating patient monitoring systems, etc.

A combination of training in hospitals and manufacturing units is very essential for medical electronics engineers and technicians to take up the demanding tasks of their profession. Then only the industry and hospitals will have competent medical electronic engineers and skilled technicians needed for this rapidly expanding field.

It is estimated that around 6,000 engineers and 10,000 senior and junior technicians would be required during the next ten years for the activities described earlier.

It may be recorded that all the estimates of manpower given in Sections 9.8 and 9.9 are purely indicative and are given as typical illustrations. They may vary considerably in different contexts.

9.10 Postscript Comment

After the preparation of the medical electronics plan, the basic assumption that the Ministry of Health will allocate Rs 25 crores for the MEE during the Plan period has been made invalid due to severe pruning of the health budget. In view of this, not only MEE for rural health services, but also medical electronics plan itself has been significantly deemphasised. In view of this, the estimates of demand, production and investment may be taken over a period considerably more extended than what is implied in the foregoing sections of this chapter.

Instruments

10.1 Introduction

The electronic instruments industry is a key industry which provides the tools necessary for research and production activities. For rapid industrialisation, the country needs an increasing variety and number of electronic instruments. The rapid strides made by electronics have diversified the application fields of electronic instruments. The instruments industry is a producer of capital goods and hence is a service industry to all research and production organisations. Many of the measurement and control processes, previously thought of as extremely difficult to accomplish or uneconomical, have been considerably simplified by the arrival of electronic instrumentation. There have been improvements by orders of magnitude in accuracy and sensitivity. One also finds that the electronic instruments industry entails a relatively high R and D investment compared to other industries. The industry is at the core of all developments designed to increase productivity through automation. Generally speaking, the electronic instruments industry is labour intensive. It requires skilled manpower capable of performing precision work and versatile enough to adapt to rapidly changing products.

The demand for electronic instruments has been continuously growing. The environmental sciences such as air and water pollution control, oceanography, meteorology, urbanisation, water resource control, etc., have created demand for new types of electronic instruments. Transportation, education and health are some of the major areas wherein electronic instruments will find increasing application.

Among the different off-line instruments considered here, test and measuring instruments form the major fraction. The defence preparedness of the country in modern times depends largely on keeping all the fighting equipment in a state of continuing readiness. The test and measuring instruments of a variety of types are required by the defence forces. The analytical instruments provide vital support to chemical and allied industries in maintaining strict quality control. The nuclear instruments will be required in large numbers for use in agriculture, medicine, power generation and research. The production of microwave test and measuring instruments is still in its infancy in the country. Post & Telegraph, Railways, Defence and Overseas Communication Service have extensive plans for setting up microwave communication networks. A wide variety of coaxial and wave guide instrumentation will be needed for supporting these links.

The Bhabha Committee had reviewed the then existing production base for test instruments. It had estimated that test instruments worth Rs. 35 crores would be required during 1966-75. The production facilities were found to be negligible and an investment between Rs. 3 and 5 crores was suggested. The Bhabha Committee Working Group on test instruments had rationalised the requirements of various users and had drawn up minimal specifications to promote the establishment of necessary base for the manufacture of instruments.

The rapid development of techniques in instrumentation has given an impetus

to the industry in India. The demand for electronic instruments has been continuously increasing in the last decade and has already grown beyond the projections of the Bhabha Committee. In addition to this, the instrument range has also been diversified. At present, there are about 200 companies mostly in the small scale sector engaged in the manufacture of electronic instruments. Although many types of instruments are presently manufactured, there is a lack of enthusiasm among manufacturers, arising perhaps from market uncertainty, to make newer and sophisticated instruments. There is a need to identify the demands and provide general guidelines for instruments manufacture. The demand profile for the coming decade will be useful in planning the investments and production. A survey was conducted by the Department of Atomic Energy and Instruments Manufacturers' and Dealers' Association (IMDA) and the report 'Instruments Industry in India' was prepared. This report brought out many relevant points regarding the problems of the scientific instruments industry. There are many problems specific to the electronic instruments industry which need special study.

Considering the urgent need to systematically develop the electronic instruments industry in the country, a Working Group was constituted by the Task Force VII. The Working Group reviewed the status of the industry pointing out the problems. The Working Group also recommended specific action-guidelines for the Fifth Plan.

The electronic instruments industry, which provides tools for technology development, requires a strong R & D base to keep pace with the progress. These R & D activities are required to transform new basic instrument prototypes that emerge from research activities into industrially produced standardised instruments. It is also necessary to design, at the request of the instrument users, specialised instruments which exactly meet the specific needs of the users. This is particularly true in defence and space applications. The R & D teams are responsible for further development and improvement of instruments, which are currently in the market, in order to keep pace with the latest technical developments. At present, most of the R & D activities in the instruments field are carried out at national laboratories and some educational institutions. A few manufacturers in the organised sector have started in-house R & D.

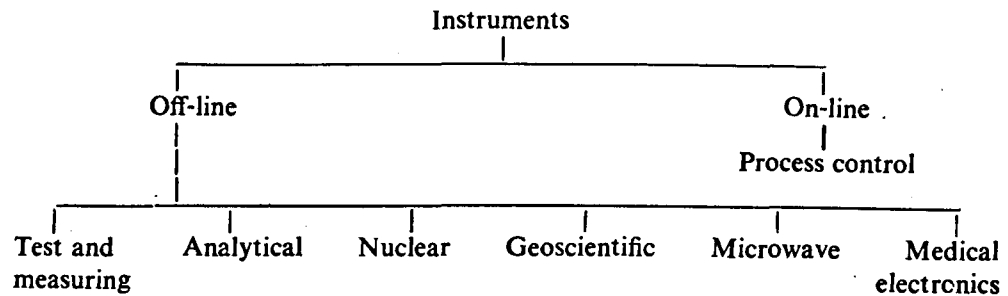
Classification of Instruments

During the last several years, the question of classification of instruments has been the subject of many discussions. According to the Standard Industrial Trade Classification, about 60 groups of articles come under the head 'Scientific Instruments'. However, details of the contents of each group are not clearly spelt out. Apart from this a number of other schemes of classification exist, based on application, technology, end-users, etc. The statistical data available on various aspects of the instruments industry cover a number of instruments ranging from laboratory apparatus, mathematical and survey instruments to electronic instruments. As a consequence, it is difficult to make a statistical analysis of the electronic instruments industry.

Again it is very difficult to define the electronic instruments sector, precisely in view of the vast range of products involved and the many areas of application that it covers. In addition to this, a large number of interdisciplinary applications are being continuously developed. In view of these difficulties, a classification, more or less similar to the one adopted by the Expert Group on Scientific Instruments of the Organisation for Economic Cooperation and Development (OECD) has been chosen.

The broad classification of instruments gives two distinct classes viz.,

(i) Off-line instruments and (ii) On-line instruments. The off-line instruments are further subdivided as shown below :



The on-line process control instruments have been covered in the chapter on control systems. Amongst the off-line instruments, the medical electronic instruments form a class by themselves due to special problems encountered and are covered in the chapter on medical electronics. The remaining five types of off-line instruments will be considered here. The general instruments falling under various classes have been indicated in the following list.

A. Test & Measuring Instruments

- | | |
|---------------------------------------|---|
| (i) Oscilloscopes and display devices | General purposes DC to 10 MHz
Sampling & high frequency
Storage type
Signal generator, built-in
Synchrosopes |
| (ii) Oscillators | AF, fixed and variable frequency
Crystal controlled
RF, fixed, pulsed and variable
Tuning fork controlled
Ultra low frequency
Voltage controlled |
| (iii) Generators | Function
AF acoustic, RF, white noise
Power—multiphase
Signal—AM and FM and pulse
Signal—TV synchronising
Signal—VHF and UHF
Sweep |
| (iv) Bridges | Capacitance
Impedence AF, RF and VHF
Inductance
Resistance
Thermister
Vacuum tube and transistor coefficients
Self balancing
Power RF |
| (v) Meters | Voltage |

	Current
	Power level
	Phase angle
	Frequency—RF, AF
	Other analog
	Electrometers
(vi) Power supplies	AC & DC, regulated DC high voltage (1 kV and above) Modular Isolated
(vii) Characteristics testers	Valve Transistor IC
(viii) Recorders	Magnetic tape Circular and strip-chart Multichannel Self balancing potentiometric Graphic X-Y Wire
(ix) Analysers	Spectrum Waveform Distortion flutter & interference Noise Video Harmonic
(x) Frequency synthesisers	
(xi) Counters	Frequency Time Pulse Binary and decade
(xii) Standards	Active Passive
(xiii) Calibrators	Frequency RF, AF, FM Voltage, current
(xiv) Automatic circuit testing instruments	
(xv) Analog-to-digital and digital-to-analog converters	
B. Analytical Instruments	
(i) Spectrographs	Ultraviolet

	Infrared Optical Mass
(ii) Spectrophotometers and absorptionmeters	Atomic absorption Ultraviolet Optical
(iii) Chromatograph systems	Gas Paper Column chromatography
(iv) Electrochemical analysis equipment	pH Conductivity Electrical titrators Polarographs
(v) X-ray analysis equipment	Diffraction units X-ray fluorescence X-ray cameras
(vi) Analytical bridges	
(vii) Thermal analysis equipment	Thermal balance Differential thermal analysis Specific heat measurement
(viii) Analysers	Photoflash Gas
(ix) Spectrometer	Nuclear magnetic resonance (NMR) Electron spin resonance (ESR) Raman laser Emission
C. Nuclear Instruments	
(i) Radiation detecting	GM counter Scintillators Proportional counters Ionisation chambers Semiconductor Fission ionisation
(ii) Radiation monitoring	Portable Environmental Personal dosimetry devices Aerosol contamination Plutonium contamination
(iii) Nuclear medical	Whole body counters

	Scintillation cameras Monitors
(iv) Industrial application	Nuclear level gauges Gamma ray radiography Nuclear density, moisture meters Beta ray thickness gauge
(v) Nuclear research	Pulse height analysers Fast pulse amplifiers Other allied instruments (e.g. coincidence analyser, rate meters, etc.)
D. Geoscientific Instruments	
(i) Exploration work	Magnetometers Resistivity SP meters Susceptibility meter Portable GM scintillation counters Moisture/density gauge Portable seismographs Time & frequency domain induced polarisation units Geophone Digital seismic data acquisition system Well logging units—electrical gamma, neutron, resistance Integrated airborne geophysical system
(ii) Non-exploration work	Laser strainmeter Accelerographs Tiltmeters with amplifiers VHF, UHF telemetry instruments
(iii) Oceanographic systems	Hydrophotometer Salinity recorders Depth recorders Vibroseismic equipment Geomagnetic electro-kinetograph Echo sounders Thermographs Porosimeters
(iv) Geophysical work	Peizograph Permeability apparatus Laser ranging instruments Infrared spectrophotometer with special accessories Chromathermograph Spectral fluorometers Fluoroscopes Mass spectrograph

Radioassay instruments

E. Microwave Instruments

- | | |
|---------------------------------------|---|
| (i) Frequency measuring instruments | Atomic beam and other frequency standards
Frequency counters
Cavity wave meters
Spectrum analysers |
| (ii) Signal generating equipment | Signal sources
Signal generators
Sweep generators
Noise sources
Frequency synthesisers |
| (iii) Impedance measuring instruments | VSWR meters
Precision slotted lines
Bridges
Ratio meters
Network analysers
TDR and sampling scopes |
| (iv) Power measuring instruments | Bolometers
Highpower meters with digital display |
| (v) Receiving instruments | Detectors
Sensitive receivers
Field strength meters |

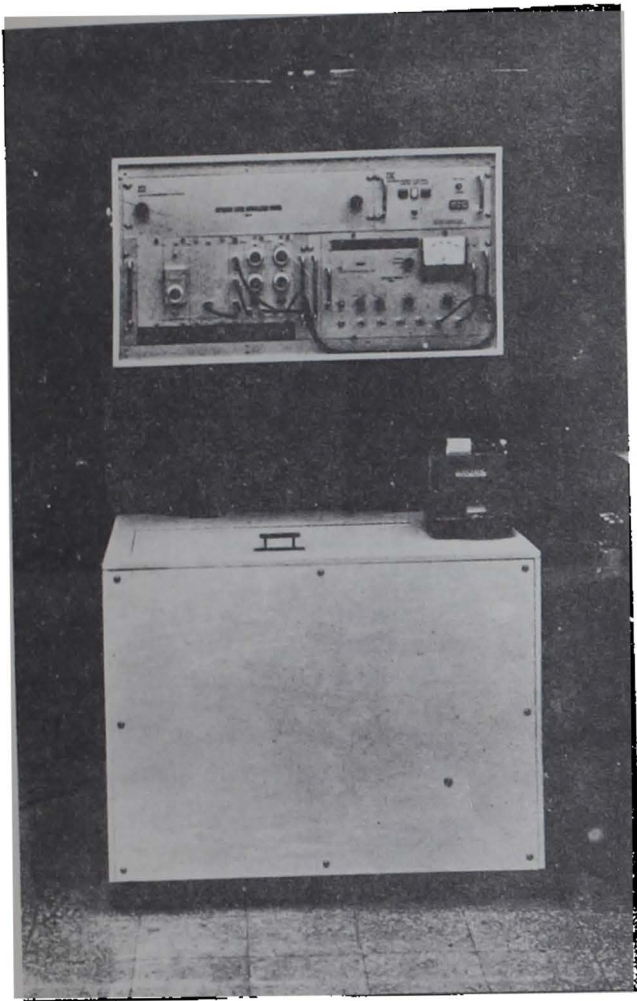
10.2 Current Status

Production Base

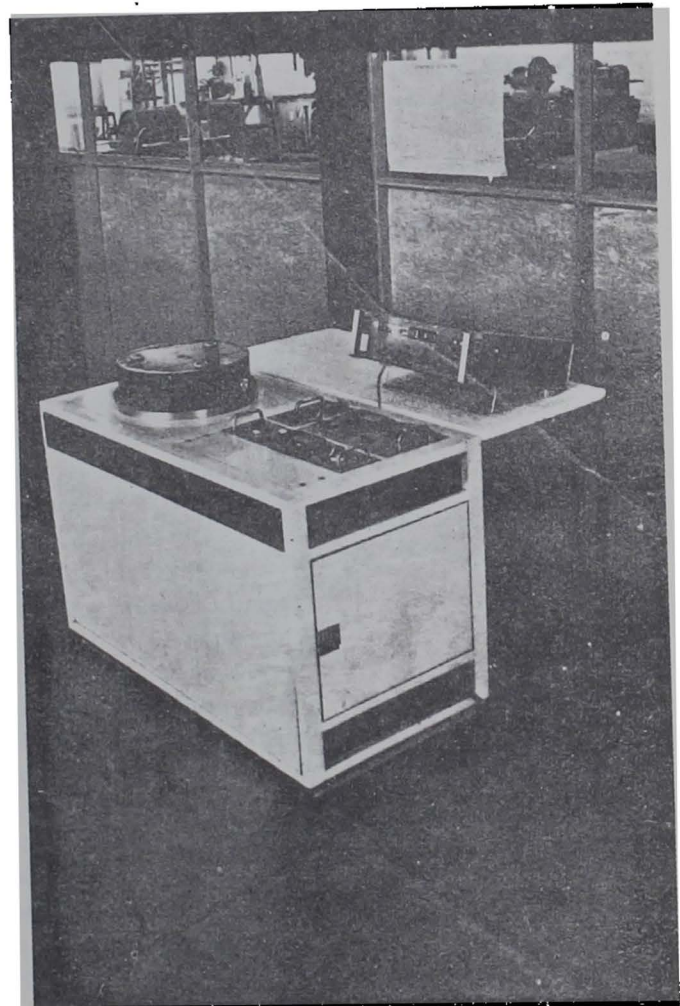
The electronic instruments industry in the country nucleated in the early 1960's. The indigenous manufacture started mainly with the general purpose test and measuring instruments like multimeters, vacuum tube voltmeters and oscillators. Within a short time, it diversified itself into other types of instruments like analytical and nuclear instruments. During this early stage of production, the industry was treated in association with the scientific instruments industry. Special efforts were not made to treat electronic instruments on a different footing. Thus a clear picture of the industry could not be obtained for the initial stages of indigenous production.

The sector-wise production of electronic instruments from 1968-69 to 1973-74 is shown in Table 10.1. The current production is shared by about 15 firms in the organised sector and over 200 firms in the small scale sector. Owing to the lack of companywise production data, it is difficult to evaluate the relative shares of the two sectors in the overall production. However, in the early phase, about 60 per cent of the production was made by units in the organised sector. Of late, instrument manufacture in the small scale sector has gathered momentum and its contribution to the total production has increased substantially.

In Table 10.1, the production statistics is given under four major classes of instruments, namely, test and measuring, analytical, nuclear and geoscientific. With the limited data available, an attempt has been made here to distribute the production between these major classes. Though microwave instruments are classified separately as mentioned earlier, in this statistical analysis they are grouped with test and measuring instruments owing to lack of reliable production data.



ECIL's Automatic Liquid Scintillation System used for low beta scintillation counting



Betaray Spectrometer developed and built by ECIL

In the case of test and measuring instruments, the production during 1968-69 was of the order of Rs. 3 crores. There was no appreciable increase in the next

Table 10.1. Production of electronic instruments (in Rs. crores).

Year	Test and measuring	Analytical	Nuclear	Geo-scientific	Total instruments production	Total equipment production	(6) as percentage of (7)
1968-69	3.00	0.80	0.30	0.15	4.25	85.00	5.00
1969-70	3.20	1.00	0.35	0.20	4.75	110.00	4.31
1970-71	3.80	1.50	0.40	0.25	5.95	138.00	4.31
1971-72	4.50	1.90	0.60	0.35	7.35	144.00	5.10
1972-73	5.60	2.10	0.70	0.40	8.80	162.00	5.43
1973-74	8.40	2.30	0.75	0.40	11.85	187.00	6.33

year. Between 1971 and 1972 production of high frequency oscilloscopes commenced which influenced the total production to some extent. The production of this category accounts for more than 60 per cent of the total instruments production plan. The production of analytical instruments registered a substantial increase in 1970-71 with a 50 per cent increase from that of the previous year. ECIL is the major manufacturer of nuclear instruments in the country. Production during the first two years, from 1968-69, remained more or less static. This was perhaps due to the fact that the production facilities originally set up at BARC was shifted to ECIL during these years. In the recent years, a few other manufacturers have come up in this field. The production of geoscientific instruments is concentrated at a few laboratories and is increasing rapidly.

In general, it may be stated that electronic instruments account for about 6 per cent of the total electronic equipment production, as it stands today. Test and measuring instruments top the distribution, which account for over 70 per cent of total production. Analytical instruments follow with an aggregate of about 20 per cent. Of the remaining 10 per cent of the total production, nuclear instruments account for about 6 per cent. Considering the total instruments production, it registered a growth of only 10 per cent during 1968-69 to 1969-70. However, there was a significant increase in the growth rate in the next two years, with 28 per cent on an average. Afterwards it has reduced again.

At this stage, it is necessary to analyse the broad spectrum of instruments manufactured in the country. Here again, test and measuring instruments form the largest category covering a wide range of instruments. Many firms, both in the organised and small scale sectors, have marketed general purpose oscilloscopes of 5 MHz. Two firms have recently marketed oscilloscopes covering a frequency range upto 50 MHz. General purpose instruments like panel meters, VTVM, signal generators, power supplies, voltage regulators, LCR bridges, pulse generators, insulator testers, transistor and valve testers, etc., are made in the country. A beginning has just been made in the field of digital instruments with the introduction of a few models of DVMs, frequency counters and timers. The future of digital instruments depends on the local availability of various semiconductor devices and professional components. The commencement of production of monochrome pattern generator, by two firms in the private sector in 1972, marked the introduction of a special class of instruments, namely, TV test instruments. With the growing potential for manufacture of TV receivers, the country is experiencing a heavy foreign exchange drain on these instruments. A number of these instruments including the sweep

generator, are yet to be made. Function generators, operational amplifiers etc., are made in the country, though in a limited scale. A few types of ultrasonic instruments are also being made locally.

The range of analytical instruments made in the country is very limited. It consists of pH meters, conductivity bridges, colorimeters, spectrometer and flame photometer. Recently two firms have started production of gas chromatographs, both with indigenous technology. Efforts are under way to productionise instruments like spectrophotometers and gas analysers.

The production of nuclear instruments started with small batch-production of GM counters and portable radiation monitors required for nuclear research at TIFR. A production set-up established at BARC for this purpose was later transferred to ECIL as the Nuclear and Allied Instruments Division. Since then the product range has considerably widened. Of late, a few manufacturers in the small scale sector have entered the nuclear instruments market.

During the last few years, the Atomic Minerals Division of the Department of Atomic Energy, Geological Survey of India, National Geophysical Research Institute, India Meteorological Department, and the Oil and Natural Gas Commission have developed the necessary expertise for the design, development and batch-production of some of the ground based and airborne geophysical exploration instruments.

With the increasing demand for the development of communication systems in the country, indigenous manufacture of microwave instruments has received considerable importance.

C and S band signal generators are being made by ECIL. TIFR has developed and batch-produced a fully solid state S band signal generator. Production is underway in the case of instruments like compensated microwave power meter, direct reading frequency meter, frequency response test set, frequency counter, etc. National Physical Laboratory has developed many microwave instruments and has plans for batch-production of these.

To get a clear picture of the production base in the private sector instruments industry, it is necessary to obtain the information regarding the licensed capacity. There are many difficulties in compiling this, as the capacity granted is expressed sometimes as numbers and some other times as value in rupees. Here again, the exact type or category of instrument to be manufactured is not clearly spelt out. The term, given as electronic test and measuring instruments, may cover any number of instruments in the wide range of products, thus making it practically impossible to assess the existing capacities exactly. It is suggested that a clear classification similar to the one given in the beginning of this chapter be followed in specifying the licences or letters of intent issued. A survey of a few units suggests that in the majority of the cases there is a wide gap between licensed capacity and actual production. Every effort should be made to improve the capacity utilisation.

Technology Base

The picture of the current status of the instruments industry in India will not be complete without a brief discussion of the existing R & D activities in the country. The R & D efforts in instruments are mainly concentrated at various educational and research institutions although some of the private manufacturers have made determined efforts to develop instruments of world standard and have entered the export market successfully. The number of such manufacturers, though small at present, is expected to grow as the necessity for in-house R & D is felt by others for innovative design and quality control. A support, in terms of adequate foreign exchange to import necessary equipment, will help the small scale units.

Some foreign collaborations in the instruments industry have helped in starting the manufacturing activity based on the foreign know-how. However, R&D units are required at such places in order to improve and modify the existing design and keep up with the technological advances. The test and development centres planned by different states will help the small scale manufacturers to utilise facilities of standardisation and environmental testing.

The instruments developed at the R&D laboratories must be transferred to the production base with minimum delay. An industry—R&D liaison unit could effectively reduce the gap.

The present production of instruments is based on two distinct sources of technology base. One is the foreign technology imported in the early stages of the industry and another is the know-how generated through the efforts of national laboratories and in-house R&D units of a few companies. In the following, both are discussed to bring out the salient points. These aspects were also discussed from the point of view of entire scientific instruments industry in the Department of Atomic Energy study referred earlier.

Role of Imported Technology

From the historical point of view the production of electronic instruments of most of the categories was started by the companies in private sector having majority equity participation of foreign companies. It was realised in the early stages of development of the national economy, that participation of foreign capital and foreign technology can be of value for the rapid industrialisation and with certain broad limitations it was encouraged. The advantages of growing the industry on foreign know-how are obvious, that the optimum level of production can be reached in a relatively short time, without the trial and error steps required in the transfer process. The disadvantages are the continued dependence on the foreign companies, drain of foreign exchange in terms of royalty payments, purchase of critical subassemblies, lump-sum payments, etc. Besides this, there was no incentives for the local R&D efforts.

A brief review of the statistics indicates that UK, USA, Japan and West Germany together account for more than 70 per cent of the total foreign collaboration/technology transfer cases. The nature of agreements has also varied considerably from the subsidiary of a foreign company to joint ventures and pure licensing to local firms. In the earlier cases, even the simple type of instruments were manufactured under foreign collaboration. Increasing restrictions have now resulted in collaborations only in sophisticated instruments field. The foreign technology has also been partly responsible for building up the technical skill in the country.

Role of Technology Developed in the Country

Over the years, the research and development efforts in the field of instruments have grown steadily. A large number of national laboratories and educational institutions have been engaged in the research and development of a large number of different instrument systems. Apart from these, a few manufacturing firms have started the in-house design and development departments to evolve the systems for the future. A classic example of instrument production based on completely indigenous know-how is the product range at ECIL.

In many of the cases of instrument development, the laboratory itself is in need of one and is unable to obtain through imports. This initiates the development work. There have also been few cases where a company has approached an R&D laboratory with a specific need and the laboratory has gone ahead with development.

On the whole, the number of cases of technology transfer from R&D to production base is still small. There are many cases where no contact to a production organisation has been made.

The National Research and Development Corporation (NRDC) acts as an intermediary in many of the technology transfer cases within the country. A number of electronic instruments know-how has been transferred through NRDC to the industry.

It should be the aim of the local R&D efforts to maximise the rate of substitution of foreign technology in a manner consistent with long term development objectives.

Non-commercial Production of Instruments

It has been observed that many of the laboratories and institutions, besides being engaged in the R&D efforts to develop the instruments, are also engaged in the production at a batch level. This non-commercial production is usually undertaken to cater the demand for custom-made instrument systems. An example of such production is the small scale batch production of transducer elements at National Physical Laboratory. It is very difficult at this stage to estimate the total value of non-commercial production of electronic instruments. The major laboratories and institutions involved are BARC, TIFR, NAL, CSIO, ONGC, NGRI, etc.

The major advantage of the non-commercial production is the import substitution of some low demand items. In the normal circumstances, the country in the absence of non-commercial production base would continue to depend on imports for such items. It should be the aim of all the advanced research institutions to set up non-commercial production base in their respective fields of specialisation. The non-commercial production has the advantage of having support from the infrastructure of highly qualified technical personnel. The close association of the research laboratories also helps in keeping touch with the contemporary technologies and the state-of-the-art. One of the areas in which non-commercial production is already taking place to some extent is the field of geoscientific instruments. The workshops of India Meteorological Department are already undertaking such production. There is further scope for this in view of the demand by oil exploration activities for special type of instruments in a small number.

The non-commercial production in instruments and allied sectors will help in building a viable technically based capital goods sector with high degree of specialisation. Thus the non-commercial production is ideally suited for high technology area like instruments.

The following table indicates a representative list of electronic instruments which have been indigenously developed in various laboratories and institutions.

I. National Physical Laboratory (NPL), New Delhi

- (1) Electronic timers
- (2) Decade counters
- (3) Preset counters
- (4) Traffic control devices
- (5) Ultrasonic interferometer
- (6) Metal detector
- (7) Rotational viscometer
- (8) Strain gauge instrumentation
- (9) VSWR meters
- (10) Power meters
- (11) Microwave signal generators

-
- (12) Noise sources and other digital microwave instruments
 - (13) Ultrasonic thickness gauge
 - (14) Ultrasonic sensors for remote control applications
 - (15) Liquid crystal display systems
 - (16) Scanning electron microscope jointly with CSIO, CEERI
 - (17) Instruments like high vacuum gauges, etc.
 - (18) Bent crystal X-ray spectrograph

II. National Aeronautical Laboratory (NAL), Bangalore

(a) Instrumentation Division

- (1) Ultrasonic hardness tester
- (2) Wire strain gauges
- (3) Strain indicators and strain measuring bridges, single, multi point
- (4) Multichannel bridge balancing units
- (5) Telemetry and flight instrumentation like lock in amplifiers, frequency synthesisers
- (6) Calibration standards for flight and gyrodynamic parameters

(b) Electronics Division

- (1) Digital voltmeter
- (2) DC amplifiers
- (3) Regulated power supplies
- (4) Solid state power controllers
- (5) Data logging systems, multichannel
- (6) Logic circuits blocks
- (7) Shaft position digitiser
- (8) Code to decimal translators and digital displays

III. Central Scientific Instruments Organisation (CSIO), Chandigarh

- (1) Suppressed zero voltmeter
 - (2) Low level preamplifier
 - (3) Preset counter
 - (4) Decade scaler
 - (5) Electronic timer
 - (6) Digital frequency meter/counter (10 MHz)
 - (7) Standard pulse generator/timer marker
 - (8) Single channel analyser with pulse amplifier
 - (9) Digital voltmeter
 - (10) In-line digital read-out
 - (11) Stabilised DC power supply
 - (12) High voltage power supply
 - (13) Time interval counter
 - (14) Stand pulse/timer generator
 - (15) EMF current convertor
 - (16) Precision potentiometer
 - (17) Operational amplifier (general purpose, low cost, differential output and FET input types)
 - (18) Programmable pattern generator
 - (19) Digital scanner
 - (20) Gamma ray spectrometer
-

-
- (21) Programmable IC tester
 - (22) Parametric amplifier
 - (23) TV column display
 - (24) Digital multimeter
 - (25) Digital pH meter, miniaturised pH meter
 - (26) Gas chromatographs and analysers
 - (27) Digital transducers for temperature and pressure
 - (28) UV, IR visible spectrophotometers

IV. Central Electronics Engineering Research Institute (CEERI), Pilani

- (1) TV pattern generator (standard model)
- (2) TV pattern generator (popular model)
- (3) TV pulse generator (popular model)
- (4) TV pulse generator (standard model)
- (5) Transistorised power supply
- (6) RF signal generator
- (7) Servo-operated pen recorders
- (8) DC millivoltmeter
- (9) Marker units
- (10) Sweep oscillator modules

V. Central Mechanical Engineering Research Institute (CMERI), Durgapur

- (1) DC chopper amplifier
- (2) A-D and D-A converters
- (3) Photometric comparator
- (4) Digital frequency meters, timers, counters
- (5) High voltage, high current stabilised power supplies
- (6) Electronic microcomparator
- (7) Electronic unit for the measurement of pulsation in a turbulent flame
- (8) Electronic millivoltmeter

VI. National Chemical Laboratory (NCL), Poona

- (1) Vapour phase chromatograph
- (2) Potentiometric stripchart recorders
- (3) Direct reading spectrophotometer
- (4) DC recording polarograph
- (5) Infrared spectrophotometer
- (6) Electron diffraction cameras
- (7) Electron spin resonance spectrometer

VII. National Geophysical Research Institute (NGRI), Hyderabad

- (1) Proton precession magnetometers for airborne and marine survey
 - (2) Laboratory fluxgate magnetometer
 - (3) Magnetic susceptibility meter
 - (4) DC earth resistivity meter
 - (5) Refraction seismic timer
 - (6) Airborne pulsed transient EM unit
 - (7) EM prospecting unit
 - (8) Rubidium vapour magnetometer
 - (9) Dual frequency EM prospecting unit
-

VIII. National Metallurgical Laboratory (NML), Jamshedpur

- (1) Electronic potentiostat
- (2) Photoelectric temperature controller

IX. Regional Research Laboratory (RRL), Jorhat

- (1) Gas chromatograph
- (2) Sequence Selector
- (3) Millivolt recorder for moving vehicles

X. Regional Research Laboratory (RRL), Bhubhaneswar

- (1) Ultrasonic flowmeter
- (2) Ultrasonic generators

XI. Bhabha Atomic Research Centre (BARC), Bombay

- (1) Double pulse generator
- (2) Single beam oscilloscope
- (3) Dual trace adapter for oscilloscope
- (4) Transistor curve tracer
- (5) RF millivoltmeter
- (6) Low voltage power supply
- (7) Beta spectrometer (two models)
- (8) Pulse height analyser (two models)
- (9) Timing single channel analyser
- (10) X-Y-Z display unit
- (11) Radiation monitor
- (12) Wide range survey meter
- (13) Radiation monitor with alarm
- (14) Gamazone monitor
- (15) Contamination monitor
- (16) Neutron flux monitor
- (17) Fast neutron flux monitor
- (18) Soft X-ray dosimeter
- (19) X and Gamma ray meter
- (20) Microwave radiation monitor
- (21) Mossbauer spectrometer
- (22) Automatic isodose plotter
- (23) Spectrophotometer
- (24) Infrared analyser
- (25) Atomic absorption spectrophotometer
- (26) Temperature programmer for gas chromatograph

XII. Saha Institute of Nuclear Physics (SINP), Calcutta

- (1) Pulse generator (two models)
 - (2) Oscilloscope (transistorised)
 - (3) Fast oscilloscope (two models)
 - (4) DC-AC converter
 - (5) RF spectrum analyser
 - (6) Ultrasonic pulse echo apparatus
 - (7) Riometer
 - (8) RF spin echo apparatus
 - (9) Single coil NMR apparatus
 - (10) NQR spectrometer
-

- (11) ESR spectrometer
- (12) Pulse height analyser
- (13) A-D Converter
- (14) 30 MHz general purpose counter

XIII. Tata Institute of Fundamental Research (TIFR), Bombay

- (1) Digital voltmeter
- (2) Frequency counter
- (3) A variety of microwave instruments
- (4) Special instruments required for physics research
- (5) Balloon flight instrumentation and telemetry
- (6) Instruments for radio active measurements
- (7) Instruments for oceanographic measurements

XIV. Atomic Minerals Division (AMD), New Delhi

- (1) Beta gamma radiation survey meters
- (2) Portable uranium/thorium scintillometers
- (3) Underwater radioactive survey equipment
- (4) Electrical resistivity equipment
- (5) Radon measurement equipment
- (6) Proton precession and rubidium vapour magnetometers
- (7) Instruments for hydrological survey by radioactive tracer techniques
- (8) Bore hole logging instruments
- (9) Scintillometers for airborne survey
- (10) Multichannel spectrometer with digital tape recording for uranium, thorium and potassium-40 measurements

XV. Vikram Sarabhai Space Centre (VSSC), Trivandrum

- (1) Digital voltmeter
- (2) Frequency counter
- (3) Digital timer
- (4) Digital clock
- (5) DC-DC-converter (two models)
- (6) Coherent demodulator receiver
- (7) Spectrum analyser
- (8) Pressure thrust transducer
- (9) Instrument sub systems for telemetry
- (10) A-D and D-A converters

XVI. Thumba Equatorial Rocket Launching Station (TERLS), Trivandrum.

- (1) Reference oscillator
- (2) Electronic clock
- (3) X-Y plotter

XVII. Physical Research Laboratory (PRL), Ahmedabad

- (1) Pulse generator
- (2) Linear sweep voltage regulator
- (3) Digital voltmeter
- (4) Electronic timer
- (5) Power supply
- (6) Low current amplifier

-
- (7) Lyman Alpha probe amplifier
 - (8) A-D and D-A converter
 - (9) Digital recording and transfer system
 - (10) Coding-decoding units
 - (11) Rubidium and fluxgate magnetometers
 - (12) Mass spectrometer for composition measurements in earths atmosphere
 - (13) Extreme ultraviolet spectrometers
 - (14) Pulse analysis instrumentation

XVIII. Space Applications Centre (SAC), Ahmedabad

- (1) Power supply
- (2) Special signal simulator
- (3) Instruments for SITE programme like high power amplifier, converters, modulators, etc.

XIX. Indian Institute of Technology (IIT), Madras

- (1) Walsh function generator
- (2) Difference amplifier
- (3) 3 GHz varactor parametric amplifier
- (4) Step recovery harmonic generator
- (5) 10 GHz IMPATT oscillator
- (6) 10 GHz Gunn oscillator
- (7) Electronic power factor meter
- (8) Transistorised phase sequence indicator
- (9) A high frequency active probe for a VTVM
- (10) Electronic smoke meter for air pollution analysis
- (11) UHF power meter for antenna patterns
- (12) Proton magnetometer
- (13) Sample hold and A-D converter for nuclear data

XX. Indian Institute of Technology (IIT), Kharagpur

- (1) Strain gauge bridge
- (2) Displacement meter
- (3) Transducers
- (4) DC earth resistivity meter
- (5) Electromagnetic amplitude and phase meters
- (6) Induced polarisation equipment
- (7) Multifrequency EM depth sounding equipment

XXI. Indian Institute of Technology (IIT), Kanpur

- (1) Amplitude distribution function analyser
- (2) Galvanic corrosion study instruments
- (3) Ultra low frequency function generator
- (4) Recording thermal analysis instruments
- (5) Photoelastic polariscope
- (6) Pulse code modulation ~~encoder-decoder~~

XXII. Geological Survey of India (GSI), Calcutta

- (1) Resistivity potentiometer
- (2) Single and dual frequency EM unit
- (3) Proton precession magnetometer

- (4) Magnetic susceptibility meter for insitu measurements
- (5) Pulse ultrasonic equipment

XXIII. Indian Institute of Tropical Meteorology, (IITM), Poona

Instruments developed

- (1) Multichannel temperature recorder
- (2) Multichannel humidity recorder
- (3) 10 channel data acquisition unit

Instruments under development

- (1) A fluxmeter for measuring heat transportation
- (2) An infrared temperature detector
- (3) Lyman hygrometer
- (4) Infrared hygrometer

XXIV. Institute of Petroleum Exploration (IPE), Oil and Natural Gas Commission, Dehra Dun

Instruments developed

- (1) Seismic unit with recording oscillograph
- (2) Sequential delay blaster
- (3) Shot instant transmission unit
- (4) Time break marker for refraction seismic survey
- (5) Cable fault locator
- (6) Power supply for electrical prospecting unit
- (7) Power supply for RNP seismic trace summator unit
- (8) Pulse generator/amplifier
- (9) Active filter for seismic unit
- (10) Gamma-gamma sonde
- (11) Well thermometer using thermistors
- (12) Photo indinometer

Instruments under development

- (1) Active filter unit having separate low and high cuts for seismic unit
- (2) Low level multiplexer for digital seismic unit
- (3) Automatic magnetic marker cum catcher for calibrating logging cable
- (4) pH and viscosity controller

XXV. Geodetic Survey Branch (GSB), Survey of India, Dehra Dun

Instruments developed/under development

- (1) Automatic recording tidegauge
- (2) Electronic distance measuring instrument

XXVI. Indian Institute of Science (IISc), Bangalore

- (1) Digital voltmeter, multimeter
- (2) Frequency counter (20 MHz) with autoranging facility
- (3) Waveform analyser
- (4) Pulse analysis instruments

XXVII. Indian Institute of Geomagnetism (IIG), Bombay

- 1) Fluxgate magnetometer
- (2) Special variometers using photocells

XXVIII. India Meteorological Department (IMD)

- (1) Seismographs
- (2) Multichannel data logger systems
- (3) Digital data display and acquisition systems
- (4) Radiosonde systems
- (5) Current weather instruments system for airports
- (6) Recording rain gauges
- (7) Global radiation measurement systems
- (8) Systems for satellite data reception
- (9) Temperature, humidity sensors and recorders
- (10) Radiometers in visible and IR region
- (11) Transmissometer and ceilometer

10.3 Demand Profile

Considering the complex interdisciplinary nature of instruments industry, planning effort of any kind is conceptually and analytically a difficult task. However, it is imperative that study of the overall growth should be taken up to help effectively optimise the investment in this key sector.

The Task force VII of the Planning Commission Steering Committee on Engineering Industries (1973) analysed the status of the industry and realised the growing potential for instruments in the country. The Task Force concluded that there is a natural doubling of production in instrumentation industry every two years. It is to be noted that for their study, the total instruments production covered off-line on-line and medical instruments. In the present report, only off-line instruments are considered. Table 10.1 indicates that the production of these instruments doubles in about three years. Presently about 6 per cent of the total electronic equipment production accounts for electronic instruments.

Table 10.2 gives a sectorwise demand profile for various types of instruments during the Fifth and Sixth Five Year Plans. Considering the present trend, the demand is likely to grow at the rate of 12 to 15 per cent on an average during the Fifth Plan period. There is likely to be a sudden spurt in demand in the first year of the Plan, as many new investments in various sectors are likely to cover investment on instruments, where as, during the Sixth Plan period the average growth rate is expected to be of the order of 10 to 12 per cent. At this stage, to project an yearly breakup of the Sixth Plan demand, is a formidable task.

In the Fifth Plan, the total demand for instruments is likely to be of the order of Rs. 163 crores. Test and measuring instruments have continuously increasing demand, totalling to Rs. 86 crores during the Plan period which is about 53 per cent of the total demand. Some of the areas from which demand arises may be identified as follows: Considering the expansion of TV network by AIR and ISRO, there will be a sizeable demand for special types of TV test instruments. These include instruments for production and servicing of TV receivers, instruments for maintenance of TV transmitters and studios, and instruments for design and development work in this field. The Panel on TV Test Instruments, constituted by the Electronics Commission has estimated a total demand of the order of Rs. 9 crores for these instruments during the Fifth Plan period. Demand for high frequency oscilloscopes is on the increase and general purpose oscilloscopes also would be required in larger numbers during the Plan period. Demand for meters would be predominant in the range of nano volts/amperes. Considering the recent trend

towards multifunction test and measuring instruments, the demand for these will be high. Digital instruments would share an appreciable percentage of the total demand for test and measuring instruments. Q-meters and field strength meters covering the VHF range would be required in substantial numbers.

With the stress on quality control in various industrial activities, the need for various types of analytical instruments would be very much increasing. The demand for these is likely to double by the end of the Fifth Plan. Instruments like spectrophotometers, spectrographs, chromatographs, gas analysers, etc., are essential tools in process industries. These instruments would be very much in demand during the Plan period. Instruments worth Rs. 43 crores are expected to be in demand during the Fifth Plan period. It is expected that this figure will double in the Sixth Plan.

Nuclear instruments, although of recent origin, are becoming increasingly important. The fact, that India has committed to power programme of fair size, is a pointer for the likely demand for these instruments in the next decade. This is in addition to the demand in the industrial and medical fields. In the next ten years the total demand is expected to exceed Rs. 25 crores.

The major demand for geoscientific instruments in the country would arise from the requirements of the Oil and Natural Gas Commission, Geological Survey of India, and the National Geophysical Research Institute for their exploratory work. These are required for ground based as well as air-borne operations. The proposed work involved in this field has been studied by a panel of experts set up by COST and it has indicated a continuously high demand for these in the next five years. This also covers the requirements for oceanographic exploration. It is expected that the demand during the Sixth Plan will be of the order of Rs. 20 crores. However, the manufacture of these instruments has not yet been taken up on a regular basis in the country.

Microwave test and measuring instruments include the instruments required for (a) installation and maintenance of microwave LOS systems, (b) research and development of LOS systems, (c) production of LOS systems, and, (d) production of various test and measuring instruments/systems.

The Panel on Microwave Components and Instruments, constituted by the Electronics Commission, has evaluated the demand for these instruments during the Fifth Plan period. The demand for microwave instruments covers the requirement for the above mentioned applications associated with the Post and Telegraphs, Railways, Defence, Overseas Communications Service, and All India Radio. In all the cases, the demand projections as given in Table 10.2 are in addition to the existing facilities. Instrument for mass production of microwave systems are

Table 10.2. Ten year demand profile for electronic instruments.
(in Rs. crores)

Category	1974-75	1975-76	1976-77	1977-78	1978-79	1983-84	Total during Fifth Plan	Total during Sixth Plan
Test and measuring	11.0	14.0	16.5	20.0	25.0	47.0	86.5	185.0
Analytical	4.0	6.5	8.5	11.0	13.0	22.0	43.0	85.0
Nuclear	1.5	1.7	2.0	2.3	2.5	4.0	10.0	15.0
Geoscientific	1.7	2.1	2.5	2.9	3.5	7.0	12.7	25.0
Microwave	1.6	1.8	2.1	2.5	3.0	5.0	11.0	16.0
Total	19.8	26.1	31.6	38.7	47.0	85.0	163.2	326.0

required mainly by ITI and BEL. The total demand for these instruments during the Sixth Plan is likely to reach Rs. 16 crores.

Considering the urgent need for achieving self-reliance, the progress initiated during the Fifth Plan period would be further strengthened during the Sixth Plan. The total demand for all categories of instruments discussed here, may be projected to about Rs. 321 crores. Though a sectorwise distribution for Sixth Plan is indicated in Table 10.2, an yearly demand profile cannot be accurately worked out at present. The total cumulative demand for instruments during the decade 1974-84 is expected to be around Rs. 500 crores.

10.4 Analysis of Gaps

Analysis of gaps in the field of instruments is a complex problem in view of the fact that it encompasses a wide range of instruments. These instruments by and large differ in many respects like function, field of application, basic technology involved etc. Hence any attempt to analyse the gaps should be taken up at the level of each individual class or type of instruments. However, various studies and analysis conducted have exposed certain general problems of this sector. An attempt is made to first analyse the gaps on general terms and then in the individual groups.

10.4.1. General Analysis

It has been pointed out that the level of sophistication achieved by the instruments made in the country is comparatively low and that technological gaps exist in this field. A typical example in this context is the digital technique. Considering the change over from analog to digital techniques the world over, significant changes have taken place in the instrumentation design on a global scale. It is only recently that the digital instruments have been taken up for development in the country. An analysis of this situation reveals certain important factors. While there is sufficient talent on the technological side, there is a considerable lag on the hardware availability. This is particularly true in the case of professional grade components, both active and passive. The nonavailability of various semiconductor devices like integrated circuits at small and medium scale integration levels may be taken as a prime factor in respect of the low level of sophistication of instruments. The trend towards miniaturisation and the need for more rugged and compact instruments with better accuracy and reliability calls for other passive components of miniature size and of professional grade. The low volume requirement of such professional grade components, and the long delivery periods offered by foreign suppliers together with the import restrictions, account to a considerable extent for this undesirable situation.

The need to have a reasonably large series for any particular type of instrument in order to achieve economies of scale in production is characteristic of the instrumentation industry. This again is necessary to achieve the desired quality standards. In general, on a first approximation basis, it works out that the individual series should be of the order of 200 pieces for service grade and general purpose instruments. For special purpose instruments where professional quality is important, the preferred series should not be less than 50 pieces. This situation highlights the need of instrumentation industry to be kept aware regularly about the requirements of the various user fields/organisations, so that production planning can be done well ahead in right quantity. The instrumentation industry suffers from lack of an efficient system which could effectively bridge this information gap. The fact that a good percentage of the instrument manufacturers are in the small and medium sectors highlight this need.

Considering the overall growth of the instrumentation industry, the gaps in the R&D activities in the field need specific attention. The entire R&D efforts

in this area are handicapped by two major factors and in the present context it is necessary to highlight these.

(a) The evaluation of a project is not generally done when the product development is completed. Technical evaluation of the product forms an essential part of the development chain. Careful evaluation based on modern production techniques and industrial engineering should be thought of as a part of the development programme itself. This is necessary to effectively utilise the scarce national resources allotted for such projects. In many cases computer-aided project analysis may be required.

(b) After the completion of a project and the successful transfer of its know-how to the production line, development work on that product is stopped completely. The product represents only a first generation instrument and efforts for the refinement of its technical specifications have to be made as and when such need arises.

The 'communications gap' between the R&D organisations and the instruments industry could be tackled on a continuing basis only through a central agency which is in close contact with both. In the present context, there exists a need to keep the instrument industry aware, on a regular basis, of the growth of user industries and organisations, so that planning for local manufacture can be done well in advance keeping in view the average lead-time of one to two years between initial product formulation and final release of the product from the production line.

Some of the basic difficulties encountered in R&D activities are as follows :

- (a) Non-availability of a wide spectrum of materials and components of high reliability
- (b) Long and tedious administrative procedures for the import of components and measuring instruments
- (c) Lack of coordination between R&D units and industry
- (d) Non-availability of good testing facilities
- (e) Lack of standardisation
- (f) Lack of information on all the facets of R&D
- (g) Personnel in R&D organisation are not readily available and orientation programme is a missing link.

One of the main reasons that triggered R&D activities in technical institutions in the country is the shortage of foreign exchange allocation for the purchase of imported instruments and other accessories. Upto 1958, more than 60 per cent of the instruments for degree institutions and 40 per cent for the diploma institutions were imported. Of late, it has been possible to reduce the foreign exchange component of their requirement to about 14 per cent for the former and 10 per cent for the latter. This situation not only encouraged indigenous manufacturing of instruments, but some of the technical institutions also diverted their resources in developing the instruments. There is also a lack of communication between the various institutions engaged in R&D activities. Due to this lack of coordination, there had been considerable duplication of the development work. This situation is unavoidable to a certain extent as the respective development projects are originated out of their own needs and requirements. It has been estimated that in the case of more than 30 per cent of the instruments developed, there was duplication of efforts by two or more institutions. It is suggested that the faculty members of the technical institutions should be permitted to do consultancy work for the industry. This will enable them to establish closer contacts with the industry and understand their problems better so that the development projects can be

properly oriented. It is also suggested that technical institutions should extend the necessary expertise and facilities to improve quality and reliability on a continuing basis. The provision of adequate foreign exchange to the R&D institutions will initiate them to under-take the development of sophisticated instruments which may need imported components to start with. A central instrument development cell should be established, which would be responsible for establishing liaison with industry to find out their requirements and assign priorities. Another major difficulty experienced is in the transition of the development project to the commercial model. Since institutions do not have pilot plant facilities, they experience difficulty in transforming the development prototypes of a particular instrument to production model. Hence the industry has to take more responsibility in this connection as the potential user of indigenous know-how.

In the following, the gaps existing in the development and production of different categories will be briefly discussed.

10.4.2. Analysis of Different Categories

10.4.2.1. Test and Measuring Instruments

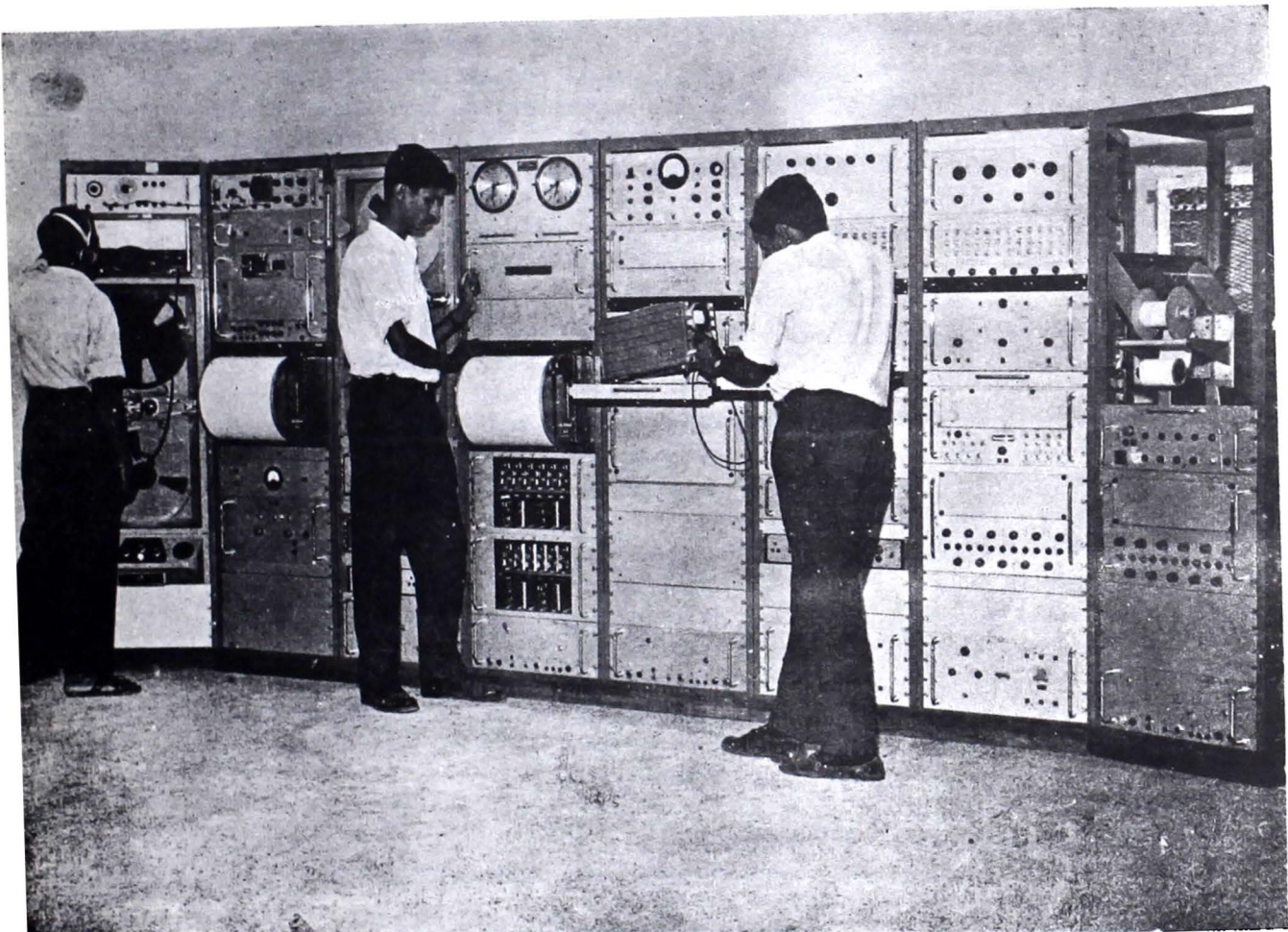
The survey of test and measuring instruments manufacturers indicates that most of the manufacturers presently concentrate on simple type of instruments like multimeters, signal generators and power supplies. In general, there is a lack of initiative in taking up the production of more sophisticated and complex test instruments. There could be two reasons for this: lack of sufficient facilities to take up initial design and see through the production, and lack of sufficient information about the market demands for special instruments. The R&D conference had indicated some of the test and measuring instruments for high priority development and immediate production. These are listed in the following:

- (a) Oscilloscope and display devices
 - (i) Further development of oscilloscopes of DC to 15 MHz range
 - (ii) Design and development of DC to 150 MHz oscilloscope, sampling and storage scopes
 - (iii) Vector scopes and spectrum analysers
 - (iv) LED and liquid crystal display systems
 - (v) Development of high voltage probes for the measurement with oscilloscopes upto 40 kV
 - (vi) Development of oscilloscope callibrators
- (b) Signal generators
 - (i) Signal generators 250 MHz to 1000 MHz
 - (ii) Power signal generators—100W upto 500 MHz
 - (iii) AM/FM type with relevant percentage modulation/deviation to international specifications
 - (iv) Signal generators employing digital techniques
 - (v) Frequency synthesisers and level oscillators
 - (vi) Sweep generators
- (c) Bridges
 - (i) Bridges of accuracy upto 0.1 per cent
 - (ii) RF bridges
 - (iii) Standard cells and their banks
 - (iv) Standard R, L & C (0.1 per cent accuracy)

- (d) Voltage and current meters
 - (i) Nano voltmeter, nano ammeter
 - (ii) Vector voltmeter
 - (iii) RF power meter above 200 MHz
 - (iv) RMS voltmeters
 - (v) RF millivoltmeter
 - (vi) Differential voltmeters (DC and AC)
 - (vii) Thermocouple meters
- (e) Q meters
- (f) TV test instruments
- (g) Digital test instruments
 - (i) Digital voltmeters both DC and AC
 - (ii) Frequency counter upto 1,000 MHz
- (h) Field strength meters upto 1000 MHz
- (i) IC-testers (in circuit and out of circuit)
- (j) Modulation monitors

10.4.2.2. Analytical Instruments

The pH meters, conductivity bridges, colorimeters, etc., are some of the



Complete recording equipment installed at the Hossur Laboratory, Seismos Station at Gauri Bidanur.

analytical instruments produced on large scale in the country. The sophisticated analytical instruments are mostly developed by the research laboratories for their own use. Sophisticated analytical instruments are of low volume high cost type and the demand in terms of number of each type may not be very large. An economical scale for production of such instruments may be typically 50 numbers. In some special purpose sophisticated instruments, it may be necessary to enter into limited technical collaboration with well established foreign manufacturers. It will be also necessary to import sample pieces of sophisticated instruments. The instruments indicated for priority development are spectrophotometers (UV, IR and atomic absorption), spectrometers, gas chromatographs, analytical bridges and gas analysers.

10.4.2.3. Nuclear Instruments

At present ECIL is the major manufacturer of nuclear instruments. It will be necessary to diversify the product range and give licences to more manufacturers. The nuclear instruments required for research which are presently manufactured, are of the valve or transistor type. It will be necessary to change the design to integrated circuit based, so that the cost is brought down and reliability increased. The need for equipment like whole body counters and scintillation cameras is expected to increase as more and more hospitals embark on radiation therapy. Special instruments for reactor control also need to be manufactured on a priority basis. It is felt that the production of simple instruments like scalers, GM counters and monitors can be done by small scale manufacturers, whereas complex instruments like pulse height analysers, reactor control instruments may be manufactured at ECIL, which has facilities for the necessary R & D work.

10.4.2.4. Geoscientific Instruments

The present production of geoscientific instruments is small compared to the demand. Considering the total requirements of geophysical prospecting and non-exploration instruments, it is felt that mass production of these through a centralised manufacturing organisation is necessary. This organisation, preferably in the public sector, could be progressively authorised to undertake the manufacture of geophysical instruments as well as meteorological and hydrological instruments which are required in large numbers in the country. The existing designs of instruments should be consolidated and handed over to this organisation for mass production so that research institutions will not be burdened by the production activity. Sophisticated instruments, the overall requirement of which is limited, may continue to be developed and made by concerned organisations. A clear distinction should be made in respect of systems such as airborne magnetometers, electro-magnetic units and scintillometer regarding the total number required. Modular construction of such instruments is needed which would require the sub-units to be readily obtained from the manufacturing agency so as to enable a consortium of technically competent instrumentation experts from different organisations to pool their resources and construct fully engineered versions of these systems. Some of the high priority geoscientific instruments to be developed include airborne survey instruments, pulsed ultrasonic equipment for seismic wave propagation studies, laser strain gauges, induced polarisation units and portable scintillometers for total gamma measurements.

10.4.2.5. Microwave Instruments

The total requirements of microwave instruments for the Fifth Plan is about Rs. 11 crores, out of which Rs. 7 crores is amenable to indigenisation and the remaining pertains to specialised use for research and development programmes, for items such as link analyser, power meters, frequency meters, frequency counters and

some miscellaneous items. The total demand for these items amounts to Rs. 4 crores, out of which ECIL is expected to supply Rs. 2 crores worth of instruments during the Fifth Plan. The remaining may have to be imported. For sophisticated items such as spectrum analyser, noise figure meters, frequency response set, etc., it may be necessary to purchase know-how from abroad so as to bridge the technological gap at the earliest. Based on this, it is estimated that production would be possible for these items during the last year of the Fifth Plan. Thus, out of a total requirement of Rs. 3 crores worth of these instruments, only Rs. 35 lakhs worth would be available indigenously during the current Plan. The production facilities so set up would therefore meet substantial requirements only in subsequent Plans. In case the know-how for these equipment is not readily available from outside manufacturers, it will be necessary to develop these instruments indigenously, in which case the time for development and production is expected to be of the order of six years. This will help form a strong base for future development programmes. Some of the microwave instruments required to be developed on a high priority basis are, spectrum analysers, link analysers, noise figure meters, power meters with compensated thermistor, frequency responses test sets, frequency meters, SHF generators, frequency counters and field intensity test sets.

10.5 Guidelines for Production and Technology Development

The present production base for instruments must be considerably substantiated to be able to satisfy the demand for instruments during the next decade. Considering the inherent characteristics of the instruments industry to enhance the productivity, a compromise has to be worked out for product range and scope for diversification. In the following, some general guidelines for the production of instruments are suggested. For effective implementation of these, some interim measures are required in addition to the long term production planning. As a first step towards increasing the productivity, the instruments developed within the country by different organisations should be productionised as soon as possible. Presently the ratio of know-how transferred to industry to know-how locally generated or developed is very small in the case of instruments. A proper method for know-how transfer must be worked out in consultation with the user industry. Since economy of scale of production is an important factor, existing manufacturers may be allowed to expand their licensed capacities for instruments which have large demand. In the case of certain types of instruments like analytical instruments, where manufacturing techniques are sophisticated, some of the existing manufacturers may be allowed to collaborate with reputed foreign firms, so that advanced technology is brought into the country. In such cases of collaboration, there will be good possibilities for export of such sophisticated instruments.

Since the area of instruments offers good scope for small and medium scale units, promotion of such units set up by qualified technocrats should be encouraged. The financial assistance in terms of low interest loans will attract many entrepreneurs. The import of special components and equipment for the manufacture, if allowed on a priority basis, will accelerate the production of sophisticated instruments. Instruments which are required for the production processes may be given highest priority and identified as items for immediate production.

The inter-relationships between science and technology, economic and social change and industrial progress are changing in a significant way. The guideline for long term production must foresee such changes and consequently, only general norms can be suggested. The problem of adaption of fast changing technology and market trends which confront electronics industry as a whole seem to be more acute for the instruments manufacturers in the small sector due to their relatively limited size and narrow economic base. A central organisation to help the small scale

instrument units in market research and product identification will be required. This organisation can also serve as an information base regarding the technological trends and availability of know-how in addition to helping in regard to licensing and administrative procedures. The long term production planning should identify the broad types of instruments and their production units. For example, the simple test and measuring instruments, like RLC bridges and frequency meters may be exclusively reserved for small scale units, whereas large test and measuring systems like oscilloscopes and frequency and spectrum analysers may be manufactured in the organised private sector. The public sector undertakings like ECIL, ITI, BEL etc., may be entrusted with the development and production of sophisticated and special purpose instruments. In general, the instruments do not require very high technology for their manufacture, and foreign collaboration is not required as most of the production process is assembly oriented. Exceptions to this are the sophisticated analytical and nuclear instruments. In many instruments like spectrophotometers, special materials for optical subassemblies are required. Efforts to develop these within the country should be made. The manufacture of various types of transducers is another area where considerable expertise must be developed. Another important aspect of the long term production planning is the development lead time. It is an important factor in successful technical innovation. The total development can be considered as the time span from the first idea for a new product to the first commercial deliveries. It may be divided into four stages :

- (i) Designation and preparation of project requirement, preliminary feasibility studies and preparation of detailed specifications.
- (ii) Design, production and testing of development phototype.
- (iii) Preparation of production drawings, tooling-up and production planning for quantity production
- (iv) Trial production, testing of initial models and debugging of these models. Launching of full scale production and delivery to customers.

These stages need not necessarily be successive and some overlap is generally possible. The lead times vary for different classes of instruments. In countries like USA and Japan, lead times are 1 to 2 years for test and measuring instruments and 3 to 4 years for analytical instruments. There is no systematic study of development lead times for Indian instruments industry. It will be important to conduct a survey to make an assessment of these times. In general, it is expected that the lead times in India will be longer, due to lack of proper raw materials, lower technology, standards, etc. The following measures will effectively reduce the lead times.

- (i) Prompt availability of components and subassemblies of both off the shelf and special types.
- (ii) Better planning of development and preproduction processes with the use of modern techniques such as PERT, CPM.
- (iii) Time reduction for tooling-up and preparation of repetitive design drawings by computer techniques.
- (iv) A closer involvement of top management in the R&D process.

The long term production planning should take into account the possible future technological alternatives. The productivity of R&D in terms of innovations will certainly increase during the next decade, since scientists and engineers will have at their disposal larger funds and improved facilities. Although it is difficult to foresee specific technical developments in particular instruments, some general trends appear fairly clear today.

(a) Improvement in Quality of Measurement : As science and technology progress and frontiers of knowledge are advanced, the sensitivity and sophistication in instruments are continuously improved. Also, precision and the rate of

possible performance will be extended through new power supplies, new electronic components and circuit design. Another trend is an increase in response rate of instruments or generally speaking, decrease in the time needed for measurements. Also, the modular concept has become popular due to need for increased reliability and quick servicing.

(b) **Diversification and Versatility of Instruments** : Another trend observed with respect to some instruments is a simultaneous use of various methods of measuring or analysis. The more a function oriented approach is introduced into instrument design, the more a mix of various techniques or scientific disciplines will be needed. It is expected that electronic techniques will be introduced in more conventional instruments such as optical, mechanical and pneumatic devices. The use of the laser, for instance with its application in metallurgy, medicine, telemetry, television, holography, etc., will be used in many instrument designs. It is also expected that there will be several varieties of the same instrument, differing in performance, sensitivity, etc., depending on the end use. This trend will considerably increase in the next decade.

(c) **Automation of Instruments** : The need for added precision, sensitivity and power in electronic instruments generally engenders greater complexity in the instrument design. This also usually means increased difficulty in handling instruments, which in turn create a need for greater skill on the part of users. It will be necessary to reduce such instrument handling difficulties as well as the time required for measurements. It follows from this that there will be a trend towards the fullest possible automation of instruments with a view to facilitating and speeding up their use. In this sense electronic instruments are ideal for automation.

(d) **Computer Compatibility of Instruments** : As the instrument use is increased, more scientists and engineers are faced with the consequences of the information explosion. Hence the increased automation in large number of cases means the use of computer for data collection and subsequent reduction. The computer compatibility will be a growing trend of the future. The instruments will increasingly have to use digital output systems in order to link up easily with computers. So far, most analytical instruments have analog outputs, in the form of strip charts. It is expected that many analytical instruments will have digital outputs using analog to digital converters. The cost increase in digitising is not expected to be high as the integrated circuits become more common. Many of the instrument manufacturers in the western countries have started incorporating small size computers as part of complex and sophisticated equipment. The instruments like gas chromatographs, NMR spectrometers, pulse height analysers, etc., will be computer controlled in future. The instrument computer systems will be common for air pollution monitoring, airborne geophysical survey, etc. With the advent of computers as integral parts of the instruments, there will be an evergrowing need for instrument software. The future instrument manufacturers will have to provide software along with instruments. The instrument systems will perform the tasks of programming the measurements, undertaking the necessary correlation studies and calculations to present the final results in a most appropriate form.

(e) **The Use of Integrated Circuits** : The rapid advancement in IC technology has already revolutionised the electronics industry. The prices of integrated circuits are falling continuously, in addition to increasing the number of functions on a single chip. New designs of instruments will exclusively use integrated circuits wherever possible. The advantages in size, reliability, speed and cost will certainly force most instrument manufacturers to use ICs in the near future.

In most of the advanced countries extensive medium and long-range planning of sales is a common feature. This sales planning in conjunction with the in-

X

creasing use of technological forecasting enables instrument manufacturer to foresee events and developments in their operations. This certainly lowers the risk of missing out on certain new developments. The science of technology forecasts has just made a beginning in our country and instrument industry should take advantage of this. The strategy for achieving self reliance in the field of instruments implies basically the need for technology development. The seminar on R&D Policy in Electronics held in 1973 at New Delhi, deliberated methods for effective technology development. The Working Group on Instruments studied the existing R&D base and the following recommendations were made.

(a) The composition of a central R&D coordinating agency consisting of representatives from universities, research organisations, public and private sector research and production units, members from Electronics Commission and Government representatives, etc., is suggested. The membership of such a body could be suitably worked out. Such agency would essentially:

- (i) make periodic updated assessments of the overall needs of the country for electronics instruments,
- (ii) identify areas of related R&D efforts as they exist in various organisations to coordinate these efforts, and decide on the priorities to be assigned to each,
- (iii) review the latest techniques on a continuing basis in areas and select those suitable for adoption, and
- (iv) monitor and review the R&D activities periodically to assess the progress made by each research team. This has specific relevance to small scale industries and individual R&D efforts.

(b) R&D efforts should be aimed at bringing down the lead time.

(c) Efforts should be made to improve the reliability and stability of existing instruments.

(d) R&D organisation should not overlook the rate of obsolescence.

(e) Inhouse R&D activities in manufacturing organisations engaged in an R&D work should be encouraged.

(f) Instruments of low cost, kit type should be developed for educational institutions.

(g) Close coordination is required between R&D groups dealing with precision components and materials, and instruments development group.

(h) The need for the development of special materials and components should be referred to a standing group on materials in coordination with the instrument group.

(i) The purchase of technology on one-time basis and the use of adaptive research to modify the performance from that stage onwards should be considered and encouraged.

(j) To remove the bottlenecks involved in technology transfer, a conglomerate of R&D organisations and industry could take up projects together to facilitate early transfer.

(k) The delay in importing components should be minimised by giving adequate foreign exchange to the R&D organisations.

(l) Servicing and maintenance facilities for imported sophisticated instruments should be created along with necessary spare parts backing for maintenance, as the effective utilisation of these sophisticated instruments is very essential. For this, centralised laboratories, where such facilities are available should be made use of. These facilities should be augmented, where necessary, to cater to all the future requirements.

(m) While considering the design and development aspects, environmental requirements should be suitably specified.

(n) The standardisation of instruments should be taken up on a priority basis.

(o) There should be a central R&D coordinating body to coordinate the activities of universities, IITs, national and Defence laboratories, public and private sector production and R&D units to evolve a meaningful, effective innovation chain.

(p) Funds should be provided to both public and private sector organisations engaged in R&D.

Subsequent to the R&D seminar, a Technology Development Council (TDC) was constituted by the Electronics Commission. The TDC Working Group on Instruments is mainly responsible for identifying the high priority development projects and allocating the R&D funds. An effective post award monitoring will be required to continuously judge the status of the R&D projects underway. It is important that the R&D projects funded be consistent with the overall development plan for the instrument industry. Also, a production agency should be identified at the very beginning of an R&D project. This will facilitate a continuous dialogue between the R&D organisation and the production agency.

10.6 Investment and Production Profiles

In this section, the investment and production profiles for 1974-84 are discussed. The projections for Fifth Plan period include detailed break-up regarding public/private sector, soft/hard foreign exchange requirements, etc. The instruments industry is rapidly expanding and many new types are being marketed continuously. It will be necessary to develop the infrastructure for the production and development so that, by the middle of Sixth Plan, the country will become self-reliant regarding the instruments requirements.

The ratios of investment required for setting up production plants to a ten year turn-over for different electronic sectors were given in the Bhabha Committee Report. In the case of test instruments, this ratio was estimated as 0.043. Subsequently it was indicated that the ratios estimated by the Bhabha Committee were on the lower side. After considering the investment trends in other countries and experience gained by the Indian manufacturing industries, these ratios were re-estimated. An important aspect of these ratios is the competitive life time of the production equipment under Indian conditions. The ratio of investment to turn-over during the competitive life time has been estimated to be 0.06, with a life time of 8 years for industrial electronics. The investment ratios for instruments are also expected to be of this order.

Table 10.3 shows additional investment for the Fifth Plan. The instruments are divided into high volume, low and medium cost instruments and low volume high cost instruments. The total production during the Fifth Plan period is expected to be Rs. 155 crores, with a terminal year production of Rs. 46 crores. Private sector has been playing an important role in the instruments industry. During the Fifth Plan period, it is anticipated that major investments will be in the private sector. The investment to five year production ratio is expected to be high for the low volume high cost instruments like analytical and nuclear instruments. The phased investment and production pattern is shown in Table 10.4.

It is expected that the manufacturing programmes initiated during the Fifth Plan would be further strengthened to reduce the import of instruments to a bare minimum. The new units set up during the Fifth Plan are expected to reach their optimal production capacity. The total investment during the Sixth Plan is expected to be Rs. 25 crores, with production going up to Rs. 351 crores. At this stage, it is very difficult to give any break up, as this will depend on the technological trends and economic situations.

In the following, the general pattern of investment is briefly discussed.

Table 10.3. Investment pattern for instruments for Fifth Five Year Plan.
(in Rs. crores)

	Total capital investment	FE content of capital investment	Raw material and component import		Production	
			Plan period	Terminal year	Plan period	Terminal year
High volume, low and medium cost instruments	9.5	4.2	8.4	1.0	119	36.5
Low volume high cost instruments	4.1	2.0	4.8	0.8	36	9.8
Grand Total	13.6	6.2	13.2	1.8	155	46.3

Table 10.4. Phased investment and production pattern for instruments for Fifth Five Year Plan (in Rs. crores).

	1974-75	1975-76	1976-77	1977-78	1978-79	Total
Investment	1.9	3.4	3.4	2.7	2.2	13.6
Production	19.0	22.8	28.5	38.4	46.3	155.0

The investment pattern in the case of instrument manufacturing varies for different categories. At present, most of the instruments are manufactured by small and medium scale manufacturers in the private sector. It is anticipated that the private sector will continue to play a major role in the instrument manufacture. The high volume, low cost instruments form the major fraction of instruments manufactured. Since the investment required to start manufacturing the type of instruments is low, most of the small scale manufacturers are expected to continue their manufacturing. On the other hand, initial investment as well as R&D support required for high cost, low volume instruments is substantial. Thus, only well established, large scale manufacturing organisations can afford to enter the field. In many cases a substantial foreign exchange may be required for the purchase of initial design and tooling/know-how. The public sector organisations and large scale units may be entrusted with the manufacture of sophisticated, special purpose instruments.

The test and measuring instruments are mostly of the low cost, high volume category. These would be continued to be manufactured in small and medium scale private sector. It may be necessary to import a few special components and materials for the manufacture of these instruments. Most of the development work required for these may be carried out by technical institutions, and know-how generated may be passed on to the manufacturers. It will be necessary to encourage the small scale manufacturers to try out new test instruments and diversify their product range. Incentives in terms of foreign exchange required to purchase special equipment will be required. It is expected that in the case of most of the test and measuring instruments, it may not be necessary to buy foreign know-how. The sample units of more sophisticated instruments may be imported to modify their design using indigenous components for local manufacture. A typical investment/production ratio for test and measuring instruments is expected to be around 1:15 in general. The test and measuring instruments are extensively used in the production facilities for the telecommunication equipment, semiconductor and electron

tube manufacturing, etc. It is expected that special instruments required for telecommunications support and maintenance will be manufactured by the unit itself. For example, Indian Telephone Industries (ITI) have been manufacturing instruments for servicing and maintenance of transmission equipment. They have planned the expansion of instrument manufacturing by setting up a separate factory. It is also not considered desirable that the manufacture of high precision sophisticated instruments should be tagged with more conventional transmission equipment where the accuracies required are of much smaller order. This indicates that public sector commitment in the manufacture of test and measuring instruments may be limited to special instruments, like those required for telecommunication.

The analytical instruments are mainly of the low volume, high cost category. The investment in this case is much more than that for test and measuring instruments. It is expected that the initial investment will involve (a) design work, (b) special tooling and (c) development of special transducers if necessary. The design work may be of two types; firstly, the design of analytical instruments from the beginning and secondly superposing the in-house R&D on the foreign know-how purchased. Except for simple instruments like pH meters and conductivity meters, considerable R&D work will be required before the country can become self-reliant in their manufacture. Complex and sophisticated instruments like chromatographs, spectrophotometers and infrared analysers involve many precision components and parts. Special tooling is required for these. It is expected that only pH meters, conductivity bridges and colorimeters will be continued to be manufactured in the small scale private sector. The larger analytical instruments should be manufactured by the medium scale or organised sector, who can afford large scale in-house R&D spending. The investment/production ratio in this case is expected to be 1:8. The national laboratories could be involved in the design and development work. Many of the analytical instruments are used in the process industries for on-line measurement and control. It would be worthwhile to establish the manufacturing facilities for both on-line and laboratory type analytical instruments as one unit. This will avoid duplication of the basic tooling and other manufacturing equipment.

ECIL, which is the major manufacturer of nuclear instruments, is expected to expand its activities and diversify the product range to meet the demand. As the design of most of the nuclear instruments involves special skills and components, considerable R&D support will be required. The nuclear instruments form an important segment of the power reactor development programme. The majority of investment is expected to be concentrated in a public sector undertaking only. Some of the simple instruments like scalers and radiation monitors may be manufactured by small scale private firms.

The manufacture of geoscientific instruments needs to be planned considering the ever increasing demand for exploration and non-exploration type instruments. ECIL is manufacturing some nuclear geophysical instruments like GM counter, scintillometers, portable gamma ray spectrometers, moisture/density gauges, etc., developed at the Bhabha Atomic Research Centre. Considering the variety and volume of highly specialised geophysical instruments required, it is considered that the establishment of an instrument manufacturing concern for the mass production of all types of geophysi-

cal instruments, ground based and airborne is necessary. This public sector organisation should carry out mass production of instruments required in large numbers and also carry out design and construction of equipment and systems for which the demand is small and ensure their effective long term maintenance. The feasibility report for such a public sector corporation which has been prepared by the National Industrial Development Corporation at the instance of India Meteorological Department should be carried forward to an investment decision as soon as possible. If work on such a Geophysical Instruments Corporation is started immediately, the production can start by the end of the Fifth Plan. The capacity of this manufacturing unit should be sufficient to meet the demand for geoscientific instruments for the next decade.

Microwave test and measuring instruments provide important support in microwave communications and many defence oriented projects. The development of microwave instruments requires special skill and equipment. Many of these instruments are under development at TIFR, NPL and ECIL. It is expected that more than one unit in the country will undertake production of microwave instruments. Consideration should be given to the demanding technology involved while deciding on the companies which are to enter the manufacture of microwave test instruments, whether on the basis of indigenous or imported know-how. The companies which will be given the necessary industrial licences should be those which already have in-house R&D facilities to satisfactorily absorb the technology bought and use this for subsequent development work, or can be expected to build up such R&D facilities and expertise rapidly.

XI

Electron Tubes

11.1 Introduction

Rapid and revolutionary changes in technology have resulted in the development of a wide variety of electronic components. It is often felt that the newer types of components would completely dominate over the older ones. This has been particularly so with regard to electron tubes. While semiconductor devices have afforded a considerable amount of substitution for the various types of electron tubes, it should be recognised that the latter still occupy an important position in electronics. The main reasons for this are the following. Firstly, the overall growth of the electronics industry has been such that a sizeable demand exists for almost every type of components developed so far. Secondly, for certain electronic functions, the electron tubes are still the inevitable choice and would continue to be so for a considerable time in the future. Mention may be made of high power, high frequency communication systems, broadcasting, power electronic equipment for industrial applications, systems using display devices like picture tubes, image tubes, cathode ray tubes, etc., as areas where the electron tubes continue to be important.

The various types of electron tubes used in the electronics industry may be classified as receiving tubes, transmitting tubes, microwave tubes, X-ray tubes, TV picture tubes and cathode ray tubes, photo and image tubes and gas filled tubes. Receiving tubes essentially refer to low power tubes in radio and TV receivers and other low power consumer and professional equipment. They consist of rectifier tubes both vacuum and gas filled types, amplifier tubes like triodes, tetrodes and pentodes and other special purpose multigrid tubes like heptodes, etc. Transmitting tubes refer to high power tubes used in communication and broadcasting equipment and for industrial applications. These consist of rectifier tubes, both vacuum and gas filled, amplifier tubes like triodes, tetrodes and pentodes and tubes like gas filled thyatrons. The types of microwave tubes that are extensively used are the magnetrons, klystrons and travelling wave tubes. The other members of the microwave tubes family are the carcinotrons, crossed field amplifying devices and hybrid tubes having the merits of power klystrons and travelling wave tubes. In the area of TV picture tubes, while black and white picture tubes are of immediate concern in the country, the colour picture tubes are of relevance in the long term. Cathode ray tubes are required for different applications such as instrumentation, radar displays, fluorescent display of alphanumerics, etc. The photo tubes include photo diodes, photo-multiplier tubes and TV camera tubes. The image tubes used, are mainly of two types, viz., image converters and image intensifiers. Gas filled tubes, which are of importance in electronics, are gas filled and vapour rectifiers, thyatrons, voltage reference tubes, TR-ATR cells, gas filled indicator tubes and some special devices like rare gas surge voltage protectors and gas lasers. Apart from the above types of electron tubes, a few other types such as VHF and UHF output tubes, ignitrons and high pressure discharge tubes are used to some extent.

Market trends in various countries indicate that electron tubes account for a significant fraction of the total components cost even today. The percentage contribution of electron tubes to the total component cost during the years 1970 and 1973, were respectively 18.7 and 19.1 per cent in USA, 23.7 and 25 per cent in UK and 21.1 and 13.5 per cent in Japan. The Bhabha Committee indicated that electron tubes would account for about 15.5 per cent of the total component cost in 1974-75 in the country.

The Panel on Special Electron Tubes constituted by Electronics Commission has made an indepth analysis of the various aspects connected with special electron tubes. The action guidelines suggested here are essentially based on the report of the said panel.

11.2 Current Status

The present status with regard to production, imports, R&D and manpower in the area of electron tubes is described in the following.

11.2.1. Production

The licensed and installed capacities for various types of electron tubes and the production figures for the years 1970-74 are given in Table 11.1.

Over 75 types of receiving tubes are being produced at BEL. Nearly the entire range of domestic requirements, except perhaps a few special types, are being met with by indigenous production. The types of transmitting tubes produced include 8 types of rectifiers covering peak current/PIV range from 300 mA/20 kV to 4 A/20 kV, 9 types each of medium and high power amplifier tubes in the operating range 260 watts/30 MHz to 120 kW/20 MHz (under class C conditions), and one type of thyratron. Over the last 6 years, about 8 types of tubes have been indigenously developed and productionised. The production of microwave tubes is presently confined to two types of magnetrons operating in the X-band with peak output power of 80 kW and 225 kW, respectively. Three types of X-ray tubes, two with stationary anode and one with rotating anode, are being produced. The stationary anode types are rated to 85 kV/18 mA (minimum) and 100 kV/45 mA (minimum), respectively. The rotating anode type operates on 125 kV single phase or 150 kV three phase with rated power of 20 kW or 40 kW (minimum). Four types of television picture tubes, namely, 19, 20, 23 and 24 inch sizes are being produced, though the major item in production is the 20 inch tube. Several types of cathode-ray tubes, including two of 7 inch size, are being produced at BEL. Apart from these, BEL has set up manufacturing facilities for some types of gas filled tubes like voltage regulator tubes and indicator tubes.

Indigenously developed TR and ATR cells are being batch-produced at TIFR. Four types of TR-cells operating in the X-band are being presently produced and production of S-band devices is expected to start shortly. Infrared sensitive image converter tubes have been developed at BARC and pilot plant scale production has been established.

Total capital investment for production of electron tubes has so far been to the tune of about Rs. 3 crores, almost entirely confined to BEL.

At present, electron tubes worth Rs. 4 crores are being imported per year. Major items in the import list are high power transmitting tubes and microwave tubes. Most of these tubes are required in relatively small quantities but are of very high cost. Thyratrons, photomultiplier tubes, camera tubes and a limited number of some special low power tubes are the other types that are being imported.

Table 11.1. Licensed capacity, installed capacity and production of special electron tubes in the country.

Sr. No.	Item	Licensed capacity	Installed capacity	Production (Qty. in nos./Value in Rs. lakhs)*				
				1970	1971	1972	1973	1974
1.	Receiving tubes (in millions)	10	8	5.01 (122.00)	5.70 (204.60)	5.02 (223.10)	4.08 (217.70)	4.55 (327.05)
2.	Transmitting tubes	36,000	15,000	13,615 (40.13)	10,867 (61.15)	11,753 (89.03)	8,984 (71.0)	12,565 (123.52)
3.	Microwave tubes	—	300	Nil	82 (5.40)	109 (16.00)	87 (11.34)	151 (19.02)
4.	X-ray tubes	3,600	1,800	779 (29.00)	1,155 (30.00)	1,186 (44.00)	1,000 (35.00)	1,128 (55.57)
5.	TV tubes	1,00,000	1,00,000	2,315 (5.10)	12,030 (32.00)	26,934 (107.00)	50,000 (176.80)	61,525 (279.59)
6.	CR tubes	—	—	677 (2.00)	1,108 (3.00)	1,108 (2.73)	1,212 (3.30)	2,404 (8.25)
7.	Photo & image tubes	—	—	—	—	—	—	—
8.	Gas filled tubes	—	—	—	—	—	—	—

* Figures in brackets represent value.

11.2.2. Research and Development

Apart from BEL which has established the electron tube development laboratory for in-house design and development, several other institutions are engaged in research and development activity in the area of electron tubes. These are CEERI Pilani, NPL Delhi, BARC and TIFR Bombay, IISc. Bangalore and IIT Bombay.

Presently, R&D work is being carried out at BEL in the areas of (i) CW magnetron, (ii) Coaxial magnetron, (iii) Tonn flat screen CRT, (iv) Camera view find monitor tube, (v) Dental X-ray tube, (vi) Diffraction X-ray tube, (vii) Short wave SW 75KW vapotran and (viii) Helium-neon laser. Development is in progress for the indigenous production of a few other types of tubes like voltage regulator tubes and gas filled indicator tubes.

CEERI Pilani has been engaged in R&D work in several types of special electron tubes. A 5 kW coaxial type power triode and 500 kW CW S-band pulsed magnetron have been developed and the latter is being batch-fabricated. Presently, R&D activity is in progress for television pickup tubes and flash tubes. Indigenous development of nickel matrix cathodes for magnetrons has reached an advanced stage of development. Development of coaxial magnetrons, CFAs and TWTs are being initiated.

The activities at NPL include the development of an L-band reflex klystron using external cavities and fabrication techniques for CR tubes and TV picture tubes. Work on high frequency cathode-ray tubes and colour TV picture tubes has been initiated.

TIFR has successfully developed X- and S-band TR-ATR cells with indigenous know-how. The product has reached the level of batch-production. With a view to master the various technologies involved in the production of highpower klystrons, TIFR has taken up the development of a 10 kW, CW klystron for operation in the S-band. Interest exists at TIFR for the development of TWTs. Work has been initiated on the development of vidicon tube with silicon wafer target.

The major activity at BARC with regard to special electron tubes is the development of image converter tubes. An infrared image converter tube has been indigenously developed and produced on pilot plant scale. R&D work on image intensifiers and photomultiplier tubes has been initiated. BARC has built up expertise in the development and production of vacuum systems and also in the various technologies involved in the production of vacuum based devices and systems. Development is in progress for hollow cathode lamps and flash X-ray tubes.

Development of high current density cathodes, special types of gas filled tubes like rare gas surge protectors and helium-neon lasers are some of the activities in progress at IISc. Training facilities for specialisation in vacuum technology and electron devices technology exist at IISc.

IIT Bombay offers post graduate courses in vacuum techniques and device technology. Development efforts are being put in the area of vacuum based devices and components by way of project works at M.Tech. level and research programmes.

11.2.3. Raw Materials

A rough analysis shows that the contribution of indigenously developed raw materials to the total requirement of raw materials, at present, is less than 12 per cent in the case of special electron tubes. There are very few institutions engaged in research and development work on materials required for electron tubes. Mention may be made of the Defence Metallurgical Research Laboratory (DMRL), Hyderabad, Special Materials Plant (SMP) at the Nuclear Fuel Complex Hyderabad, BARC and NPL, where some limited work is being carried out with regard to, indigenous development of some pure metals, glass and ceramic parts.

Considerable efforts are being put in by DMRL, National Metallurgical Laboratory, BARC and NFC for the production of nickel alloys including kovar and mu-metal. NFC is producing tantalum for use in tantalum capacitors. BARC is engaged in production of zirconium and titanium in kilogram batches. Development work on some types of ceramics like alumina is being pursued at BARC. DMRL is reported to have developed production know-how for OFHC copper. CGCRI has been making some progress in the development of special glasses and ceramics. However, considerable additional efforts are required to ensure the quality and to cover the other materials required, adequately.

11.3 Demand Forecast

For assessing the demand, electron tubes can be broadly divided into two classes. The first category would mainly consist of the receiving valves and allied low power tubes such as voltage regulator tubes and indicator tubes which are being rapidly replaced by semiconductor devices. The demand for these tubes, while continuing to be of a sizeable amount for some

more time, would have a decreasing growth rate and would ultimately taper to replacement purpose only. The other category of tubes consists of those which are not likely to be replaced by semiconductor devices in the foreseeable future to any significant extent. This includes high power tubes for broadcasting, communication and industrial applications, high power magnetrons, klystrons and TWTs, X-ray tubes, TV picture and CR-tubes, camera tubes, image tubes, etc. The demand for these tubes is expected to grow at a steady rate with the growth of the electronics industry.

The demand profile for receiving tubes has been worked out on the basis of the market trends in India and various other countries over the past few years, the market precast figures published for various countries and the overall perspective growth of the electronics industry during the Fifth and Sixth Five Year Plans. For the second category of tubes, except for a few types like TV picture tubes and CR-tubes, the demand would be, by and large, dictated by the requirements in specific user organisations like All India Radio, Overseas Communication Service, Defence, Police and Border Security Forces, Post & Telegraphs and Indian Railways. These organisations account for over 92 per cent of the total (excluding TV picture tubes) requirement of these special electron tubes. The remaining requirement is distributed between industry, trade and research.

Considering the present annual requirement and the envisaged expansion programmes of the various user organisations, the annual requirement of these special tubes by the end of the Fifth Plan period has been estimated by the Panel on Special Electron Tubes constituted by Electronics Commission. The userwise requirement gives a clear indication of the demand for some types of tubes like transmitting tubes and microwave tubes. The requirement of other types like X-ray tubes, CR-tubes, TV picture tubes and photo & image tubes has also been assessed by the Panel utilising the information available through reports and survey data.

Based on the demand forecast for various types of special electron tubes provided by the Panel, the past trends and the envisaged growth of electronics in the country, the demand pattern for various types of electron tubes has been estimated and is given in Table 11.2.

Table 11.2. Demand forecast for electron tubes (In Rs. crores).

	Average unit cost** (in Rs)	1974-75	1975-76	1976-77	1977-78	1978-79	1983-84	Fifth Plan requirements	Sixth Plan requirements
1. Receiving tubes	5.00	3.00	3.50	4.20	4.80	5.50	6.50	21.00	32.00
2. Transmitting tubes*	1,650.00	2.20	2.40	2.60	2.80	2.90	4.00	12.90	17.70
3. VHF & UHF output tubes	400.00	0.33	0.35	0.37	0.37	0.36	0.28	1.78	1.60
4. Microwave tubes	8,000.00	2.50	2.70	3.00	3.30	3.70	7.00	15.20	27.60
5. X-ray tubes	7,000.00	1.20	1.30	1.50	1.70	1.90	3.20	7.60	13.70
6. TV picture tubes	250.00	3.70	5.00	6.80	8.40	10.00	18.00	33.90	68.00
7. CR tubes	300.00	0.14	0.16	0.18	0.20	0.22	0.32	0.90	1.40
8. Photo & image tubes	900.00	0.00	0.80	1.00	1.20	1.40	3.10	5.00	12.00
9. Gas filled tubes	30.00	0.80	0.33	0.36	0.41	0.45	0.61	1.85	1.80
Total		13.97	16.54	20.01	23.18	26.43	43.01	100.13	175.80

*Includes high power gas filled and vapour rectifiers and thyratrons.

**At 1972-73 prices.

11.4 Analysis of the Demand

Television picture tubes, high power transmitting tubes and medium and highpower microwave tubes would be the important types that account for a major portion of the future requirements. The demand for camera tubes, image converters and image intensifiers is expected to grow considerably over the next ten years. A steady growth rate, though of a relatively lower value, may be envisaged for cathode-ray tubes. Extensive usage of X-ray tubes in the medical field suggests an obvious growth in demand for the device in the country. The demand for gas filled tubes, though expected to be limited, would be significant for several years more. The requirement of receiving tubes would be mostly for replacement purpose. Only in few cases such as television and hi-fi systems, a limited demand is likely to continue for some more time. While the overall demand growth is on the decline, the size of the requirement being still large, receiving tubes account for a considerable fraction of the total requirements.

The major users of transmitting tubes are All India Radio, Department of Civil Aviation, Defence, Police and Border Security Force, Railways and Overseas Communication Service. Indigenous production is catering to approximately 40 per cent of the requirement and the remaining are imported regularly. Most of the import is for the low volume, high cost types and mainly consist of water and vapour cooled amplifier tubes and thyratrons. The demand for high power rectifier tubes continues as the changeover to silicon diode stacks is still not found economically viable in the country. The projected demand for transmitting tubes by the major user organisations indicates a continuous and increasing demand for almost all types of high power tubes that are being used presently. Use of transmitting tubes will grow considerably when industrial applications of high frequency heating and ultrasonics become widespread.

The demand for microwave tubes is largely dictated by the requirements of Defence, Civil Aviation, Meteorology and Post & Telegraphs. Except for a limited number of X-band magnetrons the entire requirement of microwave tubes is being met by imports. Most of the tubes imported are of vital importance and many of them, though required in small quantities, are extremely costly. Among the microwave tubes, the demand for high power magnetrons, klystrons and travelling wave tubes would be on continual increase even beyond the next decade. It is felt that low power TWTs and reflex klystrons would be replaced, to a large extent, by solid state microwave devices in the next ten years. Apart from magnetrons, klystrons and TWTs, a few other types like carcinotron tubes and crossed field amplifier devices are likely to be in demand to a limited extent. It is expected that the newer types like hybrid tubes having the merits of TWT and power klystron would gain prominence in the future applications.

The requirement of X-ray tubes would be mainly for health services and scientific research. With the promotion of rural and urban health schemes envisaged by the Directorate of Health Services, the demand for X-ray tubes is expected to increase significantly. The demand for cathode-ray tubes would grow more or less in parallel with the growth of the instrumentation industry. The demand for radar display tubes and tubes for fluorescent display alphanumeric would be on the increase. Among the photo and image tubes, the types that need consideration are photomultiplier tubes, camera tubes (vidicons and image orthicons), image converters and image intensifier tubes. The present requirement of photomultiplier tubes is about 300 numbers per year and over the last few years the demand has been growing at the rate of nearly 20 per cent every year. The demand for vidicons and image orthicons would grow considerably with the growth of CCTV industry. A requirement of about 1000 tubes each of 1 inch vidicons and 3 inch image orthicons per year by the end of Fifth Plan period would not be an overesti-

mate. A limited demand for few other types of camera tubes like plumbicons may also be expected. The image converter and image intensifier tubes, being useful for a wide variety of defence and security applications, would be in great demand. A demand to the tune of 6000 image tubes per year valued at Rs. 80 lakhs may be expected towards the end of Fifth Plan period.

The demand for gas filled tubes would be confined to only a few types like TR-ATR cells, surge voltage protectors, a limited range of indicator tubes and gas lasers, apart from gas filled rectifiers and thyratrons which have been grouped with transmitting tubes.

11.5 Technology Trends

With the exception of receiving tube types and some relatively low power/low frequency type tubes, continual upgrading of the technology is being carried out for most of the other types of tubes.

Improvements in frequency and power capabilities of transmitting tubes have been brought about using techniques such as planar design, lighthouse type of construction and vapour cooling technology. Transmitting tube capable of dissipating 500 kW at its anode has been fabricated. This could perhaps be the upper limit for sometime to come, since high power broadcast transmitters are usually designed with several high power modules operating in parallel. With the already heavily congested frequency spectrum in the medium and VHF bands, greater utilisation of UHF and microwave bands may have to be taken recourse to and the transmitting tubes, consequently, will have to be designed centering around these frequency bands. Conventional tubes would be inefficient in this region and a change would be called for in the selection of raw materials and in the depth of design. Conventional glass envelope tubes with low dielectric factor and high loss will be replaced by all ceramic metal tubes operating with at least 65 per cent efficiency at UHF and possibly going upto L and S bands. It is reported that an all ceramic-metal tube capable of working upto L band and amplifying sound and picture signals simultaneously, has been developed elsewhere.

Trends in the development of magnetrons cover frequency range upto KA, Q and even V band operating at power levels from a few watts to few megawatts. Voltage tunable magnetrons operating in the frequency range from the megahertz to several gigahertz range and delivering power upto kilowatts range would find wide applications. It is needless to point out the importance of high power magnetrons and klystrons as high power microwave sources. Other technologies are no way near these with regards to the frequency-output power product. TWTs of 1 kW power are already coming into commercial use and higher power TWTs will certainly be a major item in the next decades requirements. Low noise TWTs having octave bandwidth at S band and below, noise figures less than 3 dB and hybrid tubes with bandwidths greater than broad band klystrons and efficiencies higher than TWTs, have already reached advanced stages of development.

In the area of TV picture tubes and CR-tubes, growing use of colour picture tubes and long persistence and storage type cathode ray tubes will necessitate the production of these items. Increasing use of fibre optics technology and highly sensitive photocathodes are contributing in a significant way to the growth in demand of photo and image tubes.

There is a distinct possibility, in the long term, of using lasers for communication. While short range systems may be centred around solid state lasers, the long range ones may be based on higher power gas lasers.

11.6 Guidelines for Production

The projected demand for various types of electron tubes clearly indicates a continued usage of almost all types of electron tubes over the next decade. While an increasing rate of obsolescence is expected for some types such as receiving tubes

and low power microwave tubes, a continuous growth in demand can be foreseen for several others like high power microwave tubes, TV picture tubes, transmitting tubes and X-ray tubes. While the production base is well established for receiving tubes and some types of transmitting tubes, magnetrons, TV picture tubes, cathode ray tubes and X-ray tubes, regular production does not exist for many other types of electron tubes. Many of the special electron tubes are required in relatively small quantities but are of very high cost. Many of the tubes are of such economic and strategic importance, that it will be highly disadvantageous to depend on imports. Considering these factors, the following guidelines are suggested for a balanced growth of the electron tube industry in the country.

11.6.1. Receiving Tubes

The indigenous production of receiving tubes is well established to meet the domestic requirements and has also captured export market. Augmentation of the existing facilities for a production target of about 15 million numbers per year is recommended, taking into account the likely growth in both domestic and export demands.

11.6.2. Transmitting Tubes

While the production of low and medium power (upto about 50mA/2kV rating) rectifier tubes should be deemphasised, the production of high power rectifier tubes may be continued until suitable solid state power diodes are produced within the country and the economic viability of the changeover is established. This aspect should be reviewed in about two years' time.

Among the amplifier tubes, production may be essentially confined to tetrodes in the power range 400 watts to 5 kilowatts and triodes in the range 8 kilowatts to 15 kilowatts and above.

In view of the economic and strategic importance, at least some types of tubes which belong to the low volume, high cost category which are not manufactured in the country yet, should be taken up for production during the Fifth Plan period. Production of the following types is recommended in the first instance.

(i) RS-2011	Vapour cooled triode
(ii) RS-2041/RS-2051	Vapour cooled triode
(iii) K 9A/K10A	Water cooled triode
(iv) BTS-15-3	Vapour cooled triode
(v) QBLS/3500	Triode
(vi) 4 CX/5000A	Ceramic tetrode

Thyratrons used in high power transmitters account for a considerable amount of the import bill every year. Since the characteristics of these tubes are susceptible for drastic changes with ageing and even the shelf life being relatively small, the inventory costs would be high. While there are indications of thyristors being replaced by solid state devices in the long run, the demand would be sizeable over the next decade. It is recommended that a limited number of these be standardised and produced in the country. The types of thyristors suggested in this regard are TQ-81, TQ-91, 5563-A and AR-64.

Tube types 4P55 and 4B85, which are presently imported, are expected to be in greater demand in the coming years. The production of equivalents of these tubes should be immediately taken up.

Low power microwave tubes like reflex klystrons, backward wave oscillator tubes and low power TWTs are semiconductor devices. The present requirement of these tubes is, however, sizable. While the future systems would increasingly use semiconductor devices, the requirement of low power microwave tubes is expected to continue for several years. Production of these tubes should be examined in the

light of the production possibilities of their semiconductor equivalents in the country, the importance of the projects involving the use of these tubes and the size of annual requirements.

Production facilities in the country for magnetrons should be augmented. Considering the demand pattern for magnetrons, the production of following representative types may be established in the first instance.

S band magnetrons

- (i) QK338
- (ii) M5030
- (iii) M501

X band magnetrons

- (i) MU509
- (ii) MN1838

If the defence projects, where the use of X band magnetron type MA 7521 is envisaged, come through, the production of this tube type has to be initiated as early as possible in view of its large requirement.

The estimated requirement of high power klystrons in the Defence sector alone is about Rs. 1.5 crores per year by 1978-79. These tubes are typical representatives of the low volume, high cost category. The unit cost of power klystrons range from a few thousands of rupees to few lakhs of rupees per piece. The production of these tubes involves a high level of technology. The processing cost being high and the number required being small, production of these devices needs a basically different culture than what is normally prevalent in conventional production organisations. Considering these factors, it is felt that these tubes can be best produced by an agency who can undertake custom-built or multiple-prototype production. These tubes need a strong, in-house R&D backup.

With regard to power klystrons and TWTs, it is recommended that the following representative types be taken up for production.

Klystron

- (i) SAL 415
- (ii) 4K3SL
- (iii) TV2030

TWT

- (i) 8232
- (ii) 9232
- (iii) 9131

In view of the high unit cost and relatively shorter life of klystrons it would be worthwhile to explore the possibilities of repair/reactivation of used klystrons. It is reported that such measures are being adopted in several countries. Facilities should be set up for reactivation of used klystrons and other costly tubes for which the process is viable. Since the reactivation process is very similar to processing of new tubes, it is recommended that this activity should be confined to the agency dealing with development and production of low volume, high cost tubes.

11.6.4. X-ray Tubes

Increasing use of X-ray tubes in medicine, industry and research indicates the need for augmenting the production facilities so as to minimise the foreign exchange drain. The rural health schemes envisaged by the DGHS includes incorporation of X-ray facilities and a sizeable demand is expected if the scheme is implemented to the degree it is planned.

The production facilities of the X-ray of tubes should be augmented for a production capacity of at least 2000 tubes per year by the end of Fifth Plan period.

Technical and economic viability of indigenous tubes, rather than their availability with one-to-one correspondence with imported tubes, should be taken as the basis for restricting import of X-ray tubes.

11.6.5. TV Picture Tubes

A production target of about 5 lakh number of TV picture tubes by the end of Fifth Plan period and about two to three times this value towards the end of Sixth Plan would be realistic. However, no new collaboration is required for production.

While 19 inch/20 inch tubes have been standardised for domestic viewing, the size of picture tubes for community viewing should in many cases be of 24 inch size.

Indigenous production of glass shells for TV picture tubes is essential and should be taken up as early as possible as the gestation period for the project is likely to be 3-4 years.

The TV glass shell represents a key intermediate product catering to both large and small scale sectors. In view of the complicated technology involved, it would be essential to acquire technical know-how through collaboration for manufacture.

Vertical integration, including manufacture of 2,00,000 TV receivers, would yield an investment-output ratio of nearly 1:2. If the glass shells and 3,00,000 picture tubes are made in the same plant, the investment ratio will be of the order of 1:0.57, but the operation can still be profitable. A policy decision will, therefore, have to be taken on the question whether TV receivers should also be allowed to be manufactured in the same plant.

11.6.6. Cathode-ray Tubes

In view of the projected demand and the existing infrastructure at BEL, the production of cathode-ray tubes may be essentially confined to BEL.

Extensive usage of cathode ray tubes for displays, including alphanumeric display, suggests the need for including 12 inch and 16 inch diameter tubes in the production range.

As in the case of TV picture tubes, indigenous production of glass shells for cathode-ray tubes is essential and should be taken up immediately. In view of the common process technology involved, this could be accommodated as a product mix in the proposed TV glass shell factory.

11.6.7. Photo and Image Tubes

The types of tubes that need special consideration are the photo-multiplier tubes, camera tubes, image converter tubes and image intensifier tubes.

Photomultipliers are vital components in a variety of instruments and the demand is likely to grow in parallel with the growth of instrumentation industry. In the case of camera tubes, image orthicon would be an obvious choice because of its versatility. Vidicon tubes also find extensive use in view of their performance characteristics and simplicity of structure. For some applications such as low light level television, image intensifier orthicons would be the preferred type. Image tubes of a large variety are available in the world market. One of the most popular types is the type 6914 infrared image converter, because of its high quality performance and convenient size. Apart from image converter tubes, which are used as active devices, image intensifiers of the category of the passive devices, would also be in demand for night vision applications.

Production of photo and image tubes in the country is found to be necessary

and viable. The following types of tubes may be standardised for production purposes.

- (i) Photomultiplier type—8053
- (ii) Photomultiplier type—8054
- (iii) Photomultiplier type—IP28
- (iv) Photomultiplier with GaInAs photocathode
- (v) Photomultiplier with extended red multi alkali (ERMA) photocathode
- (vi) Image converter type 6914
- (vii) Image intensifier type 8606 or 8856 (three stage cascaded)
- (viii) Camera tube image orthicon, 3 inch size
- (ix) Camera tube vidicon, 1 inch size

Production technology has been established in the country to the extent of batch-production for some items such as image converters. Development work has been initiated for a few others like camera tubes and image intensifiers. Any import of technical know-how for these items should thus be a judicious choice that aids the growth of indigeneous technology.

Considering the nature and the level of technology involved and the demand pattern it is essential that the production of these tube items are taken up by an agency that can undertake production of low volume, high cost tubes.

11.6.8. Gas Filled Tubes

Apart from gas filled rectifier tubes and thyratrons which have been grouped with transmitting tubes, the other gas filled tubes for which indigenous production would be viable are TR-ATR cells, a limited number of indicator tubes, surge voltage protectors, flash tubes and gas lasers.

Indigenous production of TR and ATR cells, operating in the X and S bands, has been established on pilot plant scale. There is no need to import any know-how for these items. Considering the demand pattern and the level of technology involved, these are well suited for production in an agency which has strong in-house R&D base.

While light emitting diodes and liquid crystal displays have several advantages over gas filled indicator tubes, the use of the latter is expected to continue for some more time to come. An average annual demand of about 1.5 lakhs numbers per year over the next 3 or 4 years may be assumed for production. In view of the existing facilities at BEL and the projected demand, there is no need for setting up new production units for gas filled indicator tubes.

Rare gas surge voltage protectors are being imported in significant quantities each year. Despite the relative simplicity of structure and availability of competence in the country, no efforts are being put to manufacture these. It is recommended that production of rare gas surge protectors be started in the country. The requirement of these is relatively smaller and further the demand is distributed over a wide variety of specifications. In view of this, the production of these may be uneconomical for a large scale conventional production organisation.

11.6.9. Low Volume, High Cost Tubes

Among the various things that emerge from the discussions on the current status of production and the requirements of special electron tubes in the country, the following points stand out clearly.

- (i) Most of the special electron tubes will continue to be of vital importance for a considerably long time in the future and significant growth in demand is anticipated.
- (ii) The strategic and economic importance of these tubes makes it highly

disadvantageous to depend on imports particularly at times of emergency.

- (iii) Production base exists in the country for some types of tubes like magnetrons, X-ray tubes, TV picture tubes and cathode ray tubes and some types of transmitting tubes and the future demand for these tubes may be met by augmenting the existing facilities.
- (iv) No regular production exists in the country at present for several types of special electron tubes like klystrons, TWTs, photo and image tubes, etc., and a heavy foreign exchange bill is being incurred every year.
- (v) Most of the tubes which are yet to be produced in the country, are required in relatively small numbers but are of high unit cost because of the high level of technology involved. In some cases the requirements are such that the custom built or multiple prototype production is called for. Production of such tubes involves a basically different culture than what is normally prevalent in conventional production organisations. Also the production of such low volume, high cost products is often an uneconomic proposition for the conventional production organisations.
- (vi) Considering the nature and level of technology involved, an integrated R&D-cum-production programme would be the best choice for these devices.
- (vii) Processes like 'reactivation' of used tubes have been found necessary and feasible particularly for high cost tubes like power klystrons. The production agency should undertake such programmes.
- (viii) For any R&D effort to be useful and productive, it is necessary that a manufacturing agency be identified and associated with the R&D laboratories that undertake the project. Many of the projects in the area of special electron tubes, undertaken by national laboratories and research institutions, need further development efforts from the production engineering point of view. While some of the laboratories may be given facilities for batch-production, many of the projects will have to be transferred to the production unit.

The above points indicate the need for setting up a new unit for the production of low volume high cost special electron tubes which are not being produced now in the country.

Private sector may not be in a position to undertake this responsibility, nor would it be desirable to impose it on existing public sector undertakings which have achieved the optimum size.

The new unit could draw upon the existing know-how and competence available in national laboratories and research organisations and work on a cooperative basis rather than a competitive one. The production engineering of prototypes available could be worked out by the new complex. In this regard, it could be ably guided by BEL which has established viable production lines in allied areas.

Towards the implementation of the above recommendations of the Panel on Special Electron Tubes it may be noted that a production facility is being established with the joint efforts of BEL and BARC.

The items that could be produced in the new complex include microwave tubes like high power klystrons and TWTs, photomultiplier tubes, image converters and intensifiers, special purpose gas filled tubes like surge protectors, TR-ATR cells, etc. and super power transmitting tubes needed for broadcasting. With the facilities set up and competence built up, the product range could also include other vacuum

based devices like Geiger-Muller tubes, vacuum capacitors, etc. The total plant and machinery needed is estimated to cost approximately Rs. 2.5 crores and the production would be around Rs. 3.0 crores annually when the steady state is reached. While it may be necessary to import know-how in some cases, it should be a judicious choice to aid indigeneous development efforts as far as possible. The saturation level of manpower in the new complex, estimated to be around 2,000 is expected to be attained by gradual growth in the course of 6 to 8 years. The sophistication being high, about one third of this should be well qualified engineers and scientists. The remaining would be equally divided between technical assistants and supporting technicians, by and large.

11.7 Guidelines for Research and Development

For any R&D work to be useful and productive, it is necessary that apart from country's requirements, the competence for productionising indigeneous efforts be examined critically before launching the projects. Either the organisation undertaking the development itself should be given facilities for pilot plant scale production, or a production agency be associated with the development team at a fairly early stage. It is recommended that in the light of the above, the R&D facilities at the existing centres be suitably augmented.

The type and level of R&D required for various types of tubes depend upon the relative importance of the tube, the estimated requirement and the available expertise. In addition, the choice is influenced by the cost and time constraints involved.

11.7.1. Transmitting and Receiving Tubes

In the area of transmitting tubes (including thyratrons), R&D efforts are necessary for some high power amplifier tubes of the water cooled and vapour cooled types. Typical examples are the tubes like K9A, K10A, RS2041, BTS 50-3 and thyratrons like TW81, TPI35/15 and AR64. It is to be noted that the quality of each type required is relatively small and essentially a pilot plant scale production would be sufficient. Thus considering the requirements and the technology involved, it is preferable that the same organisation which undertakes development of these tubes also produces them on the required scale. The complexity of structure and technology involved being not too complicated, developments based on improvement of existing designs seems to be the best alternative.

Tubes with ceramic envelopes are attractive by way of their superior high frequency performance and relatively small size for a given power rating. Indigenus development of ceramic tubes would be extremely useful in the long run and should be supported. A major problem in this area would be the non-availability of suitable ceramics. The development efforts should preferably be based on the types of ceramics that are available or likely to be available in the country.

11.7.2. Microwave Tubes

In the area of microwave tubes, the following types would be of importance for prolonged and futuristic applications and hence R&D work may be supported in these areas.

- (a) Coaxial magnetrons
- (b) Crossed field tubes including crossed field amplifiers (CFA) with 'cold' cathodes
- (c) High power CW and pulsed klystrons
- (d) Medium and high power travelling wave tubes

The know-how for conventional magnetrons has been improved and adopted for production at BEL. R&D efforts have to be strengthened to absorb and

develop the know-how further, so as to produce magnetrons in different frequency and power ranges.

Coaxial magnetrons having a resonant structure coupled to a cylindrical cavity and operating under circular electric mode are coming into wider use because of their superiority of performance with regard to frequency stability, peak power output, efficiency and life. While the development of coaxial magnetrons should be encouraged and adequate facilities be necessarily provided, it is also essential to keep in view, measures for bridging the gap, if any, between development and production and work out strict time schedules.

In the area of klystrons and TWTs, except for the development project for 10 kW CW klystron at TIFR and a low power reflex klystron at NPL, no major thrust has been made so far in the country. Since it is essential that dependence on import for these tubes be reduced and removed as early as possible, concentrated R&D efforts are necessary. While import of know-how for some specific types may be allowed so as to gain in lead time, indigenous skills should also be developed in associated technologies like ceramic to metal seals, preparation of high current density cathodes, design and fabrication of component parts like cavities, slow wave structures, etc.

11.7.3. X-ray, TV Picture and Cathode Ray Tubes

In the area of X-ray tubes and TV picture tubes, production has been based on imported know-how. R&D efforts on these items may be mainly confined to product diversification programmes to meet the requirements of the country. However, it is recommended that indigenous development of special types of tubes, like long persistence and storage type cathode-ray tubes be supported with the long range requirements in view.

11.7.4. Photo and Image Tubes

As regards photo and image tubes, competence has been built up in the country in several of the production technologies involved. There is, however, a need for R&D efforts in the allied sophisticated technologies like processing of electron multipliers, preparation of highly photo sensitive surfaces and targets for photo-electronic devices, fibre optics technology, etc.

11.7.5. Gas Filled Tubes

In the area of gas filled tubes, R&D may be confined to indigenous development of some special tubes like surge voltage protector, flash tubes, etc. The development efforts should include methodology of industrial engineering and productionisation of prototypes. Enough competence exists in the country in the technologies involved and there is no need to import any know-how for gas filled tubes. The production oriented development of gas lasers taken up at BEL should be supported.

11.7.6. Special Materials

Development of special materials like steatite, high purity alumina and beryllia, is of vital importance. Some work is in progress at DMRL, NPL, BARC and CGCRI. The development efforts have to be adequately supported and augmented. Development of high energy permanent magnets for magnetrons and periodic permanent magnets for TWTs are areas of importance for R&D work.

11.7.7. Special Techniques and Facilities

For the overall growth of the electron tubes industry in general, and the special electron tubes industry in particular, an innovative approach for mastering

the special techniques involved would be highly desirable. Work in this direction could be taken up at institutions of higher learning. It includes areas like:

- (i) Study of slow-wave structures for microwave tubes like TWTs and CFA tubes
- (ii) Development of new types of cathodes
- (iii) Design of electron guns
- (iv) Optimal design of envelopes, cooling systems, cavities, etc., for the various types of tubes
- (v) Substitution of imported materials by indigenous/easily available materials

Adequate facilities, financial and otherwise, are essential for any meaningful R&D and its culmination in useful production. It would be desirable to provide batch-production facilities at the R&D centres and/or identify possible manufacturers at the time of sanction of the project. R&D organisations may be allowed to import component parts and/or materials worth upto a certain amount without an import licence. Special procedures and practices for import clearance of the requirements of R&D programme should be evolved by the Department of Electronics.

XII

Semiconductor Devices

12.1 Introduction

The semiconductor industry was started in India in 1962 with Semiconductors Ltd. (SEM), Poona taking up germanium devices for production. BEL, Bangalore was the first public sector unit set up with extensive facilities for the manufacture of germanium devices. The production of silicon devices was initiated by Continental Devices (India) Ltd. (CDIL), Faridabad in 1966 followed by both BEL and Semiconductors Ltd. Most of the production of semiconductor devices today is of discrete diodes and transistors of both germanium and silicon. The production of these devices has grown over the years as shown in Fig. 12.1. The growth has been related primarily to expansion of production of radio receivers, as the industry has, by and large, catered for these comparatively large volume markets.

Since the invention of transistor in 1948, many new developments have taken place resulting in a variety of semiconductor devices. One of the major advances has been the development of integrated circuits (ICs) around 1960. Although ICs are only the result of a technological advancement rather than a conceptual change, they nevertheless have revolutionised the architecture of electronic systems besides, of course, making them smaller and more reliable. In countries like USA, ICs have received a great impetus owing to their huge astronautics and defence programmes.

As mentioned earlier, the semiconductor devices in use today are of a wide variety. These devices may be classified as (i) discrete devices—conventional and special types, and (ii) integrated circuits. The discrete, conventional devices include

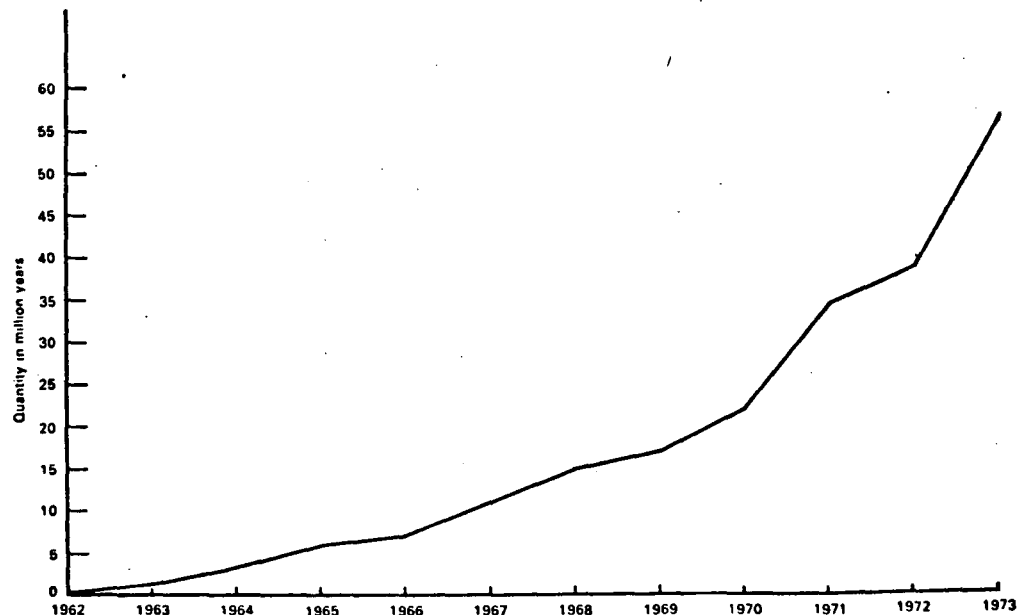


Fig. 12.1 Semiconductor devices production growth

signal diodes, rectifiers, zener diodes, thyristors, small signal transistors, power transistors and microwave transistors. The diodes and transistors are of germanium as well as silicon though silicon is replacing germanium except in some special applications. Some of the diodes and transistors are also being made with gallium arsenide for microwave applications. Among the discrete, special devices there are microwave diodes, which include Gunn, Impatt, Trapatt, LSA, tunnel and varactor diodes, and optoelectronic devices which besides display devices include semiconductor lasers. The integrated circuits may further, with regard to the type of technology, be classified as monolithic ICs and hybrid ICs. With regard to the functional type, ICs are classified into linear ICs and digital ICs. The digital ICs, in terms of the complexity of the circuits, are further classified into small scale integrated circuits (SSI), medium scale integrated circuits (MSI) and large scale integrated circuits (LSI).

12.2 Current Status

12.2.1. Production

12.2.1.1. Licensing and Present Production

The Bhabha Committee has forecast a demand of 100 million semiconductor devices valued at Rs. 17 crores by 1975 according to the following pattern :

	Nos. in million
Germanium transistors	40.0
Germanium point contact diodes	10.0
Silicon transistors	30.0
Silicon diodes & rectifiers	15.0
Thermoelectric devices	0.5
Other semiconductor devices	4.5

Against this forecast licensing has been as follows :

	Licensed	Letter of intent
	(Nos. in million)	
Transistors and diodes	145.500	83.000
Power transistors	0.200	0.600
Power rectifiers		
< 30 Amp	0.164	1.200
> 30 Amp	—	0.130
Silicon controlled rectifiers		
< 30 Amp	0.350	1.000
> 30 Amp	—	0.156
Integrated circuits	5.000	6.500

Table 12.1 presents a list of licencees, some of whom have been licensed only recently. The total production of semiconductor devices in 1973 has been worth about Rs. 10 crores.

12.2.1.2. Investment

The total capital investment so far has been about Rs.8.5 crores including about Rs. 3.5 crores on plant and machinery.

Table 12.1. Licences and letters of intent issued for the manufacture of semiconductor devices.

Name	Type	Capacity (nos. in million)	
		Licensed	Letter of intent
1. M/s Bharat Electronics Ltd.	Transistors & diodes	70.000	
	Power transistors	0.100	
	ICs	2.000	

XII

2. M/s Electronics Corporation of India Ltd.	Transistors & diodes Power transistors ICs	10.000 0.100	2.000
3. M/s Continental Devices (India) Ltd.	Transistors & diodes ICs	10.000	2.000
4. M/s Semiconductors Ltd.	Transistors & diodes ICs High Power diodes < 30 Amp > 30 Amp Silicon controlled < 30 Amp rectifiers > 30 Amp	18.000 2.000 0.200 0.020 0.150 0.020	
5. M/s Electronics & Computers (I) Ltd.	Transistors & diodes ICs High Power diodes < 30 Amp > 30 Amp Silicon controlled < 30 Amp rectifiers > 30 Amp	6.500 2.000 0.200 0.020 0.200 0.020	
6. M/s Jaipur Electronic Components	Transistors & diodes	10.000	
7. Mr. Shashi V. Mansata	Transistors & diodes	3.000	
8. M/s Andhra Pradesh Industrial Development Corporation	Transistors & diodes		10.000
9. M/s Punjab State Industrial Development Corporation	Transistors & diodes		10.000
10. M/s Hindustan Semiconductors Ltd.	Transistors & diodes		10.000
11. M/s K. K. Khandewal	Transistors & diodes High Power diodes < 30 Amp > 30 Amp Silicon Controlled < 30 Amp rectifiers > 30 Amp	1.000 0.200 0.020 0.200 0.020	
12. M/s Mulchandani Electrical & Radio Industries Private Ltd.	Transistors & diodes		10.000
13. M/s Indian Aluminium Cables Ltd.	Transistors & diodes		10.000
14. M/s Man Radio & Electrical Ltd.	Transistors & diodes		10.000
15. Mr. S. K. Rajgarhia	Transistors & diodes		10.000
16. M/s Usha Rectifiers Corporation of India Ltd.	Transistors & diodes High Power diodes < 30 Amp Silicon controlled < 30 Amp rectifiers	0.010 0.020	10.000
17. Mr. R. Paul Gupta	Transistors & diodes ICs		2.000 0.500
18. M/s Hind Rectifiers (P) Ltd.	Transistors & diodes Power transistors High power diodes < 30 Amp Silicon controlled < 30 Amp rectifiers	3.000 0.084 0.055	0.100

XII

19.	Mr. D. C. Gupta	Transistors & diodes		3.000
		ICs		1.000
20.	M/s Hindustan Con- ductors (P) Ltd.	Transistors & diodes		12.000
21.	Mr. K. S. Taneja	Power Transistors		0.500
		High power diodes	< 30 Amp	0.200
			> 30 Amp	0.020
		Silicon controlled	< 30 Amp	0.200
		rectifiers	> 30 Amp	0.020
22.	M/s NGEF Ltd.	High power diodes	< 30 Amp	0.010
			> 30 Amp	0.010
		Silicon controlled		
		rectifiers	> 30 Amp	0.016
23.	M/s Ruttonsha Interna- tional Rectifiers (P) Ltd.	High power diodes	< 30 Amp	0.060
		Silicon controlled	< 30 Amp	0.200
		rectifiers	> 30 Amp	0.020
24.	M/s United Electrical Industries Ltd.	High power diodes	< 30 Amp	0.200
			> 30 Amp	0.020
		Silicon controlled	< 30 Amp	0.200
		rectifiers	> 30 Amp	0.020
25.	Mr. T. V. Visvanathan	High power diodes	< 30 Amp	0.200
			> 30 Amp	0.020
		Silicon controlled	< 30 Amp	0.200
		rectifiers	> 30 Amp	0.020

12.2.1.3. Employment

The semiconductor industry now employs about 2,500 persons including about 215 graduate engineers.

12.2.1.4. Imports

In spite of the large unutilised capacity of about 50 per cent, there have been considerable imports of semiconductor devices into the country. The imports of devices have mostly been for the professional electronic equipment and the value of these imports would presently be about Rs. 2 crores a year.

12.2.1.5. Type Availability, Chip Import and Cost Structure

Availability of types from indigenous production has been limited because of volume considerations as mentioned before. However, the catalogues published by CDIL, SEM, E & C and Hindustan Conductors show a large selection of devices as being made in the country. These are mainly intended to cover small-volume requirements of professional users and are produced from imported chips.

The bulk of devices sold in India are silicon small signal transistors. The total manufacturing cost is of the order of Rs. 1.20 for plastic device and Rs. 2.10 for metal encapsulated device. Though the cost is about Rs. 1.20 for a plastic device, the element of profit has still to be reckoned with. A fully integrated factory to make about 5 million devices may involve a total investment of about Rs. 1 crore and such an investment should at least provide a net 10 per cent return on capital or a gross pre-tax return of at least 20 per cent. This would mean a return of Rs. 20 lakhs on an investment of Rs. 1 crore. At a 5 million level, this would imply a profit element of 40 paise per device. The selling price, therefore, gets marked-up from Rs. 1.20 to Rs. 1.60.

If integration is sacrificed and investments are restricted to packaging only,

the mark-up due to profit can be less. The penalties will be a greater drain of foreign exchange for importing chips and other component parts and an industry without deep roots.

If the scale of operation is enlarged, the burden on account of the profit element will come down for, as mentioned above, 5 million devices would involve a total investment of about Rs. 1 crore, whereas 20 and 40 million devices would involve a total investment of Rs. 2 crores and Rs. 3 crores respectively. The mark-up on account of profit element could therefore, come down from 40 paise to 20 paise at a level of 20 million and 15 paise at a level of 40 million.

As production in India is at a low level (a market of about 20 million silicon devices in 1972 shared by over 5 manufacturers), the profit element in the price is significantly high to protect investments. The investment in silicon transistor industry should not have been more than Rs. 2 crores in total, whereas it now stands at nearly Rs. 4 crores. High prices of devices are diagnosed to be the result of excess capacity and therefore under-utilisation of plant, low production and a small market.

12.2.1.6. Exports

Very little export has taken place so far. As mentioned earlier, the manufacturing cost of the devices in India is over a rupee while the export market prices are of the order of 50 paise which makes exports difficult.

12.2.1.7. Foreign Equity, Technical Collaboration

The foreign equity participation in the semiconductor industries is as follows :

CDIL	49%
SEM	30%
Ruttonshah-IR	24%
Khandelwal-Hermann	25%

Hind Rectifiers had a technical collaboration with Westinghouse-Brake Signal Co. of UK on the basis of royalty. The arrangement has since been terminated. Production in BEL of both germanium and silicon devices was setup in technical collaboration with Philips, Holland on the basis of down-payments and royalty. The collaboration has been terminated. BEL now has a tieup with RCA in respect of ICs and other professional devices.

12.2.1.8. Representative Status of Technology—Device Design and Manufacture

(a) Small Signal, Entertainment Types

(i) At present, manufacture is based on foreign device designs. Complete manufacture from diffusion stage is being done for most of the production at BEL.

(ii) Capability exists to design these devices.

(b) Small Signal, Professional Types

(i) Present production by CDIL and E&C is largely based on imported diffused chips or wafers. Zeners made by ECIL are of their own design.

(ii) Capability to design has to be developed.

(c) Power Transistors

Totally indigenously designed devices upto 115 watts (NPN) with suitable PNP drivers are coming out into the market from ECIL. BEL is also introducing the type 2N3055 with local diffusion and own header.

XII

(d) Power Rectifiers and Thyristors

Hind Rectifiers, whose foreign collaboration has now been terminated, do their own alloying for low voltage rectifiers. They are also attempting to do diffusion. Ruttonshah-IR have foreign collaboration and produce devices based on imported diffused chips. Both firms import expensive glass-to-metal and ceramic-to-metal seals. ECIL and SEM produce high current rectifiers with local diffusion.

12.2.1.9. Representative Status of Technology—Process

Adequate facilities for the manufacture of germanium devices exist at BEL and SEM. The following presents the process status with respect to silicon technology.

(a) Mask Making

BEL is the dominant manufacturer in the country to have complete mask making facility for discrete and SSI devices. Recently, BEL has augmented their facility to include CAD and mask making for MSI and LSI devices. ECIL has a coordinatograph and they get their masks made by BEL and Solid State Physics Laboratory (SPL). Both of them still import some of their requirements of masks. Others depend mainly on imports for the requirement of masks. SEM has a chromium mask duplicating facility. Special high resolution photographic plates and chemicals are required and involve imports.

(b) Silicon Crystal Growth

BEL (Float zone and Pulling) and ECIL (Pulling) are the dominant units which grow silicon single crystals from imported polycrystalline silicon. Both of them are reported to have a surplus capacity. Other units are importing the wafers including those with epitaxial layers for some devices.

(c) Wafer Processing

Most of the firms have capacity for their requirements; imported machines are used except for SEM who have indigenous lapping machines in regular use. If single crystal ingots are supplied to the firms, they would be able to process the same. Many of the firms will require balancing equipment to update their processes. Many of the manufacturers have also got facilities for epitaxy.

(d) Photo-Lithography

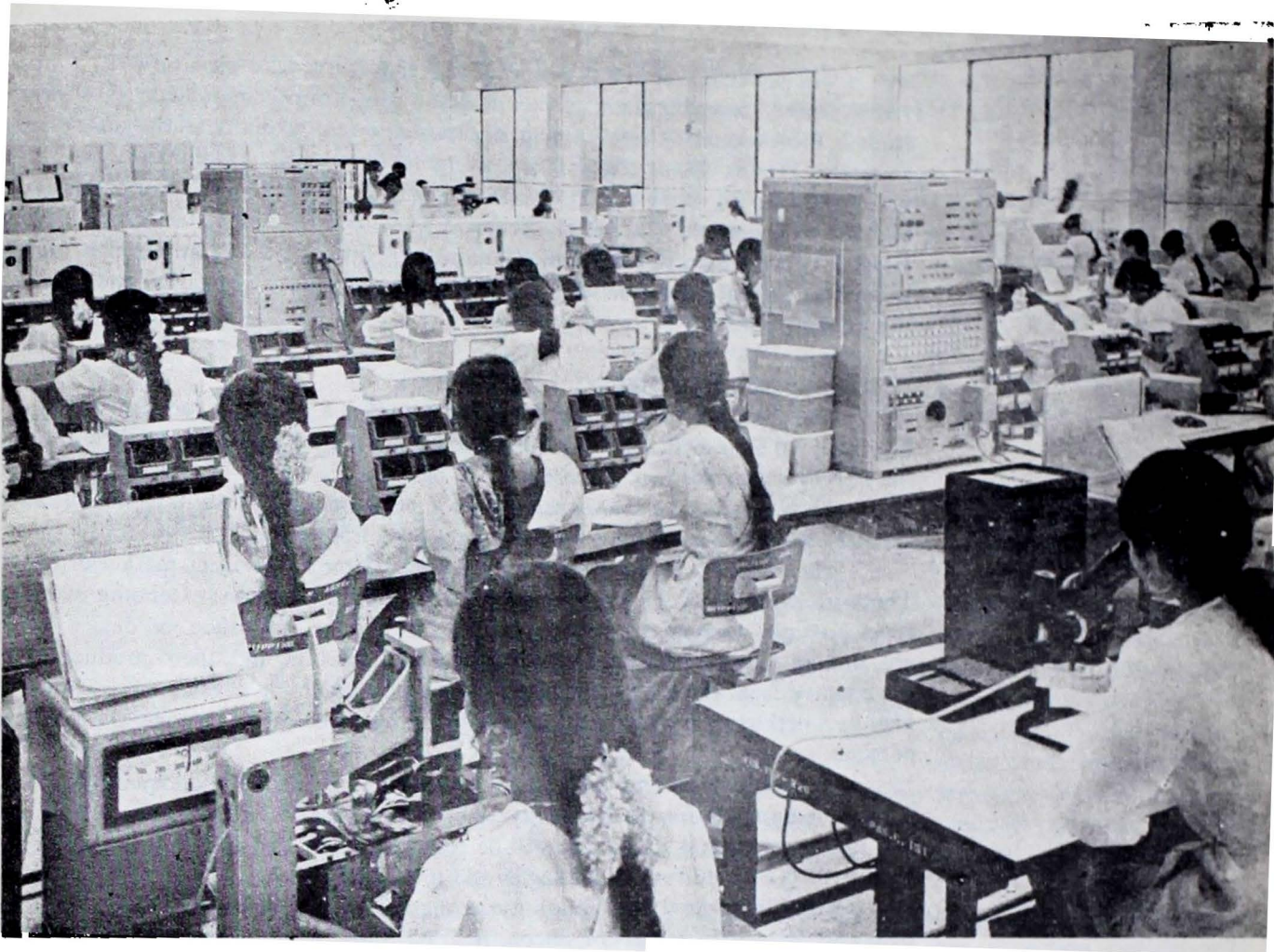
Most of the firms have spinners and mask aligners; but to come up to the full capacity, they may need balancing equipment. The equipment and the photo resist materials are mostly imported.

(e) Diffusion

A total of about 80 tubes are available for diffusion work. Capacity in some of the units is not adequate to cover the range of their products. Size of the tube varies from $1\frac{1}{4}$ to 3 inch wafer capacity.

Most of the diffusion furnaces used successfully at present have been imported. Manufacture of diffusion furnaces indigenously has been attempted with varying success, but their performance does not seem to be upto the required standard.

It is to be noted that some firms manufacturing high current diodes and silicon controlled rectifiers, are not adequately equipped with diffusion furnaces and they start manufacture from imported diffused chips/pellet sandwiches. Almost all doping materials (solid, liquid and gaseous) are imported. Considerable difficulty



A view of Silicon Semiconductor Assembly in BEL

is experienced all over, in obtaining gases; consistency of purity is also a major problem. BEL has its own gas making facility except for argon.

(f) Metallisation

The capacity available is reasonably adequate. Indigenous equipment has been used by some firms and found to be satisfactory.

(g) Bonding (Die/Wire)

Although some of the earlier imported equipment have been developed with suitable modifications, most of the units will require some additional contemporary equipment to meet the licensed manufacturing capacity.

Scribing equipment is adequate for discrete devices and ICs.

(h) Encapsulation

Moulding powder used for encapsulation is imported. Facilities available for encapsulation are reasonably adequate for metal can types though some balancing equipment may be needed.

BEL uses the SOT-25 construction for plastic encapsulation involving transfer-moulding. The design uses fixed pins for a lock-fit on printed boards. CDIL uses a ceramic disc with cold setting epoxy seal and flexible leads. SEM also

XII

uses a similar technique. HC and E&C use the TO-92 encapsulation of comparatively more recent origin. The devices are transfer-moulded with flexible leads. Professional devices in metal encapsulation are made by all the companies in standard TO-18, TO-5 construction using imported headers and cans. BEL has been planning to make the TO-18/TO-5 header. Until recently, five parties, viz., Silicon Ceramic Pvt. Ltd., Hyderabad, Maheshwari Associates, Delhi, Acme Glass Pvt. Ltd., Bombay, R.K. Jhunjhunwala, Bombay and Sajyan Kumar, Giridh, have been given licence/letter of intent to manufacture packages and package component parts.

12.2.1.10. Industry Status

The growth of semiconductor industry in India has been presented through Fig. 12.1. The growth has been almost linear until 1969 while the growth rate on the 1970 base would be of the order of 20 per cent.

There has been excess capacity in the semiconductor industry, the installed capacity being presently unutilised to the extent of 50 per cent.

The industry is essentially entertainment (radio receiver) market oriented. The current demand for professional devices (about 6 million) extending over 600 types pose problems of the scale of production. This multitude of device types are, in many cases, specialities of different manufacturers and their production in the country from diffusion stage would involve considerable development work. It may be worthwhile to standardise majority of these devices to reduce the number of types.

The manufacturing equipment and processes, though adequate for the devices being made for the domestic radio receiver market, have to be modernised and import of capital equipment will be required by the existing units in order to keep in step with current technologies and techniques.

Fully integrated production for germanium has been established both by BEL and SEM. In respect of silicon, BEL has fully integrated facilities and other firms are in the process of establishing similar facilities.

The industry is dependent upon imported raw materials and component parts. While this import content is to the extent of 15 paise per entertainment type plastic device, it is higher in the case of professional devices owing to the import of cans and headers.

By and large, adequate testing facilities exist, though they are not in all cases highly automatic. Semi-automatic testing facilities have also been developed indigenously by most of the firms. Highly automated test equipment may have to be imported.

Attempts have been made to develop, with suitable modifications, a number of imported machines. While these have helped to a small extent, the industry still requires import of sophisticated equipment to keep in step with technological trends abroad. Development and manufacture of such machinery and equipment would be desirable.

12.2.2. Research and Development

R&D effort in the semiconductor area was initiated only about 10 years back. The organisations involved in R&D of semiconductor devices presently in the country may be categorised as (a) industries, (b) national laboratories and, (c) academic institutions. The following description is typical of the R&D infrastructure rather than an attempt at exhaustive coverage.

(a) Industries

Among industries, ECIL, BEL, SEM and CDIL are perhaps the only ones

to have been doing some R&D. While SEM and CDIL have contributed to this activity mainly by way of developing capital equipment, ECIL and BEL have developed a number of devices.

ECIL produces silicon zener diodes and power transistors which are the outcome of a followup of the development work done at Bhabha Atomic Research Centre (BARC), Bombay. The items under development at ECIL include thermo-electric cooling elements, glass-to-metal seals, solid state radiation detectors, silicon single crystals including epitaxial growth of silicon.

BEL has developed a few types of diodes and transistors. It is also developing TTL integrated circuits and varactor diodes in collaboration with TIFR and SPL respectively. It provides upto 5 per cent of the turnover for the expenditure on R&D. The development work is target-oriented and R&D activities have been of sustaining type.

(b) National Laboratories

There are four main laboratories which are engaged in semiconductor device work.

Solid State Physics Laboratory (SPL) which is a defence R&D Organisation was started in 1962. The laboratory has been involved in R&D of solid state materials and devices. The devices developed by SPL include silicon point contact diodes, silicon varactor diodes, silicon planar power transistors, epitaxial VHF transistors and solar cells. So far, no substantial industrial production of these devices seems to have taken place except, of course, varactor diode, the production of which is being tried at BEL. While the laboratory seems to be well equipped for characterisation and evaluation of materials, only modest facilities exist for device work. The total investment in the laboratory, to date, is estimated to be about Rs. 94 lakhs.

Central Electronics Engineering Research Institute (CEERI) which has been engaged with R&D in various areas of electronics has a section dealing with semiconductor devices. CEERI has also been engaged with the development of silicon planar transistor. Present R&D activities include high power high frequency silicon transistors, varactor diodes for use in parametric amplifiers, thin film components and silicon integrated circuits. In silicon integrated circuits 4-input TTL-NAND gate has been started. The institute is also known to have developed the know-how for TO-18 and TO-5 headers. The facilities include a coordinatograph, semi-automatic step and repeat camera, an epitaxial reactor, diffusion furnaces, photolithographic setup, probing, scribing and bonding equipment. The investment in capital equipment is estimated to be about Rs. 12 lakhs.

Tata Institute of Fundamental Research (TIFR) has a division dealing with R&D of semiconductor devices. The devices developed include silicon planar transistors, point contact diodes, Gunn diodes, medium and high power silicon controlled rectifiers and digital integrated circuits. The know-how developed for TTL series is being exploited for production at BEL. TIFR has also started work on thin film hybrid circuits. The institute has all facilities for carrying out processes starting from silicon wafers except, of course, the mask making facility. The capital equipment, worth about Rs. 8 lakhs, comprises of photolithographic equipment, diffusion furnaces, vacuum evaporation and sputtering equipment, etc.

In the devices area, National Physical Laboratory (NPL) has been working on thin film properties and rectifier device technology. The laboratory is known to have capital equipment worth about Rs. 8.5 lakhs for the semiconductor development work which include the facilities for silicon material development.

XII

(c) Academic Institutions

Among academic institutions, Indian Institute of Science (IISc), Bangalore and the IITs have been engaged with some R&D of semiconductor devices. Most of the projects undertaken are of open-ended nature and centre around phenomenological studies.

At IISc, the Department of Electrical Communication Engineering, Department of Physics and Department of High Voltage Engineering are engaged in the R&D of semiconductor devices. The areas of work include silicon power rectifiers, pyroelectric infrared detectors, amorphous and oxide semiconductors, Hall-effect devices, junction field effect transistor structures, thin film components and surface elastic wave devices.

At IIT Kharagpur, the work is in progress in the area of Gunn oscillators and surface elastic wave devices. The work on ferri-magnetic devices and lasers is being taken up.

IIT Kanpur is setting up a laboratory for semiconductor devices. Besides working on the analysis and design of semiconductor devices, with the aid of computer, the institute has started work on silicon planar diodes, GaAs schottky barrier diodes, microstrip transmission line and other microwave integrated circuits, etc.

The semiconductor device work at IIT, Delhi is mainly carried out in the Department of Physics. Their activity includes work on MOS transistors, p-n junction photo devices, amorphous semiconductor devices and thin films.

At IIT Bombay, R&D of mainly thin film components and hybrid circuits is being carried out. The institute has also started work on microwave integrated circuits. Some equipment for semiconductor device work, viz., diffusion furnace, epitaxial reactor, junction depth measuring unit and ion implantation unit are also reported to have been developed.

IIT Madras has recently started a semiconductor devices R&D programme. The work on p-i-n diodes, MOS field effect transistors and integrated circuits has been initiated. Use of laser for device technology is also being planned.

It may be noted that a meaningful R&D effort in our country has started only recently. None of the organisations is fully equipped and the funding level has been very low. The total capital investment on R&D, including equipment, building, etc., is estimated to be of the order of Rs. 2 crores and the annual funding has been of the order of Rs. 20 lakhs.

12.3 Technology Profile and the Available Alternatives

In planning for the industry, it is necessary to take note of the technology profile and the various alternatives available together with their relative merits and demerits. This is of special significance to semiconductor industry for it involves sophisticated technology. As mentioned earlier, there is a wide variety of devices in use today and they fall into two main categories viz., (i) discrete devices—(a) conventional, (b) special, and (ii) integrated circuits. An analysis of the US semiconductor device market as presented in Table 12.2, provides the technological trend vis-a-vis the two main categories of semiconductor devices and the types therein. It can be seen that the production of discrete devices would decline and that of ICs increase. Bipolar shows a declining trend while MOS devices exhibit a very sharp increase.

In the following, the status of technology with respect to each of the device categories is given.

12.3.1. Discrete, Conventional Devices

12.3.1.1. Germanium

(a) Point Contact

Germanium point contact signal diodes are being produced for signal detectors

XII

upto 100 GHz. Due to low noise level and low forward voltage drop, germanium point contact diodes will continue to be used as detectors in radio receivers in the foreseeable future.

(b) Alloy Junction

Germanium alloy junction rectifiers have been replaced by silicon devices except where low forward voltage is mandatory. Germanium alloy junction transistor was the earliest type of transistor produced commercially and is still widely used. This transistor affords higher emitter efficiency and is ideal for low frequency, high power, high current applications. It will continue to be used for audio output stages in consumer electronics in the foreseeable future.

Table 12.2. Semiconductor devices market in USA.

	1972 (per cent)	1975* (per cent)
Discrete devices		
Conventional	37.8	28.8
Special (including optoelectronic devices)	13.0	13.8
Integrated circuits		
Digital	31.5	34.8
Bipolar, total	21.7	19.5
SSI	16.4	11.6
MSI	4.2	4.2
LSI	1.1	3.7
MOS, total	9.8	15.3
Linear	7.1	9.2
Op. Amplifiers	4.3	6.8
All Others	2.8	2.4
Hybrid	8.3	10.5
Others	2.3	2.9

*Based on a predicted growth trend.

(c) Diffused Junction

The high frequency performance of alloy junction transistors is limited by large base width and field free base region due to uniform base resistivity. This is overcome in diffused junction devices by very narrow base width drift field base region, achieved by diffusion techniques. Diffused junction devices, both in mesa and planar structures, offer frequency range upto 1.5 GHz at low power levels and are suitable for high frequency and switching applications where the operating temperature is limited to 55°C. Silicon epitaxial planar devices have supplanted these devices.

(d) Epitaxial Planar

High collector resistivity for good transistor characteristics and low collector resistivity for low collector series resistance are achieved in epitaxial planar structure where a thin high resistivity layer is grown over a low resistivity substrate. Low noise germanium epitaxial and germanium epitaxial mesa transistors are available with cut-off frequency upto 500 MHz. However, this technology has not been widely used due to difficulties in surface passivation.

12.3.1.2. Silicon

(a) Alloy Junction

Alloy junctions were used in the early stages of development of silicon technology and have since been replaced by the diffused junction and planar processes. However, alloy junction zener diodes are still being manufactured. Alloy junction silicon transistors are used for chopper amplifiers and for saturated switching purposes even now.

(b) Diffused Junction

First silicon n-p-n diffused emitter and base transistor with an f_T of 120 MHz was fabricated in 1955. Different structures have been developed after this double diffused device, such as double diffused mesa for high speed and low leakage, and triple diffused mesa for high speed and low saturation. The development of epitaxial mesa in 1960 is another significant event in diffused junction devices. With the development of the planar process, the diffused junction process has been replaced for small signal applications. However, this technology continues to advance in the realm of power and r-f applications. Different geometries such as annular, interdigitated and overlay have been developed to improve the power, voltage and frequency.

(c) Planar

Jean A. Hoerni patented the planar process in 1960 which replaced the mesa structure. This provided a major breakthrough in the semiconductor technology and mass production of low cost high stability devices became possible. The active junctions and crystal surfaces are passivated by a thermally grown oxide. This process is widely used in unipolar, bipolar and MOS devices. This has paved the way for monolithic integrated circuits.

(d) Epitaxial Planar

Independent control of resistivity and thickness of epitaxially grown layer offers more design flexibilities in device fabrication such as combining higher breakdown voltage with low collector series resistance. Epitaxial process combined with planar passivation and diffusion techniques offers various structures, such as double diffused epitaxial planar for high speed low leakage and low saturation, double diffused epitaxial base mesa for high speed low saturation, etc. In conjunction with various geometries developed since then, such as annular, interdigitated and overlay, the frequency and power handling capacity are continuously on the increase. Devices delivering 100 watts at 0.07 GHz down to 2 watts at 3 GHz are available.

(e) Schottky Barrier

Schottky barrier diodes are metal semiconductor junctions and, unlike p-n junctions, are majority carrier devices. These store no charge and can be used for fast switching applications. This technique yields excellent microwave diodes (upto 50 GHz); more rugged and of low burnout capability than junction diodes having operating frequencies upto 1 GHz only. Another feature of Schottky barrier diodes is their low forward voltage drop.

(f) Junction Gate Field Effect Transistors

Though it was developed as early as in 1925, the first field effect transistor, as suggested by Shockley in 1952, was fabricated in 1953 at Bell Laboratories. Subsequent development of these devices took place with the development of diffusion, epitaxial and planar techniques, and today, both diffused and epitaxial planar devices are available. In diffused devices, the channel width is defined by the junc-

XII

tion depth and has the drawback of uncontrolled thickness of the channel region. The epitaxial planar process overcomes the diffused structure limitation by giving channel region of well defined sheet resistance. The topology of the device is of importance, i. e., the upper gate electrode must be of such geometry that it completely surrounds the drain and source, which makes it impossible for the current to flow directly from the source to drain, or around the edge of the gate electrode. This is achieved by annular and inter-digitated structures. The main features of this device are very high input impedance (of the order of meg Ohms) and zero off-set voltage which make it ideal for chopper amplifier. Though n-channel JFETs with frequency range of 500 MHz and p-channel JFETs with 2 MHz are easily available and are still used, MOS field effect devices may replace the junction devices.

(g) MOS Field Effect Transistors

Proposed by Shockley in 1948, this differs from JFET by having the gate electrodes insulated from the channel by a thin layer of insulating material usually SiO_2 . There are two types of this device : (i) P-channel enhancement mode device, normally off and conducting only when a negative bias is applied to the gate. This is popular in digital applications. (ii) N-channel depletion mode normally conducting and controllable with negative bias applied to the gate. This is popular in linear and signal processing applications upto a frequency of 800 MHz. Though MOS processing involves less number of operations, the devices are difficult to fabricate being very sensitive to surface conditions. Instability of the oxide-silicon interface has been overcome by exposing the wafer to a phosphorous ambient at 800°C . Stable MOS FETs were available by 1965. Devices rated upto about 300/ MHz, 30V, are in commercial production though they have already been produced to ratings upto 10 GHz.

12.3.1.3. Gallium Arsenide

A few experimental alloyed emitter, double diffused bipolar transistors were developed in the early stages, but were given up due to difficulties in fabrication and also because development of new design geometries in silicon enabled microwave transistors to be made with better reliability and at a lower cost. However, gallium arsenide FETs and Schottky diodes are still of interest. GaAs FET was developed at RCA in 1967 with silicon nitride as gate material and using hydride vapour technique. The device gives a gain of 22 dB at 200 MHz as against the gain of 16 dB using silicon of the same geometry. Plessey, UK, has developed an N-channel FET rated at 1.5 GHz with 3.5 dB gain.

12.3.2. Discrete, Special Devices

12.3.2.1. Microwave Diodes

(a) Tunnel Diodes

Tunnel diode, which is essentially a degenerately doped p-n junction, is well known for its high frequency capabilities afforded by low values of parastics associated with the tunneling p-n junction. The differential negative resistance property of the tunnel diode leads to its utilisation in high frequency switching circuits. The role of the tunnel diode oscillator is, however, limited to applications where RF or microwave signal of high spectral purity rather than high power level is required.

(b) Gunn Diodes

Gunn or transferred electron device (bulk samples of GaAs, InP, CdTe, ZnSe; GaAs being the most popular) exhibit a voltage controlled negative resistance

XII

which makes it useful for oscillator applications. Gunn oscillators in Ku, K and M bands are available commercially. A voltage tunable oscillator rated at 1.5 GHz, 100 mW costs about \$ 100.

(c) Impatt Diodes

Impatt (Impact Avalanche Transit Time) or Read diode is essentially a junction diode operating under a reverse bias field with the junction in avalanche breakdown. If the avalanche of charge carriers starting from the avalanche region, located at one end of a high resistance region, is allowed to drift through the rest of that region, the device can exhibit a negative resistance which makes it useful for oscillator applications. Impatt diodes are generally epitaxial silicon devices. Avalanche breakdown being a noisy phenomenon, these devices are inherently noisy. Gallium arsenide Impatt devices are also available. Germanium Impatts are also attracting attention owing to their being less noisy. They will, however, have less power output capability than the silicon devices.

(d) Trapatt Diodes

Trapatt (Trapped Plasma Avalanche-triggered Transit Time) or Change diodes give higher power and at higher efficiencies than do Impatt devices. A Trapatt cycle starts in a normal Impatt mode. But then a second Impatt-triggered avalanche occurs, forming an avalanche zone which moves through the diode in much less than the normal transit time.

(e) LSA Diodes

LSA (Limited Space Charge Accumulation) mode of a bulk device affords lower capacitance and greater power output capability than either Impatt or Gunn devices, and a power-impedance product nearly independent of frequency owing to the device not being transit time limited. High field travelling domains, characteristic of bulk effect devices, are not allowed to form in this mode of operation. The oscillating field across the device rises above and falls back to the threshold level too quickly for domains to form.

While all the devices mentioned above are useful as microwave power generators, they differ from one another in their frequency and power capability and so also the efficiency. Figs. 12.2 and 12.3, respectively give the state of art in frequency-power and frequency-efficiency capability of these devices.

(f) Varactor diodes

The variable capacitance diode tuner is familiar in UHF/VHF TV sets, but they have not been designed for AM radios because of the larger capacitance ratios required to tune over the broadcast band. Electronic tuning of radios has now been shown to be feasible with a matched varactor chip by Valvo (Philips Germany). The new design approach breaks the tuning diode into 3 separate segments but permits synchronous tracking over the AM broadcast range. The diode is a triple diode or a triplet that consists of three identically fabricated diode sections on a common plastic encapsulated silicon chip measuring 0.056 sq. inches.

The other microwave diodes now in common use include point contact and schottky barrier diodes for mixer and detector applications, p-i-n diodes for phase shifting and switching and step recovery diodes for higher order multiplication.

12.3.2.2. Optoelectronic Devices

(a) Light Emitting Diodes

The p-n junction light emitting diodes (LEDs) which convert electrical

XII

energy into visible radiation, find their application in displays. The semiconductors—silicon, germanium and GaAs—do not have any use in LEDs owing to their band gap being within 2 eV, that being the minimum for having the emission in the visible range. Though many materials that include GaJnP, GaAlAs and SiC are talked of as being useful, LEDs were the first to be produced and offer luminescence throughout the visible spectrum, but they are becoming less attractive owing to the very high temperature processing that is involved. Debating the virtues of GaAsP and GaP is of no point, for the choice depends mainly on the application. The luminous efficiency of GaP is about the same as GaAsP when both types are operated at their recommended current levels (GaP at low current, GaAsP at high current). As it stands now, GaP is well suited for use in low current indicators, but GaAsP is ideal for displays. GaAsP can give both red and amber colours and GaP produces green in addition to red and yellow. GaP chips emit light in all directions, while GaAsP diodes provide a well defined forward lobe. And with the added brightness achieved in pulsed operation, dot matrix GaAsP arrays are ideal for alphanumeric character display and film recording. (Some recorders using such arrays record 30,000 characters per second). The lead that GaAsP enjoys in the major application for LEDs—seven segment numeric displays—is due mainly to its lower cost. In fact, for the price of a single GaP diode chip, a large bar of GaAsP can be bought. Several diodes can be diffused in the bar raising the segment luminance and also affording a monolithic display. GaP, on the other hand, requires a grown-junction process; the diodes being produced by dicing the wafer. GaAsP is also suitable for high-temperature applications.

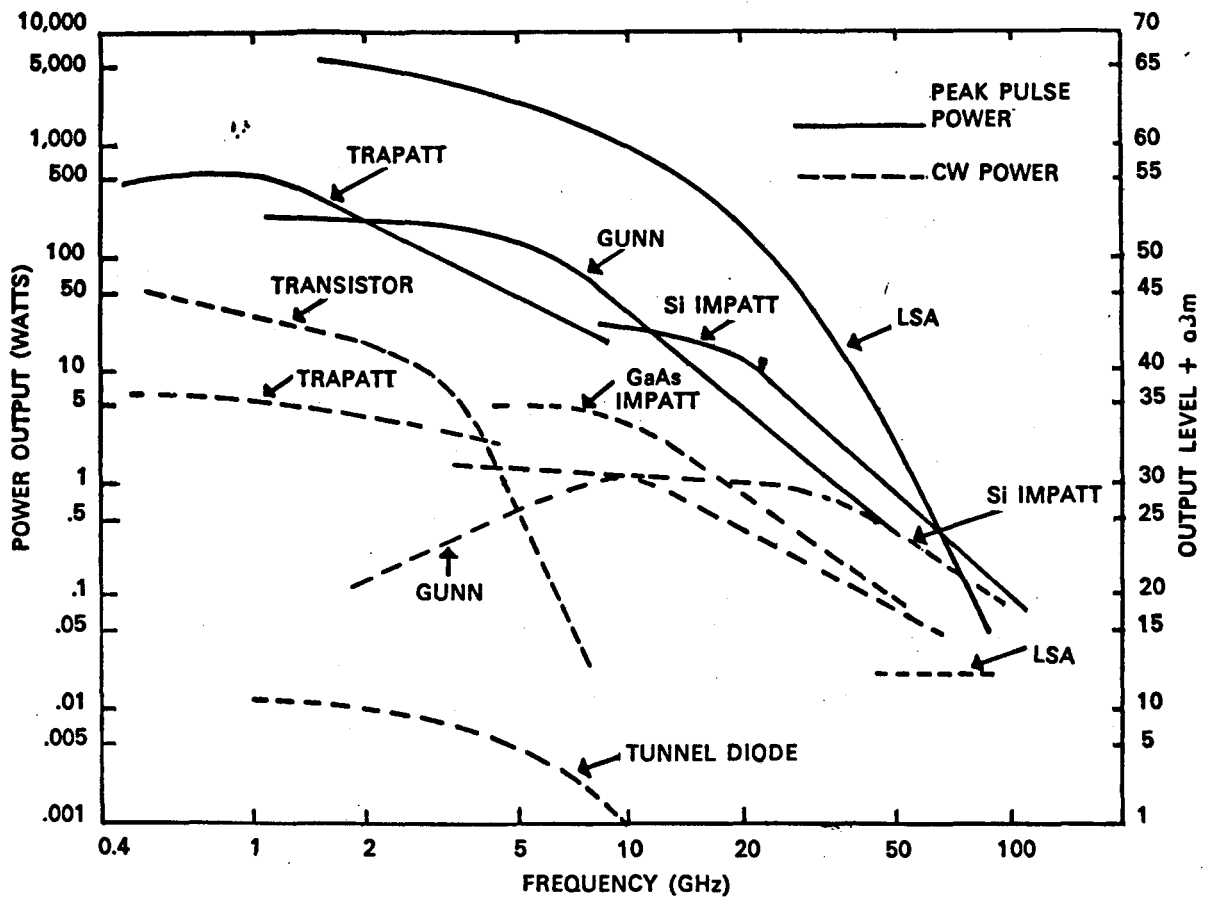


Fig. 12.2 Output power characteristics of microwave solid state oscillators

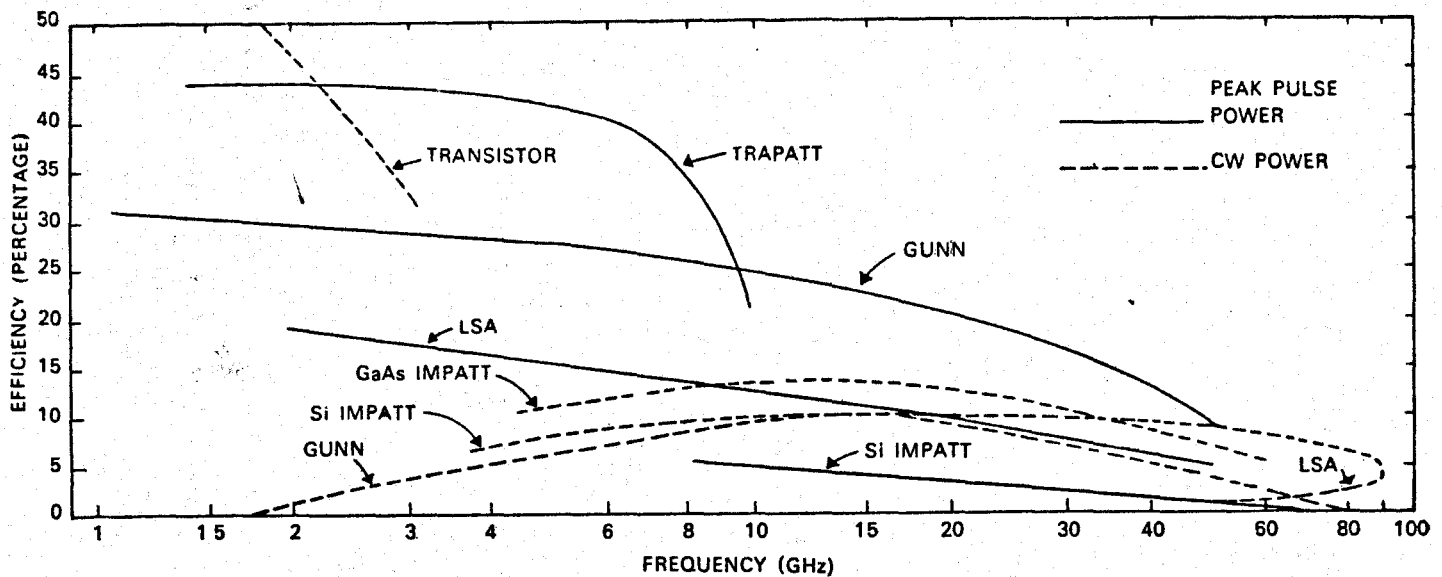


Fig. 12.3 Efficiency vs. frequency characteristics of solid state microwave oscillators

(b) Liquid Crystal Displays

Liquid crystals form a new class of display devices and are posing a challenge to LEDs. They are of recent origin; their feasibility as displays having been first demonstrated by RCA in 1968. Owing to their ordered molecular structure, the optical properties of liquid crystals are much like those of crystalline solids. Neumatic liquid crystals, involving one of the three general classes of molecular structures, which are clear liquids, become opaque in the presence of an electric field. Displays are obtained by having a thin layer of the liquid between two glass plates, one of which is completely coated with a transparent conductive film (tin oxide) and the other coated in a pattern to form the seven segments of a display. With the application of the electric field between the electrodes, the liquid gets turbulent and scatters ambient light in the form of the rear electrodes pattern. Liquid crystal displays have the advantages of a very low cost (owing to their simpler fabrication and low material cost) and a much smaller (microwatt) dissipation. They, however, suffer from the disadvantage of utility in a limited temperature range (0 to 50°C). Liquid crystals have already been exploited for use in wrist watches, panel meters, etc.

A comparative summary of the performance of various display devices is given in Table 12.3.

(c) GaAs Injection Laser

GaAs injection laser converts the high current electrical input to a forward biased p-n junction into a coherent infrared radiation. These lasers provide CW power output of upto about 10 watts and under pulsed operation can go upto about 100 watts. They can be directly modulated by electrical voltage in X-band. Owing to their small size and higher efficiency they are suitable for radar applications. The problem with these lasers, however, is that they need very large current and should be cooled to very low temperature.

12.3.3. Integrated Circuits

The term 'integrated circuit (IC) implies the realisation of a circuit in which active and passive elements and their interconnections are all formed through common fabrication steps and the components usually share a common material. This technique has resulted in a large reduction in the size of a circuit. Today integrated circuits have attained a compactness of over 3,000 parts per Cm^2 . The importance

of ICs, however, lies less in making the circuits smaller than in making them faster, cheaper and more reliable. The reduced size, of course, contributes to speed as well as reliability. With regard to the type of technology, integrated circuits are classified as (i) monolithic ICs, and (ii) hybrid ICs; whereas from the point of view of the functional type, they are classified as (i) digital integrated ICs, and (ii) linear ICs.

Table 12.3. Comparison of the performance of various display devices*.

Point of comparison	Display type			
	Gaseous discharge "Nixie", etc.	Light emitting diode (LED)	Liquid-crystal	
			Reflective	Transmissive
Readability				
Brightness	Good in low to medium ambient lighting. Acceptable in fairly high ambients with polarising lens.	Same as the Nixies	Poor in low ambient lighting. Excellent in high ambients or bright sunlight.	Excellent under both low and high ambient conditions.
Maximum viewing distance	>25 feet	≈10 feet	>25 feet	>25 feet
Viewing angle	Horizontal ≈100° Vertical ≈100°	≈150° ≈150°	≈150° ≈150°	≈150° ≈150°
Lifetime	>150,000 hrs	>250,000 hrs	>10,000 hrs	>10,000 hrs
Character size and configuration	0.3 to 2 inch character heights; normally 10 individual character cathodes; seven segment configuration also available.	0.12 to 0.51 inch character heights; seven segment & dot array configurations available.	No real size limitation; seven segment configuration.	Same as reflective.
Operating and storage temperature	Operating: 27° to +70°C Storage: 55° to +85°C	-55° to +100°C -55° to +100°C	+10° to +90°C -20° to +90°C	Same as reflective
Response time	Turnon: 10 microsec Turnoff: 10 microsec	< 1 microsec < 1 microsec	10 microsec 200 microsec	Same as reflective
Power consumption				
Display	660 mW/digit	800 mW/digit	800 mW/digit	Same as reflective
Decoder driver	75 mW/digit	300 mW/digit	Counter decoder driver 40 mW for 3-1/2 digits	Same as reflective
Backlighting				≈ 2W for 3-1/2 digits
Cost				
Display	\$ 2/digit	\$ 7.50/digit	\$ 5/digit	Same as reflective
Decoder/driver	\$ 1.56/digit	\$ 1.65/digit	None currently available	

* Source : EDN, July 1972, P 24-31.

XII

12.3.3.1. Monolithic ICs

The monolithic technology is the true realisation of the integrated process. The basic technological processes essential for the fabrication of monolithic integrated circuits are, (i) epitaxy (ii) oxidation, (iii) diffusion and (iv) metallisation. Each major step includes a sequence of minor process steps, the slice being handled about 150 times in all.

The most important aspect of ICs is the cost per function. The controlling economics in IC industry today has graduated from consideration of chip yield and packaging costs to a consideration of total system costs. At the system level, the cost of the printed circuit board required for mounting may be about the same as the integrated circuits themselves, so that the emphasis has to be on optimising the total system cost. The basic relationship in this optimisation are the cost of the chip (yield) and packaging cost. The size of the circuit chip should generally be increased until yield losses offset the advantage of assembly within a minimum number of packages. This type of analysis must be applied to each application since irregularities in the yield and packaging the cost curves are uniquely related to specific situations. Based on the complexity, yield, and other technological factors, the needed adjustments must be made.

12.3.3.2. Hybrid Integrated Circuits

As monolithic technology matured, performance limitations became evident which renewed the interest in hybrid circuits. Hybrid circuits are finding wide applications in arrays of digital ICs, high-power and high-voltage circuits, high frequency and microwave applications and linear circuits where precision passive components are required. Hybrid technology can be treated as complementary to micro-miniaturisation rather than a technique to compete with monolithic technology. This technology is being used as a packing approach, to take advantage of all available active and passive components to achieve optimum circuit performance. To some extent, one can consider hybrid circuits as an extension of earlier discrete component electronics in that they are assemblies of components either formed on or fixed onto the surface of an insulating substrate. The most common techniques for hybrid circuit fabrication are (i) thick film technique and, (ii) thin film technique.

(i) Thick Film Hybrid ICs

In thick film technology, layers of resistive, dielectric and conductive materials are deposited on a ceramic substrate. The deposition process is like silk-screen process and the interconnection patterns are produced by photolithographic means. This technology which has mainly been developed by IBM, is now finding wide applications in the high-reliability space systems and low-cost consumer areas. Some typical applications in professional equipment are IF/audio stages, voltage regulators, active filters, high-power op-amps, attenuators, etc. In consumer area, they are used in TVs, hi-fi stereo systems, etc.

(ii) Thin Film Hybrid ICs

In thin film technology, the choice of the material is not very straightforward, as is the case of monolithic technology. There is a much wider choice of materials and processes that can be used to perform a specific electric function. Thin film hybrid circuits are prepared by evaporation or sputtering processes and using a film thickness between 250 and 25,000 angstroms. The typical substrate materials are glass, and polished and glazed ceramic. The active components are discrete silicon diffused planar transistor and diode chips mounted on suitable conducting

pads and connected into the circuit by thermo-compression bonding. For patterning of thin films, usual photolithographic technique can be used. The important applications of thin film hybrid circuits are, (i) ultra high reliability and radiation resistant modules for space applications, (ii) UHF/microwave modules, and (iii) high/microwave resistor and RC-networks for use in D-A converters, oscillators, filters, etc.

12.3.3.3. Comparison of Monolithic and Hybrid Technology

Specific application and requirement under consideration mainly govern the type of technology to be used. The custom-monolithic circuits are economical only when 10,000 or more circuits are needed to justify the large tooling cost. In hybrid technology, one can use either thick film or thin film approach. In general, thick film hybrid circuits can be produced more economically, with no compromise in performance, than thin film ones. In microwave applications, thin film hybrid circuits should be used because of need for critical precision control.

A cost comparison for the fabrication of a hypothetical circuit using various techniques is shown in Table 12.4. It can be seen that the monolithic ICs offer the most economical unit price. However, if the tooling cost for design and art work (about \$ 1000 for either conventional printed circuits and thick film circuits, about \$ 1500 for thin film circuits, and about \$ 30,000 for monolithic circuits) is taken into account, it may not be economical to design monolithic ICs if the quantity required is less than 10,000 units.

One more key factor that needs consideration in choosing the type of technology for a given application is the time required for circuit development. For either conventional printed or hybrid circuits, it is about six to eight weeks, as compared to six months often required to design and fabricate a prototype monolithic circuit.

Table 12.4. Estimated cost comparisons for fabricating a circuit by using various assembly techniques. (Cost in Dollars)

Number of circuits	1-25	26-100	101-1,000	1,001-10,000	10,001-100,000	100,001-1,000,000
Conventional printed	45.0	40.0	35.0	30.0	20.0	15.5
Monolithic integrated	35.0	25.0	17.5	10.0	8.0	4.5
Thick film hybrid	50.0	40.0	30.0	25.0	15.0	12.0
Thin film hybrid	75.0	60.0	45.0	32.5	20.0	15.5

(Source : Topfer, M. L., Thick-Film, Microelectronics, Van Nostrand Reinhold Co. 1971)

12.3.3.4. Bipolar and MOS Technologies

The active devices used in ICs are divided into bipolar and metal-oxide-semiconductor (MOS) types. Today majority of products are made using bipolar technology but MOS technology is growing rapidly. The production of MOS devices has become feasible as a result of advances in controlling the surface characteristics of silicon. The technology involved in the fabrication of both bipolar and MOS is currently such that the incorporation of both in future large arrays is possible. Some of the important aspects of these areas are briefly reviewed below.

XII

(a) Bipolar Technology

Bipolar technology is being extensively used for linear and digital applications. There is a large number of alternatives available for fabrication of bipolar ICs. The most common techniques are standard buried collector (SBC), collector diffusion isolation (CDI), base diffusion isolation (BDI), TRI mask process (TRIM), vertical anisotropic etch (V-ATE), isoplanar, etc. The development of these new techniques has reduced the number of masking steps (CDI, BDI, and TRIM process) and the chip area (V-ATE and isoplanar methods). Now it is possible to have over 1000 gates per square inch. Due to very keen competition and new technologies, the prices of bipolar devices have fallen steeply.

(b) MOS Technology

The major interest in MOS technology has come from its process simplicity, less die area, and lower power dissipation. However, due to many production problems like surface control and oxide contamination, the wide use of MOS technology was delayed. Now with the better yield, improved speed, controlled threshold voltage, and suitability for large scale integration, MOS technology has a lot to offer. The improvement in materials and processes has significantly narrowed the speed gap between bipolar and MOS devices and now MOS is in close competition with bipolar in the digital applications.

MOS devices are available in a large number of different configurations and structures but the most common ones are p-channel MOS, n-channel MOS, and complementary MOS (C-MOS). Even though n-channel devices offer speed and size advantages over p-channel, because of manufacturing problems p-channel devices are more available than n-channel. The C-MOS which was developed in 1967 by RCA is expected to make a great impact on consumer areas such as electronic watch and pocket calculator. In addition, C-MOS offers great advantage at MSI levels of complexity. Some of the other terms which frequently appear in MOS literature are metal nitride oxide MOS, (MNOS), aluminium oxide (Al_2O_3) gate MOS, silicon gate MOS, refractory MOS (R-MOS), floating gate avalanche injection MOS (FA-MOS), double diffused MOS (D-MOS), ion implantation MOS (I-MOS), silicon on insulator substrate (SOIS) and C-squared technology. Most of these terms have essentially appeared because of the change in dielectric type (oxide, nitride) or some change in fabrication process. These technological modifications would help bring out better and cheaper MOS devices.

12.3.3.5 Comparison of Bipolar and MOS Devices

As mentioned earlier, both of these technologies are suitable for ICs. However, a detailed comparison as presented in the following will give a clear picture of the relative advantages of each one of them.

(a) Fabrication Process Steps

Table 12.5 summarises the process steps necessary for manufacturing MOS and bipolar ICs. Due to reduction in high temperature diffusion and masking steps, the yield of MOS arrays greatly exceeds those of bipolar chips of comparable complexity. Furthermore, the bipolar fabrication process is about 45 per cent more difficult than the MOS fabrication process.

(b) Processing Cost Comparison

Table 12.6 is representative of the processing cost comparison. It is clear that the factory cost per function for MOS device is much less than bipolar device.

XII

(c) Device and Functional Density

MOS offer a possibility of obtaining higher density circuits since no isolation junctions are required in these devices, whereas in bipolar ICs 40 to 50 per cent area is covered by isolation junctions. Thus a typical double diffused bipolar planar transistor takes about 24 sq. mils chip area, whereas a typical MOS transistor takes only 1sq. mil area. Also diffused resistors of bipolar ICs occupy a large area. For instance, a 2K diffused resistor covers an area of 0.2 mm² whereas in MOS ICs, this resistance may be realised through MOS channels, the area of which is much smaller and its value may be raised to as large as 100K ohms. Finally with MOS transistors for performing the same logic function, sufficiently less number of elements are required than with bipolar. For making a shift register, six MOS transistors are needed and for equivalent circuit with bipolar transistor logic 15 transistors and 21 resistors are required ; with diode-transistor logic 12 transistors, 14 diodes, and 12 resistors are required,

(d) Speed and Power Considerations

Present major disadvantages of MOS are slow speed of operation and lower output capability. However, with the advancement in technology, MOS is approaching bipolar rapidly. Even the present speed of MOS is enough for a large number of applications.

Table 12.5. Comparison of metal gate P-channel MOS and double diffused epitaxial bipolar fabrication process.

	MOS	Double diffused epitaxial
Diffusions	1	4
Process Steps	38 to 45	130
High temperature process steps	2	10
Masking steps	4 to 5	8

Table 12.6. Processing cost comparison, bipolar vs MOS.

	Bipolar	MOS
Typical die size	4 Function/Die 40 x 40 mil	1000 Function/Die 120 x 120 mil
Total die per wafer	1800	200
DC-functional probe yield	60%	50%
Factory processing cost	\$ 20.0	\$ 15.0
Cost per good die	1.85c	15.00c
Factory cost per function	0.46c	0.015c

(Source : Status of Integrated circuits. Mid Year 1971, ICE corp. 1971)

12.3.3.6. Level of Complexity

With the advancement in the planar technology and photolithographic process, there has been a continual trend to increase the complexity of ICs by increasing the number of circuits on a single chip. This has resulted in the integration of systems from integration of circuits as is done in ordinary ICs. The reasons underlying the trend to increase the complexity are mainly economical, the aim being to reduce the cost per function (the cost per equivalent gate in the case of digital circuits). The level of complexity is defined in terms of the following:

XII

SSI : 2 to 12 equivalent gates/chip

MSI : 12 to 100 equivalent gates/chip

LSI : above 100 equivalent gates/chip

There is, of course, no universal agreement on these definitions and boundaries are accepted to be quite flexible.

Though there is strong motivation to increase the complexity of the integrated circuits, one is simultaneously faced with a number of problems. The increase in component density and circuit complexity, no doubt, appears to reduce the costs of circuitry in the subsystem or system, but it is not a simple relationship of putting more components on a chip for the same money. The more circuits we put on a chip larger the chip area becomes, reducing the yield drastically. This is due to the fact that the larger the chip area, greater is the possibility of chip including a defect. Of course, improvement in the resolution with photolithography and etching steps have helped increase the complexity without actually increasing the chip area and thus yield has improved over the years. It should be noted that, as the complexity goes up, the engineering costs go up too. Therefore, the cost per circuit is not noticeably reduced unless the production level of ICs is large enough to make each circuit share only a small fraction of the engineering cost.

The trend in increasing circuit complexity is, however, continuously growing as is evident from Fig. 12.4. In fact, a fast growing trend is single-chip systems for complex calculators, central processors for computers, and small special-purpose computers for control applications. It is now possible to integrate systems of about 10,000 equivalent-gate complexity on a single chip. This type of single-chip approach results in more reliable systems and is more economical owing to the fact that it cuts down the system assembly cost. A cost comparison of a 1,000 equivalent-gate digital system with discrete components, TTL gates, MSI and ICs, six MOS-LSI chips, and single MOS chip is given in Table 12.7. For the calculation

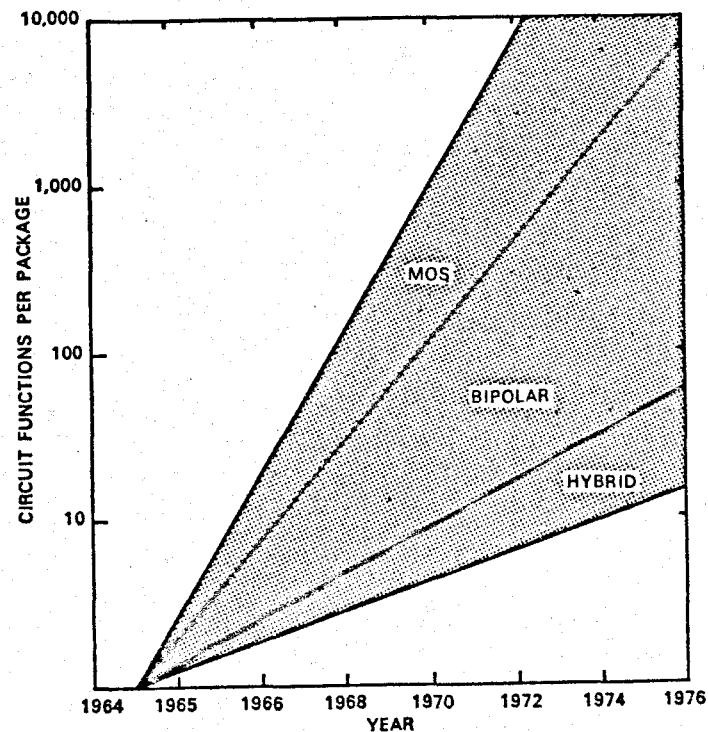


Fig. 12.4 Integrated circuit complexity vs time
(Source: Status of Integrated circuits. Mid year 1971, ICE Corp. 1971)

XII

purpose, it is assumed that the subsystem requires 4,500 discrete components at 5 cents each. The discrete components then be replaced by 300 digital ICs (either DTL or TTL) at 20 cents each, or by 100 TTL or DTL/MSI at an average price of 40 cents each or by six MOS ICs at \$ 6.0 each or by a single chip at a price of \$ 20.0. The cost for the printed circuit board labour, material, and amortised tooling is assumed to be about 1 cent per PC board hole for all the cases excepting the last two where 3 cents per hole is used. It is apparent that in single-chip approach, the total cost is reduced sharply. However, due to heavy special tooling cost (typically \$ 60,000), such systems can be economical only when produced in quantities of the order of tens of thousands. Single-chip monolithic central processing units are being produced by a number of manufacturers abroad.

Table 12.7. Cost comparison of a 1,000-gate subsystem.
(cost in \$)

Element type	No. of connections	Assembly cost	Component cost	Assembly + component cost	Special device tooling cost
Discrete	11,000	110.0	22.5	132.5	0
ICs (TTL)	4,000	40.0	66.6	106.6	0
MSI and ICs	2,500	25.0	40.0	65.0	0
6-chip MOS	180	5.0	36.0	41.0	120,000
1-chip MOS	40 or less	1.2	20.0	21.2	60,000

(Source : Sevin, L. J, Electronics, 25th Oct., 1971.)

12.3.3.7. Digital Integrated Circuits

Digital systems may be characterised as processors of discrete information, usually in the form of bivalued voltage levels. In these systems, since one deals with variables that can assume only two distinct values, the information content associated with any given processing stage is small and, therefore, a large number of repetitive circuits are required for even modest functions. At the same time, as com-

Table 12.8. Percentage market composition of digital integrated circuits in USA.

	Market composition (% Total Dollars)			
	1971	1972	1973	1976
Integrated circuits				
Digital logic	59.3	59.4	57.0	50.3
Digital memory	10.1	12.4	15.1	22.0
Others (linear, hybrid and other digital functions)	30.6	28.1	27.9	27.7
Digital logic				
Bipolar Total	70.8	67.3	61.9	49.6
RTL	2.1	0.9	0.8	0.4
DTL	18.8	13.1	9.9	3.8
TTL	35.3	41.8	40.2	32.7
ECL	14.6	11.3	11.0	12.7
MOS (including CMOS)	29.2	32.7	38.1	50.4
Digital memory				
ROM (including programmable)	28.0	30.8	32.4	27.9
Bipolar	11.9	17.3	22.5	22.1
MOS	16.1	13.5	9.9	5.8
Random access	25.9	35.8	43.0	57.8
Bipolar	9.5	16.3	21.2	29.2
MOS	16.4	19.5	21.8	28.6
Shift register	46.1	33.4	24.6	14.3

XII

pared to the design of analog circuits, which deal with variables assuming a continuum of values, the digital circuit design is simpler and less critical. The ease of performing a function by repeatable circuit blocks together with the feature of simplicity of circuit design make digital circuits ideally suited for integration. It is interesting to note that about 75 per cent of all ICs manufactured presently are of digital type. Just as an illustration, percentage market composition of digital integrated circuits for USA is given in Table 12.8. Apart from their use in digital instruments and communication, switching and control, digital integrated circuits have the largest use in digital computers and desk calculators. The progress made in the digital integrated circuit technology over the years is easily seen from Fig. 12.5, which presents how more complex digital ICs have been introduced in computers and calculators. The digital circuits that go into computers and other digital instruments are basically logic gates. Computers and calculators being the largest users of digital circuits, it is enough to cover the subject of digital ICs under the two heads—logic and memory.

(a) Logic

Integrated circuits have become the accepted choice for logic gates and there is a variety of logic gate ICs available commercially. These include RTL, DTL, TTL, ECL, etc., in the bipolar and P-MOS and C-MOS devices. Among the bipolar

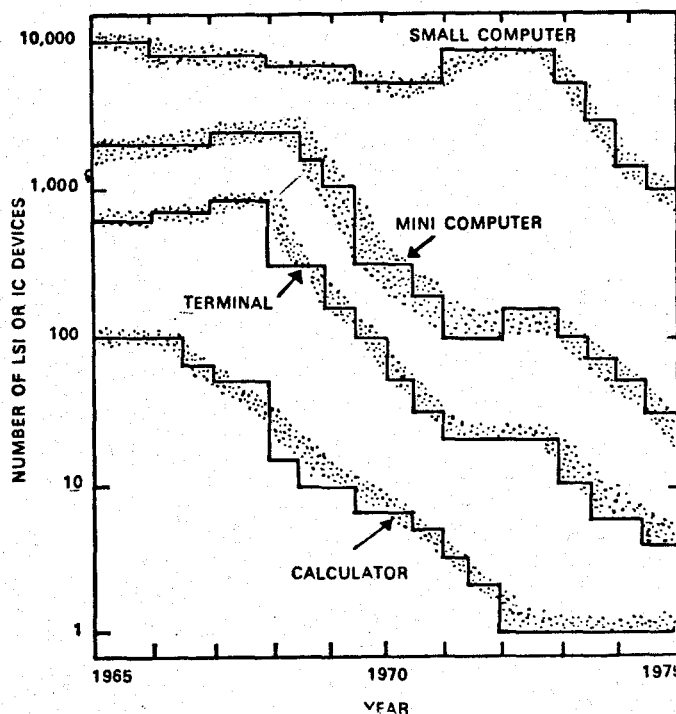


Fig. 12.5. Lower limits of DSI and IC devices in minicomputers (Source : Rudenberg H. J., AFIPS Conf. Proc., Vol. 40, 1972)

Table 12.9. Comparison chart of the major IC digital logic families.

Sr. Parameters No.	RTL	DTL	12-ns TTL	6-ns TTL	4-ns ECL	2-ns ECL	1-ns ECL	PMOS	CMOS
1. Positive logic function of basic gate	NOR	NAND	NAND	NAND	OR/NOR	OR/NOR	OR/NOR	NAND	NOR or NAND
2. Typical high-level output impedance (ohms)	640	6k to 2k	70	10	15	6	6	2k	1.5k

3. Typical low-level output impedance	R_{sat}	R_{sat}	R_{sat}	R_{sat}	15 ohms or 2.7 mA	6 ohms or 6.7 mA	6 ohms or 21 mA	25k	1.5k
4. Fan-out	5	8	10	10	25	25 inputs or 50 ohms	10 low-Z inputs or 50 ohms	20	50 or higher
5. Supply voltage	3.0V $\pm 10\%$ 3.6V $\pm 10\%$	5.0V $\pm 10\%$	5.0V $\pm 10\%$ 5.0V $\pm 5\%$	5.0V $\pm 10\%$ 5.0V $\pm 5\%$	-5.2V +20% -10%	-5.2V +20% -10%	-5.2V ± 10	-27 \pm 2V -13 \pm 1V	4.5 to 16V
6. Typical power dissipation per gate	12mW	8mW or 12mW	12mW	22mW	40mW load	55mW plus	55mW plus load	0.2 to 10mW	0.01mW static 1mW at 1 MHz
7. Propagation delay per gate (ns)	12	30	12	5	4	2	1	300	70
8. Typical clock rate for flipflops (MHz)	8	12 to 30	15 to 30	30 to 60	60 to 120	200	400	2	5

(Source : Garrette L. S, IEEE Spectrum, Dec. 1970)

devices, TTL and ECL are the important ones while in MOS devices C-MOS is becoming popular. The performance of logic can be specified in terms of parameters like operating speed, threshold voltage, noise, fan-in and fan-out, operating speed, power dissipation and operating temperature. These characteristics of functions for each of these logic families are presented in Table 12.9. It has been mentioned earlier and is also clear from Table 12.9, that bipolar devices are superior to MOS devices as far as the speed of operation is concerned. Even in bipolar, there has been a continuous improvement in speed capabilities, the emitter coupled logic (ECL) or current-mode logic (CML) being the fastest owing to its non-saturation of operation. In TTL itself, there has been a continued trend of speed improvement and recently a more high speed version (Schottky gate TTL) has been brought out incorporating the Schottky diode between the base and collector of transistor to prevent the transistor from going into saturation. Although bipolar transistors hold a superiority over MOS transistors in respect of switching speed, MOS transistors, as already mentioned, offer the most important advantage of higher circuit densities owing to their inherent self isolation.

As the complexity of a chip is increased, the cost per gate of packaging is reduced, since more or less the same cost is shared by a large number of gates. However, increasing the complexity increases the chip area, lowers the yield, and therefore increases the cost per gate. Thus, as the complexity increases, one comes across the opposing cost trends, viz., the increasing chip cost per gate. Another important factor that should be considered while deciding on the level of integration is the assembly cost relating to the subsequent system cost. As already mentioned, as the number of circuits in IC package increases, the cost of PC board assembly decreases. To arrive at the overall cost per gate, one should, therefore, add the packaging cost per gate and the PC board assembly cost per gate. Fig 12.6 is constructed only to illustrate these three cost trends and the overall cost per gate in relation to the number of gates per chip both for bipolar and MOS (A ratio of 2 for bipolar to MOS chip cost per gate has been assumed). The factors that contribute to lower chip cost for MOS are the improved yield owing to smaller number of process steps and smaller chip area for MOS devices. It may be seen from Fig. 12.6 that there is an optimum value for the complexity of the chip and that it is relatively high for MOS. When the chip complexity is not high, the

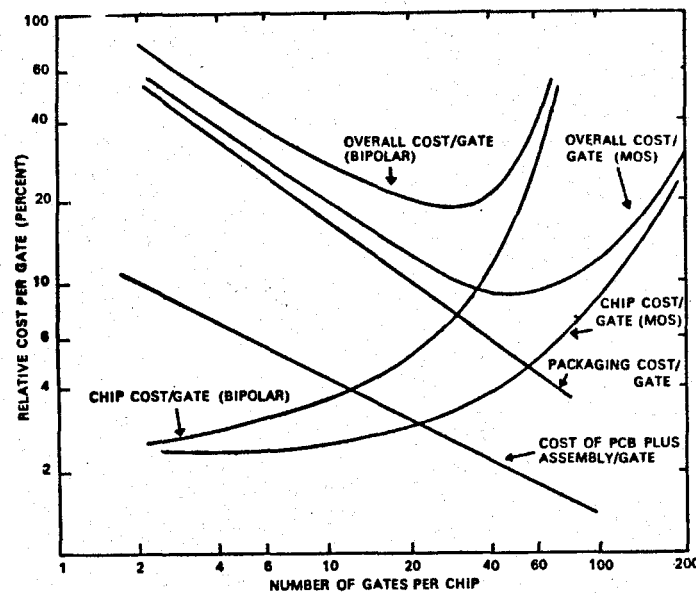


Fig. 12.6. Relation between cost per gate and complexity of ICs.

high cost per gate is evidently due to the high packaging cost while at higher complexities it is the lower yield that raises the cost. It must, of course, be mentioned that the optimum value of the number of gates per chip is expected to increase and the associated minimum cost per gate to decrease with improvements in yield by improvements in technology. Apart from factors like improvements in technology, the cost per gate greatly depends on the volume of production. Fig. 12.6 is, therefore, drawn to give only the relative cost per gate as a function of level of complexity of the chip.

Coming back to the different families of logic gates, it must be mentioned that ECL offers a higher speed only at a higher cost. TTL, though less fast as compared to ECL, has the flexibility of making more logic functions available. MOS, which lags behind bipolar in the matter of speed, affords higher circuit densities. Since TTL, ECL and MOS have both their merits and demerits, the choice rests essentially on the type of application and the trade-off among the three main variables, the cost per gate, the gate circuit delay and the level of integration.

(b) Memory

Many computers use magnetic devices (ferrite core, plated wire) for the main frame memory. The semiconductor memory which was introduced in around 1965 has become cost competitive with these magnetic memories and has come to replace them particularly in minicomputers and programmable desk calculators, where the size of the memory is not too large. The semiconductor memories, in addition to their cost competitiveness, offer superior performance and greater freedom of organisation. Unlike with magnetic memories, it is possible with semiconductor memories to include the address decoding function as well as the memory function on the chip. Including the decoder on the chip reduces the number of lead bonds that must be made to the chip. The fabrication techniques used for the semiconductor memories are the same as those used for logic functions of CPU and they offer speed comparable to those in CPU. While this applies to bipolar semiconductor memory, recent developments in MOS technology offer signal levels compatible with bipolar techniques. In cases where some interface circuits are needed (as in dynamic MOS), the complexity and performance requirements for the interface circuits are less severe than the magnetic memory interface circuits.

Bipolar and MOS semiconductor memories differ in cost, organisation and performance. In general, MOS memories offer lower cost but slower performance than bipolar. While bipolar memories use a relatively standard flip-flop as the storage element, different MOS memories (static and dynamic) are available. Dynamic MOS circuits, which make use of the very low leakage current that is associated with the gate circuits and junctions of properly designed MOS devices, are less expensive and faster but require more elaborate drive signal as compared to the static MOS which, like bipolar, use flip-flop as the storage element. Both types of MOS memories may be organised as random-access memory (RAM) or as serial (shift-register) memory.

The economic considerations associated with semiconductor memory fabrication are quite different from those associated with magnetic memories. The optimum semiconductor memory module size is, as already discussed in the case of logic circuits, determined by the number of chips yielded per wafer, the cost of processing the wafer, the cost of packaging and the loss associated with packaging. While the present optimum complexity seems to be just about 1024 bits per chip, it would shift to much higher values in the near future.

The choice of the type of memory for a machine rests on the type of application and the possible trade-off among the factors like, speed, the cost per bit and the total memory size. However, since majority of minicomputer applications demand relatively moderate speeds and not too large a size of memory, MOS memories (particularly dynamic MOS) would be most popular.

Although dynamic MOS read/write random access memories (RAM) are good enough for the majority of minicomputers, MOS RAM with bipolar decode and read/write circuitry may also be used for higher speed levels (as scratch pad memories). In addition to the read/write memories, read-only memories (ROM) may also be made with MOS. ROMs may be used as substitutes for part of read/write memory. In general, because the memory cells are very small, many more bits of ROM than RAM can be fabricated on a chip of given size. Bipolar ROMs of 1024 bits (50 ns access) and MOS ROMs of 4096 bits (750 ns access) are now available. MOS technology is also well suited for accumulators and other hardware registers and also for applications involving the replacement of a delay line or a small drum memory.

12.3.3.8 Linear Integrated Circuits

Linear circuits, viz., DC/AF/HF amplifiers, oscillators, modulators, demodulators, etc., are the building blocks of analog systems. As parameters like gain, frequency response, selectivity, input/output impedance and noise are of significance in these circuits, the specifications of linear circuits for use in analog system are very stringent. Unlike in the case of digital systems which can be easily realised from mass produced digital integrated circuits of only a few types, a considerable functional diversity of linear circuits is necessary to build analog systems. It is for this reason together with the difficulty of integrating inductors and capacitors that the progress of integrated circuits in linear areas has been slow. However, the growing need for miniaturisation of communication equipment associated with greater reliability and superior performance has, of late, been demanding a greater attention towards linear ICs.

It is obvious that linear integrated circuits designed for mass production should be either exceptionally versatile devices that can be adapted to provide many different types of circuit functions in various electronic equipment, or devices performing specialised functions in high volume applications (like TV and radio). RCA, one of the leading manufacturers of linear integrated circuits, in fact, market the basic classes of linear integrated circuits such as differential amplifiers (general

purpose), operational (voltage and transconductance) amplifiers and multipurpose amplifiers, in addition to some special purpose circuits, mainly for consumer applications.

In a radio receiver, since the local oscillator and mixer used for translation to a standard intermediate frequency share similar problems, the critical processing requirements make it attractive to design a receiver 'front end' into a single block. Since economical bandpass filtering is at present impossible with monolithic circuits, the mixer/bandpass/IF stage interfaces are logical points for partitioning of circuit functions.

The television industry in the countries abroad has shown a great rush in incorporating ICs in TV sets. Though the size and weight reductions that are afforded by using ICs are only marginal due to the fact that they are determined to a large extent by the display tube, deflection transformers and power supplies, the justification for using them is that they cut down assembly costs, increase reliability and reduce servicing problems. The front end receiver (tuner assembly) and the high power deflection circuits still present some problems, though experimental circuits where the whole of the tuner assembly is integrated in a single block have been fabricated. Even the problem of integrating power amplifiers seems to have been overcome to some extent. Many IC manufacturers now offer monolithic power amplifiers ranging from 2 to 5 W output and are presently working on increasing the power capability further. These would be suitable for radio and TV receiver applications. In video amplifiers, ICs do not present any problem as long as the signal levels are not too large. In TV applications where input signal levels range from tens of volt to a few hundred volts, the complete integration of video amplifier may not be feasible in which case one can use currently available ICs in conjunction with a transistorised output stage. The sound section of a TV receiver can be easily integrated. In fact, RCA-CA 3041 and CA 3042 comprise, on a single monolithic chip (in a 14-Lead DIP package), the sound channel of a TV receiver. Each type contains a wide band three stage IF amplifier-limiter, an F-M detector stage, a zener diode regulated power supply and an audio pre-amplifier drive section. The sync. separator accepts demodulated video from the video detector and, besides providing noise cancelled sync. signal at its output, provides AGC for VIF and delayed AGC for RF. The deflection circuits provide deflection voltage for the picture tube. It is practical to have an IC performing all the functions of the sync., and scanning circuits of the deflection system except, of course, its output stages.

In addition to the applications of linear ICs in analog instrumentation, communication systems, radio, TV and other entertainment electronic systems, linear ICs find an important place in interface circuits, viz., line drivers, memory drivers, sense amplifiers and peripheral drivers.

12.3.3.9 Packaging Technology

While planning for semiconductor industry, a careful consideration of packaging technology is necessary. Due to high degree of innovation and development, IC technology has greatly advanced in recent years. However, packaging technology could not keep abreast with this development. Today's packages were not developed functionally for ICs but are products of a technology borrowed (with only modest modification) from vacuum tubes and discrete components. Due to neglect of this area, present IC packages are less functional and costlier. A point has now been reached where the packaging cost can, and many times does, exceed the chip cost. Even though the cost per active device will come down to a minimum, the main contributing factor to the total cost of the device will be the package only. It is also observed that the majority of device failures are either assembly or packaging oriented.

(a) Packaging Configurations

The basic configurations for packaging are (i) TO-type (ii) flat packs (iii) dual-in-line package (DIP), and (iv) nonstandard package.

(i) TO-Type

These hat-shaped metal packages were originally very popular as high reliability transistor packages, and have also gained some popularity as IC packages. The most common types are TO-5 and TO-18. However, they are available in a variety of sizes and number of leads. TO-5 package is made with leads numbering 2 to 12; TO-18 is a smaller version of TO-5. The package cost range from \$ 50 per thousand for a three pin TO-5 package (no gold) to \$ 125 per thousand for eight to ten lead TO-5 package (no gold) in volume of 25K to 50K.

These packages are very inconvenient to handle automatically and thus are less cost effective for large assemblies. Further, they have limited number of leads (twelve). In spite of these limitations, the TO-type packages have found wide acceptance because of the hermeticity that they offer and due to ready availability of the packages in small volume at a reasonable price.

(ii) Flat Packs

Due to light weight and small size, flat packs are used extensively in aerospace industry. Flat packs are available both in rectangular and round shapes and it is almost the only package that allows high number of lead (over 80) in relatively small space. These packages are available in plastic and ceramic construction as well as in metal and glass construction.

Flat packs are relatively costly, ranging from 25 cents for small flat packs purchased in high volume (100K) to more than \$ 5 each for large, more complex packages. Further, these packages cannot be handled automatically because the leads can be easily bent and damaged. To avoid this, special carriers and jigs are used which further adds to the cost.

(iii) Dual-in-line Package

Dual-in-line packages (DIPs) are the most popular packages in these days and are best suited for automatic insertion. The 14-lead DIP costs 10 to 15 cents each

Table 12.10. Summary of relative merits of semiconductor device packages.*

Package type	Functional density (at the PC board)	Layout versatility (of the PC board)	Ckt. performance (System speed)	Assembly cost	Parts cost	Field serviceability	Power dissipation	Current device availability	Environmental reliability	Major limitation
TO-5	4	4	3	4	2	4	3	4	2	Pin-limitation
Flat pack	1	3	1	4	3	4	4	3	1	Assembly cost and design restraints
DIP-plastic	2	2	2	2	1	3	4	2	5	Reliability acceptance (Many space and military designers still reject this package)
CERDIP	2	2	2	2	1	3	3	1	3	Processing temperature (too high for most MOS and linear ICs) Cost
COFIRED	2	2	3	2	3	3	3	3	3	

*Numbers represent rating. 1 = Superior; 2 = Good; 3 = Average; 4 = Poor; 5 = Unacceptable.

Source : Rogers B.C, The electronics Engr., Vol. 31, March 1972, p. 26.

in large volume and plastic DIP costs less than 10 cents each. The most popular DIPs are with 16 and 24 pins with pin spacing of 100 mils and 600 mils from centre to centre. These packages are also used for LSI packaging where large number of pins are required. Although these large DIPs with pins upto 50 are more costly, their general ruggedness is making them a favoured package for LSI chips. The large DIP remains inexpensive compared to flat packs. The biggest disadvantage of DIPs is the low ratio of overall size to available chip mounting area.

For the near future, the most common package for LSI applications will be ceramic or plastic with an average of 40 pins. The DIP is the most common configuration today and it houses not only chips but also passive components. This trend will remain prevalent for the next few years. For complex functions, multichip packages may be used in which a number of LSI chips are inserted inside a package.

(iv) Nonstandard Packages

Nonstandard packages are mostly used for packaging hybrid integrated circuits to fit into special needs. Generally these are plastic materials. Even for extremely complex monolithic ICs, such nonstandard packages are used. Nonstandard packages are used in much lower volume than either dual-in-line or the flat-pack. The examples are the high power packages and IBM packages. IBM packages have square ceramic substrates with 28 pins coming out of the bottom. There are other types of packages emerging in the market, which are not yet well known.

A summary of the relative merits of the commonly available packages is given in Table 12.10.

12.3.4. New Technologies and Techniques

12.3.4.1. Charge Coupled Devices

A new class of MOS devices called charge coupled devices (CCD) was first announced by Bell Laboratories in 1969. These devices represent a conceptually simple form of functional charge-storage devices that cannot be constructed from discrete components. These are junctionless devices and store a minority-carrier charge in a potential well created at the surface of the semiconductor and transport the charge along the surface by moving the potential well. These devices can be fabricated in a much simpler way since no diffusion is required for their active parts. Conceptually they can be fabricated with just two masks, one for the metal pattern, another to define the region where thick and thin insulating films are required. Due to the simple structure and small area, overall yield in CCD is high and higher packing density is obtained.

Charge coupled devices promise a number of applications, like high-density MOS memory with packing density of 1 million bits/sq. inch, solid state image sensors, analog delay lines for audio/video systems and filters. The CCD memories can operate at 10-20 MHz data bit rates, consume only 5 microwatt power/bit as compared to 5 MHz and 100 microwatt/bit for MOS memories. It is expected that the CCD memory cost will be five times less than the existing MOS memory prices.

12.3.4.2. Amorphous Semiconductor Devices

Amorphous semiconductors, which exhibit only a short range order in the arrangement of atoms, have aroused world wide interest since Ovshinsky first reported the threshold and memory switching in them in the year 1968. The interest in the field has been further activated by nonvolatile reprogrammable memories developed at Energy Conversion Devices, Inc. USA, recently. These read-mostly memories contain a thin film of amorphous semiconductor material deposited on a single crystal silicon substrate in series with a silicon diode.

The attractive features of amorphous semiconductor devices are the extremely low cost of raw materials, easier processing, low power requirements and high radiation resistance. Energy Conversion Devices and Intel Corporation are collaborating in the production efforts of RMM memories. Other possible applications of amorphous semiconductors are electroluminescent displays, computers mass memory and high speed computer print-out. It must, of course, be mentioned that the future of this technology is still uncertain for the problems of lack of reproducibility and reliability of these devices have not been fully overcome as yet.

12.3.4.3 Ion Implantation

Ion implantation offers a quantitatively different means of introducing dopant atoms into crystal than that involving diffusion. With ion implantation, doping process can be carried out at a relatively low temperature, compared with equivalent diffusion temperature avoiding undesirable effects that may accompany the high temperature diffusion process. This also provides a method of implanting materials for which diffusion is difficult in a highly controlled way. Ion implantation gives significantly less lateral scattering of impurities as compared to diffusion. Thus one can get a uniform junction depth over a large area. Also, the impurity profile can be carried over a large limit, leading generally to Gaussian nonmonotonic profile.

With ion implantation, the drain and source of MOSFET can be exactly aligned with the gate with little overlap. This reduces the parasitic capacitance by a factor of 15 (higher than by any other self-alignment technique), thus giving higher operating speed.

Due to very high sheet resistivity (10^5 ohms per sq. compared to 10^3 ohms/sq. for diffused resistors), the chip area is reduced by a factor of about 100; the temperature coefficient of the ion implantation resistor is much lower and has better tolerance (within 1 to 2 per cent).

The most practical consequence of ion implantation has been the manufacture of improved MOSLSI devices. The important ones are memories, shift registers, multiplexers, operational amplifiers, n-channel MOS with bipolar-compatible switching voltages, etc.

The other areas of importance for ion implantation are microwave devices and the production of very abrupt uniform junctions. The Impatt diodes fabricated using ion implantation can go upto 50 GHz as compared to 10 GHz for ordinary Impatts using diffusion methods.

Although ion implantation provides attractive opportunities for significant improvement in the performance, its ultimate utility will be decided by performance/economics tradeoff which means that ion implantation will not totally replace conventional diffusion technology but will only complement it. A custom-built, 300 kV versatile laboratory ion implantation system providing a broad range of implantation parameters will cost about \$ 120,000. The capital cost for an ion implantation system custom-made for batch production of p-channel MOS ICs will cost nearly \$ 45,000.

12.3.4.4 Electron-beam Technique

The minimum line width which can be faithfully replicated by conventional photolithographic contact printing is generally considered to be about 2 μ m. Electron beams can create patterns with higher (submicron) resolution than is possible with photolithography because, beams can be focussed to a spot diameter that is two or three orders of magnitude less than the wavelength of light. Light rays passing through a photographic mask are diffracted to a line broader than the slit in the mask. Even with electron beam, electron scattering broadens the pattern drawn, but the resulting minimum line width is much less than that of the light beam. The electron beam can be deflected by electrical control and programmed to

write a complex pattern with the help of a computer. By using this technique it has been possible to fabricate acoustic surface wave transducer operating up to 2.5 GHz, whereas the upper frequency limit of these transducers made by photolithographic technique is around 500-800 MHz. The use of electron beam lithography can yield LSI circuit patterns with more than an order of magnitude increase in component density. This close packing resulting from reduced area per device, can also afford higher yields of LSI circuits. The capital cost for a digital computer and scanning electron microscope, both commercially available, for programmed pattern creation costs at least \$ 140,000, the cost of process development being separate.

12.3.4.5. X-ray Lithography

Two impediments to a wider utilisation of the high resolution pattern definition afforded by electron beam lithography are the need to sequentially expose all patterns, and the cost and complexity of the scanning electron beam equipment. The former, viz., the need to separately expose each pattern of each device, point by point, makes it particularly costly, so that an ideal solution would be to use scanning electron beam only to generate high resolution masks, and then replicate these masks onto substrate. Though electron projection systems have been proposed for the replication of these high resolution patterns, such systems are also complex and expensive. A new technique, just about two years old, has been demonstrated to be useful for replicating sub-micron resolution patterns. This technique, called X-ray lithography, utilises soft X-ray (10 angstroms as against 4000 angstroms for light) as the exposing radiation, and thus avoids all the wavelength related diffraction problems inherent in photolithographic contact printing, while permitting a finite mask-sample separation.

12.3.4.6 Automation in the Semiconductor Design Cycle

Computer aided design (CAD) of integrated circuits was developed and implemented as early as in 1966 by Norden Division of United Aircraft Corporation, USA. Their system, one of the first to work online, employed a light pen and a CRT display for circuit layout. Today, though different semiconductor houses have their own variations of CAD systems, the basic automation cycle is more or less the same, as shown in Fig. 12.7. The entire cycle can be briefly described as follows.

Though the CAD system can be had to permit entry at any stage, one may start with system specifications and system logic design. Once this is ready, the first step would be to verify the system logic through a simulation program. Next thing is the system partitioning which is the division of system logic into a number of chips, the complexity of which may range from the complete system logic to individual gates. Partitioning can be automated to a degree; the system manufacturer being most knowledgeable about his own system assembly costs and goals, optimum partitioning can be achieved only through an interaction with the system manufacturer. Partitioning results in a set of chip logic diagrams and an associated set of performance specifications. Once the partitioned drawings are obtained, the next step is to convert the drawings to a set of logic prints constructed of 'cells' that are predesigned building block circuits whose characteristics are stored in the computer. Because all subsequent steps are based on these individual chip logic diagrams, individual chip designs are verified by simulating the chip logic. In the course of this step, a test program for that chip may also be generated which can be used to test the chip after it is fabricated. Thus far, what is available is the interconnections of the library cells describing the logic function of the chip. Remaining to be defined are the physical placement of each cell and the actual route the interconnections are to take, or in other words one proceeds to generate the mask from there. The two common methods to generate the data for driving the mask preparation system are the CRT graphic display method and the digitiser

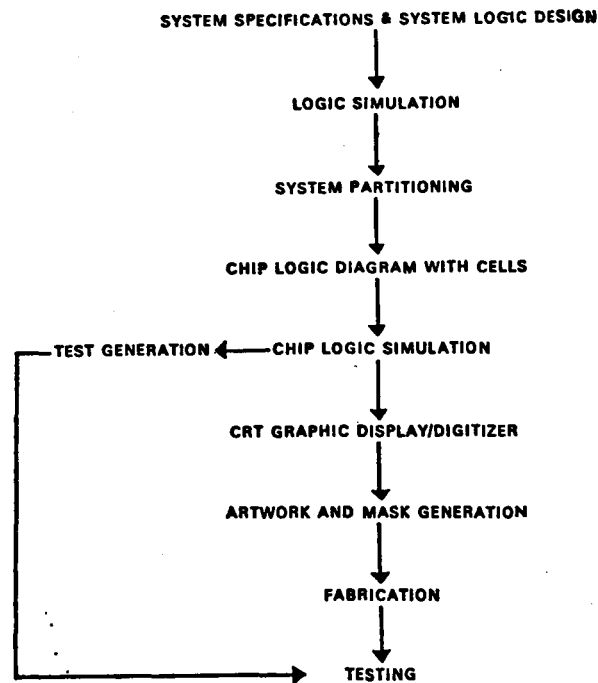


Fig. 12.7. The semiconductor design cycle automation

method. The CRT provides the designer with an interactive capability. Next, computer aided mask generation data tape or set of cards (which contains all the layout information in equipment language that has been generated for the circuit on the chip) that have been prepared either by digitiser or by CRT/light pen, functional key board and teletypewriter, is used to drive mask generating system. There are again two alternatives in the hardware to be used for generating the actual mask. One is to make use of a plotter that comes with interchangeable heads, so that it can cut rubylith film, directly expose photographic film or make multiple-line-width ink drawing on paper or synthetic materials. In the rubylith mask generation process, which is the most common method of mask generation, one usually obtains an ink composite drawing of the mask from the plotter for a visual check before cutting the rubylith. After cutting, the rubyliths are manually stripped, then photo-reduced and stepped to produce a master mask. In the second mask-generation method—optical pattern generation—a pattern generator, under computer control, optically turns out the actual mask artwork which is then proto-reduced and stepped to produce the master mask. When the wafer has completed the fabrication processing sequence, it is sent to a computer-controlled probe station for testing.

It is worthwhile noting that computer aids for IC design, layout and mask generation, which until three to four years ago were considered to be a luxury, are now being used very widely by semiconductor manufacturers. Today CAD systems are available for just about \$ 100,000. In fact, Macrodata's front-end design information system (FEDIS) which is one of the only turnkey systems to provide automation for the entire semiconductor design cycle sells for a little more than \$ 100,000. A library of software programs is offered with the system. The basic parts of the system include a digitiser, cursor, digital readout and menuboard, a computer with a teletypewriter, a disk memory, magnetic tape and a pen plotter. Options include additional digitisers, a printer, a card reader, and a CRT display system. The user can enter the system with logic equations, or he may choose to create his own composite of the chip for digitising.

12.4 Demand Profile

The importance of realistic and reasonable estimates of future requirements of vital components like semiconductor devices cannot be overemphasised in a planned economy, where also the resources, in terms of raw materials, technical skills as well as production facilities will, in view of their limited availability, have to be optimally deployed for maximum benefit.

While there are several ways in which the forecast of the demand can be arrived at, the method followed here is a composite one which consists in breaking down (valuewise) of the perspective plan for electronic equipment for first to the total semiconductor component content and then to individual semiconductor device categories. In doing so, while the international percentages (derived from the market statistics published in recent issues of Electronics) have formed the basis, it has been assumed that the electronic equipment (not the systems that would also include a considerable, nonelectronic hardware like wires and cables) demand would grow from Rs. 250 crores in 1974-75 to Rs. 500 crores in 1978-79) and to Rs. 1,100 crores in 1983-84 and that the total semiconductor component content would

Table 12.11. Demand forecast of semiconductor devices (Values in Rs. crores).

Device	Average unit price (in Rs.)	1974-75	1975-76	1976-77	1977-78	1978-79	1979-80	1980-81	1981-82	1982-83	1983-84
1. Equipment, total		250.00	300.00	360.00	432.00	500.00	595.00	702.00	821.00	953.00	1100.00
2. Semiconductors											
2.1. Discrete											
2.1.1 Discrete, conventional											
(a) Signal diodes	1.50	1.40	1.50	1.65	1.70	1.80	1.86	1.91	1.95	1.98	2.00
(b) Rectifiers	—	1.40	2.00	3.10	4.20	5.70	7.40	9.60	11.66	13.45	15.50
(c) Zener diodes	2.00	0.60	0.70	0.77	0.80	0.90	0.96	1.01	1.05	1.08	1.10
(d) Thyristors	—	0.30	0.50	0.70	1.00	1.46	1.92	2.77	3.00	3.47	4.00
(e) Transistor, small signal	1.65	5.23	6.68	6.76	6.80	7.10	7.55	7.75	7.90	8.00	8.10
(f) Transistor, power	6.25	1.60	2.50	3.20	4.30	6.00	7.70	10.30	12.80	14.40	17.00
(g) Transistor, microwave	340.00	0.04	0.07	0.12	0.17	0.24	0.32	0.43	0.55	0.68	0.80
2.1.2 Discrete, special											
(a) Microwave diodes	380.00	0.08	0.15	0.25	0.43	0.60	0.84	1.10	1.38	1.70	2.00
(b) Optoelectronic devices	5.00	0.05	0.10	0.65	1.10	1.50	1.95	2.73	3.65	4.60	5.50
2.2. Integrated circuits											
2.2.1 Linear	10.00	0.18	0.25	0.55	1.15	1.90	2.60	4.00	5.64	7.64	9.00
2.2.2 Digital											
(a) SSI/MSI	6.00	0.90	1.40	2.10	4.00	5.70	7.30	9.40	12.00	14.50	16.00
(b) LSI	100.00	0.50	0.80	1.50	3.10	5.00	6.80	9.70	12.40	15.40	19.00
2.2.3 Hybrid	45.00	0.22	0.35	0.65	1.25	2.10	2.80	4.30	6.02	8.10	10.00
Semiconductors, total	—	12.50	17.00	22.00	30.00	40.00	50.00	65.00	80.00	95.00	110.00

grow from 5 per cent (of the total equipment value) to 8 per cent in 1978-79 and to 10 per cent in 1983-84. The figures so generated have been checked and suitably modified after individually considering the requirement of these devices in some major sectors of electronic equipment/system, e. g., entertainment electronics, computers and calculators. The demand forecast thus arrived at for ten year period 1974-84 is given in Table 12.11. It must, of course, be mentioned that the later 3 years are too far not to involve some uncertainty in the demand figures, for any major technological developments could considerably change the demand pattern for those years.

It may be seen that the semiconductor devices demand is expected to grow from the level of Rs. 12.5 crores in 1974-75 to the level of Rs. 40 crores in 1978-79 and Rs. 110 crores in 1983-84.

12.5 Analysis of Gaps

Having arrived at the demand forecast, it is necessary to examine the indigenous production capability with respect to each of the devices and identify the gaps that exist. Table 12.12 is intended to present this in a concise manner.

Table 12.12. Indigenous production capability for semiconductor devices

Device family	Product group/technology	Present installed capacity (in million)	Remarks on indigenous production capability
1. Discrete, conventional Signal diodes	Germanium : Point contact (RF)	~4.00	Installed capacity for glass diodes in 50-15 and DC-7 outlines has been increased by duplication of the manual and semi-automatic machines imported in the early sixties. Additional capital equipment is required for meeting the present demand of diodes in DC-7 package. Projected large requirements can be met economically only with high-speed automatic machines for which indigenous capability does not exist. Leading manufacturers abroad have cut costs substantially by fully integrated processing and assembly lines.
	Gold bonded		No indigenous production capability. Development is in progress for a few types.
	Silicon : Point contact (RF) Point contact (Microwave)	3.25	No indigenous capability. Obsolete technology. Some types are under development in laboratories. Present requirements in professional equipment are being met with imported devices.

	Schottky barrier (Microwave)	No existing production capability. Low current devices are available in DO-7, DO-14 and low inductance mini-plastic packages abroad. As these are being used in UHF/Microwave mixer and detector applications in professional equipment, facilities will have to be created in the country as soon as possible. Some development work is in progress at TIFR.
	Alloy junction	No indigenous capability. Obsolete technology.
	Planar/ switching	Existing transistor diffusion and packaging facilities are being used for the assembly of a few types in non-standard outlines. Some types are also being assembled in axial-lead DO-7 packages with imported chips, connectors and glass-to-metal seals. Leading manufacturers abroad are manufacturing these diodes in spring contact glass (DO-7), transfer moulded plastic (DO-14) and hard glass whickerless construction on automatic line machines. These are also available in beam-lead/flip-chip and micro-T (plastic moulded or ceramic) outlines for convenient assembly on hybrid microcircuits and strip line circuits. Indigenous capability does not exist for the complete manufacture of these diodes in the above outlines. Projections indicate a large requirement of these types in both professional and consumer fields.
Rectifiers	Germanium : Alloy junction	Alloying and packaging facilities established for junction transistors are being used for the manufacture of alloy junction diodes/rectifiers in TO outlines. No specific additional investment will be needed for meeting the future requirement of these devices.
	Diffused junction	No existing capability. Obsolete technology.
	Silicon : Alloy junction	No indigenous capability. Obsolete technology.
	Diffused (high voltage, low current	Low frequency rectifiers upto 3000 V and medium frequency rectifiers upto 300 V are being encapsulated in a

	Alloy/diffused (low voltage, high current)		wide range of metal and plastic outlines. Facilities have to be created for processing and packaging of high voltage (10-20 kV).
	Alloy/diffused (high voltage, high current)		Imported diffused elements are being packaged in metal and plastic outlines for a wide range of voltage/current rating. Some of the existing manufacturers are establishing diffusion capability. Only cold potted rectifiers are available indigenously, while the state-of-the-art devices are transfer moulded. No production capacity exists for glass-to-metal seals for current ratings upto several hundred-amperes.
	Alloy/diffused (high voltage, high current)		No indigenous capability. NGEF has plans for manufacture of a few types under collaboration.
Zener diodes			Limited facilities exist for diffusion and assembly of 400 mW, 1 W and 3 W zeners in axial-lead or TO outlines. 1.5 V to 200 V zeners with power ratings ranging from 100 mW (DO-7) to 50 W (DO-5) are standard products in professional electronics. No indigenous capability exists for zeners with higher voltage, higher power ratings and lower temperature coefficient.
Thyristors	SCR, triac, etc.	0.06	120 V, 30 amp SCRs have been recently introduced in the market with imported glass-to-metal seals. Types under development/pilot production are available in limited quantities. There is no indigenous capability for triacs and triggers. SCRs and triacs are available abroad in plastic moulded, TO-39, TO-56, TO-3, TO-48, TO-205, stud (TO-83, TO-94) and other outlines with greater heat-sinking capacity. Triggers are available in TO-18, TO-92, DO-7 and other plastic moulded packages. Indigenous production capability, covering the manufacture of the various glass/ceramic-to-metal seals needs to be established at the earliest to make this industrially important device family available at low cost.

Transistor,
small signal

Germanium : 14.40
Alloy junction,
alloy diffused

Jigs and fixtures oriented processing and assembly lines have been established. Installed capacity has been increased by the duplication of the imported equipment, except for critical machinery and furnaces. Assembly lines are labour intensive. Projected requirements, mainly from the consumer electronics field, can be met by indigenous manufacture of assembly and processing equipment and import of critical machinery and furnaces. Substantial reduction in unit cost of foreign exchange content cannot be effected without heavy investment in mechanisation and the indigenous availability of pure chemicals at international prices. TO-1 and TO-7 headers and cans are being produced indigenously while TO-5 headers are still being imported.

Silicon : 39.49
Planar (low
voltage RF)

Planar (high
voltage RF)

Planar (low
voltage UHF)

Planar
(switching)

Planar (junction
FETs)

Planar (MOS
FETs)

Available mask fabrication equipment with manual art work outting and manual/semi-automatic step and repeat cameras can meet the qualitative requirements of small signal discrete devices for wafers upto 1.25 inch diameter. State-of-the-art equipment can handle 3 inch wafers and are fully automatic for greater accuracy and design flexibility. Existing diffusion facilities with some additional diffusion pipes can produce a wide range of devices. Some equipment will have to be added or modified for increasing wafer handling capability from 1.25 inch to 2 or 3 inches. Manual or semi-automatic packaging facilities are available for metal and plastic outlines. Glass-to-metal seals are being imported. Development/production of these has been taken up by several firms under licence from NRDC. High speed TO-92 and TO-18/TO-5 assembly lines will minimise material and labour cost and make products competitive in the world market. Additional facilities are required for MOSFET devices. A wide range of devices will be required in

Transistor
powerGermanium : 0.10
Alloy junction

flip chip, beas-lead of microminiature Micro-T outlines for thick film and thin film stripline circuits.

Existing equipment have been supplemented with gold sealing TO-3 package facility for batch production of power transistors. Projected large demand can be met with additional equipment such as precision conveyor furnances, projection welders, etc. Indigenous manufacture of metal parts and glass-to-metal seals for TO-3, TO-36 and TO-66 headers are yet to be established. Devices of 30W, 6 amps ratings are available indigenously, while 250 W, 150 amps transistors are standard products abroad.

Silicon : 0.10
Planar double/
triple diffused

Existing mask fabrication facilities will have to be supplemented with suitable lenses for large geometry power transistors. A few types of NPN and PNP transistors are being diffused and packaged in imported TO-3 headers. A maximum of 50 W, 5 amps transistors are available indigenously while 625 W, 250 amps transistors are standard for the technology. TO-39, TO-8, TO-56, TO-3 TO-36 and TO-63 are some of the standard metal packages for professional requirements. High speed assembly lines are being used abroad for low cost devices in plastic TO-5, TO-220 or maxi watt outlines for consumer electronics.

Transistor,
microwaveSilicon :
planar overlay

Production capability will have to be established for a wide range of devices which are being imported at present for professional electronics. State-of-the-art emitter-ballasted power transistors cover a range from 75 W at RF to 10 W at UHF/microwave frequency. While TO-39, TO-60, TO-216, TO-217 headers are popular for HF, VHF and UHF frequencies, co-axial, ceramic TO-215 and strip line packages are being used for UHF/microwave bands. Foreign exchange saving

2. Discrete, special
Microwave
diodes

can be expected by the production of these types, only if packages are also produced indigenously. Fabrication of packages for RF/microwave devices involve additional equipment and new technologies for glass to metal seals, beryllia heat sinks and selective gold plating of glass/ceramic. As the power of frequency barriers are being constantly pushed upwards, facilities for overlay power transistors will have to be constantly reviewed and updated with newer technology and equipment.

No existing indigenous capability. Some development work is in progress at SPL for varactors and for Gunn diode at TIFR. Junction and bulk effect microwave devices such as Gunn, avalanche and IMPATT diodes, covering the S, C, X, J and Ku bands are available abroad in ceramic coaxial packages.

Optoelectronic
devices

No existing indigenous capability. Infrared and visible (amber, green and red) light emitting diodes (LEDs), LED arrays, alpha-numeric seven-segment displays, upto isolators and a variety of read-out devices are available abroad in glass and epoxy leads TO-18, coaxial and multipin dual-in-line packages. As very large requirement of these devices are indicated in the calculator, computer, industrial controls and test instruments in the country, indigenous capability covering all aspects of this device family must be established at the earliest.

3. Integrated
circuits
Bipolar

Linear,
digital
(SSI/MSI)

Existing mask fabrication facility with additional equipment under procurement will meet the requirement of 2.5×2.5 inch mask for these families. Material fabrication and diffusion equipment on order can handle 1.25 to 2 inch diameter wafers. Additional diffusion furnaces and accessories will be required for type diversification. Assembly and

			testing equipment on order can handle multi-lead TO-5, dual-in-line ceramic and plastic packages upto a maximum of 24 leads. Indigenous capability does not exist for the manufacture of multi-lead TO-5 packages, dual-in-line lead frames and ceramic flat packages.
		LSI	No existing capability. State-of-the-art subsystems require computer controlled mask design and fabrication facility.
MOS		Digital (SSI/MSI)	No indigenous capability. Equipment under procurement will meet the requirement of some types in dual-in-line plastic and ceramic outlines. Low threshold device in this family will require additional equipment specifically designed for 'clear' conditions to minimise ionic contamination.
		LSI	No indigenous capability. Memories and custom/standard subsystems are being produced abroad in 24 pin and 48 pin ceramic and plastic packages using computer aided design, processing and testing facilities. 128 pin packages are under development. Economic production in large volumes is feasible only with advanced ion implantation techniques and facilities. Production facilities will have to be supplemented with equipment for purifying gases and water as well as the working ambient for extremely small geometry devices. Rapid advances in this technology require frequent updating of capital equipment.
		CMOS	BEL has entered into a licence agreement with RCA.
Hybrid		Thick & thin films	Some circuits have been developed using thick film technology and are under pilot production. Thin film networks are under development. State-of-the-art hybrid ICs include ladder switches, high power amplifiers, D/A converters. current/ voltage regulalors, active filters, UHF broadband amplifiers, TV receiver circuits and automative electronic circuits in multipin TO-3 radial lead stud, ceramic and a variety of custom plastic moulded packages.

12.6 Proposed Guidelines**12.6.1 Interim Production**

The aspects like licensing, packaging technology, import of technology, foreign equity, chip import, etc., which are directly related to production are discussed below.

12.6.1.1 Licensing

The estimated requirements of semiconductor devices have been presented in Table 12.11. The estimate indicates a requirement of Rs. 23.2 crores worth of discrete conventional devices, Rs. 2.1 crores worth of discrete special devices and Rs. 14.7 crores worth of integrated circuits (of which Rs. 2.1 crores is the share of hybrid integrated circuits) in the year 1978-79. Large number of types are involved and it is estimated that at least 880 types would be required in 1978-79. This diversity may tend to reduce production quantity in the country because, production may not be feasible in cases where the demand is small. The share of germanium devices is going to decline over the years and it is expected that in the year 1978-79, they will account for about Rs. 5.7 crores in the total of Rs. 23.2 crores worth of discrete conventional devices' requirement. In the following, guidelines for production are given for each of the device categories.

(a) Signal Diodes, Small Signal Transistors and Zener Diodes

Germanium signal diodes and small signal transistors may be required to the tune of about 26 million (about 12 million diodes and 14 million transistors) valued at Rs. 3.9 crores in 1978-79. The present installed capacity of these germanium devices is of the order of 18 million (about 14 million for transistors). The production is shared by only two manufacturers, viz., SEM and BEL. While capacity for transistors is just enough, capacity for diodes would need a substantial expansion (from about 4 million to about 12 million). There should, however, be no difficulty for the existing units to meet this demand and no further industries need, therefore, be licensed for these devices. Some of the additional equipment required for expansion of existing units can be locally fabricated. Renewal and replacement of some of the equipment may arise in a small way and import can be considered on a case-by case basis.

Silicon signal diodes, zener diodes and small signal transistors may be required to the tune of about 46 million (about 37 million transistors, 4 million signal diodes and 5 million zeners) valued at Rs. 5.9 crores in 1978-79. The present installed capacity of these silicon devices is about 42 million (about 39 million for transistors and 3 million for signal and zener diodes). There are six active licensees (BEL, CDIL, SEM, ECIL, EC&T and HC) producing these devices. BEL has the substantial share of the licensed capacity and production. Some of the production of these devices is with imported chips. The policy regarding chip import is separately discussed in Sec. 12.6.1.5. The number of manufacturers of these devices being more than enough, no further licensing is necessary. The demand can be easily met by the existing manufacturers. They may, however, need supplementary equipment including that for improved methods of assembly and encapsulation, whiskerless construction for diodes/zeners and MIL-specification testing facilities. This should be permitted.

(b) Rectifiers and Thyristors

Rectifiers will be required, in 1978-79 to the tune of Rs. 5.7 crores (roughly 10 million nos.) including about Rs. 3 crores worth of high current (greater than 30 amp.) rectifiers (roughly 0.15 million nos.) for Railways and other power applications. While there will be a small requirement of germanium rectifiers in the initial years and no special efforts are called for in this direction, it is expected that

XII

by the year 1978-79 most of the rectifiers needed will be of silicon. The present installed capacity of silicon rectifiers is a little over 3 million. Thyristors will be required, in 1978-79, to the tune of Rs. 1.46 crores (roughly 0.18 million nos.) including about Rs. 1 crore worth of high power thyristors (roughly 0.05 million nos.). The present installed capacity of thyristors is about 0.06 million.

BEL is producing one type (1500 V, 1 amp.) of rectifier. ECIL is producing a few types. CDIL and SEM are also producing low current devices mainly for the electronic industry. The major producers of rectifiers presently are Ruttonsha and Hind Rectifiers. There is scope for further licensing in this area. Some of the manufacturers are importing diffused chips and component parts for packages and they sell these devices at fairly high prices. It would be desirable to stop import of chips and encourage these manufacturers to do their own diffusion (see Sec. 12.6.1.5 on chip import). This, besides cutting down the foreign exchange content, would help in growing the technology with deep roots.

There may be need to import technology for high voltage, high current devices (say 3 to 5 kV, 300 amp. rectifiers required by Railways). The technology should cover device fabrication as well as packaging.

(c) Power Transistors and Microwave Transistors

Power transistors will be required to the tune of Rs. 6.0 crores in 1978-79. The germanium and silicon may respectively account for Rs. 1.8 crores (about 3.6 million) and Rs. 4.2 crores (about 6 million). The present installed capacity for power transistors is about 0.1 million each for germanium and silicon. Microwave transistors including microwave power transistors will be required to the tune of 0.007 million valued at Rs. 0.24 crores in 1978-79.

The entire area is of great significance to the professional electronics industry so that indigenous availability of these devices is important. Both BEL and ECIL have made a start in the field. BEL has access to RCA's technology in this field and the communication equipment design in BEL is oriented towards a set of standardised devices over the power/frequency spectrum. ECIL's technology is being locally developed. No further import of technology is called for as the primary base has been created and most of the future requirements can be developed locally.

(d) Microwave Diodes

Microwave diodes will be required to the tune of Rs. 0.6 crores in 1978-79, the requirement in numbers of each type during the Fifth Plan being as shown in table 12.13. These diodes are of great significance to the professional electronics industry. Introduction of this family of devices involves new device and packaging technologies. These diodes are available abroad in pill, cartridge, stud, low inductance plastic packages and ceramic coaxial packages.

These devices should be produced through local development. The production (of at least gallium arsenide based devices) may be undertaken at the proposed semiconductor complex at an appropriate time.

Table 12.13. Numberwise requirement of different microwave diodes during the Fifth Five Year Plan.

Diode type	For microwave LOS communication system			For microwave systems other than LOS communication systems	Total
	2 GHz	4/6 GHz	7 GHz		
Mixer diodes	1800	6400	4000	800	13000
Detector diodes (Point contact/ Schottky barrier)	2250	4000	2500	1300	10050

XII

Varactor diodes	450	3200	4000	900	8550
Tuning varactors	1800	3200	2000	800	7800
Avalanche diodes (Impatt/Trapatt)	—	—	—	50	50
Step recovery diodes	1800	6400	4000	800	13000
P-i-n diodes	—	—	—	10000	10000
Phase detector chips	900	3200	2000	800	6900
Schottky barrier diodes (matched pairs)	900	3200	2000	1000	7100

(Source : Panel on Microwave Components)

(e) Opto-electronic Devices

These devices will be required to the tune of Rs. 1.5 crores with LEDs (about 1 million diode lamps and 0.5 million digits) accounting for about Rs.1.25 crores. The entire opto-electronic devices area is of great importance. However, their production should be based on local R&D. The production of LEDs should particularly be based on a vertically integrated facility including the synthesis of gallium arsenide. The development followed by production of LEDs may be undertaken at the proposed semiconductor complex in collaboration with other competent laboratories.

(f) Integrated Circuits

Integrated circuits will be required to the tune of Rs. 14.7 crores in 1978-79. The capacity for ICs in the country is beginning to be established.

Integrated circuit manufacture calls for considerable investments. Even manufacturers having discrete planar facilities will have to invest not less than Rs. 25 lakhs for equipment and facilities.

(i) Linear ICs

Linear ICs will be required to the tune of about 2 million valued at Rs. 1.9 crores in 1978-79. The demand for these devices in the professional area is not likely to be large. While all firms who are licensed for bipolar ICs could make linear ICs, the production of professional types may rest with those manufacturers who have adequate test facilities and ensure conformity with MIL specifications.

(ii) Digital SSI/MSI

These devices will be required to the tune of about 9.5 million valued at Rs. 5.7 crores in 1978-79. The major contribution to this area is going to come from bipolar logic circuits for which there are three choices namely conventional TTLs (54/74, 54H/74H), Schottky TTLs (54S/74S) and ECL.

ECL is now very commonly used in large computers and Motorola's 10,000 series and Fairchild's 95100 series have become industry standards. The more recent Schottky TTLs are challenging ECLs and may find acceptance in minicomputers. Bipolar logic circuits could be made by all companies who are licensed for bipolar ICs.

(iii) LSI

These devices will be required to the tune of about 0.5 million valued at Rs. 5.0 crores in 1978-79. Memory design and memory manufacture has now become a speciality and the trend in the US is for firms to specialise in these areas. Systems like single chip calculators and microprocessors are also specialities. The rapid growth of MOS LSI memories and its importance to the production of future generation of computers suggest that some immediate steps should be taken to

establish the technology/production as gestation time of such products is of the order of 2 or 3 years.

In order to make such devices available in the country in the near future, the technology for MOS LSI should be imported on a one-time basis. The production may be set up in the proposed semiconductor complex. For bipolar LSI indigenous R&D should be depended upon.

(iv) Hybrid ICs

Hybrid ICs will be required to the tune of about 0.5 million valued at Rs. 2.1 crores in 1978-79. They are useful in professional as well as consumer applications. In the automobile field, hybrid circuits find application as voltage regulators for alternators. The technology can also be used to build passive networks required in large numbers in communication systems. The technology is essential in the microwave area for development and production of MICs.

BEL has a development facility and a few circuits have been developed and used. SPL also has a development facility. BEL is planning to enlarge its facilities to meet its own requirements. ITI is expected to use hybrid circuits in fairly large numbers and may, therefore, need in-house facilities for the production of hybrid circuits.

In view of the close link with professional communication equipment design and development, expansion and creation of new facilities should be planned and necessary support given for import of equipment.

12.6.1.2. Packaging Technology

Packaging materials/components for semiconductor devices is an important area where development/production cannot be neglected. For Rs. 40 crores production in 1978-79, over Rs. 6 crores worth of packaging materials/components will be required. Whereas cans and headers with glass-to-metal seals can be locally made without much import of know-how, in the case of ceramic and other packages for ICs and LSIs import of technology may be necessary. The proposed semiconductor complex should set up a separate division to undertake manufacture of packages. Standardisation of packages is also necessary, for it would help in reducing the number of types required.

12.6.1.3. Import of Technology

Apart from the import of know-how necessary for high voltage/high current rectifiers, MOS LSI and special package, no substantial import of know-how for devices would be necessary for the present. For important areas of bipolar LSI, GaAs microwave devices and liquid crystal display devices, indigenous R&D should be dependent upon as mentioned earlier.

12.6.1.4. Foreign Equity

Steps should be taken to ensure that companies with foreign equity progressively reduce the foreign holdings. Future expansion of such firms should be strictly subject to the stipulations laid down by Foreign Exchange Regulation Act, 1973.

12.6.1.5. Chip Import

Import of chips and packaging has been an easy approach to enter the semiconductor market. Whereas import of chips may be a method to meet the large type diversity requirement, it is undesirable from the point of view of technology growth. Further, such an operation involves little capital expenditure and yields disproportionately high profits. It may therefore be necessary to impose severe restrictions on the import of chips. For example,

- (a) no import of chips may be allowed in respect of large volume entertainment types,
- (b) only firms who actually diffuse and make at least 70 per cent of the devices they market may be allowed to import chips,
- (c) chips may be cleared for import type by type,
- (d) at least 2 sources in the country must be available for any device made by chip import, so that reasonable prices can be established on the basis of competition, and
- (e) chip import may be permitted only in cases where imported packaging material cost plus chip import cost plus shrinkage cost does not exceed the import cost of the devices.

12.6.2. Technology Development

The current status of R&D in semiconductors area in the country has been discussed earlier. It has been mentioned that the facilities are dispersed and no R&D centre is fully equipped. Whereas SSPL is well equipped, they also have very diversified activity in the area of materials and other projects and the facilities for technology development/device development are inadequate. All the laboratories suffer because of poor service support (gas, demin-water, etc.) facilities.

The reasons underlying the lack of progress so far in indigenous R&D effort in the semiconductor technology have been the following :

(a) Diffusely defined goals and inadequate financial grants. In most areas, programmes have been operated at a low key, due to meagre inputs and limited resources.

(b) Reluctance on the part of the manufacturers to set any store by the indigenous R&D effort on the plea that production methods are lacking; and the manufacturer's desire to obtain the know-how needed by him for the manufacture of components in 'cook-book' fashion and the current inability of the local R&D organisation to supply this.

(c) The non-existence of an interface between the R&D scientists and the manufacturing agencies, and the capacity that it breeds in the R&D personnel to grasp the manufacturer's problems and requirements and vice-versa.

(d) Reluctance of influential users to accept products based on indigenous know-how.

While the present R&D laboratories may be strengthened by augmentation of necessary equipment and facilities and increased funding levels, and by collaboration between laboratory and industry ensured by groupings at the stage when projects are initiated, it is to be noted that R&D has better chances of success in an industrial environment as complicated processes are involved and only yields will ultimately determine whether a process is production viable or not. Since limited resources would not permit each manufacturing organisation to have its own R&D to support its activities, it appears necessary to set up a massively funded semiconductor research laboratory/corporation contiguous to a semiconductor house where semiconductor devices involving high level technologies are produced. This could be achieved by setting up the proposed semiconductor complex.

12.6.3. Semiconductor Complex

While the discrete conventional devices area and bipolar ICs would be taken care of by the existing manufacturers, there are gaps involving new area and technologies which the existing manufacturers may not be able to fill owing to these areas presenting a major deviation from their present line of manufacture and also because the future requirement of these devices would be fairly large. These areas include

MOS LSI for calculators, memories and instrument subsystems, GaAs based devices for microwave and opto-electronic applications and packages for LSI.

In view of the above and in order to prevent heavy imports that would arise if these devices are continued to be imported, it is necessary that a semiconductor complex, in the public sector, be set up without delay. Apart from serving as a production unit for these high technology devices, the semiconductor complex is envisaged to have the much needed intensive R&D backup. This semiconductor complex should have all the sophisticated facilities like CAD and ion-implantation facilities.

The product mix or areas of activity of the semiconductor complex would include (i) memories, (ii) calculator chips, (iii) shift registers, (iv) MOS micro-processors, (v) packages, and (vi) LEDs. The complex will be completely vertically integrated starting from single crystal silicon growth to sophisticated mask making. The complex would have an annual turnover of about Rs. 16 crores at full production and is expected to involve a capital investment of about Rs. 12 crores including about Rs. 3 crores for R&D. The running cost may be of the order of Rs. 6.5 crores including about Rs. 2 crores for R&D. The breakup of the turnover would be roughly as follows :

	Turn-over (in Rs. crores)
LSI	12.50
LEDs	1.50
Packages	2.00
Total	16.00

12.6.4. Long Term Production

It may be seen from Table 12.11 that the demand of semiconductor devices beyond 1978-79 will grow on the same pattern as that for earlier years except for the fact that demand of ICs and particularly LSI will grow faster. The long term production of semiconductor devices would, therefore, involve only an expansion of the activities that would have already be initiated. This, of course, is subject to the condition that no major changes occur in the semiconductor technology.

12.6.5. Capital Equipment Production

The requirement of capital equipment over ten year period may be about Rs. 26 crores with Rs. 11 crores during 1974-75 to 1978-79 and about Rs. 15 crores during the next five years. These equipment will include mask making equipment, CAD facilities, ion-implant equipment, diffusion furnaces, epitaxial reactors and a line of conventional equipment for photo-lithography, probing, scribing, bonding, encapsulating, testing, etc. Considering the magnitude of foreign exchange involved in importing these equipment, it appears necessary to initiate steps to produce at least some of these equipment in the country. However, pseudo-manufacture involving kit import and assembly may not be permitted. Proposals for setting up industries to make these equipment should be considered on a case by case basis, taking into account the import content and the ultimate cost to the local industry.

12.6.6. Materials for Semiconductor Devices

The semiconductor industry will require material worth about Rs. 11 crores in 1978-79. The materials include metals and alloys, high purity metals, semimetals and semiconductors, conductive and resistive parts, glasses and ceramics including alumina substrates, high purity chemicals, photomask materials and plastics including moulding compounds.

About 80 per cent of the present requirement of these materials is being met through imports. While every effort may be made to produce these materials indigenously, the import of some of the materials would be inevitable, for the production of all the materials in the country would hardly be possible in view of the variety and small volume requirements in a number of cases. In the interests of the growth of semiconductor device industry, the import levies on the materials must be brought down considerably from its present high level. Steps need also be taken to hasten the process of clearing an item for import by DGTD.

12.7 Investment Forecast

12.7.1 Production Investments

A total capital expenditure of Rs.43.5 crores over the ten year period is forecast with the following breakup.

	Capital expenditure (in Rs. crores)
Land and building	8.7
Equipment	26.1
Service and support facilities	8.7

Service and support facilities include provisions for air conditioning, gas facilities, demineralised water facilities, compressed air and installation expenditure. Also, electric power substation and cabling are included.

The part of the capital expenditure to be incurred in the first five years may be of the order of Rs. 18.5 crores with Rs. 3.7 crores, Rs. 11.1 crores and Rs. 3.7 crores required, respectively, for land and building, equipment and service and support facilities. The breakup of this investment of Rs. 18.5 crores according to agencies likely to undertake the production would be as follows :

	Investment (in Rs. crores)
Semiconductor Complex	12.0
BEL, ECIL and other public sector industries	4.0
Private sector	2.5
Total	18.5

The proposed semiconductor complex would involve about Rs. 4.8 crores in land and building and service and support facilities and about Rs. 7.2 crores in equipment. These include a total of about Rs. 3 crores for R&D facilities. The equipment in the semiconductor complex would include sophisticated mask making facilities and ion-implantation machine.

12.7.2 R&D Expenditure

The investment of Rs. 12 crores in the semiconductor complex includes Rs. 3 crores for R&D facilities in it. The recurring expenditure on R&D would be of the order of Rs. 2 crores.

The funding support for other existing laboratories and academic institutions is difficult to determine. However, the level of funding would have to be adequate. A provision of Rs. 9 crores over the ten years may be made for R&D expenditure in these laboratories and institutions.

XIII

Passive Components

13.1 Introduction

The growth of electronics industry depends, to a large extent, on the status of the component industry. The wide variety of components used in electronic equipment may be grouped under various heads depending upon the characteristics and/or the nature of application of the components. The broad classification that is generally followed consists of identifying them as active components, passive components electromechanical components and other miscellaneous components. While many of the components may be identified as belonging distinctly to one or the other classes mentioned above, it is rather difficult to do so for several others. In the absence of any universally accepted list of components in each category, the identification of a component as belonging to a particular category is often based on the need of the time. This is particularly so with regard to the latter three categories.

In the present context, passive components have been dealt with under two headings:

(A) General Passive Components; and

(B) Microwave Passive Components.

The following components are included in the category of general passive components:

1. Resistors (fixed and variable)
2. Capacitors (fixed and variable)
3. Loudspeakers
4. Microphones
5. Crystals
6. Magnetic heads
7. Cartridges
8. Stylii
9. Magnetic tapes
10. Ferrites (soft and hard)
11. Transformers, chokes and coils (including TV deflection components)

Microwave passive components include general purpose microwave components like couplers, attenuators, terminations, connectors, special purpose microwave components like filters of various types, high power components, investment-cast components required for specific purpose, etc.

A. General Passive Components

13.2 Current Status

While integrated circuits have afforded a major thrust in technology that may be expected to affect significantly the future of discrete components, the overall growth of electronics has been such that a large demand still continues for the discrete passive components. Functions involving tuning, filtering, power levels in excess of a few watts, realisation of high inductances, high capacitances and low resistances, operating into highly reactive loads, etc.,

will continue to need discrete components as long as integrated circuits are based on planar technology. Different design concepts have to be developed and tested before the discrete components can be completely replaced by ICs in communications use. Further, a user will not easily replace discretely by ICs unless the economics is distinctly favourable. These factors indicate that passive components would continue to be in great demand for a considerable time in the future.

Passive components have been the pace-setters for the electronic components industry in the country. Starting with two small scale units producing resistors and capacitors in the early fifties, the industry grew gradually with some radio manufacturers going into the production of a few types of passive components such as paper capacitors, IF transformers, etc., mainly for captive use. With the setting up of Public Sector industries like BEL, ITI and ECIL and the rapid growth of the consumer electronics industry, the production of passive components grew steadily. The production in the organised sector over the last four years is given in table 13.1. A significant production of these exists in the small scale sector also. In the absence of precise information regarding production figures, it is estimated that the total production in this sector is around 30% of that in the organised sector. The production of transformers, chokes and coils is widely distributed and includes several manufacturers of consumer and professional electronic equipment who have in-house facility for winding transformers and coils. The production of EHT transformers and linearity coils for the television industry, however, maintains a separate identity. Production of items like magnetic heads, cartridges and styli is largely confined to small scale sector. Further details of production of passive components in the country are discussed in the later sections.

Table 13.1. Production of passive components in the organised sector during 1970-1973.

(Quantity in million Nos. Figures in brackets represent values in Rs. million).

Item	1970	1971	1972	1973
Resistors	65.5 (11.8)	97.0 (15.5)	83.0 (16.2)	143 (20.4)
Capacitors	89.8 (34.6)	104.8 (40.34)	82.5 (40.2)	96.5 (35.6)
Loudspeakers	2.188 (19.18)	2.235 (17.20)	2.314 (19.37)	2.42* (20.42)
Crystals	0.124 (6.057)	0.20 (10.33)	0.216 (11.455)	0.257 (13.33)
Permanent magnets	367.7 tons (23.84)	400.1 (26.91)	339.57 (22.13)	260.6 (20.5)
Magnetic tapes	—	—	21.24 mil.ft (0.54)	85.80 mil.ft (1.29)
Ferrites	164.45 tons	99.77 tons	116.73 tons	155.77 tons
Soft	(7.88)	(5.00)	(5.685)	(7.28)
Hard	2.38 tons (0.34)	7.44 tons (0.435)	56.91 tons (1.567)	115.95 tons (2.635)
IFTs & IF coils	—	—	4.25* (3.50)	3.0* (4.5)

* estimated figures.

XIII

The import of passive components during 1973-74 is estimated to be Rs. 2.8 crores, mainly for professional use. Export is being built up for some types of passive components over the last few years. About Rs. 90 lakhs worth of resistors and capacitors have been exported during 1973.

Details regarding the current status, the anticipated demand and suggested guidelines for development and production for various types of passive components are described in the following.

While the production of passive components in the country is fairly well established, it is largely confined to the consumer grade types, and to a limited extent, to the industrial grade. The production of defence grade components is small in comparison to other types. While foreign collaborations and foreign know-how have been deployed in setting up the production, the technology has been well absorbed and disseminated at large for several types of passive components. Several manufacturers, including small scale industries, have also developed indigenously some of the production machinery needed.

Production details of various types of passive components along with the estimated value of import during 1973-74 are given in Table 13.2. An analysis of the consumption of various types of components and total electronic equipment production in the past (Ref. IPAG Analysis Report No. 22) indicates that the percentage contribution of various types of components to the total equipment cost has been more or less the same so far and is likely to continue to be so. The average percentage contributions for various types of passive components under consideration are as follows:

Component	Percentage
Resistors	1.80
Capacitors	3.70
Loudspeakers	1.80
Magnetic heads	0.04
Crystals	0.90
Magnetic heads	0.04
Cartridges & stylii	0.13
Ferrites (Total)	1.10
Soft	1.00
Hard	0.10
Transformers, chokes & coils (Including TV deflection components)	5.20

The present status of the industry, the developments under progress, current trends in technology and usage with respect to each type of passive component are described below.

13.2.1. Resistors

A large number of firms, both in the organised and small scale sectors, are producing resistors of almost all types. The types of resistors which are extensively used are the carbon resistors, both composition and the film types, metal film and metal oxide film resistors and the wire-wound resistors in the category of fixed resistors, and the carbon track, wire-wound and cermet resistors in the category of variable resistors. Apart from these, there are

XIII

Table 13.2. Status of passive components industry in India.
(Quantity in million nos. Figures in brackets represent values in Rs. million).

Item	Licensed capacity	Letters of intent issued	Installed capacity	Production in 1973-74			Imports*
				Organised sector	Small scale*	Total	
1	2	3	4	5	6	7	8
1. Resistors (fixed)							
Carbon film	203.0	394.0	132.95	164.0 (124.0)	30.0 (26.0)	170.0 (136.0)	7.0 (70.0)
Metal film/ metal oxide/ high stability types	14.0	30.0	6.0	0.52 (12.0)	0.15 (4.0)	0.67 (16.0)	0.83 (20.0)
Wire-wound	2.25	0.05	2.05	0.91 (4.50)	1.3 (6.5)	2.21 (11.0)	2.5 (15.0)
Thermistors & Varistors	4.0	3.0 + 13 tons	2.50	1.17 (9.98)	0.4 (3.3)	1.57 (13.28)	0.93 (9.0)
2. Resistors (variable)							
Carbon track	11.4	17.0	4.0	4.78 (67.0)	2.0 (30.0)	6.4 (98.0)	0.6 (10.0)
Cermet/wire- wound	0.50	—	0.50	NA	NA	NA	—
3. Capacitors (fixed)							
Paper	12.1	0.60	10.3	3.80 (34.3)	1.0 (8.1)	5.53 (47.0)	1.5 (10.0)
Plastic film	114.7	347.5	67.92	33.5 (97.71)	7.25 (26.5)	39.0 (139.0)	5.0 (15.0)
Electrolytic aluminium	49.3	150.5	22.4	13.1 (177.8)	5.0 (50.0)	17.0 (156.5)	1.0 (10.0)
Tantalum	0.75	13.25	0.30	0.15 (19.36)	Nil	0.13 (15.36)	0.37 (15.0)
Ceramic	97.0	375.0	49.0	51.4 (79.5)	4.0 (7.0)	50.3 (79.0)	26.0 (35.0)
Mica	24.4	—	24.4	1.66 (9.5)	0.9 (5.0)	2.56 (14.5)	0.44 (2.0)
4. Capacitors (variable)							
Gang condensers	5.0	13.0	3.5	2.40 (108.3)	0.80 (35.0)	3.11 (143.0)	0.30 (15.0)
Trimmers	23.24	46.5	8.64	6.6 (23.4)	2.1 (7.3)	8.5 (30.0)	5.5 (20.0)
5. Transformers, chokes & coils							
TV deflection components	0.08	1.0	—	—	—	—	—
IFTG & coils	4.23	—	—	3.0 (45.0)	—	—	—
IP/OP transformers	—	—	—	—	—	—	—
Loudspeakers	3.54	8.0	2.7	2.64 (226.0)	0.75 (90.0)	3.17 (294.2)	0.09 (9.0)

XIII

1	2	3	4	5	6	7	8
Microphones	0.01	0.12	NA	0.1 (45)	—	0.1 (45.0)	—
Crystals	0.25	—	0.25	0.247 (122.5)	—	0.257 (133.3)	(10.0)
Magnetic heads	—	0.05	—	—	—	—	—
Cartridges	0.30	—	0.25	0.087 (13.03)	0.19 (13.0)	0.1 (10.0)	—
Stylii	0.35	1.5	0.20	—	0.08 (0.70)	0.08 (0.20)	—
Magnetic tape	110 mmts	5.45 mmts	80 mmts	28.25 mmts (15.5)	5.25* mmts	31.0 mmts	—
Ferrites					(2.5)	(15.4)	
Soft	350 tons	575 tons	125 tons	155.10 tons (72.0)	50 (24.0)	205.77 (96.8)	70 tons (30.0)
Hard	580 tons	—	250 tons	134.0 (31.00)	—	116.0 (26.35)	—
Permanent magnets	742 tons	—	742 tons	284.6 (224.0)	—	260.6 tons (205)	—

*estimated figures.

a few other types like thermistors and varistors. Fixed resistors can be classified as:

- 1) General purpose carbon resistors (film & composition types) and wire-wound resistors
- 2) High stability precision resistors (carbon film, metal film, oxide film, metal glaze and precision wire-wound types)

Carbon composition resistors are relatively inexpensive, small in size and, in the insulated form, reliable enough for professional use. Despite their replacement by other types like carbon film and metal film resistors, there is a significant consumption of the composition type resistors. Although one firm has been licensed, there is no regular production of this type in the country and the requirements are almost entirely met with by imports.

Carbon film resistors are essentially general purpose resistors and are being manufactured in large quantities by several industries like ECIL, Asian Electronics, Philips India, Baroda Electronics, Rescon and Eastern Electronics. These are available in the range 10 Ω to 5M Ω . While the entire production is suitable for consumer use, carbon film resistors of the professional grade are being made by a very few number of firms and considerable import still continues. The carbon film resistors are usually made in the non-insulated form. The insulated type, while being desirable from the point of view of professional applications, are not attractive owing to increased cost and size. Export of carbon film resistors in sizeable numbers started around the year 1970 and the present level of export is about 70 million numbers.

Metal film and metal-oxide film resistors are replacing carbon film resistors in many cases owing to their superiority over the latter in respect of reliability, size, ruggedness and temperature coefficient of resistance. Metal film resistors are known to be even superior to metal oxide film resistors in respect of the characteristics indicated above. They are, however, larger in size. Metal film resistors, both the insulated and non-insulated types are being produced by ECIL and Asian Electronics. Some types of metal film resistors produced in the country have been type approved for professional use.

Fixed wire-wound resistors are generally used when higher power dissipations are involved. They are better in respect of temperature coefficient and smaller in size than the metal oxide resistors of corresponding wattage. These resistors are usually produced either in vitreous enamel or silicone coat finish. Wire-wound resistors are being produced in the country by a large number of firms mostly in the small scale sector. While the demand for fixed wire-wound resistors for consumer application is being met from indigenous sources, the demand for professional requirements is being met mostly through imports.

Variable resistors (potentiometers) of the wire-wound type are being produced in the country by many firms such as ECIL, Pankaj Electricals, Analog and Digital Measurements, Indian Electronics, and R. V. Mehta and Sons. A variety of wire-wound potentiometers such as sine/cosine, servo, slide wire, rectilinear and helical type potentiometers, including the precision types, are being produced by ECIL. Except for some professional applications, the demand for wire-wound potentiometers is being met from indigenous sources.

The nonwire-wound type of variable resistors (carbon track potentiometers) are being produced in a limited range by Philips India, Kel Components, Eastern Electronics, M. R. Electronics, etc. Development of cermet trimmers of the unsealed variety has reached an advanced stage. A considerable amount of ceramic trimmers are, however, being still imported for professional applications.

Thermistors and varistors are being produced in the country by a few firms. In some cases indigenous know-how has been used for production. Some of the major manufacturers of these components are Semiconductors Ltd., Tempo Semiconductors and Shekhar Electronics. Import of thermistors and varistors, however, still continues for some special applications.

The overall picture that emerges out of the resistor industry in the country is that a substantial production has been established and the competence is being built upto satisfactory levels. Industrial grade and some types of defence grade resistors are being produced. However, the regular production of several types of resistors to meet stringent defence specifications is yet to be established. Some of the manufacturers have also developed the production machinery.

Several manufacturers and some of the research and development organisations have been putting continuous development efforts to upgrade the existing products and develop and/or absorb the know-how for the newer technologies such as metal oxide film resistors, thick film resistive networks, etc.

13.2.2. Capacitors

There is a large number of big and small, firms in the country producing various types of capacitors. Among the fixed capacitors, the types which are in use are the paper, plastic film, electrolytic, ceramic and mica capacitors and a few special types such as glass and vitreous enamel based capacitors. Among the variable capacitors the gang-condensers with air or plastic as dielectric medium and trimmers with mica or PVC as dielectric are common. Some special varieties like ceramic, glass or quartz dielectric types are also being used.

The paper capacitor industry is one of the earliest to be set up in

the country. Paper capacitors are now being largely replaced by plastic film capacitors. However, they are still needed in significant quantities for high voltage (upto 10 kV DC) applications. Some types of high voltage paper capacitors are being produced by ITI, Bush, Remco, Nippon, etc.

Plastic film capacitors are produced by a large number of firms in the country. All the three types viz., polyester, polystyrene and polycarbonate types are being extensively used. Polyester capacitors are replacing the paper capacitors owing to their higher dielectric strength, better capacitance stability, smaller size and lower losses. Some firms like Philips India and Bush, produce the foil type polyester capacitors while others like Asian and Nippon produce the metallised polyester capacitors. Polystyrene capacitors are characterised by very low dielectric loss, low temperature coefficient, high insulation resistance and capacitance stability. Unprotected type polystyrene capacitors are being produced by Nippon Electronics, Asian Electronics, Peak Electronics, Uranus, etc. Some of the manufacturers are attempting to produce the protected type. Hermetically sealed types for professional applications are not being made in the country. Polycarbonate capacitors have better capacitance stability than polyester types. They are, however, bigger in size and higher in cost for a given capacitance. The plastic films needed for these capacitors are being imported. The know-how for plastic film capacitors is well established and competence exists in the country for making some of the production machinery needed.

Electrolytic capacitors in use are of two types, namely the aluminium and tantalum electrolytic capacitors. Both of them can be either wet type or solid type. Wet aluminium type is of poorer tolerance but has the advantage of larger capacitance range and higher working voltage. The solid aluminium capacitor, on the other hand, has better capacitance stability, lower leakage, smaller size and a wider temperature range of operation. While wet aluminium capacitors are being produced by many firms like Philips India, Bush, Rescon, etc., solid aluminium types are yet to be produced in the country. Tantalum electrolytic capacitors are superior to aluminium types in respect of size, operating voltage, leakage current and capacitance stability. Wet tantalum capacitors offer higher capacitance values than the solid and foil types. While solid tantalum capacitors are being produced by ECIL, the production capacity is rather small. Dipped and moulded tantalum capacitors are known to be under development at ECIL. Development work is in progress at CECRI for solid tantalum capacitors.

Ceramic capacitors of a wide variety are being used in the electronics industry. They may be broadly classified as follows.

- (i) Low voltage types (up to 90 V rating)
- (ii) Medium voltage types (up to 500 V)
- (iii) High voltage types (up to 5 kV)
- (iv) Temperature compensated types
- (v) High voltage, high RF-current types
- (vi) Feed-through, and multilayer types

The low voltage types are being produced by BEL, Philips India, and Asian Electronics. Some of the high voltage types are being produced at BEL and on a pilot scale, at NPL. BEL is exporting ceramic capacitors in large quantities. The zero temperature coefficient miniature tubular ceramic capacitors are not being produced in the country. These are used in transistor radio sating type, larger size, high permittivity, ceramic capacitors are produced

by Philips India in tubular form and by BEL in disc form. Some types of these indigenous ceramic capacitors are known to meet the professional standards. High voltage ceramic capacitors beyond 8 kV rating and those that can withstand high RF current, are not produced in the country in significant quantity. The medium voltage types which are extensively used in the tube light industry are being produced by BEL and Microceramics. R&D efforts are being put in at NPL for several types of ceramic capacitors.

Mica capacitors are useful for high voltage, high temperature, high insulation resistance and low power factor operations. These are relatively inexpensive and smaller in size. Moulded and dipped type mica capacitors are being made in the country by BEL, Peak Electronics, Kemet Traders, etc. Some types of high voltage mica capacitors are being produced by Kemet Traders.

Apart from the above, other types of capacitors like vacuum capacitors, oil filled capacitors and capacitors withstanding high RF current and very high voltages are used in electronics. While their requirements are relatively small, their unit cost is high.

The production of variable capacitors had until recently, been relatively low. Production is now being strengthened and to a limited extent, the professional types are also being produced. The air dielectric variable (gang) condensers for consumer applications are being replaced by plastic dielectric gang condensers. Some of the major manufacturers of these are Murphy India, Philips India, Remco, Eastern Electronics, Bush and Asha Brothers. Air dielectric gang condensers (single and multi-gang) used for professional applications are being imported in significant quantities. Attempts are being made to produce indigenously air dielectric gang condensers of professional standards. Among the trimmer capacitors, the air dielectric types are popular in professional applications because of high stability with respect to temperature variations. Ceramic trimmers are also used to a large extent in view of their advantages by way of smaller size and stability against shock and vibrations. Mica trimmers are used in consumer applications and only in a limited way for professional applications. Glass and quartz dielectric trimmers are perhaps the best of all as far as professional requirements are concerned. They are stable against shock and vibration and superior to ceramic trimmers in respect of temperature coefficient, operating temperature ranges and working voltage. Ceramic, glass and quartz type trimmers are not being produced in the country and there is a sizeable import of these every year.

R&D work is being carried out in many of the capacitor plants to upgrade them to meet stringent specifications. Development of wet tantalum, dipped solid tantalum and high voltage RF mica capacitors, and thick and thin film capacitors are some of the projects in progress in the country at places like BARC, ECIL, CECRI, etc.

13.2.3. Loudspeakers

The major share of consumption of loudspeakers is in the consumer electronics field. They account for nearly 4 per cent of the total cost of components in consumer electronics applications. A large number of firms, small and big, are manufacturing loudspeakers and good production base exists in the country to meet the requirements. The Alnico type permanent magnets used in loudspeakers are being rapidly replaced by ceramic magnets as the latter are

XIII

economical and also permit design of shallow and compact speakers. Some of the manufacturing organisations have been carrying on R&D work to improve the performance characteristics and efficiency of loudspeakers. Competence exists in the country to produce high quality speakers. Component parts for loudspeakers such as permanent magnets, frames, spiders, cones, etc., are being produced by several small scale industries.

13.2.4. Microphones

The major types of microphones that are used in electronics are the moving coil microphones, condenser microphones, ceramic microphones and electret microphones. The moving coil type is a general purpose microphone having a wide frequency response and low output impedance. Condenser microphones are of the high quality type having high sensitivity. Ceramic microphones are being used in tape recorders and public address systems and are also of the high sensitivity type.

The production of microphones in the country is at a low level and is mainly confined to a few medium and small scale industries. ITI has developed the know-how for microphones used in handset and headgear assemblies. CEERI, Pilani has developed know-how for several types of microphones. A special purpose microphone (geophone) has been developed at NGRI, Hyderabad and pilot plant scale production is being set up.

13.2.5. Crystals

The crystals under consideration essentially refer to quartz crystals used in oscillator and filter circuits. They are fabricated from natural and synthetic quartz. The natural quartz available in the country has not been much useful in the production of crystals so far.

The production of crystals is presently confined to BEL, Bangalore who produce them mainly for captive use. The frequency range covered is from 16 KHz to 125 MHz. BEL also produces, in limited quantities, associated items such as ovens for temperature controlled operation of crystals, crystal filters, etc. A unit is being set up by the Kerala State Electronics Development Corporation for production of crystals.

13.2.6. Magnetic Heads

Magnetic heads form an important component of all sound recording and reproducing equipment and the quality of the magnetic head essentially determines the fidelity of the system. While 'Erase' and 'Record' operations are carried out in many cases with separate magnetic heads, a single unit for both the operations is becoming more popular.

Regular commercial production of magnetic heads is just being established in the country. Letters of intent have been issued for producing 50,000 heads per year. CEERI, Pilani, has developed a magnetic head with track width of 0.1 inch and frequency response within ± 2.5 dB from 50 Hz to 12KHz for the spool type. Magnetic head for cassette tape recorders is under development at CEERI.

13.2.7. Cartridges

Cartridges are used in turntables or record changers to translate the mechanical vibrations of the stylus into electrical impulse. Ceramic cartridges are used in most of the record playing equipment. For high fidelity repro-

duction, magnetic types are preferred. In stereo systems two cartridges are contained in a single unit, each cartridge producing the voltage for one of the channels. A single stylus can drive both cartridges in a stereo system. Cartridges made of bimorph crystal of Rochelle salt give larger output voltages. The newer types of cartridges are made of semiconductor materials in which a change in the dimensions results in a change in the electrical resistance.

Production of cartridges in the country is largely confined to small scale industry. Cartridges both for mono and stereo record players are being produced by Electrical & Electronic Industries Calcutta, Gramophone Co. of India Ltd., etc.

13.2.8. Stylus

Reproduction of sound from a record is accomplished by the stylus whose mechanical vibration is converted into electrical energy by the cartridges. Styli are differentiated in terms of tip radius and tip material. While for normal records (78 rpm) the tip is 3 mil in diameter, those required for stereo records and long play records is generally 0.5 mil to 1 mil in diameter. Stylus tip is made of diamond or synthetic sapphire. Soft sapphire tips are cheaper and have an average life about 125 hours while diamond tipped styli are hard, expensive and have much longer life. Presently, the production level is estimated to be about 80,000 styli per year and is confined to very few industries. The Gramophone Co. of India Ltd., and Electrical & Electronic Industries, Calcutta, are known to be producing styli.

13.2.9. Magnetic Tapes

Magnetic tapes find extensive application in audio, video and data processing equipment. For a considerably long time the use of magnetic tapes in the country was mostly confined to professional use in organisations like AIR, Defence, Civil Aviation Department, etc. However, with the advent of the cassette tape recorders, magnetic tape has become a consumer item and consequently the demand has increased several folds.

Present production in the country is only of audio tapes. These are being produced by several industries like Jai Electronics, Tarzian, Magnotape Co., and Vimal Enterprises, to quote a few. Indigenous know-how has been developed to the stage of pilot plant production at NPL. Gamma ferric oxide is being developed at NCL also. While triacetate films could be used as the base material for nonprofessional use, polyester is preferred because of its extra strength, flexibility, low water absorption and high insulation resistance and this material is being imported.

13.2.10. Ferrites

Ferrites find wide application both in consumer and professional electronics (for antennas, TV deflection yokes, pot cores, etc., in communication circuits, memory cores, etc.). Realising the importance of ferrites in electronic equipment, the Department of Electronics constituted a Technical Panel on Ferrites in January, 1972. The Panel submitted its report in February, 1973. The Panel has examined in detail all the aspects connected with the development and production of ferrites needed in the electronics industry.

Several manufacturers like Semiconductors, Morrite and Elpro at Poona, Ferroelectrics at Hyderabad, Permanent Magnets, Bombay, and Ferrites & Electronic Components, Bangalore are producing ferrites in the country. In

the case of simple ferrites (like radio ferrites), there are about six manufacturers in India. However, the production of antenna rods is running below full production capacity. It is estimated that total installed capacity for such ferrites in the country is about 5 million rods. Expansion of production facilities is being planned by several of the leading manufacturers.

NPL has developed a process of mixing ferrite powder with plastic moulding powder, moulding the part to close tolerance and sintering. Local manufacturers are using imported thread cutting machines to obtain close tolerances. Pilot production on some ferrite parts for use in TV has been started, based upon the developments made by NPL. The TV ferrites developed by NPL (both 1030 and 1040 types) have been supplied to manufacturers of TV deflection components for large scale testing. However, pot cores of desired quality are still not manufactured in the country although some headway has been made by NPL. Production of 80 mil and 50 mil ferrite memory cores on large scale has been set up at NPL. The present trend is, however, to use 18/20 mil cores.

In case of microwave ferrites, SPL and NPL have done some development work. NPL and NCL have done significant work on hard ferrites. Some manufacturers have set up production facility for hard ferrites. A few soft ferrite manufacturers have set up additional hard ferrite facility for 250 tonnes per annum. Recently, another project involving foreign equity has been approved to produce 120 tonnes hard ferrites per annum (in addition to 80 tonnes per annum for export). A few small scale manufacturers are expected to produce 100 tonnes per annum. It is estimated that in the case of hard ferrites, a capacity of about 700 tonnes per annum would be available shortly. Gamma ferric oxide for magnetic tapes has been developed by NPL and NCL.

13.2.11. Transformers, Chokes & Coils

Transformers, chokes and coils are components, the demand for which has been relatively unaffected by the advent of IC technology. A wide range of transformers is needed in the electronics industry. While input/output transformers, intermediate frequency transformers and EHT transformers are needed in large quantities in both consumer and professional sectors, a large number of other types such as pulse transformers, differential transformers and high power rated types including modulation transformers are also needed for special applications.

Apart from a large number of small scale industries, many of the Professional and consumer electronic equipment manufacturers have in-house facilities for producing transformers, chokes and coils. Production of TV deflection components based on indigenous know-how has started and a sizeable number of firms have been licensed. With the growth of power electronics industry, transformers for operation in the range 3 kVA to 50 kVA are finding increasing use. Some types of coil winding machines are being fabricated in the country while many of the special types are being imported.

13.3 Demand Forecast

The overall growth of electronic equipment production and the extent to which hybrid and monolithic integrated circuits can be used both in consumer and professional electronic equipment together govern the pattern of demand in the future for passive components. As pointed out earlier, there are reasons to expect a sizeable requirement of the passive components

for a considerable time in the future. National and international market trends for passive components and the market forecasts published for various countries strongly support this view. Hence the percentage contribution of various types of passive components to the total component/equipment cost is not likely to change significantly for some considerable time. The rate of growth of demand may, however, be expected to decrease more rapidly during the Sixth Plan period and beyond.

Consumer electronics accounts for a major fraction of the requirement of passive components. The Bhabha Committee had envisaged a production target of about Rs. 75 crores by 1975 in the area of consumer electronics. This, however, did not take into account the growth of the television industry. With the starting of the television industry, the growth is expected to be higher and is expected to reach a level of about Rs. 100 crores by 1975. The radio receiver industry would still be a key factor for the growth of passive components industry. The demand for radio receivers, while nearly saturated in the urban areas over the past few years, is likely to grow in view of the anticipated promotional measures for the growth of radio receiver industry and the penetration of the vast unexplored rural markets. If adequate promotional measures are initiated in time, it is expected to nearly double over the next five or six years. The television industry which is still in the nascent stage is expected to grow steadily in the future. A large growth is expected for tape recorders also. While the growth in demand for record players and record changers is expected to be marginal, the demand for stereo systems, PA systems and miscellaneous items like electronic kits, toys, clocks, musical instruments and hearing aids is likely to grow at about 20 per cent rate over the next decade.

The production of professional electronic equipment has been growing uniformly since the time of Bhabha Committee report. An analysis of the yearly production of professional equipment by the major public sector undertakings indicates that the total production of professional equipment is likely to increase to at least twice the present value by the end of the Fifth Plan.

The Panel on Passive Components constituted by Electronics Commission has estimated the demand for various types of passive components taking into account the anticipated growth of the electronics both in the consumer and professional sectors, the role of passive components in these areas, and the likely impact of newer technologies on the growth in demand for different

Table 13.3. Estimated demand pattern for passive components*.
(Values in Rs. crores)

(1)	Average	1974-75	1975-76	1976-77	1977-78	1978-79	1983-84	Total re-	Total
	unit cost (Rs)							quirement during Fifth Plan period	requirement during Sixth Plan period
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1. Resistors (fixed)									
Carbon film	0.07	0.95	1.20	1.40	1.80	2.10	4.00	7.50	14.00
Metal film/metal oxide film	2.00	0.35	0.45	0.60	0.80	1.00	2.00	3.20	6.50
Wire-wound	0.60	0.42	0.53	0.64	0.75	0.90	2.00	3.25	6.00

XIII

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Thermistors & varistors	0.80	0.07	0.09	0.12	0.16	0.21	0.50	0.65	1.50
2. Resistors (variable)									
Carbon track	1.60	1.40	1.80	2.40	3.00	3.60	7.00	12.20	22.00
Wire-wound/cermet	5.00	0.40	0.50	0.65	0.80	1.00	2.20	3.35	6.00
3. Capacitors (fixed)									
Paper	0.80	0.80	0.85	0.90	0.95	1.00	1.20	4.50	6.00
Plastic film	0.36	1.80	2.20	2.80	3.40	4.00	8.00	14.20	25.00
Electrolytic (Al)	0.80	2.00	2.60	3.40	4.20	5.00	12.00	17.20	28.00
Electrolytic (Ta)	12.00	0.40	0.55	0.70	0.85	1.00	3.00	3.50	7.00
Ceramic	0.16	1.50	1.80	2.20	2.60	3.00	7.00	11.10	20.00
Mica	0.56	0.45	0.55	0.70	0.85	1.00	2.00	3.55	5.00
4. Capacitors (variable)									
Gang condensers	4.80	2.20	2.70	3.40	4.20	5.00	11.00	17.50	35.00
Trimmers									
Consumer electronics	0.50	0.50	0.80	1.10	1.60	2.00	4.00	6.00	12.00
Professional electronics	2.00								
5. Loudspeakers	8.00	4.20	5.10	6.20	7.50	9.00	18.00	32.00	60.00
6. Microphones	45.00	1.00	1.50	2.00	2.50	3.00	10.00	10.00	20.00
7. Crystals	45.00	1.70	2.20	2.80	3.70	4.60	9.00	15.00	30.00
8. Magnetic heads	10.00	0.30	0.40	0.50	0.60	0.70	1.20	2.50	6.00
9. Cartridges	10.00	0.30	0.35	0.42	0.48	0.60	1.20	2.15	5.00
10. Stylii	8.00	0.42	0.48	0.57	0.70	0.82	1.80	3.00	6.00
11. Magnetic tape									
(a) Consumer use	0.30	2.00	3.00	4.20	5.30	7.00	12.00	21.50	45.00
per metre									
(b) Professional use	1.00	1.80	2.40	3.30	4.50	6.00	12.00	18.00	40.00
per metre									
12. Ferrites									
(a) Soft	60,000	1.60	2.00	2.50	3.20	4.00	8.00	13.30	35.00
per tonne									
(b) Hard	52,000	1.00	1.30	1.70	2.20	3.00	6.00	9.20	25.00
per tonne									
13. Transformers, chokes & coils:									
TV deflection components	50.00	0.40	0.60	1.00	2.00	3.00	10.00	7.00	15.00
IFTs & coils:									
Consumer electronics	0.70	1.80	2.40	3.00	4.40	5.20	12.00	16.80	28.00
Professional electronics	3.00	0.35	0.45	0.60	0.80	1.00	2.50	3.20	6.00
IP/OP transformers									
Consumer electronics	10.00	6.00	7.00	8.00	10.00	12.00	25.00	43.00	85.00
Professional electronics	—	7.00	8.20	10.30	12.50	15.00	30.00	53.00	100.00
14. Permanent magnets	65,000	1.50	1.60	1.80	2.00	2.10	3.50	9.00	12.00
per tonne									

*The figures are exclusive of export figures.

XIII

types of passive components. Based on the finding of the Panel, the demand pattern for passive components has been arrived at and presented in Table 13.3.

The demand pattern indicates that, on the average, the demand for passive components towards the end of Fifth Plan would increase to nearly three times the present requirements. While the growth in demand is expected to be low for some types of passive components, a steady growth is anticipated for many others.

Increasing usage of carbon film and metal film resistors both for professional and consumer applications is envisaged. The carbon composition resistors are being replaced by carbon film resistors except in some cases where size and high frequency performance are critical. High stability, precision resistors and professional grade resistors of the carbon film, metal film metal oxide film, metal glaze and wire-wound types, though required in relatively less quantities, account for a significant fraction of the total value. The demand for carbon track, wire-wound and cermet potentiometers is expected to grow nearly in parallel with the growth of the electronics industry.

Among the capacitors, the demand for paper capacitors is not expected to increase much as they are being largely replaced by plastic film capacitors. The demand for plastic film, aluminium electrolytic and low voltage ceramic capacitors is expected to grow at over 20 per cent per year over the next five years. Electrolytic, ceramic and mica capacitors for high voltage and high current operations would be in greater demand. Among the variable capacitors, the future requirement is expected to be mostly for the plastic dielectric type gang condensers and ceramic trimmers. The demand for loudspeakers, microphones and crystals is expected to grow steadily. Increasing use of magnetic ceramics is likely to curb the growth in demand for metal alloy permanent magnets. The percentage contribution of transformers, chokes and coils to the total equipment cost is expected to remain more or less constant over the next decade at least, and hence, the growth in demand for these items would be proportional to that of total electronic equipment production.

13.4 Analysis of gaps

The present status of production and the projected demand for various types of passive components indicated in Tables 13.2 and 13.3, respectively suggest that for many of the items production has to be stepped up considerably. A further comparison of the projected requirements with the total approved capacities for production (Table 13.2) indicates that for some of the components the approved capacity is already much in excess of the anticipated demand in the terminal year of the Fifth Plan. Carbon film resistors, metal film resistors, paper capacitors, plastic film capacitors, aluminium electrolytic capacitors and trimmers are some examples. It may, however, be noted that the progress of implementation has been poor and the installed capacity for most of the components is low in comparison with the projected demand. The know-how for low volume production is fairly well established for many components. However, since a large portion of the requirement of passive components is in the area of consumer electronics, manufacturing efforts have been mainly directed towards producing only consumer grade components. Although several manufacturers both in public and private sectors have been producing some types of components which have been type approved for professional use, the industry is yet to make any significant import of professional grade components, particularly for defence applications. While there

could be several reasons for this, recent trends are, however, indicative of brighter prospects in this regard in the near future.

For some passive components, while the production, in general, is fairly well established, some particular types among them are not being produced in any significant scale. Notable among these, for which the future demand is likely to grow, are capacitors for high voltage and high RF current operations, cermet potentiometers, ceramic trimmers, zero temperature coefficient miniature ceramic capacitors, condenser microphones and magnetic tapes for professional use. Apart from the production of components, an important issue, which is intimately connected with the production and has not been receiving required attention, is the development of production of special purpose machines and test equipments needed for mass production of components.

13.5 Guidelines for Production and R&D

The Panel on Passive Components, constituted by the Electronics Commission, has examined in detail the various aspects connected with the development and production of passive components for a balanced growth of the electronics industry. The recommendations made by the Panel include general recommendations for the overall growth of the passive components industry and specific recommendations for various types of passive components. The Panel has attached special significance to the production engineering and testing aspects of passive components. The guidelines for production and R&D of passive components suggested by the Panel are described below.

The general recommendations are given in Section 13.5.1. The major issues covered in this include broad licensing norms, guidelines for assessing the know-how available in the country, test facilities necessary, development and production of special purpose machines and test equipments and availability of raw materials for the production of passive components. The specific recommendations with respect to each type of component are discussed in Sections 13.5.2 to 13.5.11. It is further felt that the production engineering aspects and testing and evaluation of the passive components need serious and immediate attention for a healthy growth of the industry. In view of this, these two aspects have been dealt separately in Sections 13.5.12 and 13.5.13, respectively.

There have been several occasions when the need for clearly defining consumer and professional grade passive components has been strongly felt. It is recommended that the following definitions be used for distinguishing the consumer and professional grade components.

(a) Consumer grade components are those which meet the category III of the ISI specifications with the exception that the high temperature range may be limited to 40°C only.

(b) Professional grade components are those which meet categories I and II of the ISI specifications and/or JS specifications.

It may be noted that category III of ISI specifications is meant for components used in electronic appliances mainly confined to domestic use such as radio, television, stereo sets, etc. Category I & II are meant for defence and industrial applications.

13.5.1. General Recommendations

On examining the approved capacities, installed capacities and production figures for various types of components and the projected demand, it

XIII

is noted that in several cases, there has been excess capacity approved with the long term requirements in view. Typical examples are carbon film resistors, plastic film capacitors, and aluminium electrolytic capacitors. There have been many cases in which the entrepreneurs have not shown any progress even several years after the issue of letters of intent and which have automatically lapsed.

It is recommended that not more than 70 per cent excess capacity over the projected demand be licensed during the Fifth Plan period. In all such cases, where the licensed capacity is higher than this, immediate action should be taken to revoke licences/letters of intent issued where the parties have not shown progress for over two years from the date of issue of the letter of intent.

For consumer grade components no single firm should be licensed to a capacity of more than 30 per cent of the projected demand. This, however, need not be applicable to export oriented production.

Availability of indigenous know-how has been claimed for many of the passive components and the level at which the know-how is available may be classified as follows:

- (i) Know-how developed at the laboratory level only and not tried for pilot plant scale production
- (ii) Know-how developed and pilot plant scale production established
- (iii) Know-how for which viable production is established with existing manufacturers

Recognising the importance of declaring the availability of know-how in the country, following course of action is recommended in this regard.

A three man committee consisting of representatives from NRDC, DGTD and Electronics Commission/Department of Electronics should be constituted. This committee should evaluate the know-how available on the following basis.

(a) In general the know-how availability can be considered for further action only if pilot plant scale production is satisfactorily tried.

(b) For such components which are exclusively developed for entertainment equipment, the component should be tried for user acceptance by giving the same to three, or more, reputed user organisations. Further, the component should be evaluated against category III of the ISI specifications (with the exception that high temperature range may be limited to 40°C only) and the necessary certificate produced from one of the national test centres.

(c) For such of those components which are used in entertainment and professional equipment, the component should be tried for user acceptance by three or more reputed user organisations (like BEL, ITI, ECIL, etc.). Further, it should be evaluated against category II of ISI specifications and the necessary certificate produced from one of the national test centres.

(d) If the components are developed for defence application, they should be tried for user acceptance by manufacturers of defence equipment. Further, they should be evaluated against JSS/Cat. I of ISI reports, JSS wherever available, and necessary certificate produced from one of the national test centres.

It may also be necessary to prescribe norms for transfer of know-how to interested parties so as to minimise claims for import of know-how on such basis like disagreement, between the entrepreneurs and organisations that give the know-how regarding terms and conditions, etc. It is recommended that,

for such items for which know-how is available with manufacturers in the country, the committee should settle the minimum terms for the transfer of know-how and make it available to the public

The need for setting up test facilities for electronic components, is being felt more and more. While some facilities have been created at places like CIL, NPL and BARC for environmental tests and evaluation of component specifications under stringent conditions, it is necessary to augment the existing facilities and set up at least four full-fledged test centres in the country. With the increasing complexity of electronic systems, it is necessary that the reliability data (failure rate) be evaluated for components, particularly for those needed in defence applications. These facilities have to be created in the country in the national test centres. Further, in view of the vastness of the country, some subsidiary units providing test facilities have to be set up at appropriate places. A standing committee should be set up for coordinating the working of the test centres at CIL, NPL, BARC and NTH and the proposed subsidiary test centres.

An important aspect with regard to production of electronic components in general, and the passive components in particular, is the availability of special purpose machines and test equipment needed for mass production. Immediate efforts are necessary to set up a centre (or centres) to develop and fabricate these special purpose machinery.

It is needless to point out the importance of the availability of raw materials for production of passive components. A major problem of immediate concern is the high import duty on essential raw materials. The tariff, on materials like teflon, diallylphthalate, epoxy moulding powder, ceramics like forestrite and alumina, and special glasses, is very high. Critical and sophisticated raw materials for the passive components industry should be available with lower tariff so as to make the indigenous components cheaper.

The radio receiver industry would still be a key factor for the growth of the passive components industry during the Fifth Plan period. This industry has nearly reached a saturation level and the growth has been stagnant over the last few years. Every effort should be put in to promote the growth of the radio receiver industry. In particular, strategies should be worked out to penetrate the rural radio market and to improve the hardware and software aspects of broadcasting.

While the above recommendations indicate the guidelines for a proper growth of the passive components industry in general, there are several distinguishing characteristics among the individual type of components that merit separate discussion on each type.

13.5.2. Resistors

Resistors are classified into fixed type and variable type.

13.5.2.1. Fixed Resistors

It would be appropriate to classify fixed resistors as

- (i) General purpose carbon resistors (film and composition types)
- (ii) High stability, precision resistors (carbon film, metal film, metal oxide film, metal glaze types)
- (iii) Wire-wound resistors
- (iv) Thermistors and varistors

The classification is essentially based on the nature of application of the various types of fixed resistors.

General Purpose Carbon Resistors

This consists of the carbon composition resistors and the carbon film resistors. Carbon film resistors are likely to replace the carbon composition types in almost all applications. However, where size and high frequency performance are critical, the composition resistors may still be preferred until suitable varieties in the film type are produced in the country.

It is recommended that until the insulated, subminiature type carbon film/metal film resistors are available in the country and their suitability established, imports may be allowed for carbon composition resistors for use in professional equipment.

The indigenous know-how for carbon film resistors should be assessed and acquired by a central agency for dissemination to new entrepreneurs. Presently, know-how is readily available in the country at least for the production of entertainment (grade II) type resistors using a semi-automatic process.

The epoxy/phenolic compression moulding technique for carbon film resistors gives better protection and is useful for production of professional grade components. R&D efforts should be initiated to standardise the technique and develop the machinery needed.

High Stability, Precision Resistors

Intensive R&D work is necessary for these resistors. Know-how is available to a limited extent in the country at places like ECIL, Asian Electronics, CECRI, etc. The available know-how for these resistors should be thoroughly examined and a demonstration plant set up to establish the viability of production.

Ceramic and glass substrates of high purity and good surface finish, in the form of rods, tubes and plates are required for the resistor industry and are not produced in the country. The ceramics produced indigenously are found suitable only for general purpose applications. Intensive R&D efforts are necessary to produce ceramics (like steatite, forestrite, beryllia and alumina) that are needed for high stability, precision resistors. (These materials are also needed for fabrication of hybrid circuits and production of defence grade wire-wound resistors).

Wire-Wound Resistors

While the technology is well established for consumer grade wire-wound resistors, R&D efforts are necessary to produce the defence grade wire-wound resistors. Development and production of core materials for these resistors are essential. These core materials are also useful in thick and thin film circuits. Further licensing may be essentially confined to small scale industries as the demand grows.

Thermistors and Varistors

These components are required in relatively small quantities. There seems to be no need for additional R&D efforts for these. The existing types have to be improved by the manufacturers or R&D laboratories that developed the know-how.

XIII

13.5.2.2. Variable Resistors (Potentiometers)

The main types that are needed in the electronics industry are the carbon potentiometers, wire-wound potentiometers and cermet potentiometers. Trimming potentiometers of wire-wound and cermet types also find extensive applications.

Carbon Potentiometers

Know-how is available indigenously for some types of carbon track potentiometers. However, the know-how for composition type potentiometers is not available in the country. These are required for professional applications. Know-how for carbon tracks is being developed indigenously. NRDC should acquire the know-how from available sources and establish the viability of production by assisting in the setting up of demonstration plants. A period of about six months may be allowed to assess the indigenous know-how for the production of carbon potentiometers. If the indigenous know-how is not found viable for production, import of know-how may be allowed at a suitable level to aid indigenous production.

Hot moulded carbon potentiometers of the sealed type for defence applications need R&D efforts. This, however, may have to be weighed against the likely growth in demand for cermet potentiometers which offer some distinct advantages. Thus, R&D efforts for carbon potentiometers may be encouraged in a limited way for the next two or three years and the situation reviewed at that stage.

Wire-wound Potentiometers

In general, no special development efforts are required for this component. However, it is noted that the high precision, miniature wire-wound resistors are being imported. It is recommended that existing manufacturers be encouraged to put in efforts to produce these types. Further licensing may be confined to those who do not need foreign know-how.

Cermet Potentiometers

Cermet potentiometers offer the following advantages.

- (i) Have higher reliability without hermetic sealing because of the glassy surface finish
- (ii) Can withstand higher operating temperatures and are smaller in size for a given wattage
- (iii) Possess low temperature coefficient (about 100 ppm against 1200 ppm of carbon track potentiometers)
- (iv) Have higher stability (1 per cent stability against 15 per cent stability of carbon track potentiometers)

In view of the above, cermet potentiometers would find extensive applications in future.

It is recommended that all support be given for the development and production of cermet potentiometers. The major R&D work in cermet types pertains to the development of materials involved namely the thick film conductive, resistive and dielectric pastes, (silver, palladium and borosilicate compositions). R&D efforts for these items should be encouraged. Efforts should also be put in to develop special purpose machines like laser trimming machines.

XIII

Trimming Potentiometers

Indigenous development and production of wire-wound and cermet type trimming potentiometers be given a special consideration and R&D efforts encouraged in this direction.

13.5.3. Capacitors

Capacitors are also classified into two types, namely, fixed and variable.

13.5.3.1. Fixed Capacitors

Paper capacitors, plastic film capacitors, electrolytic capacitors, ceramic capacitors and silver mica capacitors fall under this category.

Paper Capacitors

Paper capacitors are used both in the electronics and electrical engineering industries. For electronic applications, paper capacitors are being replaced by plastic film capacitors to a large extent. The paper and oil for paper capacitors are being imported. While, in general, the paper capacitors are becoming obsolete, some special types like oil filled metallised paper capacitors in the range 1-40 μ F rated upto 20 kV are needed in defence and power electronics industry. The requirement of these is, however, small but it would be worthwhile making them in the country in view of their economic importance.

There is no need for creating further capacity for the production of paper capacitors for electronic applications as the demand, likely to arise in electronics industry, can be met by existing manufacturers. It is, however, recommended that development of special types of paper capacitors required in defence and power electronics industry (including high power transmitters) should be taken up by the existing manufacturers. Any R&D effort for this component may essentially be confined to the development of raw materials involved (like tissue paper, oil, etc.).

Plastic Film Capacitors

No further licensing seems to be necessary for plastic film capacitors during the Fifth Plan period unless it is for 100 per cent export or decided on special merits of individual cases. The know-how for polystyrene capacitors is available in the country. Several manufacturers, including small scale industries, have also fabricated some of the production machinery indigenously. Other metallised and nonmetallised plastic film capacitors like mylar, polycarbonate, etc., can also be produced in the country if the machines are allowed to be imported. If any licences are issued for plastic film capacitors it should be confined to those who do not seek foreign know-how. Existing manufacturers should be encouraged to produce hermetically sealed plastic film capacitors.

An important aspect with regard to production of plastic film capacitors is the availability of bare and metallised plastic films. The estimated requirement of metallised plastic for these capacitors is about 10-15 tonnes per year. (The cost of metallised plastic to bare plastic is roughly in the ratio 3:1). It is noted that metallised plastic films are being produced in the country for some non-electronic applications by two firms, each with a capacity of about 400 tonnes per year. It was also learnt that 3 or 4 schemes for the production of electronic grade metallised plastic films are under consideration. Production of electronic grade metallised plastic films should be given all encouragement.

XIII

Countries like UK and USSR may be considered for purchase of know-how as the required machinery are also readily available in these countries.

Electrolytic Capacitors

Three types of electrolytic capacitors, namely, aluminium, tantalum and niobium types are discussed below.

Aluminium Electrolytic Capacitors

The following points are noted in connection with the development and production of aluminium electrolytic capacitors of the foil type.

The demand for aluminium electrolytic capacitors has been increasing considerably. The television industry has made a significant contribution to the increase in demand for high voltage aluminium electrolytic capacitors. The economic scale of production of aluminium capacitors is about 5 million nos., and above per annum, and inclusive of the etching plant the investment would be more than Rs. 7.5 lakhs. Combining of etching, forming and assembly operations would be uneconomic if production is on a small scale. Indigenous know-how has been developed for etching of aluminium foil and an industry is being set up for making etched foils with indigenous know-how. The cost of a typical etching plant of capacity 15 tonnes per year is about Rs. 3 lakhs. High voltage capacitors need more quantity of the foil. The same licensing norms as in the case of plastic film capacitors may be followed in regard to foil type of aluminium electrolytic capacitors.

Etching of the aluminium foil and the assembly of capacitors need not be compulsorily combined for small scale units while they should be combined for large scale units. Until the etched foils are locally produced and their suitability established, import may be allowed for those who have not set up the etching units.

Since the high voltage types need more quantity of the foil, the allocation of raw materials should be made according to the end products.

Presently, aluminium foils of about 99.5 per cent purity are being produced in the country. Development of high purity (99.99 per cent) aluminium foil should be encouraged. The development work may be supported in a suitable organisation like Materials Division of the Department of Atomic Energy, National Metallurgical Laboratory, etc. The other raw materials required for these capacitors, which are not available in the country, are paper, microcrystalline wax and ethylene glycol. Indigenous production of these materials, to the required grade, must be encouraged.

Aluminium electrolytic capacitors, that are being produced in the country, have been found suitable for operation over a limited temperature range. For defence applications, capacitors capable of withstanding wider temperature range, are required. Also aluminium electrolytic capacitors, having longer life, higher reliability and which can withstand higher ripple currents (in power filter applications), are in demand. It is recommended that R&D efforts should be encouraged for developing these capacitors to meet stringent specifications like extended temperature range, high reliability, and high ripple currents.

Tantalum Electrolytic Capacitors

Solid tantalum capacitors are being produced in the country upto 35V rating. Wet tantalum capacitors have been developed and the samples are

XIII

under evaluation. The requirement of tantalum capacitors is rather limited compared to aluminium electrolytic capacitors. It is recommended that efforts should be put in to extend the voltage rating of tantalum capacitors upto about 100V.

Niobium Electrolytic Capacitors

Niobium electrolytic capacitors have been successfully developed by several countries abroad. Japan is producing niobium capacitors upto 25 volts rating. It is learnt that Fansteel, Belgium has also been producing these types. In view of the abundant raw material (niobium) availability at NFC Hyderabad, R&D efforts should be put in, to develop and produce niobium capacitors.

Ceramic Capacitors

Among the various types of ceramic capacitors used in electronics industry, the lower voltage types (upto 90V) account for nearly 90 per cent of the total requirement. While some types of these are being produced in the country, several other types are being imported. The zero temperature-coefficient miniature tubular ceramic capacitors are extensively used both in consumer and professional equipment and are popular because of their low cost and small size. The high voltage ceramic capacitors, though required in relatively smaller quantities, are of economic importance. Several organisations have developed some of the raw materials required such as ceramics of desired composition, high temperature silver pastes and phenolic compounds (needed for protective coating). Materials, like barium carbonate and titanium dioxide, are available in the country and could be used for development of barium titanate. However, the general awareness of these developments seems to be lacking. It is necessary that a proper assessment of the know-how available in the country for ceramic capacitors (including that of raw materials and machinery needed) be made and disseminated to the public at large. Demonstration plants should be set up to establish the viability of production using indigenous know-how.

Development and production of zero temperature coefficient miniature tubular ceramic capacitors should be given priority. Ceramic capacitors withstanding high voltage and high RF currents, feed through capacitors and multilayer capacitors need intensive R&D efforts. Import of know-how may be considered for professional grade ceramic capacitors.

High temperature (800°C) silver pastes are being produced by NFL, NCL, DRL(M) and Arora Mathews. However, the indigenous product seems to be still not widely accepted. It is recommended that this material be supplied to manufacturers like BEL, Philips India and Asian Electronics for user acceptance and assistance be provided for modifications and improvements (silver paste is also required for various other components like silver mica capacitors, cermet potentiometers and thick and thin film circuits).

Silver Mica Capacitors

There seems to be no serious problem connected with silver mica capacitors. Only some amount of foreign exchange drain is involved (about 2-3 paise per piece on the average) for materials like silver paste and phenolics. Production of this component may be essentially confined to the small scale sector. R&D work may be encouraged for high voltage mica capacitors.

XIII

13.5.3.2. Variable Capacitors

Gang condensers and trimmer capacitors fall under this category.

Gang Condensers

For the air dielectric type, the know-how is available in the country. It is only for the PVC types that the know-how is not established in the country. The latter types are expected to be in greater demand in the future. It is recommended that for PVC dielectric type gang condensers, a one-time transfer of know-how in the form of design, drawing for tools jigs, etc., and associated machinery (like high speed transfer press) may be allowed. For the air dielectric types, further licensing may be done only when there is revoking of the existing ones.

Trimmer Capacitors

Ceramic trimmers (disc and drum types) for HF and VHF applications and piston trimmers of glass, quartz, ceramic, etc., used in the microwave range, are being imported. No attempt has been made in the country so far to produce these.

In this area, if suitable know-how transfer is possible without equity participation, it should be allowed. This should, however, take into account an overall saving of foreign exchange within a five-year period. R&D activities should be initiated at the earliest on these components.

13.5.4. Loudspeakers

There is no need for any type of import of know-how for loudspeakers. DE/NRDC should examine the availability of indigenous know-how for loudspeakers and its component parts so as to acquire the same and disseminate it at large. Further licensing in this area should be confined to only small scale industries.

13.5.5. Microphones

There is a substantial gap between the production and requirement of microphones, particularly, the special quality types and professional grade types. Very few organisations are engaged in the development and/or production of microphones. Present production is based on assembly operation with imported component parts. While, for the general purpose types, only the augmentation of the existing facilities is necessary, those used in professional applications need considerable development efforts.

It is recommended that know-how available at CEERI, Pilani, be evaluated for production. CEERI should be encouraged to develop the special types of microphones including those required in small quantities. The development, however, should be to the level of batch-production and the necessary facilities may be provided to them.

ITI has the know-how for microphones used in handsets and head gears. This should be made available to others through a suitable agency.

13.5.6. Crystals

Piezoelectric quartz crystals and crystal filters used in electronics would be of major concern. Special types, like sodium iodide crystal used in nuclear instrumentation, are not dealt with here as they are needed only in small quantities and production may be essentially confined to R&D organisations.

The production of quartz crystal at BEL is mainly for captive use. The projected demand for crystals indicates the need for increased production in the country. Further capacity for production should, therefore, be created.

Development efforts should be put in to produce highly stable crystals with temperature controlled ovens for high stability oscillator applications and for crystal filters (with quartz, PZT, BaTiO₃, etc.) for use in professional communication equipment.

Natural quartz available in the country is not found suitable for direct applications. It is recommended that intensive R&D efforts be put in, to convert this into the synthetic quartz type for producing crystals. (It is learnt that large quantities of Indian quartz are being exported to Japan where it is converted into synthetic quartz form). Work on PZT and barium titanate, that is being carried out at places like NPL and CEERI, should be encouraged.

13.5.7. Magnetic Heads

While foreign collaboration with export commitment may be allowed, it is recommended that all encouragement be given for indigenous development and production of magnetic heads. Those who have developed magnetic heads for cassette tape recorders should be encouraged to take up development of magnetic heads for stereo, video and professional tape recorders.

13.5.8. Cartridges and Stylies

Additional production capacity should be created for the production of cartridges and stylies for mono and stereo sets.

The availability of know-how in the country should be examined by NRDC, Department of Electronics and DGTD. If by the end of 1975 no successful implementation of indigenous know-how is established, the import of know-how may be allowed for cartridges for stereo sets.

It is recommended that R&D work on the ceramic element should be encouraged. NPL and ARDE which are working in this area may be encouraged.

13.5.9. Magnetic Tapes

The demand for audio tapes over the Fifth Plan period is likely to be met by the units which are licensed, and this has to be noted while issuing new licences, as it is estimated that each new unit licensed would need a foreign exchange to the tune of Rs. 8 lakhs for machinery alone. However, the implementation rate has been rather poor and indigenous production is yet to reach satisfactory level. The major areas that need attention are the development and production of tapes for professional use, video tape recorders and computers, and the raw materials.

It is recommended that production of computer and VTR tapes should be started in the country immediately. Manufacturers of audio tapes be encouraged in this direction.

There is much anomaly in the customs duty procedures for polyester film and it forms a disincentive for indigenous production. (Duty on magnetic tapes is about 60 per cent whereas that on polyester film is about 208 per cent). This has to be rectified suitably.

XIII

13.5.10. Ferrites

It is expected that during 1978-79, 1200 tonnes of ferrites would be required. This represents nearly four-fold increase as compared to 1972-73. In the order of sophistication and specialisation of technology as well as markets, the various ferrite types needed are:

- (i) Isotropic magnets
- (ii) Radio antenna rods
- (iii) Radio and TV tuning parts
- (iv) Oriented magnets
- (v) TV deflection parts
- (vi) Telecommunication pot cores
- (vii) Computer memory cores
- (viii) Special ferrites

The break-up of demand for some types of ferrites towards the end of Fifth Plan is estimated to be as given in Table 13.4.

Table 13.4. Demand profile for various ferrites (1978-79).

Application	Type of ferrite	Estimated demand 1978-79		
		Number (million)	Quantity (tonnes)	Value (Rs. lakhs)
1. Radio				
Antenna rods	Mn, Ni-Zn	8	400	100
Other ferrite parts	"	40	80	50
2. TV				
Deflection yokes	Mn-Zn	0.5	100	100
U-cores	"	0.5	50	60
Other ferrite parts	"	—	10	20
3. Pot cores				
Telecommunication multiplexing equipment	Mn-Zn	2.2	22	80
High frequency application	Ni-Zn	—	0.5	3
			(approx.)	
1. Memory cores	Li-Zn	200	0.5	60
5. Gamma ferric oxide	—	—	20	100
6. Hard ferrites				
Isotropic	Ba, Pb		150-200	30-40
Oriented	Ba, Sr, Pb		400-500	150-200
7. Inverter cores	Mn-Zn	0.25	25	25
8. Special ferrites	—	—	—	—

The basic technology is the same for all ferrite productions. The variations for different final products lie in raw material, machining precision, tool accuracy, special production method, etc. The economics of process-wise balanced plant is given in Table 13.5.

It should, however, be noted that there is not much scope for small-scale industry. For future licensing, plants with less than 50 tonnes annual capacity should not be encouraged. New licensing should not involve foreign

XIII

equity unless worthwhile and reliable export commitment is involved.

For a balanced growth of the ferrites industry in India, the Technical Panel on Ferrites has made the following recommendations.

- (i) The required growth for radio antenna rods can be achieved without any additional technological input.
- (ii) For small radio and TV parts, manufacturers should be allowed to import special thread cutting and grinding equipment.
- (iii) Raw material import for TV ferrites should be allowed till local material is available. It is expected that import of TV ferrites after 1975-76 will not be needed.
- (iv) In view of small requirements of memory cores and the rapidly changing technology, import of untested cores in bulk may be considered instead of making special efforts to produce them indigenously.
- (v) For microwave ferrites, process developed by SPL should be exploited for commercial production.
- (vi) For hard ferrites, new units without any foreign equity should be opened.
- (vii) For gamma ferric oxide, highest priority should be awarded to the development of indigenous know-how.
- (viii) Cheap raw material should be made available by encouraging manufacturers of chemicals.
- (ix) Import of specialised capital equipment can be allowed for the present time.
- (x) Extensive R&D activity should be initiated to develop materials for making ferrites for professional equipment.

Table 13.5. Economics of process-wise balanced plant for ferrites.

	Less sophisticated ferrites	More sophisticated ferrites (e.g. TV ferrites and pot cores)
1. Total assets (Rs. lakhs)	20-25	30-35
2. FE (Rs. lakhs)	8-10	15-20
3. Turnover (tonnes)	80	50
4. Turnover, value (Rs. lakhs)	50	50
5. Assets: Turnover	1:2	1:1.5

The Panel on Passive Components has further suggested the following. NPL should be encouraged to produce 18/20 mil ferrite memory cores and ECIL and BARC be asked to make the stacks and evaluate the performance of cores produced in the country.

Gamma ferric oxide has been developed by NCL. It is suggested that this be supplied to the various magnetic tape manufacturers for evaluation and approval.

Single crystal ferrites and ferrites with very high values of permeability ($\mu \approx 50,000$) would find potential applications in the future. It is recommended that R&D grants be given for the development of these special ferrites. Production of 'Dust Iron' cores is not well established in the country and about Rs. 5 lakhs worth of these are being imported annually. Efforts should be put in to develop and produce them indigenously after examining the economics of production.

XIII

Ferrites for microwave applications are dealt with in Part B on microwave passive components.

13.5.11. Transformers, Chokes and Coils

While there seems to be no major problem with regard to transformers, chokes and coils used in electronics industry, it is felt that development efforts are necessary for some types.

Development and standardisation of transformers in the range 3 kVA to 50 kVA for application power electronics is recommended.

R&D efforts are necessary to develop better laminations (like Grade 41 type) and insulating materials.

The TV deflection components need development efforts for ferrites and self bonding wires. The pack value for import of TV deflection components should be renewed after six months time (end of 1975).

13.5.12. Capital Equipment for Production of Passive Components

Having recognised that production engineering aspects including the development and fabrication of special purpose machines and test equipment is the weakest link in translating the laboratory know-how to economical production, greatest importance should be given for the production of capital equipment needed for the mass production of passive components. No effort has been put in so far, to arrive at a tangible solution to this problem at the national level although there is considerable evidence that competence exists in the country for producing many of the machinery and instruments required in the passive components industry.

The first step in tiding over the situation would be to identify the essential machinery and test equipment needed for the component industry which are not being produced in the country. The optimum strategy for the development and production of these machines and test instruments in the country, however, needs a thorough analysis of the electronic components industry.

The important types of special purposes machines and test instruments needed for the production of passive components have been examined and a consolidated list is presented in Table 13.6. Every effort should be put in to

Table 13.6. A list of special purpose machine and test equipment needed for the production of passive components.

Brief description of machine or equipment	Applications	Approximate CIF price (in Rs. lakhs)	Availability
(1)	(2)	(3)	(4)
1. Marking/printing machines for cylindrical or flat components; speed 2000 to 3600/hr with drying arrangement	Printing on all types of electronic components	0.20	Rejafix, UK, Marken, USA
2. Reel packing/taping machine for axial lead type components; speed 3600/hr	Reel packing on adhesive tapes of all components	0.25	USSR, Japan, USA
3. Printing and drying machine with conveyor; speed 3600/hr; should occupy minimum space (say 12 ft long, 4 ft wide, 12 ft high)	Resistors, capacitors, coils	0.60	USSR, Japan, E. Germany
4. Winding and welding machine	For winding & lead welding of plastic film and paper capacitors	0.30	Japan, W. Germany, USA

XIII

(1)	(2)	(3)	(4)
5. Transfer molding machine; 10/25/50 ton; 50 to 100 cavities; rate 1000 to 2000 pcs/hr	For molding resistors, capacitors, with epoxy resin	0.60	Hull, Corp-USA, Daniel, UK, Japan
6. Hydraulic presses; 60 ton to 100 ton; 36000 pcs/hr	For pressing performs in tantalum capacitors, (also for ferrites, g-m seal, etc.)	10.00	Dorst, W. Germany
7. Compression molding presses; 60 ton to 100 ton; 100 cavities; 1000 pcs/hr	For molding resistors (grade II)	1.00	Japan, USA
8. Welding machines	For resistors, tantalum capacitors, piston trimmers	0.60	Japan, W. Germany, USA
(a) Copper lead to steel/brass caps; single/double welds; 3000 pcs/hr	Tantalum capacitors, trimmer potentiometers, piston trimmers	0.30	UK, USA
(b) Nickel/kovar to copper and other metals	Aluminium electrolytic capacitors	0.50	Japan, W. Germany
(c) Copper to aluminium; single weld	For carbon film resistors	0.50	W. Germany
9. Cap fixing machine; 10,000 pcs/hr	For adjusting resistors	0.60	W. Germany, Japan
10. Helical groove cutting machine; 2000/hr	For testing resistors and capacitors with rated voltage or wattage	0.50	USSR, Japan, W. Germany
11. Voltage/wattage stress equipment; rate 3000/hr	For 'aging' the components	1.00 to 2.00	UK, USA, Japan
12. Dynamic aging evens; capacity 10,000 pcs	For hermetic sealing of capacitors and g-m seals for trimmers	1.50	UK, USA, Japan
13. Hermetic RF sealing equipment; 3000 pcs/hr	For carbon film coating	0.50	W. Germany
14. Furnaces	Metal oxide	0.30	Japan
(a) Continuous type with inert gas for grade II; 3000/hr; 1000°C	For production of thick & thin film resistors	1.30	Hind Hivac, Bangalore
(b) Vacuum (Batch type) for grade I; 700°C	For thick film ckts; ceramic & mica capacitors	0.75	Electronic equipment, Bombay
(c) Metal films; high vacuum; 300°C	For producing tantalum parts	5.00	Degussa, W. Germany
(d) Conveyor furnace; 800°C	For sintering ceramic rods, tubes and other parts	3.00	Bengal Lynn Wester Works
(e) Sintering furnace; vacuum type; 2200°C	For metallised polyester poly-carbonate capacitors	2.00	USSR, UK, W. Germany
(f) Sintering tunnel kiln (for ceramics); upto 1350°C	For ceramic, silver mica capacitors, and thick film resistors	1.00	USSR, UK, W. Germany
(g) Vacuum metallising equipment	For checking and sorting (aluminium, tantalum capacitors)	1.00	Sweden, W. Germany, UK
15. Screen printing machine	Sorting of resistors	1.00	Japan, USSR
16. Automatic checking sorters as per tolerance, DF and DCL	For sorting capacitors	1.00	USA, Japan
17. Automatic sorters for ordinary, high stability and precision resistors			
18. Automatic sorters for capacitors			

XIII

(1)	(2)	(3)	(4)
19. Multispindle coil winding machines	Precision wire-wound resistors and potentiometers	0.35 to 0.50	USA, W. Germany, UK
20. Air abrasive trimming machine	Cermet resistors and potentiometers, thick and thin film components and circuits	0.50	USA, Japan
21. Ultrasonic trimming machine	Thick and thin film components	NA	Japan, USA
22. Laser trimming machine	Thick and thin film components	2.00	Japan, USA
23. Component comparators (required in hundreds)	Inward and outward inspection of components (R, L, C)	0.03	USA, Japan, USSR (Electronic Business, M/C Madras, have developed some types. DCM has given know-how to NRDC)
24. Stitching and stacking machine	Electrolytic capacitors	NA	Reported to have been indigenously developed. To be encouraged. Japan
25. Curling machine	Sealing of Al. electrolytic capacitors		Japan
26. Screen printing machine with normal and high resolution (automatic and manual)	Cermet potentiometers hybrid circuits, etc.	1.00 (Auto)	USA, Japan
27. Slitting machine	Cutting small widths of aluminium and plastic foils	3.00	USA, Japan

produce these machines in the country in required quantities during the Fifth Plan period.

It may be noted that while the list is prepared mainly for passive components, several of the machines and equipment like marking/printing machines, trimming machines, etc., are useful for the production of several other types of components. The strategy for production of these equipment should, therefore, be evolved by a team consisting of representatives from Electronics Commission, DGTD, NRDC and an expert from a leading machine tools industry (like HMT or CMTI). This team should take up the problem in its totality considering all types of electronic components (active, passive and electromechanical). The following should be included in the terms of reference.

(i) Identify the types of machines which are being extensively used in the country and workout the detailed specifications for the commonly accepted types.

(ii) Identify the machines which have been duplicated in the country

by various manufacturers and recommend the courses of action to productionise the same.

(iii) Keeping in view the appropriateness of the technology involved and the level of automation required in relation to the needs of the country, recommend the types of machines to be developed and produced in the country, indicating the order of priority.

(iv) Recommend the courses of action for acquiring the know-how if any, and for production of these machines/equipment by examining whether a given machine or equipment can be produced by component manufacturers who have successfully multiplied similar items, or by existing tool rooms/workshops, or whether a new centre/centres are to be created

(v) Indicate the level and type of R&D needed.

(vi) Identify potential locations for production and R&D of these machines/equipment.

A high priority should be given to this task as it has been recognised to be a vital matter of immediate concern in the production of electronic components.

13.5.13. Test and Evaluation Facilities

With the increasing complexity of electronic systems, it has become necessary to evaluate the probable life and reliability (failure rate) for various components used. Also to assist the manufacturers to upgrade the existing products, testing and evaluation facilities are essential. It may not be economical for manufacturing units to have their own test centres to carry out all the required tests. To meet these needs, adequate test facilities have to be maintained in the country at several places.

It is recommended that the present test facilities at CIL, NPL, BARC and Allipore Test House should be augmented and atleast one of these test centres should have, as its objective, a continual upgrading of equipment to keep pace with the latest techniques in testing. In view of the vastness of the country, subsidiary test centres should be set up atleast with limited facilities near places where the component industries are concentrated or growing. These may be taken up in a phased programme. A standing committee should be set up to coordinate the working of the various test centres.

Manufacturing organisations which produce defence grade components should be provided with technical and financial assistance to equip themselves with facilities for evaluation of the failure rate of components.

To assess the reliability (failure rate) data from the accelerated tests carried out in the testing laboratories, the correlations between the data collected under actual operating conditions and by accelerated tests, is to be established. It is recommended that a project be sponsored to collect the relevant data under actual conditions and establish the correlation between actual and accelerated tests.

It may be noted here that test and development centres have already been set up in several States with the assistance of the Department of Electronics.

The recommended courses of action indicated above are largely oriented towards meeting the long range requirements of the industry. It is from this point of view that emphasis has been laid on indigenous development efforts. It may, however, be noted that variation in equipment production targets and impact of new technologies have wide repercussions on the

passive components industry as these components are needed in much larger quantity than others like active components and electro-mechanical components. Another feature of the electronic components in general and the passive components in particular is the diversity of requirements, both in quality and quantity, in the consumer and professional electronics areas. Further, the market trends abroad, export potential of consumer electronic items and renewed application of some of the conventional passive components in fast growing technologies (for example, electrolytic capacitors in computers and instrumentation) affect the demand pulls significantly. These factors suggest the need for a reappraisal of guidelines for the production of passive components more frequently than for other electronic components. It may often become necessary to adapt specific short term strategies. For example, norms for export oriented production vis-a-vis foreign collaboration, import pack value, etc., may change in step with overall export promotion drive which, in turn, is governed by the year to year foreign exchange balance of the country. This aspect is being looked into by the Electronics Commission/Department of Electronics on an annual basis and is brought out in the journal "Electronics : Information & Planning" and also as part of "Guidelines for Industries", published by the Ministry of Industrial Development.

13.6 Investment

Production details over the last few years indicate that, on an average, it is about 70 per cent of the total installed capacity for passive components. Considering the projected demand, the installed capacity has to be, on an average, three times the present value by 1978-79 and about twice that value by the end of the Sixth Plan. In several cases, the total approved capacity is much in excess of the projected demand. A conservative estimate of about 40 per cent of the holders of letters of intent, setting up production facilities during the Fifth Plan period, may be assumed for several of the components like carbon film resistors, plastic film capacitors, electrolytic capacitors, etc. A rough estimate on the above basis indicates that an additional investment to produce about one and half times the present production, in excess of the anticipated production resulting from the holders of letters of intent, would be necessary. Taking the competitive life time of manufacturing equipment under Indian conditions as 7 years, the ratio of investment to life time turnover for passive components is estimated to be about 0.06. On this basis, an additional investment of about Rs. 5 crores during the Fifth Plan period would be necessary.

B. Microwave Passive Components

13.7 Classification of Microwave Passive Components

All microwave systems employ large numbers of passive subsystems. These include general purpose microwave components such as couplers, attenuators, terminations, connectors, adapters, bends, matching transformers, various ferrite devices and special purpose microwave components like filters of various types, high power components, investment-cast components required for specific purposes, etc. Components required for radar, tropo and satellite systems need hardware capable of handling high power whereas in LOS, as also in low power stages of radar, tropo and satellite systems, power handling capacity is not an important factor. Airborne and missileborne microwave equipments need light-weight components.

XIII

In manufacturing microwave passive subsystems, waveguide, coaxial, stripline and microstrip constructions are used. Microwave integrated circuits (MIC) have been effectively used for some applications. Recently slot lines and coplanar waveguides have also been proposed with advantages in specific cases. There are also a number of fabrication methods available to realise these components in each of these configurations. The choice of any transmission line and/or fabrication technique depends upon a number of factors like cost of engineering and production, line loss, power capability, frequency of operation, circuit isolation, bandwidth capability, environmental stability, integration with semiconductors, ferrites and lumped elements, etc.

The above diversification in types of microwave passive components and fabrication techniques make their classifications possible in various ways (for example, classifications based on their functions, according to transmission types commonality in the process technology, power level, frequency bands, etc.). A representative cross section of such classification is given in Table 13.7. Depending upon the need of the time, any or more of the classifications are adapted. From systems manufacturers point of view, the available components should be such as to result from intelligent configuration and fabrication technology mix for various components which conglomerate into optimum performance of the system taking into account the reliability, cost and compactness. Therefore, keeping in view the radar and communication systems requirements for the coming years and the present state-of-the-art, the microwave components can be broadly classified along the following lines:

(i) Coaxial components	: L-band (both high and low power), and S-band (low power)
(ii) Waveguide components	: S-band (high power) C to X-band (both high and low power)
(iii) Waveguide components	: 15 GHz and above including millimetre components
(iv) Stripline components	: L to X-band
(v) MIC subsystem	: L to C-band

Table 13.7. Classification of microwave components.

(a) Functional:	
Plumbing	: Bends, compensated compact bends, twists, flexible sections
Transitions	: WG to WG, coax to WG, MIC launches, etc.
Frequency selective	: Filters of low pass, band pass, high pass with desired skirt response, signal processing such as pulse compression, resonators of desired frequency stability, etc.
Mechanically tunable or movable devices	: Tunable cavities, phase shifters, attenuators, impedance matching sections, contacting or non-contacting movable shorts, switches, etc.
Multiport coupling devices	: Power dividers, directional couplers, hybrids.
Ferrite devices	: Nonreciprocal phase shifters, isolators, circulators, latching devices, etc.
Microwave diode mounts	: For mixers, detectors, modulators, oscillators, amplifiers, etc.

XIII

-
- | | | |
|----------------------------|---|--|
| Primary radiative elements | : | Horns, apertures, dipoles, arrays, etc. |
| Lossy elements | : | Matched terminations, fixed and variable attenuators, anechoic wall material, etc. |
- (b) Transmission lines:
- Heat transfer, etc.
 - Waveguide
 - Co-axial
 - Stripline
 - Micro-strip
 - Helical line
 - Slot line
 - Coplanar waveguides
 - Surface wave
- (c) Frequency bands:
- Metre
 - Centimetre
 - Millimetre
- (d) Power:
- | | | |
|-----------------|---|-------------------|
| Low power | : | mW |
| Medium power | : | Watts |
| High power | : | Hundreds of watts |
| Very high power | : | Kilo watts |
- (e) Materials and processes:
- Cast components
 - BeCu components
 - OFHC components
 - Electroformed components
 - Pressure formed components
 - Precision machining
 - Thin films
 - Dip brazing
 - Furnance brazing
 - Torch brazing
 - Heliarc
 - Printed circuits
 - Evaporated circuits
 - Micro electronic bonding, etc.
- (f) Environmental:
- Temperature range
 - Pressurisation or vacuum
-

13.8 Demand Profile

The requirements of microwave passive components for productionising microwave systems both for civil and defence uses during the Fifth Five Year Plan, have been estimated by the Panel on Microwave Components, constituted by Electronics Commission. Their requirements for various LOS systems are given in Table 13.8. Because of strategic reasons, such details

XIII

for defence requirements (including radars for civilian uses) have not been provided. However, typical profile of the requirements for microwave systems other than LOS systems, classified as high power and low power passive components has been given in Table 13.9. Requirements for R&D work, may be assumed to be about 10 per cent of the total production requirements and another 10 per cent for the miscellaneous hardware components not considered above. Considering all the above requirements, the total demand for microwave passive components valuewise during the Fifth Five Year Plan has been estimated as Rs. 7.5 crores by the Panel on Microwave Components and Instruments. This does not include system oriented components like filters of various types. Phasing in accordance with the system requirements of various uses, demand profile for microwave passive components (excluding connectors and filters) have been worked out in Table 13.10. With the rapid advances in MIC technology, it may be expected that low power components at lower microwave spectrum end would be partly integrated by the end of this decade. However, high power discrete components in whole of the band and high frequency discrete components would continue to exist. With the above factors in view, the demand for the discrete microwave passive components during the Sixth Five Year Plan may be expected to grow upto Rs. 10 crores.

Table 13.8. Requirements of microwave passive components for various LOS systems during Fifth Five Year Plan.

Components	For 7/8 GHz system	For 4/6 GHz system	For 2 GHz system	Total quantity
1. Isolators/circulators (3 and 4 ports)	6000	12000	3000	21,000
2. Sampling coupler/detector	900	4800	900	6,600
3. Attenuator	900	3200	450	4,500
4. Matched load	900	1600	450	2,900
5. E&H bends	900	3200	—	4,100
6. W/G to coax. adaptor	1800	3200	—	5,000
7. W/G transformer	—	2000	—	2,000
8. Filters of various kinds	3000	4600	2250	9,850

Table 13.9. Typical profile of the requirements of microwave passive components for purposes other than microwave LOS systems during Fifth Five Year Plan.

Item	Approximate quantity
1. High power components:	
Phase shifters	5000
Directional couplers	1000
Circulators/isolators	1500
WG to coaxial adapters	500
RF loads	1000
TR switches	300
Duplexers	300
Rotating joints	300

XIII

2. Low/medium power components:	
Circulators/isolators	1000
Attenuators (variable)	500
Sampling coupler/detector	300
WG to coaxial adapter	1500
Transition, reduced guide to standard guide, rectangular to elliptical guide, etc.	1500
Matched loads	1000
Directional coupler (coupling ranging from 3 dB to 60 dB)	2000
Bends, twists	18000

Table 13.10. Demand profile for standard microwave passive components during 1974-84.
(In Rs. lakhs)

	1974-75	1975-76	1976-77	1977-78	1978-79	Total for the period 1974-79	Estimated demand for the period 1979-84
Microwave passive components (excluding filters and connectors)	36	85	150	204	275	750	1,000

13.9 Current Status

13.9.1. Development

As far as microwave waveguide components are concerned, enough competence exists today in the country. Most of the components are made by conventional machining, fitting and brazing, using plates and other milled forms and electroforming. Once the component scales up, techniques of investment casting and other mass production methods would be most economical.

TRC designs most of the components required for their systems. For narrow band 7 GHz and broad-band 6 GHz systems, general components like E bend, H bend, cross guide coupler, variable attenuators, waveguide to coaxial adapter, waveguide transformer, termination and special components like circulator, mixer and filters were designed and developed by them and these are now productionised by ITI. A number of components in waveguide, coaxial and stripline constructions for 2 GHz 120 channel and 4 GHz broad-band systems have been developed. In short, TRC designs and develops most of the components required for their systems under development and their competence of component design covers wide varieties of microwave components.

NPL has developed T-junctions, directional couplers, attenuators, matched terminations, tuners, short circuits, horns, twists, bends, detector mounts, slotted sections, probes, etc. for 10 Cm, 5 Cm, 3 Cm, 2 Cm and 1.5 Cm microwave bands, broad band ferrite devices like 3-port circulators and isolators for 5 Cm and 3 Cm microwave bands.

TIFR has developed microwave components for use in transmit-receive systems of radar, microwave instruments, and high power electron beam devices. Among the high power components developed are isolators, circulators,

rotary joints, duplexers, precision slow wave structures, high power dry loads, and power measuring loads. Other types of components developed include high-Q cavities in Invar, folded magic T, directional coupler, hybrids and some of the conventional ferrite devices. In addition to using standard machine shop practices for microwave component fabrication, the following processes suitable for batch production and mass production are in development and use, namely, electroforming in copper and nickel, investment casting, hydrogen furnace assembly, double registration MPC, and thin film MIC.

DLRL has developed varieties of passive components required for radar and IFT systems which include hybrids, directional couplers, power dividers, filters, rotary joints, ferrite devices, etc., to perform a variety of functions like signal sampling, signal selection and signal transmission. These components have been realised in different transmission line structures. LRDE has also developed components needed for specific systems development. HRPU has also developed a series of microwave components like tunable filters, mixers, directional couplers, etc, for 2 GHz Tropo scatter system.

MID-SAC has developed some of the hardware components right from 1.7 GHz to 40 GHz for its own systems development. ESCES-SAC has developed passive components for trans-receive chain at 4 and 6 GHz for earth stations.

ITI has developed 7 GHz waveguide components for Railways and microwave equipment for Dehradun earth station. They are presently engaged in the development of microwave components, particularly system oriented, for the new family of LOS systems.

13.9.2. Production

So far, most of the microwave passive components manufactured in the country are of waveguide construction. ECIL has developed and manufactured test components worth Rs. 7 lakhs in 1972-73 and about Rs. 10 lakhs in 1973-74. The components span the frequency band from 2.6 GHz to 12.4 GHz and cover most of the passive components range. KLB Electronics and SICO Ltd., are manufacturing microwave hardware components with NPL know-how, the former making almost all the components developed by NPL. These components are tested by NPL. During 1972-73, KLB Electronics produced microwave components worth Rs. 2 lakhs and SICO about Rs. 1 lakh mainly for use in educational institutions.

ITI and BEL have been manufacturing waveguide passive components for their own uses. ITI has been manufacturing most of the components required for their production of 7 GHz narrow band and 6 GHz 960 channel microwave LOS systems. Most of the low power microwave passive components required for radar systems manufactured by BEL are also made in their in-house machine shop. The components manufactured so far are made by conventional machining, fitting and brazing using plates and other milled forms.

13.10 Analysis of Gaps and Guidelines for Development and Production

The range of passive components, utilised both in communication and radar systems, is extensive in that they cover all the possible transmission line configurations. The suitability of a particular configuration is dependent on system design needs.

There is sufficient R&D knowledge available in the country as far as

XIII

conventional components are concerned. However, these efforts are thinly spread over a large number of institutions and the components are mostly fabricated by conventional machining, fitting and brazing, using plates and other melted forms and electroforming. Fabrication methods suitable for mass production have to be established. Further R&D efforts are needed to design, develop and manufacture coaxial components, miniaturised components, space qualified components and high power applications hardware.

For detailed analysis of gaps, and subsequently, evolving the guidelines for development and production, the whole gamut of microwave components is divided into following categories:

- (i) Ferrite devices
- (ii) Standard passive hardware
- (iii) Filters
- (iv) Microwave integrated circuits.

13.10.1. Ferrite Devices

The range of ferrite devices, used both in communication and radar systems, cover high as well as low power circulators, isolators and phase shifters in different configurations. The requirements of the conventional low and medium power isolators and circulators are significant in the 2 GHz to X-Band region of frequencies. While the number of pieces of high power devices to be used in Tropo and radar systems in the L, S, C and X-Bands may not be as high as the low power units, they are of strategic importance. Keeping in step with the rest of the world, as far as radar system technology is concerned, calls for giving serious thought and effort for development of phased array systems. An important component, which has a great bearing on the economics of phased array systems, is the ferrite phase shifting element. Therefore, the development of this component assumes considerable significance. YIG tuned devices are of special significance in spectrum surveillance systems and their development within the country is essential.

An analysis of the futuristic trend, the demand forecast and the present capability of the country in this field reveals the following:

(i) Development capability has been demonstrated for circulators and isolators from L to X-Band within the country. On the line of the current 6/7 GHz LOS systems, the future LOS systems are also planned to use indigenous ferrite devices.

(ii) Majority of the high power ferrite devices, used in Tropo as well as radar, are being imported.

(iii) There is a need to establish the development and production capability for ferrite phase shifters required for futuristic systems.

(iv) No significant development activity in YIG tuned devices has been initiated in the country.

Based on the above analysis, the following guidelines for development and production of ferrite devices have been suggested.

(a) The requirements of the ferrite devices for LOS systems should be mostly met by in-house capabilities of the system manufacturers.

(b) The development and production efforts in octave band width devices, ferrite phase shifters, microstrip and miniature ferrite devices and high power ferrite devices should be considerably augmented to meet the strategic and futuristic needs.

13.10.2. Standard Passive Hardware

As far as development of professional grade microwave hardware is concerned, there are a number of organisations, primarily system-oriented, who design and develop the hardware as and when the needs arise out of systems consideration. The in-house capability of such system manufacturers as ITI, BEL and HAL cater to meet their immediate production. The existing microwave components manufacturers have not yet entered the field of professional microwave components on mass scale. The specifications of these professional components, in terms of performance and ability to withstand environment, are quite stringent for defence and space applications. These call for more efforts and continuous updating of knowledge on the part of the components manufacturers in respect of the materials to be used, the methods of fabrication and assembly.

Although the system manufacturers such as ITI, BEL and HAL will be meeting part of their requirements of microwave components by in-house capabilities, there is a need for augmenting the existing manufacturing capacity for professional grade components. The envisaged production capacity of major manufacturers of microwave components (including in-house capabilities of system manufacturers) leaves a significant gap for high power professional grade components and some specialised components for which facilities should be created. To bridge the gap, the Panel on Microwave Components has recommended the following two alternatives.

(i) ECIL could be directed to augment its development and production facilities to meet this demand.

(ii) In case they are not in a position to undertake the same, a new unit for manufacturing such components should be set up. This new unit, in that case, also should be entrusted with other components such as ferrite devices to make it economically viable. Setting up of a separate facility would also help in creating a strong base for meeting the evergrowing requirements of sophisticated microwave devices such as ferrite phase shifters which form an important element for the futuristic radar systems.

13.10.3. Filters

While the specifications for other microwave passive components are not entirely system dependent, the category of components pertaining to filters are specific to each system under design.

Filters that are planned to be used in these systems can be conveniently categorised into (a) low power filters which include bandpass, SSB, low pass, etc., which can be interdigital, direct or line coupled resonator filters, and, (b) high power filters which are mostly in waveguide construction and are direct or line coupled resonator filters, and typically, the order of power to be handled by these filters is of the order of 1 MW at S-band or more with or without calling for pressurisation.

Most of the requirements of filters today are met by in-house development or import by the system designers. In the field of LOS Communication Systems, the low power filters used in the branching networks are being designed by ITI and TRC for application in these specific systems at 2, 4, 6, 7 and 8 GHz. In the case of radars, high power filters are currently being designed in-house by BEL at S-band. Low and medium power filters used in such radar systems as Secondary Surveillance Radars at L-band, have also been designed by DLRL for the specific system under development.

In the case of Tropo systems under design by HRPV and BEL for 2 GHz and 4 GHz, in-house development of the filters is carried out.

Presently, ITI is manufacturing filters in waveguide configuration for 6/7 GHz systems. BEL is also planning to fabricate the high power filters for their S-band radars. The requirements of most of the filters for all systems are likely to be met by in-house design, development and production. However, in common with other microwave components, design and development work (skirt selectivity, bandwidth, insertion loss, phase linearity, etc.) should be accelerated.

13.10.4. Microwave Integrated Circuits

The technology of microwave components is undergoing considerable amount of changes with greater accent on miniaturisation, broad banding, and reliability. While, for certain applications, conventional microwave technology can go on for a few years, for airborne, missileborne and portable versions, it is essential to have facilities to design and fabricate miniaturised circuits. Even for ground based systems, MICs provide a tool for low cost high volume repetitive manufacture.

The integrated circuit technologies can be broadly classified into two major types.

(i) Monolithic Technology: This is the more complicated of the two and would be economical only when the demand of MICs is very large.

(ii) Hybrid Technology: Hybrid technology can be treated as complementary to microminiaturisation rather than a technique to compete with monolithic technology. This technology is being pursued as a packing approach to take advantage of all available active and passive components to achieve optimum circuit performance, and centres around the microstrip fundamentals.

Hybrid microwave integrated circuits have been constructed with both thick and thin film deposition techniques. The former implying deposition of conductors, resistors and capacitors by a painting process, and the latter implying some form of vacuum deposition, to be followed by plating, etching, oxidation, etc. For microwave work, the dimension control obtained by thin film processes usually leads to their being preferred, although thick film techniques are receiving attention for certain applications where feasibility and economy are of prime importance. Further, the thin film technology is preferred for frequency about 2 GHz, in view of the inherent limitation of higher losses due to the presence of a glass phase in the conductive materials of thick films.

Hybrid MIC technology realisation would require coordinated efforts from technologists working in various fields, viz., circuit and system designs, material techniques, device fabrication techniques, etc. The institutes, where appropriate infrastructure already exists, should be allowed to intensify their efforts by providing better facilities for work like computer aided design facilities, precision microwave printed circuit aids, etc.

Presently, MIC facilities are being set up by R&D laboratories such as BEL, TIFR, LRDE, DLRL, ITI, etc. This is in conformity with the trend all over the world where the design engineer is closely associated with the development of the specific module called for in the design. However, these

XIII

facilities are mainly geared for development and not for production on a larger scale. MIC techniques particularly lend themselves for mass production as the need for miniaturisation and solid state devices increases. Standardisation of the modules and fabrication on a larger scale should be seriously thought of.

XIV

Mechanical and Electrical Components

14.1 Introduction

In this chapter, the following mechanical and electrical components have been covered :

- (i) Connectors
- (ii) Relays
- (iii) Switches
- (iv) Printed circuit boards
- (v) Micromotors
- (vi) Batteries

Connectors, relays and switches having several common factors are discussed in Section 14.2 under the heading of electromechanical components. All the electromechanical components primarily have to withstand mechanical operations necessitating the use of proper materials. This section is further divided into several subsections. The present status of the electromechanical component industry is given in Subsection 14.2.2 which is followed by a ten year demand profile for these components. As standardisation is of crucial importance in this area, it is covered in Subsection 14.2.4. The discussion on printed circuit boards is given separately in Section 14.3 followed by a discussion on micromotors in Section 14.4 and on batteries in Section 14.5. The general problems of the industry and the guidelines for production are discussed in the last section.

The Panel on Mechanical and Electrical Components set up by the Electronics Commission had reviewed various aspects of the electromechanical and other components and had suggested remedial measures for their indigenous production. The recommendations and suggestions made by the Panel form the basis of this chapter. The recommendations made in the conference on R&D policy in electronics have also been included here.

14.2 Electromechanical Components

Electromechanical components most widely used in electronic equipment are connectors, relays and switches. In general, all these components consist of precision metal parts, a range of insulators manufactured to stringent tolerances and assembled together in many configurations to meet different functional requirements. In spite of dynamic changes in technology (e.g. the development of large scale integrated circuits), the impact of solid state circuitry on the demand of electromechanical components has not been large. However, it is essential that the design of these components be improved constantly so as to meet the changing requirements of equipment and systems.

Electromechanical components industry in India is still in its infancy. Accepting the recommendations of the Bhabha Committee, certain steps were taken to ensure indigenous production of these components. In some cases, foreign collaboration was also allowed. A basic production infrastructure exists at present in both organised and small scale sectors. However, lack of standardisation, poor tooling facilities and nonavailability of raw material are still the main bottlenecks in the growth of this industry. The problem of standardisation is very

important because of the wide variety of equipment produced under collaboration/licence from different countries and the wide diversity in the type of components used.

14.2.1. Present Status

At the time when the Bhabha Committee submitted the report, the total annual production of electromechanical components was of the order of Rs. 25 lakhs only. The components produced were mostly of the general purpose type and therefore, no expensive tooling or sophisticated skill was involved. According to the Bhabha Committee Report, the total demand for electromechanical components by 1975 was estimated at Rs. 9 crores for the production of equipment worth Rs. 300 crores. The industry has grown rapidly during the past few years and, the present production level (1973) is nearly Rs. 8.30 crores, which meets 75 per cent of our requirements. The import of components worth Rs. 3.3 crores in this area is mainly confined to professional applications only. The present status of the electromechanical components industry is given in Table 14.1. There are more than 45 units making various types of electromechanical components. The requirements of professional grade components are largely met by organised sectors because of the availability of proper manufacturing facilities, know-how and tooling and test facilities with them.

Table 14.1. Present status of the electromechanical component industry in India.
(All figures in million nos. Figures in brackets represent values in Rs. crores)

Item	Licensed capacity	Letters of intent	Approved capacity	Installed capacity	Production in 1973				Total demand 1973	
					Organised sector	Small scale*	In-house	Total Import*		
Connectors	1.014	7.000	8.014	1.014	0.25 (0.40)	1.30 (1.40)	1.00 ¹ (0.30)	2.55 (2.10)	0.83 (1.50)	3.38 (3.60)
Relays	0.150	0.700	0.850	0.150	0.15 (0.60)	0.03 (0.10)	1.60 ² (4.00)	1.78 (4.70)	0.40 (1.00)	2.18 (5.70)
Switches	5.750	5.750	11.500	4.400	2.0 (0.85)	1.26 (0.60)	0.04 ³ (0.05)	3.30 (1.50)	0.20 (0.80)	3.50 (2.30)

* Estimated by the Panel on Mechanical and Electrical components

1. Jacks and plugs produced by ITI and Telecom Factory
2. BPO and pentaconta type relays produced by ITI
3. Lever key switches produced by Telecom Factory

Connectors

Connectors are very important interconnection systems and have a variety of applications ranging from DC and low frequency to microwave frequencies. There are over 15 units, mostly in the private sector, manufacturing connectors of various types. It is estimated that during 1973, the total demand for connectors was of the order of Rs. 3.60 crores and the indigenous production was nearly Rs. 2.10 crores. Most of the connectors used are required in professional area (mainly in defence equipment) where high quality control and rigid specifications are involved, which have not been completely met by indigenous products. Therefore in 1973, connectors worth Rs. 1.50 crores have been imported. The various types of connectors produced in the country are described below.

XIV

(a) Coaxial Connectors

These include single pair connectors in which the centre conductor is surrounded by a dielectric material which, in turn, is surrounded by a metal sheet. They are generally used for radio frequency applications. The coaxial connectors commonly used in the country are BNC, TNC, UHF, N, SMA, SMC, etc. At present, certain types of BNC, TNC, N and UHF connectors are produced in the country while the demand for other types is being met by imports. The known manufacturers of coaxial connectors in the country include Allied Electronics Bombay, Amphetronix Poona, Electromechanical Radio Industries Ahmedabad, Hindustan Aeronautics Hyderabad, Hindustan Electro-technology Bangalore, Mc-Gogia Bombay, Poly-Qual Delhi, Progressive Engineers Delhi, Southern Electronics Madras, and a few others. A few types of adaptors used for joining two or more mechanically incompatible connectors are at present being manufactured by Poly-Qual and Electromechanical Radio Industries.

(b) Cylindrical Connectors

This type includes all circular multipin connectors which are housed in cylindrical shells. The type of cylindrical connectors mainly used in the country are (i) bayonet coupling (environment resistant, miniature), (ii) threaded coupling, and (iii) audio. Presently some types of cylindrical connectors viz., audio and a few types of MS connectors are being manufactured by Amphetronix, Dattatraya Industries Poona and Sarit Manufacturing and Research Centre Bangalore. The indigenous products, however, have not yet met the professional standards adequately. A wide range of multipin sealed and unsealed connectors are being imported at present.

(c) Rack and Panel Connectors

Rack and panel connectors include multipin connectors in which one half of the connectors is installed on the electronic equipment. The production of these connectors is very limited in the country. A few types of rack and panel connectors with pin contacts, blade contacts and ribbon contacts are being produced by Amphetronix and HAL. There is no production of high density miniature type rack and panel connectors and they are imported at present.

(d) Printed Circuit Connectors

Printed circuit connectors are those used in conjunction with printed circuit boards. They are used as edge connectors thus directly plugging on to a printed circuit board or two piece connectors in which a plug is soldered on to a printed circuit board and used with a receptacle. A few types of edge and two part connectors are produced by Allied Electronics, Amphetronix, Elcom Precision Bombay, BAL, Mc-Gogia and Telemechanics, Bangalore. However, the miniature types and those required for double sided printed circuit boards are not produced in the country.

(e) Miscellaneous Connectors

This category covers miscellaneous connectors like plugs, sockets, jacks, links, etc. At present a variety of mounting sockets, links, jacks, telephone plugs and sockets, and some types of connectors used in consumer applications are produced in the country. These connectors are manufactured by Bright Star Bombay, Elcom Precision, Hindustan Electro-technology, Indian Telephone Industries Bangalore, Rajkumar Industries Bombay, Villait Electronics Calcutta and Texonic Instruments Madras. The production base is fairly well established and the production level is adequate to meet much of the demand. Imports in this area is confined to some special types of connectors required for specific applications.

Relays

Relays are primarily switching devices used either to control large power or to perform a series of switching operations. There are over ten units making various types of relays in the country. The total requirements of relays in the year 1973 is estimated to be around Rs. 5.70 crores out of which captive production by Indian Telephone Industries Bangalore accounts for nearly Rs. 4 crores. Other indigenous production of relays will be approximately Rs. 0.7 crores. It is estimated that relays worth Rs. 1 crore were imported during 1973 mostly for professional use. A brief description of various types of relays produced in the country is given in the following.

(a) Armature Type Relays

This term is used to cover the broad spectrum of electromagnetic relays which have an armature hinged or pivoted to the fixed yoke of the relay. Hermetically sealed relays find applications in aircraft, missiles, space craft and ground support equipment. Miniature, industrial and sensitive types of hermetically sealed relays are being produced at O/E/N (India) Cochin. High-speed relays and TO-5 'can relays' are currently being imported.

Telephone type relays include British Post Office (BPO) 3000 and 600, and pentaconta relays which are mostly manufactured and used by Indian Telephone Industries. A small quantity of telephone type relays are also produced by Indian Engineering Co., Bombay. Most of the present demand of this type of relays is met by indigenous supply only and import in this area is negligible.

Other unsealed types of miniature, industrial and sensitive relays are being manufactured by a few units like Aero Control Bangalore, Electronic Research Bangalore, O/E/N Cochin, Pla Electro Appliances Bombay and Soudhamini Industries Poona. The production of subminiature type and high speed relays does not exist and they are being imported at the moment.

(b) Reed Relays

This category of relays includes dry reed relays and mercury wetted relays. Dry reed type relays are being produced by Pla Electro Appliances Bombay and Mygeri Electronics (III ancillary) Bangalore. No substantial production base exists for mercury wetted reed relays and at present they are being imported. A limited variety of dry reed capsules, used for making relays, are being produced in the country by Delta Electronics, Delhi.

(c) Miscellaneous Relays

This category includes thermal, stepping, vacuum and other types of relays. A few types of thermal and stepping relays are produced in the country by HTL, Madras and ITI, Bangalore. However, special types of relays required for specific applications are being imported at present.

Switches

There are over 20 units making various types of switches in the country. The total demand of switches in 1973 was approximately Rs. 2.3 crores of which indigenous supply was of the order of Rs. 1.5 crores. The balance demand of Rs. 0.8 crores was met by imports. A brief description of various types of switches that are being produced in the country are given in the following.

(a) Rotary Wafer Switches

Rotary wafer switches are being made by Eastern Electronics Faridabad, Golden Industries Calcutta, Kaycee Industries Bombay, Nippon Electronics

Bangalore, O/E/N Cochin, Remco Bangalore, etc. The indigenous production of miniature rotary switch is not upto the required standards and consequently most of the requirements in this area is met by imports.

(b) Rotary Power Switches

Rotary power switches capable of switching 10-200 amperes at 125-500 volts A.C. find some applications in electronics. A limited range of these switches are being produced by Indian Engineering Co. Bombay, Kaycee Industries Bombay, M.C. Engineering Co. Delhi, Kel Components Madras and a few others. An adequate indigenous production base exists for these switches.

(c) Pushbutton Switches

Pushbutton switches are being produced by Asha Pavro Electronics Bombay, Essen Deinki Chandigarh, Golden Industries Faridabad, Indian Engineering Co. Bombay, Remco Bangalore and Telecom Factory Bombay. Some special types and self-illuminated pushbutton switches, for which the present requirement is small, are not produced in the country.

(d) Toggle Switches

A number of manufacturers like Elico Hyderabad, Indian Engineering Co. Bombay, Kaycee Industries Bombay, M.C. Engineering Co. Delhi, MCE Products Sales New Delhi and a few others are making unsealed and sealed toggle switches. Whereas in some cases professional standards have been met, in others considerable efforts are necessary to improve the quality for meeting the professional requirements. At present miniature and sealed toggle switches are being imported.

(e) Sensitive (micro) Switches

These switches are being produced by Essen Deinki Chandigarh, Kaycee Industries Bombay, MCB Bombay and a few others. While normal and miniature types of micro switches are produced in the country, subminiature micro switches are imported in large quantities. Attempts are being made by some manufacturers to develop subminiature type of micro switches. The indigenous production of micro switches do not fully meet the professional requirements.

(f) Slide Switches

These switches are mostly used in commercial applications like radios, TVs, etc. Slide switches are being manufactured by Elcom Precision Bombay, Golden Industries Calcutta, Kel Components Madras, Nippon Electronics Bangalore, Philips Bombay, Rajkumar Industries Bombay, Remco Bangalore and a few others. The production base is fairly well established for this class of switches. However, the present requirements of miniature slide switches are being met by imports.

(g) Lever Key Switches

These switches are mainly used in telephone equipment and are being produced by Indian Telephone Industries Bangalore and Telecom Factory Bombay. Some other manufacturers have also initiated the production of these switches.

(h) Reed Switches

Presently dry reed capsules are being manufactured by Delta Electronics Delhi. A few more firms have been licensed for the production of reed capsules. The production of mercury wetted type reeds has not yet started in the country. Also, the type of reeds (6VA and 15VA) required for telephone exchanges are not produced in the country at present.

(i) Miscellaneous Switches

This category of switches includes items like rocker, knife, mercury, step foot, lock and coaxial switches which find application in many areas. However, the requirements of each type is relatively small. Some of these switches are being produced indigenously.

14.2.2. Forecast of Requirements

It is observed that in countries abroad the consumption of electromechanical components during the past few years have been 3 to 4 per cent of the total cost of equipment and nearly 10 to 15 per cent of the total cost of components. The percentage share of electromechanical components is higher for countries having larger basis for defence and space programmes. For countries like Japan, where the production of consumer items is larger than other professional equipment, the use of these components is small. Based on these international trends, the Bhabha Committee also assumed that for India, electromechanical components will account for nearly 3 per cent of the cost of the equipment. From the analysis carried out by the Panel on Mechanical and Electrical Components, after obtaining the requirements (both present and future) of the major users of these components, it is found that electromechanical components account for nearly 6.5 per cent of the cost of the equipment. The consumption of connectors is 2.1 per cent, relays is 2.8 per cent and switches is 1.6 per cent of the equipment cost, as against the trends of 1.5, 1 and 0.5 respectively assumed by the Bhabha Committee.

For calculating the demand for electromechanical components, the present and future production plans of existing units like BEL, ITI, ECIL, HAL, HTL, etc., have been taken into account. Also the projections made by Task Force VII regarding the production of consumer and professional electronics during the Fifth Plan have been considered. In arriving at a ten year demand profile, the general growth rate envisaged for electronic equipment industry during the decade 1974-84 has been taken into account. It is assumed that a production of Rs. 250 crores a year will be achieved in the year 1974-75 which would grow to Rs. 500 crores by 1978-79. The production will reach a level of Rs. 1,100 crores per year by 1983-84. The corresponding requirements of electromechanical components are given in Table 14.2. Most of the requirements are for professional applications only which is clear from Table 14.3 where a break-up of the requirements for professional and consumer applications is given for the year 1978-79.

It must be mentioned here that even though the large scale use of integrated circuits has displaced many discrete components like resistors and capacitors, its impact on electromechanical components will continue to be small.

14.2.3. Standardisation

There is a general need for standardisation in the choice of components used in equipment design and hence in the type of components produced in the country. The need for standardisation is particularly important for electromechanical components because of large tooling cost involved in their production and consequent uneconomic nature of production of small quantities of wide varieties of each type of components. Therefore, manufacturers prefer to make only those types of components which are required in good number so that the unit price is comparable to imported one. This situation has resulted in a large amount of import of these components, the varieties of which will be well over thousand but which are quantitywise small.

The Panel on Electrical and Mechanical Components has discussed the question of standardisation of electromechanical components in considerable detail and has recommended standard lists of electromechanical components which should be

Table 14.2. Ten Year demand profile for Electromechanical components.
(All figures in Rs. Crores)

	Average unit price (Rs.)	1974-75.	1975-76.	1976-77.	1977-78.	1978-79.	1983-84.	Fifth Five Year Plan 1974-79	Sixth Five Year Plan 1979-84
						5th Plan Terminal year	6th Plan Terminal year		
Connectors, total		4.50	5.65	6.80	8.40	10.50	21.00	35.85	81.00
Coaxial	15	1.00	1.15	1.35	1.55	1.85	3.50	6.90	14.00
Cylindrical	20	0.85	1.00	1.15	1.30	1.45	3.00	5.75	10.00
Rack and panel	20	0.85	1.05	1.20	1.35	1.50	3.00	5.95	10.00
Printed circuit	15	1.40	2.00	2.60	3.60	5.00	11.00	14.60	42.00
Miscellaneous	2	0.40	0.45	0.50	0.60	0.70	1.50	2.65	5.00
Relays, total		7.15	8.45	10.30	12.15	14.00	28.00	52.00	110.00
Armature type, total		6.00	7.00	8.50	10.00	11.50	22.00	43.00	85.00
Hermetically sealed	200	1.00	1.20	1.45	1.70	2.00	4.00	7.35	13.00
Telephone type	25	4.50	5.20	6.35	7.45	8.50	16.00	32.00	65.00
Unsealed type	40	0.50	0.60	0.70	0.85	1.00	2.00	3.65	7.00
Reed	17	0.40	0.55	0.70	0.85	1.00	3.00	3.50	12.00
Miscellaneous	150	0.75	0.90	1.10	1.30	1.50	3.00	5.55	13.00
Switches, total		3.35	4.25	5.30	6.50	8.00	18.00	27.40	64.00
Rotary, wafer	12	0.70	0.85	1.05	1.30	1.60	3.50	5.50	14.00
Rotary, Power	30	0.05	0.07	0.09	0.12	0.15	0.35	0.48	1.50
Pushbutton	5	0.40	0.50	0.65	0.80	1.05	2.20	3.40	7.00
Toggle	9	0.90	1.20	1.50	1.80	2.22	4.50	7.62	18.00
Sensitive	5	0.04	0.05	0.07	0.09	0.12	0.25	0.37	1.00
Slide	2.5	0.50	0.60	0.70	0.85	1.00	2.00	3.65	7.00
Lever	15	0.16	0.20	0.24	0.30	0.36	0.70	1.26	2.50
Reed	5	0.30	0.38	0.50	0.62	0.75	2.00	2.55	6.00
Miscellaneous	10	0.30	0.40	0.50	0.62	0.75	2.50	2.57	7.00
Electromechanical total		15.00	18.35	22.40	27.05	32.50	67.00	115.25	255.00

Table 14.3. Requirements of electromechanical components for professional and consumer applications in the year 1978-79.

(Quantity in millions, value in Rs. crores)

	Professional		Consumer	
	Quantity	Value	Quantity	Value
Connectors, total	7.20	9.60	3.0	0.90
Coaxial	0.80	1.35	0.5	0.50
Cylindrical	0.34	1.15	0.5	0.30
Rack and panel	0.76	1.50	—	—
Printed circuit	3.30	5.00	small	—
Miscellaneous	2.00		2.0	0.10
Relay, total*	4.55	14.00		
Armature type, total	3.85	11.50		
Hermetically sealed	0.10	2.00		

Telephone type	3.50	8.50	Requirement of relays for consumer applications is negligible	
Unsealed type	0.25	1.00		
Reed	0.60	1.00		
Miscellaneous	0.10	1.50		
Switches, total	2.80	3.00	10.0	5.00
Rotary, wafer	0.28	1.10	1.0	0.50
Rotary, power	0.05	0.15	—	—
Pushbutton	0.10	0.05	1.5	0.75
Toggle	0.22	0.22	2.5	2.25
Sensitive	0.24	0.12	—	—
Slide	—	—	4.0	1.00
Lever	0.24	0.36	—	—
Reed	1.50	0.75	—	—
Miscellaneous	0.17	0.25	1.0	0.50
Electromechanical, total	14.55	26.60	13.0	5.90

* Signalling relays used by railways have not been taken into account in this.

used for future professional and commercial applications. The following factors have been considered in recommending the standards for future applications: (i) requirements indicated by the equipment designers/manufacturers and (ii) varieties needed to encompass the spectrum of requirements. The following reduction in varieties of components has been effected by the standards recommended by the Panel. For connectors, MIL (US) specifications include over one lakh types whereas the Panel has compressed this to nearly 1,600 types. In the case of relays, the MIL specifications span over 300 types, but the Panel has recommended only 14 types. In the case of switches the varieties, the MIL specifications are more than 400 but the Panel has recommended about 50 types. The Panel has analysed the present and future requirements and it is of the view that the recommended list of standards will cover most of the requirements in the country.

The types quoted in the list of standards recommended have been taken from the joint services specifications prepared by the Electronic Components Standardisation Organisation (LCSO) as these are the basic specifications in the country available in a complete form. While the recommended standards are basically intended for professional applications, the Panel has suggested that with certain relaxations—permitting the use of alternative materials and processes—the same components could be adopted for consumer applications also. The work relating to the standardisation of electromechanical components for consumer applications may be taken up by the Standardisation Organisation.

Connectors

Connectors could be broadly classified as low frequency (including DC) connectors and high frequency (coaxial) connectors. The low frequency connectors include the printed circuit connectors, cylindrical connectors and rack and panel connectors

(a) Coaxial Connectors

The types of coaxial connectors generally used in the country are BNC, TNC, N, SMA, SMC and UHF series. The general characteristic features of these connectors are given in Table 14.4.

BNC connectors are miniature size connectors (having outer diameter approximately 14.3 mm to 16.7 mm) and as general purpose connector, they are

Table 14.4. Summary of the general characteristic features of coaxial connectors.

	Series BNC	Series TNC	Series N	Series SMA	Series SMC	Series UHF
Coupling	Bayonet	Threaded	Threaded	Threaded	Threaded	Threaded
Characteristics						
Frequency range	0-4 GHz	0-11 GHz	0-11 GHz	0-12.4 GHz	0-10 GHz	0-300 MHz
Impedance (ohms)	50	50	50	50	50	Non-constant
Voltage rating at sea level (max.)	500 V (rms)	500 V (rms)	1000 V (rms)	250 V (rms)	335 V (rms)	500 V (rms)
VSWR (max.) (with cables)	1.35 (500 MHz-4 GHz)	1.30 (500 MHz-11 GHz)	1.30 (500 MHz-11 GHz)	1.20+0.025 (f) GHz	1.25+0.04 (f) GHz	—
RF leakage (db min.)	-55 at 2 to 3 GHz	-60 at 2 to 3 GHz	-90 at 2 to 3 GHz	-60 at 2 to 3 GHz	-60 at 2 to 3 GHz	—
RF insertion loss (db max.)	0.35 at 3 GHz	0.20 at 3 GHz	0.15 at 10 GHz	0.06/(f) GHz	0.25 at 4 GHz	—
Environmental severities (Refer to JSS 50101)						
Temperature (°C)	-55/+85 (for PTFE+200)	-55/+85 (for PTFE+100)	-55/+85 (for PTFE+200)	-55/+85 (for PTFE+200)	-55/+85 (for PTFE+200)	-55/+85 (for PTFE+200)
Damp heat	H 13	H 13	H 13	H 13	H 13	H 13
Air pressure (low)	P 17 : 4.4 kPa (20,000)	P 17 : 4.4 kPa (20,000 m)	P 17 : 4.4 kPa (20,000 m)	P 17 : 4.4 kPa (20,000 m)	P 17 : 4.4 kPa (20,000 m)	P 17 : 4.4 kPa (20,000 m)
Acceleration (steady state)	A 10 : 170 m/s ²	A 10 : 170 m/s ²	A 10 : 170 m/s ²	A 10 : 170 m/s ²	A 10 : 170 m/s ²	A 10 : 170 m/s ²
Vibration	V 13 : 10-2000 Hz	V 13 : 10-2000 Hz	V 13 : 10-2000 Hz	V 14 : 10-2000 Hz	V 14 : 10-2000 Hz	V 13 : 10-2000 Hz
Impact (shock)	S 12 : 500 m/s ²	S 14 : 1 Km/s ²	S 14 : 1 km/s ²	S 14 : 1 km/s ²	S 14 : 1 km/s ²	S 12 : 500 m/s ²
Materials						
Shell	Brass	Brass	Brass	Stainless steel or beryllium-copper	Brass	Die cast zinc or brass
Finish	Silver	Silver	Silver	Gold	Gold	Silver
Contact						
Male	Brass	Brass	Brass	Brass	Brass	Brass
Female	Beryllium copper or phosphor bronze	Beryllium copper or phosphor bronze	Beryllium copper or phosphor bronze	Beryllium copper	Beryllium cop- per	Beryllium copper phosphor bronze
Finish	Silver or gold	Silver or gold	Silver or gold	Gold	Gold	Silver or gold
Dielectric	PTFE, rexolite	PTFE	PTFE, rexolite	PTFE	PTFE	PTFE, rexolite, DAP, melamine and mica filled bakelite

extensively used. They have good RF Characteristics upto 4GHz and can be used at higher frequencies when vibration or shock is not anticipated. The main features of BNC connectors are overlapping dielectrics, a wiping outer contact and a gasketed spring-loaded sleeve construction. Table 14.5 gives the list of BNC connectors recommended by the Panel.

TNC connectors are also miniature size connectors (having outer diameter approximately 14.3 mm to 16.7 mm) and are the threaded version of the BNC connectors. TNC connectors can be used upto 11 GHz. The features of TNC connectors are gasketed interface, overlapping dielectrics and a wiping or butt-jointed outer conductor. Table 14.6 gives a list of TNC connectors recommended by the Panel.

Table 14.5. Specifications for coaxial (BNC) connectors.

JSS pattern (JSS 52401)	MIL number	UG/U	Description	Characteri- stic impedance (in Ohms)	Type of mounting	Type of termination
1. J52401/01-01	M39012/16-0001	88G	Plug, male, unsealed, cabled	50	—	Solder
2. J52401/02-01	M39012/17-0001	89D	Plug, female, unsealed, cabled	50	—	Solder
3. J52401/03-01	M39012/20-0001	913B	Plug, right angle, unsealed, cabled	50	—	Solder
4. J52401/04-01	M39012/19-0001	909C	Socket, female, unsealed, cabled	50	Jam nut	Solder
5. J52401/05-01	M39012/21-0001	625C	Socket, female, unsealed, uncabled	50	Jam nut	Solder pocket
6. J52401/06-01	M39012/22-0001	290B	Socket, female, unsealed, uncabled	50	Flange	Solder pocket
7. J52401/07-01	M39012/24-0002	912B	Socket, female, hermetically sealed, uncabled	50	Jam nut	Solder eyelet
8. J52401/07-02	M39012/24-0001	911B	Socket, female, hermetically sealed, uncabled	50	Jam nut	Solder eyelet

Table 14.6. Specifications for coaxial (TNC) connectors.

JSS pattern (JSS 52401)	MIL number	Description	Characteri- stic impedance (in Ohms)	Type of mounting	Type of termination
1. J52401/20-01	M39012/26-0001	Plug, male, unsealed, cabled	50	—	Solder
2. J52401/21-01	M39012/27-0001	Plug, female, unsealed, cabled	50	—	Solder
3. J52401/22-01	M39012/30-0001	Plug, right angle, unsealed, cabled	50	—	Solder
4. J52401/23-01	M39012/28-0001	Socket, female, unsealed, cabled	50	Jam nut	Solder
5. J52401/24-01	M39012/31-0002	Socket, female, unsealed, uncabled	50	Jam nut	Solder pocket

6.	J52401/24-02	M39012/31-0001	Socket, female, unsealed, uncabled	50	Jam nut	Solder pocket
7.	J52401/25-01	M39012/32-0001	Socket, female, unsealed, uncabled	50	Flange	Solder pocket
8.	J52401/26-01	M39012/34-0002	Socket, female, hermetically sealed, uncabled	50	Jam nut	Solder eyelet
9.	J52401/26-02	M39012/34-0001	Socket, female, hermetically sealed, uncabled	50	Jam nut	Solder eyelet

N-connectors are among the alter type medium sized connectors (approximately 19 mm to 25.4 mm outer diameter). They use a threaded coupling sleeve with gasketed interface and a dielectric bead design gives an air-dielectric interface. They are rated for use upto 11 GHz. Table 14.7 gives a list of N connectors recommended by the Panel.

Table 14.7. Specifications for coaxial (N) connectors.

JSS pattern (JSS 52402)	MIL number	UG/U	Description	Characteristic impedance (in ohms)	Type of mounting	Type of termination
1.	J52402/01-01	M39012/01-0002	21H Plug, male, unsealed, cabled	50	—	Solder
2.	J52402/02-01	M39012/02-0003	1186B Plug, female, unsealed, cabled	50	—	Solder
3.	J52402/03-01	M39012/05-0001	594C Plug, right angle, unsealed, cabled	50	—	Solder
4.	J52402/04-01	M39012/03-0002	160E Socket, female, unsealed, cabled	50	Jam nut	Solder
5.	J52402/05-01	M39012/04-0002	58B Socket, female, unsealed, uncabled	50	Flange	Solder
6.	J52402/06-01	M39012/04-0001	680B Socket, female, hermetically sealed, uncabled	50	Jam nut	Solder pocket

SMA connectors are subminiature size connectors (having outer diameter approximately 7.9 mm to 11.1 mm) with threaded coupling. They have butt-mated outer conductor and relatively low VSWR. The shells of these connectors are presently available in stainless steel or beryllium copper construction. Beryllium copper shells are generally preferred as they assure rugged mechanical performance and their yield-strength is three times that of stainless steel. Use of this alloy also allows twice the coupling nut torque. Beryllium copper is easier to machine and gold plating adheres much more readily to a copper based alloy. Table 14.8 gives a list of SMA connectors recommended by the Panel.

Table 14.8. Specifications for coaxial (SMA) connectors

JSS pattern (JSS 52405)	MIL numbers	Description	Characteristic impedance (in ohms)	Type of mounting	Type of termination	
1.	J52405/01-01	M39012/55-3007* 55-4007**	Plug, male, unsealed, cabled	50	—	Solder
2.	J52405/02-01	M39012/56-3007* 56-4007**	Plug, male, right angle, unsealed, cabled	50	—	Solder

XIV

3.	J52405/03-01	M39012/57-3007* 57-4007**	Plug, female, unsealed, cabled	50	—	Solder
4.	J52405/04-01	M39012/59-3007* 59-4007**	Socket, female unsealed, cabled	50	Jam nut	Solder
5.	J52405/05-01	M39012/60-3001* 60-4001**	Socket, female, unsealed, uncabled	50	Flange	Solder pocket
6.	J52405/06-01	M39012/61-3001* 61-4001**	Socket, female, unsealed, uncabled	50	Jam nut	Solder
7.	J52405/07-01	M39012/62-3002* 62-4002**	Socket, female, hermetically sealed, uncabled	50	Jam nut	Solder eyelet

*Shell material : stainless steel

**Shell material : beryllium copper

SMC connectors are the smallest RF connectors (having outer diameter approximately 6.35 mm) with a threaded coupling. They are not gasketed and have an overlapping dielectric and butt-mated outer conductor. Because of small size, they can be densely packaged while maintaining excellent RF characteristics upto 10GHz. Table 14.9 gives a list of SMC connectors recommended by the Panel.

Table 14.9. Specifications for coaxial (SMC) connectors

JSS pattern (JSS 52405)	MIL number	UG/U	Description	Characteristic impedance (in ohms)	Type of mounting	Type of termination
1. J52405/40-01	M39012/73-0002	1465	Plug, female, un- sealed, cabled	50	—	Solder
2. J52405/41-01	M39012/74-0002	1467	Plug, male, unsealed, cabled	50	—	Solder
3. J52405/42-01	M39012/75-0002	1466	Plug, female, right angle, unsealed, cabled	50	—	Solder
4. J52405/43-01	M39012/76-0002	1468	Socket, male, unsealed, cabled	50	Jam nut	Solder
5. J52405/44-01	M39012/77-0002	1464	Socket, male, unsealed, uncabled	50	Jam nut	Solder pocket
6. J52405/45-01	M39012/78-0002	—	Socket, male, hermeti- cally sealed, uncabled	50	Jam nut	Solder

UHF connectors were one of the earliest RF connectors and are medium size connectors (having outer diameter approximately 19 mm to 25.4 mm), with a threaded coupling. These connectors give satisfactory performance upto 300 MHz. These are not designed for impedance matching and have nonconstant impedance. Table 14.10 gives a list of UHF connectors recommended by the Panel.

Table 14.10. Specifications for coaxial (UHF) connectors.

JSS pattern (JSS 52401)	MIL number	Description	Characteristic impedance	Type of mounting	Type of termina- tion
1. J 52401/ 40-01	PL 259	Plug, male, unsealed	Non-constant	—	Solder
2. J 52401/ 40-02	PL 259A	Plug, male, unsealed	Non-constant	—	Solder
3. J 52401/ 41-01	SO 239	Socket, female, unsealed	Non-constant	Flange	Solder

An adaptor helps the joining together of two or more mechanically incompatible connectors. Adaptors are either 'straight' or 'angle' or 'tee'. The straight adaptor joins like (male-male or female-female) connectors of the same series. The angle adaptor usually has a male end and a female end and is used where an angle connection is needed and an angle plug cannot be used. The 'tee' adaptor joins three connectors together and can have any combination of ends, such as three female ends, two female ends and one male end and so on. There are also between-series adaptors which provide transition from one series to another. The Panel has recommended 40 types of adaptors (Table 14.11).

Table 14.11. Specifications for coaxial connector adaptors.

JSS pattern (JSS 52408)	UG/U	Description (Adaptor, radio frequency)	Type of contact	Charac- teristic imped- ance (in ohms)
1. J52408/01-01	491B	Series BNC, unsealed	Male-Male	50
2. J52408/02-01	492D	Series BNC, pressurised	Female-Female	50
3. J52408/03-01	306B	Series BNC, unsealed (right angle)	Male-Female	50
4. J52408/04-01	274C	Series BNC, tee, unsealed	Female-Male-Female	50
5. J52408/05-01	—	Series TNC, unsealed	Male-Male	50
6. J52408/06-01	—	Series TNC, unsealed	Female-Female	50
7. J52408/07-01	—	Series TNC, unsealed (right angle)	Male-Female	50
8. J52408/08-01	—	Series TNC, tee, unsealed	Female-Male-Female	50
9. J52408/09-01	57B	Series N, unsealed	Male-Male	50
10. J52408/10-01	29C	Series N, unsealed	Female-Female	50
11. J52408/11-01	27D	Series N, unsealed (right angle)	Male-Female	50
12. J52408/12-01	28A	Series N, tee, unsealed	Female-Female-Female	50
13. J52408/13-01	—	Series SMA, unsealed	Male-Male	50
14. J52408/14-01	—	Series SMA, unsealed	Female-Female	50
15. J52408/15-01	—	Series SMA, unsealed (right angle)	Male-Female	50
16. J52408/16-01	273	Series BNC to series UHF, unsealed	Female-Male	50
17. J52408/17-01	1034	Series BNC to series N, unsealed	Male-Male	50
18. J52408/18-01	606	Series BNC to series N, unsealed	Female-Female	50
19. J52408/19-01	335	Series BNC to series N, unsealed	Male-Female	50
20. J52408/20-01	201	Series BNC to series N, unsealed	Female-Male	50
21. J52408/21-01	—	Series BNC to series TNC, unsealed	Male-Male	50
22. J52408/22-01	—	Series BNC to series TNC, unsealed	Female-Female	50
23. J52408/23-01	—	Series BNC to series TNC, unsealed	Male-Female	50
24. J52408/24-01	—	Series BNC to series TNC, unsealed	Female-Male	50
25. J52408/25-01	—	Series BNC to series SMA, unsealed	Male-Male	50
26. J52408/26-01	—	Series BNC to series SMA, unsealed	Female-Female	50
27. J52408/27-01	—	Series BNC to series SMA, unsealed	Male-Female	50
28. J52408/28-01	—	Series BNC to series SMA, unsealed	Female-Male	50
29. J52408/29-01	—	Series N to series TNC, unsealed	Male-Male	50
30. J52408/30-01	—	Series N to series TNC, unsealed	Female-Female	50
31. J52408/31-01	—	Series N to series TNC, unsealed	Male-Female	50
32. J52408/32-01	—	Series N to series TNC, unsealed	Female-Male	50

33.	J52408/33-01	—	Series N to series SMA, unsealed	Male-Male	50
34.	J52408/34-01	—	Series N to series SMA, unsealed	Female-Female	50
35.	J52408/35-01	—	Series N to series SMA, unsealed	Male-Female	50
36.	J52408/36-01	—	Series N to series SMA, unsealed	Female-Male	50
37.	J52408/37-01	—	Series TNC to series SMA, unsealed	Male-Male	59
38.	J52408/38-01	—	Series TNC to series SMA, unsealed	Female-Female	50
39.	J52408/39-01	—	Series TNC to series SMA, unsealed	Male-Female	50
40.	J52408/40-01	—	Series TNC to series SMA, unsealed	Female-Male	50

(b) Cylindrical Connectors

The various parameters of cylindrical connectors are dependent upon size and construction of the shell, contact size, mounting, termination insulation and environmental severities. The general characteristics for all types of cylindrical connectors are given in Table 14.12.

Bayonet coupling (miniature, environment resistant) cylindrical connectors use bayonet coupling which provides quick connect and disconnect facility. These connectors have either solder or crimp terminations. The bayonet coupling cylindrical connectors recommended by the Panel are listed in Table 14.13.

Threaded coupling cylindrical connectors have larger shell sizes to accommodate more number of contacts. The shell construction recommended are solid shell, split shell and environment resistant types of shell. In the case of receptacle, box mounting has been recommended. The type of threaded coupling cylindrical connectors recommended by the Panel are given in Table 14.14.

Audio connectors are designed for use in audio and other low-level circuits where reliability and the elimination of mechanical interference are necessary. Provision of bayonet coupling facilitates quick connection and disconnection. The contacts of these connectors can be either rigid or non-rigid. Non-rigid contacts are spring-loaded and provide positive electrical connection with minimum voltage drop. The number of contacts available are 5 and 10. The types of audio connectors recommended by the Panel are given in Table 14.15.

Table 14.12. Summary of the general characteristic features of cylindrical connectors.

	Threaded coupling						Bayonet coupling		Audio	
	5	9	22	41	73	135	5	15	sealed	Unsealed
Current rating, A (contact size)	(—)	(—)	(16)	(12)	(8)	(4)	(20)	(16)	500 mA	3
Proof voltage at sea level, V AC (rms)	1000, 4500	2000, 7000	2800	3500			1500	2300	500	500

Contacts	Shell size	No. of contacts	Shell size	No. of contacts	No. of contacts	No. of contacts
	1	2, 3 & 6	8	2, 3 and 4	5 and 10	3 and 5
	2	12	10	6		
	3	25	12	3 and 10		
	10 SL	3	14	5, 12, 15 and 19		
	14 S	6	16	8 and 26		
	18	5 and 10	20	16, 39 and 41		
	20	5 and 6	24	61		
	22	3 and 19				
	24	4 and 24				

	28	12 and 15		
	32	4 and 35		
	36	48		
Environmental severities (Refer to JSS 50101)				
Temperature severity (°C)	-55/+125, -40/+85	-55/+125	-55/+85	-40/+70
Damp heat severity	H13	H13	H13	H12
Air pressure (low)	-	p 17 : 4.4 kPa (20000 m)	p 16 : 8.5 kPa (16000 m)	
Acceleration (steady state)	A 10 : 170 m/s ²	A 11 : 500 m/s ²	A 10 : 170 m/s ²	A 10 : 170 m/s ²
Vibration	V 11 : 10 to 500 Hz	V 13 : 10 to 2000 Hz	V 10:10 to 55 Hz	V 10 : 10 to 55 Hz
Impact (shock)	S 12 : 500 m/s ²	S 12 : 500 m/s ²	S 12 : 500 m/s ²	S 12 : 500 m/s ²
Materials				
Shell	Aluminium, aluminium alloy and aluminium plated with chromate and cadmium	Aluminium alloy, olive drab chromate over cadmium	Stainless steel (passivated)	Brass/Die-cast zinc, nickel plated
Insert	Melamine or DAP, polychloroprene (resilient)	Polychloroprene	DAP (or phenolic for lower severities)	Phenolic or black polycarbonate
Contacts	Brass or copper alloy, gold plated	Copper alloy, gold plated	Copper alloy, gold plated	Male : Brass, silver plated Female : Phosphor bronze, silver plated

Table 14.13. Specifications for miniature cylindrical (environment, resistant bayonet coupling) connectors.

JSS pattern (JSS 50813)	MIL Number	Description	Shell sizes	Contact size
1. J50813/01	MS 3114 F	Socket, environment resistant rear mounting jam nut type, sealed, solder termination (to mate with J 50813/02)	8, 10, 12, 14, 16, 20, 24	16, 20
2. J50813/02	MS 3116 F	Plug, straight environment resistant, sealed, solder termination (to mate with J 50813/01)		

XIV

- | | | | |
|----|-----------|-----------|---|
| 3. | J50813/03 | MS 3124 F | Socket, environment resistant, crimp termination (to mate with J 50813/04) |
| 4. | J50813/04 | MS 3126 F | Plug, straight environment resistant, crimp termination (to mate with J 50813/03) |

Table 14.14. Specifications for cylindrical (threaded coupling) connectors.

JSS pattern (JSS 50812)	MIL number/ DEF number	Description	Shell sizes	Contact size
1. J50812/01	MS 3102 R	Socket, box mounting, environment resistant, sealed. (to mate with J 50812/03, 04, 05)	10 SL	
2. J50812/02	MS 3102 A	Socket, box mounting, solid, unsealed (to mate with J 50812/03, 04, 05)	14 S 18	16 12
3. J50812/03	MS 3106 A	Plug, straight, solid, unsealed (to mate with J50812/01, 02)	22 24 28	4
4. J50812/04	MS 3108 B	Plug, right angle, split, unsealed (to mate with J 50812/01, 02)	32	
5. J50812/05	MS 3108 R	Plug, right angle, environment resistant, sealed (to mate with J 50812/01,02)		
6. J50812/21	Pattern 104 of DEF- 5325-2	Socket, sealed (to mate with J 50812/22)	1	5A and 19A at 250 V AC (rms)
7. J50812/22	Pattern 104 of DEF- 5325-2	Plug, sealed		

Table 14.15. Specifications for cylindrical (audio) connectors.

JSS pattern (JSS 50831)	MIL number	Description	No. of contact	Type of contact	Type of termina- tion	Type of sealing
1. J50831/01	U-183/U	Socket	5	Non-rigid	Solder pocket	Water proof
2. J50831/02	U-228/U	Plug	5	Non-rigid	Solder pocket	Water proof
3. J50831/03	U-229/U	Plug	5	Rigid	Solder pocket	Water proof
4. J50831/04	U-77/U	Plug	10	Rigid	Solder pocket	Water proof

5.	J50831/05	U-78/U	Plug	10	Non-rigid	Solder pocket	Water proof
6.	J50831/06	U-79/U	Socket	10	Non-rigid	Solder pocket	Water proof
7.	J50831/07	U-127/U	Plug, right angle	10	Rigid	Solder pocket	Water proof
8.	J50831/11	—	Plug, straight	3	—	Solder pocket	Unsealed
9.	J50831/12	—	Socket	3	—	Solder eyelet	Unsealed
10.	J50831/13	—	Plug, straight	5	—	Solder pocket	Unsealed
11.	J50831/14	—	Socket	5	—	Solder eyelet	Unsealed

(c) Rack and Panel Connectors

Rack and panel connectors are employed in a large variety of applications and normally are rectangular in shape with multiple contacts. The contacts for these connectors are of either pin or ribbon or blade type. These connectors are classified on the basis of size, type of polarisation and environmental considerations. The general characteristics of these connectors are given in Table 14.16.

The miniature polarised shell rack and panel connectors are available in general purpose, nonmagnetic and sealed shell construction. Nonmagnetic connectors are intended for use in application where the presence for residual magnetism must be held to very low levels to avoid interference with nearby sensitive instrumentation. The Panel has recommended 10 types of polarised shell rack and panel connectors which are listed in Table 14.17.

In other type of rack and panel connectors, polarisation is accomplished by mechanical means such as guide pins, guide sockets or jack screws. The types of such connectors recommended by the Panel are given in Table 14.18.

Table 14.16. Summary of the general characteristics of rack and panel connectors.

	Polarised shell (miniature)	Other than polarised shell
Characteristics		
Current rating, A (max.)	7.5	5, 7.5, 22
Proof voltage (at sea level), VAC (rms)	1000	1000 for connectors with contact size 16 1200 for connectors with contact size 20
Environmental severities (Refer to JSS 50101)		
Temperature (°C)	-55/+125	-55/+125
Damp heat	H 13	H 13
Air pressure (low)	P 17 : 4.4 kPa (20000 m)	P 17 : 4.4 kPa (20000 m)
Acceleration (steady state)	—	—
Vibration	V 14 : 10 to 2000 Hz	V 11 : 10 to 500 Hz
Impact (shock)	S 12 : 500 m/s ²	S 12 : 1 k m/s ²

XIV

Materials		
Shell		Steel, cadmium plated with High grade aluminium alloy yellow chromate finish (for or corrosion resistant steel general purpose applica- with cadmium plating tins); brass, cadmium plated (for non-magnetic applications)
Insert		Glass filled DAP Glass filled DAP
Contacts		
Male		Brass, gold plate over silver plate : Brass, gold plated
Female		Beryllium copper, gold plate over silver plate Spring temper phosphor bronze, gold plated

Table 14.17. Specifications for rack and panel (miniature, polarised shell) connectors.

JSS pattern (JSS 50820)	MIL number	Description	Number of contacts	Number of Shell sizes	Contact size	Type of termination
1. J50820/01	MIL-C-24308/5	Non-magnetic, female contacts	9, 15, 25, 37 & 50	5	20	Solder
2. J50820/02	MIL-C-24308/7	Non-magnetic, male contacts	9, 15, 25, 37 & 50	5	20	Solder

Table 14.18. Specifications for rack and panel (other than polarised shell) connectors.

JSS pattern (JSS 50821)	MIL number/ IEC number	Description	Number of contacts	Number of shell sizes	Contact size	Type of termination
1. J50821/01	MIL-C-28748/1	Male contacts	9,14,20, 34,50,75 and 104	7	16	Solder
2. J50821/02	MIL-C-28748/2	Female contacts	do	7	16	Solder
3. J50821/03	MIL-C-28748/5	Male contacts	do	7	20	Solder
4. J50821/04	MIL-C-28748/6	Female contacts	do	7	20	Solder
5. J50821/07	MIL-C-28748/3	Male contacts	do	7	16&20	Crimp
6. J50821/08	MIL-C-28748/4	Female contacts	do	7	16&20	Crimp
7. J50821/09	130-5IEC-16PC	Male, blade type	16	1	-	Solder
8. J50821/10	301-5IEC-16SC	Female, blade type	16	1	-	Solder
9. JS0821/20	-	Male contacts	8	1	-	Solder
10. J50821/21	-	Female contacts	8	1	-	Solder
11. J50821/22	-	Male contacts	24	1	-	Solder
12. J50821/23	-	Female contacts	24	1	-	Solder
13. J50821/24	-	Male contacts	16	1	-	Solder
14. J50821/25	-	Female contacts	16	1	-	Solder
15. J50821/26	130-5IEC-30PC	Male, blade type	30	1	-	Solder
16. J50821/27	130-5IEC-30SC	Female, blade type	30	1	-	Solder

(d) Printed Circuit Connectors

The various parameters of printed circuit connectors are dependent upon their construction (one piece or two piece), contact spacing, number of contact positions, type of contact, type of termination and mounting. The general characteristics for all types of printed circuit connectors are given in Table 14.19.

Table 14.19. Summary of the general characteristics of printed circuit connectors.

	General purpose	Edge connectors
Characteristics		
Current rating, A (max.)	5	4
Voltage proof (at sea level)		
V AC (rms)	375 1800 1800	750
Contact spacing (mm)	1.270 3.962 5.080 2.540	
No. of contact positions	6, 10, 12, 15, 17, 18, 22, 23, 25, 28, 29, 35, 36, 41, 43, 47	11, 25 and 33
Environmental severities (Refer to JSS 50101)		
Temperature (°C)	-65/+125	-40/+125
Damp heat	H 13	H 12
Air pressure (low)	P 17 : 4.4 kPa (20000 m)	P 17 : 4.4 kPa (20000 m)
Acceleration (steady state)	A 11 : 500 m/s ²	A10 : 170 m/s ²
Vibration	V 13 : 10 to 2000 Hz	V 12 : 10 to 2000 Hz
Impact (shock)	S 14 : 1000 m/s ²	S 12 : 500 m/s ²
Materials		
Insulator	Green glass-fibre-filled DAP, asbestos-filled DAP, bluemineral- filled DAP	Plug-Glass filled nylon socket—poly- carbonate
Contacts		
Plug	Brass,	Profiled brass
Socket	Phosphor bronze	—Copper nickel alloy
Plating	Gold over copper	Gold plated
Guide pins	Cadmium plated brass with gold iridescent chromate finish	—
End caps	Stainless steel (passivated)	

In order to reduce the varieties without impairing the spectrum of requirements, the Panel decided to standardise around the following details :

- a) General purpose connectors — Contact spacing -5.08 mm, 3.962 mm and 1.27 mm, number of contacts-6 to 86.
- b) Edge connectors — Contact spacing -2.54 mm, number of contacts 11, 25 and 33.

The contact spacing 5.08 mm is included for two piece connectors to serve the special requirements as in airborne applications and 1.27 mm contact spacing is included for future design requirements.

The types of printed circuit connectors recommended by the Panel are given in Tables 14.20 and 14.21.

Table 14.20. Specifications for printed circuit (general purpose) connectors.

JSS pattern (JSS 50806)	MIL number	Description	Contact spacing (mm)	No. of contact positions	Terminations
1. J50806/01	MIL-C-21097/7	Male adaptor, Type C contacts (to mate with J50806/02)	3.962	6, 10, 12, 15, 18 and 22	Solder
2. J50806/02	MIL-C-21097/6	Socket, card insertion type A contacts (to mate with J50806/01)	3.962	6, 10, 12, 15, 18 and 22	Solder
3. J50806/03	MIL-C-21097/1	Socket, card insertion, type AD contacts (to mate with the P. C. board of 1.587 mm or 2.381 mm or 3.175 mm thickness)	3.962	6, 10, 15, 18, 22, 28, 36, and 43	Solder
4. J50806/04	MIL-C-21097/4	Socket, composite, alternate dual row type CR contacts (to mate with J50806/05)	5.080	17, 23, 29, 35 and 41	Solder
5. J50806/05	MIL-C-21097/5	Male adaptor, alternate dual row type CS contacts (to mate with J50806/04)	5.080	17, 23, 29, 35 and 41	Solder
6. J50806/06	MIL-C-21097/13	Socket, composite, alternate dual row type CR contacts (to mate with J50806/07 and J50806/08)	5.080	17, 23, 29, 35 41 and 47	Removable (solder or crimp)
7. J50806/07	MIL-C-21097/14	Male adaptor, type CS blade contacts (to mate with J50806/06)	5.080	17, 23, 29, 35 41 and 47	Solder
8. J50806/08	MIL-C-21097/15	Male adaptor, alternate dual row type CS blade contacts (to mate with J50806/06)	5.080	17, 23, 29, 35, 41 and 47	Solder
9. J50806/09	MIL-C-21097/20	Socket, card insertion, type AD contacts (to mate with PC board of 1.587 mm thickness)	1.270	6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21 22, 23, 24, and 25	Solder

Table 14.21. Edge connectors (2.54 mm contact spacing).

JSS pattern (JSS 50805)	IEC	Description
1. J50805/01	IEC 130-11 Type C	Plug, printed wiring board
2. J50805/02	IEC 130-11 Type C	Plug, printed wiring board
3. J50805/03	IEC 130-11 Type A	Socket, bracket mounted

XIV

Relays

The various parameters of a relay include coil voltage, pick up voltage, dropout voltage, operate time, release time, contact rating, termination, mounting dimensions, sealing and environmental severities. The general characteristics for all types of relays have been given in Table 14.22.

Table 14.22. Summary of the characteristic features of relays.

	Armature type		Reed type
	Hermetically sealed	Other than hermetically sealed	
Characteristics			
Contact rating V (max.)	50 mV, 28 and 100 VDC 115 V AC (400 Hz)	24 V DC 115 and 230 V AC	28 V DC
A (max.)	0.1, 1, 2, 5 and 10	1, 2, 3 and upto 5	1
Coil voltage, VDC	6, 12, 26.5, 48 and 110	3, 6, 12, 24, 48, 110 and 230	6, 12, 26.5 and 28
Environmental severities (Refer to JSS 50101)			
Temperature severity (°C)	-65/+125	-40/+70	-55/+85
Damp heat severity	H 13	H 12	H 13
Air pressure (low)	P 17 : 4.4 kPa (20,000m)	P 14 : 30 kPa (8500 m)	P 17 : 4.4 kPa (20,000 m)
Acceleration (steady state)	A 10 : 170 m/s ²	A 10 : 170 m/s ²	A 10 : 170 m/s ²
Vibration	V 13 : 10 to 2000 Hz	V 11 : 10 to 500 Hz	V 14 : 10 to 2000 Hz
Impact (shock)	S 14 : 1 km/s ²	S 10 : 300 m/s ²	S 14 : 1 km/s ²
Contact material	—	Fine silver, cadmium silver and cadmium silver oxide	—

(a) Armature (Hermetically Sealed) Relays

These relays are intended for use in DC and AC (single phase) electronic and communication equipment as a means of controlling the making and breaking of circuits in electrically operated equipment and devices. The coil voltage for these relays ranges from 6 Volts to 115 Volts and the contact rating ranges from a few microamperes to 10 amperes. The contact arrangement available ranges from single pole double throw (SPDT) to 6 pole double throw (6PDT). The types of armature type (hermetically sealed) relays as recommended by the Panel are listed in Table 14.23.

Table 14.23. Specifications for armature type (hermetically sealed) relays.

JSS pattern (JSS 50701)	MIL number	Description	Coil voltage current	Contact rating	Termination
1. RYA 01	—	Stud mounting 1A with DPDT contacts	12, 26.5, 48 and 110 VDC	1A (Max.)	Plug-in
2. RYA 02	—	Stud mounting, 1A with 4 PDT contacts	12, 26.5, 48 and 110 VDC	1A (Max.)	Plug-in
3. RYA 03	MIL-R-5757/10	2A with DPDT contacts	6, 12, 26.5, 48 and 110 VDC	Low level & 2A (Max.)	Solder lug, pin, wire

XIV

4. RYA 04	MIL-R-5757/9	Flange mounting subminiature 2A with DPDT contacts	6, 12, and 26.5 VDC	2A (Max.)	Solder lug, pin, wire
5. RYA 05	—	Plug-in 2A with DPDT contacts	26.5 VDC	Low level & 2A (Max.)	Pin
6. RYA 07	MIL-R-5757/15	Stud mounting 5A with 4 PDT contacts	26.5 VDC 115 VAC (400 Hz)	5A (Max.)	Solder lug
7. RYA 08	MIL-R-5757/16	Stud mounting 5A with 6 PDT contacts	26.5 VDC and 115 VAC (400 Hz)	5A (Max.)	Solder lug
8. RYA 09	MIL-R-5757/23	2 holes flange mounting miniature 10A with DPDT contacts	6, 12, 26.5 and 48 VDC	10A (Max.)	Solder lug
9. RYA 10	MIL-R-5757/18	Stud mounting, 10A, 4 PDT contacts	26.5 VDC 115 VAC (400 Hz)	10A (Max.)	Solder lug
10. RYA 11	MIL-R-5757/13	Sensitive 40 mW, 2A, DPDT contacts	6, 8, 13, 18, 40 and 90 mA	2A (Max.)	Solder lug
11. RYA 12	MIL-R-5757/38	Low level to 1A SPDT contacts	6, 9, 12, 18 and 26.5 VDC	Low level & 1A (Max.)	Pin, wire
12. RYA 13	MIL-R-5757/40	Low level to 1A DPDT contacts	6, 9, 12, 18 and 26.5 VDC	1A (Max.)	Pin, wire

(b) Armature Type (Other than Hermetically Sealed) Relays

These relays are used in electronic equipment where electrical, mechanical and environmental requirements are not very stringent. The Panel has not standardised these relays since adequate information was not available.

(c) Reed Relays

A reed relay consists of two reeds which are sealed into a narrow glass tube and overlap at their free end with a small separation between them. The actuating coil is wound on the glass tube and assembly is encapsulated with leads projecting out on either side. In certain applications mercury wetted relays are used essentially to prevent arcing. Reed relays have excellent isolation between input and output (coil and contacts). The coil voltage for these relays varies from 6 volts to 48 volts and contact rating ranges from a few microamperes to 1 ampere. The contact arrangement available ranges from single pole single throw (SPST) to 4 pole double throw (4 PDT). The types of reed relays recommended by the Panel are listed in Table 14.24.

Table 14.24. Specifications for reed type relays.

JSS pattern (JSS 50703)	MIL number	Type description	Contact rating	Coil voltage (V)	Contact arrange- ment
1. RYR 01-A	MIL-R-5757/29	Dry reed	500 mA 28 V DC	6	SPST to 4PDT
2. RYR 01-B	MIL-R-5757/29	Dry reed	500 mA 28 V DC	12	SPST to 4PDT
3. RYR 01-E	MIL-R-5757/29	Dry reed	500 mA 28 V DC	26.5	SPST to 4PD
4. RYR 02-F	MIL-R-5757/34	Dry reed	250 mA 28 V DC	28	SPST to 4PST

Switches

The various parameters of a switch are dependent upon design and construction, type of contact, contact rating and environment severities. The general characteristics of the switches commonly used are given in Table 14.25.

Table 14. 25. Summary of the general characteristic features of switches.

	Rotary			Pushbutton		Toggle	Sensitive	Tele- phone key	Reed
	Wafer	Thumbwheel	Power	Illu- minated	Non illu- minated				
Characteristics									
Current rating DC	125mA-2A	125mA	5A-200A	max 2A-10A	1A-10A	1.5-80A	2-40A	0.5A	125mA-1A
AC	12.5mA-0.5A	62.5mA		2.5A-15A	1A-2.5A	0.5-15A	2.5-15A	0.5-5A	-
Voltage rating DC	28V	28V	28V	28V	28V	28V	28V	28V	28V
AC	230V	230V	125-500V	230V	230V	230V	230V	230V	-
Environmental severities (Refer to JSS 50101)									
Temperature (°C)	-65/+125 -65/+85	-65/+85 -	-55/+85 -	-55/+85 -	-55/+85 -	-55/+85 -	-65/+125 -55/+95	-65/+85 -	-55/+85 -
Damp heat	H 13, H 12	H 13	H 13	H 13	H 13	H 12, H 13	H 12, H 13	H 12	-
Air pressure (low)	P 18 26000m, 2kPa	P 12 3500m, 60kPa	P 16 16000m, 8.5kPa	P 17 20000m, 4.5kPa	P 16 16000m, 8.5kPa	P 17 20000m, 4.4kPa	P 16 16000m, 8.5kPa	P 14 8500m, 30kPa	-
Acceleration (steady state)	A11 : 500m/s	A10 : 170m/s ²	A10 : 170m/s ²	A10 : 170m/s ²	A10 : 170m/s ²	A11 : 500m/s ²	A10 : 170m/s ²	A10 : 170m/s ²	A10 : 170 m/s ²
Vibration	V11 10 to 500 Hz	V13 10 to 2000 Hz	V12 10 to 2000 Hz	V11 10 to 500 Hz	V11 10 to 500 Hz	V11 10 to 2500 Hz	V12 10 to 000 Hz	V11 10 to 500 Hz	V13 10 to 2000 Hz
Impact (shock)	S12 : 500m/s ²	S14 : 1000 m/s ²	S13 : 750 m/s ²	S13 : 750 m/s ²	S14 : 1000m/s ²	S12 : 500m/s ²	S12 : 500m/s ²	S11 : 300m/s ²	S12 : 500 m/s ²

Materials									
Insulation	Ceramic (HT, HF), DAP (GP), phenolic (GP), mycalex (GP) silicon glass (HT)	Polycarbonate (GP), Nylon, PTFE (HT)	Ceramic (HT and heavy current)	Polycarbonate, phenolic (GP), melamine	Polycarbonate, phenolic (GP), melamine	Phenolic (GP), nylon filled moulding	Glass and mica melamine phenolics	Phenolic (GP)	Glass
Contact	Silver plated brass, silver alloy	Metal clad laminates plated with nickel or gold (stator) precious metal alloys (rotor)	Silver plated	Copper alloy, gold alloy, crown or nickel base silver	Gold alloy, fine silver	Silver and phosphor bronze for fixed contacts, gold plated coin silver for moving contacts	Silver	Platinum silver	Gold, cobalt rhodium
Spring	Index spring-Beryllium copper	Brush base and detent spring-heat treated beryllium copper	Beryllium copper	18% B nickel silver, phosphor bronze	18% B nickel silver, phosphor bronze	Dual spring-beryllium copper or phosphor bronze	Trident spring-beryllium copper	Beryllium copper, phosphor bronze	
	Shaft-cold rolled steel	Thumb-wheel-phenolic	Shaft steel	Plunger-stainless steel	Plunger-stainless steel, bakelite	Lever-steel	Plunger-nylon aluminium oxide based, ceramic with PTFE coating	Plunger-stainless steel	

HT : High temperature; HF : High frequency; GP General purpose.

XIV

(a) Rotary Wafer Switches

Rotary wafer switches consist of an index or detenting mechanism, spacers and screws known as the frame and the electrical switching portion called sections or wafers. These sections have rotating insulators or rotors, rotating current carrying members or contacts, stationary insulators called stators; and stationary current-carrying members called clips. Apart from a satisfactory mechanical arrangement, the most important part of the switch is the wafer itself. It must have good dielectric strength, good arc resistance and a high insulation resistance. The various angles of throw included are 18°, 20°, 30°, 45°, 60° and 90°. The maximum wafer size covered is 65.07 mm. These switches could be either open or enclosed and are available with spindle seal or bushing seal or both. Table 14.26 gives a list of rotary wafer switches recommended by the Panel.

Table 14.26. Specifications for rotary wafer switches.

JSS pattern (JSS 51207)	MIL number	Rating	Size of wafer (mm)	Shaft construc- tion	Type of termina- tion	Angle of throw (in°)
1. SRW 01	SR 19 (MIL-S- 3786)	10 mA, 28 V DC	12.70	Single shaft	Solder	30
2. SRW 02	SR 05 (MIL-S- 3786)	200 mA, 28 V DC	25.40	Single shaft and concen- tric	Solder	30, 60
3. SRW 03	SR 03 (MIL-S- 3786)	500 mA, 28 V DC	35.50	Single shaft and concen- tric	Solder	30, 60
4. SRW 04	SR 02 (MIL-S- 3786)	500 mA, 28 V DC	31.75	Single shaft and concen- tric	Solder	30, 60, 90
5. SRW 05	SR 32 (MIL-S- 3786)	200 mA, 28 V DC	39.67	Single shaft and concen- tric	Solder	10, 15, 30

(b) Rotary Thumbwheel Switches

A thumbwheel switch is a panel mounted switching device which provides a visual indication of switch position. These switches are used for low power switching. A rotating drum carries a set of wipers enabling contact to be made between a common terminal and any one of the outlets. The design is normally for 360° rotation but mechanical stops can be arranged at any desired position. Round the periphery of the drum, a series of indentations carrying digital markings and the finger profile allow one digit shift per finger movement. Usually there are ten positions marked 0, 1, ...9. However, a wide variety of positional arrangements and alphabet/numerical codings may be utilised. Any number of switch modules can be stacked in line, thus effecting great economy in switching space. More complex switching is possible by gauging individual units to give multipole, multiway action. The current rating covered by these switches is upto 125 mA. These switches are available in sealed and unsealed types and also illuminated and non-illuminated types. The different angles of throw covered range from 9° to 45°. Table 14.27 gives a list of thumbwheel switches recommended by the Panel.

XIV

Table 14.27. Specifications for rotary printed circuit (thumbwheel) switches.

JSS pattern (JSS 51209)	MIL number	Description	Angle of throw (in°)	Maximum number of stations
1. SRPC 01	MIL-S-22710/12	Sealed, illuminated and non-illuminated	20, 30, 36	15
2. SRPC 02	MIL-S-22710/15	Sealed, illuminated and non-illuminated	36 or 45	15
3. SRPC 03	MIL-S-22710/16	Unsealed, non-illuminated	9 or 9.7	10
4. SRPC 04	MIL-S-22710/10	Unsealed, non-illuminated	22, 30, 36 or 45	5
5. SRPC 05	MIL-S-22710/11	Unsealed, illuminated or non-illuminate	22, 30, 36 or 45	15

(c) Rotary Selector Power Switches

Selector power switches are heavy current type of rotary switch used for power-switching in electronic instruments. Selector power type rotary switches are used in power circuits capable of making, carrying and breaking electric loads upto 10 amperes. The type of termination available is screw type with open construction. The section sizes included in the standard are 31.75 mm to 60 mm. Table 14.28 gives a list of selector power switches recommended by the Panel.

Table 14.28. Specifications for rotary power switches.

JSS pattern (JSS 51208)	MIL number	Rating	Size of section	Type of termina- tion	No. of sections
1. SRP 01	MS 21994	5A, 230 V AC (rms)	43.66	Screw	3
2. SRP 02	MS 21995	5A, 230 V AC (rms)	43.66	Screw	3
3. SRP 03	MS 25002	5A, 230 V AC (rms)	31.75	Screw	—
4. SRP 04	MS 90547	10A, 230 V AC (rms)	56.36	Screw	25
5. SRP 05	—	10A, 250 V AC (rms)	60.00	Screw	4

(d) Pushbutton Switches

Pushbutton switches are used as panel displays and switching devices in AC and DC applications. These switches include single button open and enclosed switches, box-type illuminated switches, and gauged (or interconnected) pushbutton switches. In addition to the illuminated box switches, the single button and gauged interlocking switches are available with internal illumination. The current rating covered by illuminated switches is upto 5A and that of non-illuminated is upto 10A. The switch functions included are single pole single throw (SPST), single pole double throw (SPDT), double pole double throw (DPDT) and 4 pole double throw (4PDT). These switches are available with watertight sealing and dusttight sealing along with the unsealed types. A list of pushbutton switches recommended by the Panel is given in Table 14.29.

Table 14.29. Pushbutton switches.

JSS pattern (JSS 51205 and JSS 51206)	MIL Number	Description
1. SPN 01	MIL-S-8805/3	Momentary pushbutton, non-illuminated
2. SPN 02	MIL-S-8805/23	Momentary non-illuminated
3. SPN 03	MIL-S-8805/23	Momentary non-illuminated
4. SPN 04	MIL-S-8805/25	Alternate non-illuminated
5. SPN 05	MIL-S-8805/25	Alternate non-illuminated
6. SPN 06	MIL-S-8805/38	Momentary non-illuminated
7. SPN 07	MIL-S-8805/64	Momentary non-illuminated
8. SPL 06	MIL-S-22885/8	Momentary pushpull illuminated
9. SPL 07	MIL-S-22885/11	Momentary and alternate illuminated
10. SPL 08	MIL-S-22885/11	Momentary and alternate illuminated
11. SPL 09	MIL-S-22885/56	Momentary and alternate illuminated
12. SPL 10	MIL-S-22885/56	Momentary and alternate illuminated

(e) Toggle Switches

These switches cover a range of rating from 1A to 20A and the switch functions included are single pole single throw (SPST), single pole double throw (SPDT), double pole double throw (DPDT) and 4 pole double throw (4PDT). The types of terminations available are solder and screw. The types of sealing included are barrier sealed, barrier and panel sealed and both. These switches have mounting bush diameters of 6.35 mm, 12 mm and 15 mm. A list of toggle switches recommended by the Panel is given in Table 14.30.

Table 14.30. Toggle switches.

JSS pattern (JSS 51201)	MIL Number	Rating	Function
1. ST 01	—	3A, 250 V AC	SPST
2. ST 02	—	3A, 250 V AC	SPST (with bias spring housing)
3. ST 03	MS 35058	6A, 230 V AC 10A, 230 V AC	SPDT SPDT
4. ST 04	MS 35059	6A, 230 V AC 10A, 230 V AC	DPDT DPDT
5. ST 05	MS 24655	3A, 115 V AC	SPDT
6. ST 06	MS 24656	3A, 115 V AC	DPDT
7. ST 20	MS 25125	10A, 115 V AC	SPDT (lever lock)
8. ST 21	MS 25126	20A, 115 V AC	DPDT (lever lock)
9. ST 22	MS 25127	20A, 115 V AC	4PDT (lever lock)

(f) Sensitive (Micro) Switches

These switches cover a range from 1A to 40A and switch functions included are single pole-single throw (SPST), single pole-double throw (SPDT), 4 pole double throw (4PDT) and 6 pole double throw (6PDT). The types of terminations

available are solder, screw and turret. Turret type of termination is employed for simplified wiring or printed circuit use. Table 14.31 gives a list of sensitive switches recommended by the Panel.

Table 14.31. Specification for sensitive switches.

JSS pattern (JSS 51204)	MIL number	Description	Rating	Function	Type of termination
1. SSO 1	MIL-S-8805/1	Unsealed	2A, 28 V DC	SPDT	Solder and screw
2. SSO 2	MIL-S-8805/2	Unsealed	5A, 28 V DC	SPDT	Solder and wire terminals
3. SSO 3	MIL-S-8805/4	Unsealed	7A, 28 V DC	SPDT	Wire terminals
4. SSO 4	MIL-S-8805/27	Unsealed	10A, 28 V DC	SPDT	Screw
5. SSO 5	MIL-S-8805/77	Unsealed	10A, 28 V DC	DPDT	Solder

(g) Slide Switches

These switches are of interest mainly in consumer industry. ISI may finalise the list of standards for these switches.

(h) Telephone Key Switches

The current ratings covered range from 100 to 300 mA. Telephone key switches produced in the country mostly conform to the UK specification which covers 6 types. They have all been recommended by the Panel and are given in Table 14.32.

Table 14.32. Specifications for telephone key switches.

JSS pattern (JSS 51203)	RCL153	Description	Rating		Type of termina- tion
			Silver contacts	Platinum contacts	
1. STK 01	Pattern 1	Lever, small frame type	300 mA at 250 VAC	600 mA at 250 VAC	Solder
2. STK 02	Pattern 2	Lever, large frame type	300 mA at 250 VAC	600 mA at 250 VAC	Solder
3. STK 03	Low capaci- tance type	Lever, low capa- cittance type	—	500 mA at 250 VAC	Solder
4. STK 04	Post office type	Plunger, post office type	300 mA at 250 VAC	600 mA at 250 VAC	Solder
5. STK 05	Roller move- ment type	Plunger, roller movement type	300 mA at 250 VAC	600 mA at 250 VAC	Solder
6. STK 06	Pattern 3	Lever	300 mA at 250 VAC	600 mA at 250 VAC	Solder

(i) Reed Switches

Reed switches are used in circuits where magnetically-actuated, hermetically sealed switch contacts are required. The current ratings covered are from 125 mA to 1A with different switch functions such as single pole-single throw (SPST) and single pole-double throw (SPDT). Table 14.33 gives a list of reed switches recommended by the Panel.

Table 14.33. Specifications for dry reed type switches (capsules).

JSS pattern (JSS 51213)	MIL number	Description	Rating	Function
1. SC 01	MIL-S-55433/1	Normally open contacts	1A at 28 V DC	SPST
2. SC 02	MIL-S-55433/2	Normally open contacts	125 mA at 28 V DC	SPST
3. SC 03	MIL-S-55433/3	Changeover contacts	500 mA at 28 V DC	SPDT
4. SC 04	MIL-S-55433/4	Changeover contacts	250 mA at 28 V DC	SPDT
5. SC 05	MIL-S-55433/5	Normally open contacts, offset gap	250 mA at 28 V DC	SPST

14.2.4. Investment

Production of electromechanical components requires precision machines, sophisticated tooling facilities and many measuring test equipment. The production process generally consists of metal forming and finishing operations, moulding the insulators and various types of assembly operations which are again mostly mechanical. These may involve staking, rolling, spinning, dimpling, punching, rivetting, soldering, brazing, welding, hot stamping, glass to metal sealing and bounding operations. Testing and quality control will involve measurement of various electrical and mechanical parameters and also functional evaluation of the components for their own specification and also as a part of an equipment or a system.

It is recognised all over the world that electromechanical component industry is a highly capital intensive industry. For producing professional grade components, the investment to turnover ratio will be nearly 1:1 on single shift basis. This ratio can be improved by having more than one shift and having a suitable product mix. Some important capital equipment required by electromechanical industry are listed in Table 14.34. The prices given here are approximate (base year 1972-73) and may vary with the model. The number of such machines required for the production of electromechanical components worth Rs. one crore is also indicated in this table. This list does not include details of quality control equipment, tooling and special purpose machinery. The total cost of machinery would be nearly Rs. 50 lakhs. Tooling is expected to cost around Rs 30 lakhs. Therefore, the total investment required would be of the order of Rs. one crore for a production of about the same value.

Table 14.34. List of important machinery required for a typical electromechanical component industry.

Equipment	Unit price (Rs. lakhs)	Nos. required
Automatic punch press	1.5	2
Transfer moulding press	2.5	6
HF pre-heater	0.3	6
Injection moulding press	2.0	2
Pelleting machine	0.4	3
Air compressor	0.6	2
Hydraulic press of 1T/2T/5T capacities	0.2	12
Surface grinder	0.8	1
Profile grinder	1.0	1

Milling machine	1.6	2
Lathe	0.4	4
Capstan 40 mm	1.0	1
Automat 25 mm	1.5	1
Automat sliding head 10 mm	2.0	1
Automat sliding head 5 mm	2.0	1
Drilling machine	0.2	2
Electroplating equipment	5.0	—
Effluent disposal equipment	1.5	—
Chemical lab equipment	2.0	—
Quality control lab equipment	5.0	—

14.3 Printed Circuit Boards

Printed circuit boards are metal clad laminates that are used to define wiring schemes for an electronic circuitry. These consist of an insulating laminate over which metal has been deposited or clad. The metal is generally copper although kovar clad laminates are also used where very low thermal expansion characteristics are essential. Nickel is sometimes used when low contact resistance is required. Most of today's printed circuit boards are made from high-pressure laminates having copper foil bonded to one or both sides. A laminate consists of layers of fibrous material bonded together under heat and pressure with thermo-static resin. There are two types of printed circuit boards longer time—rigid and flexible flat conductor wiring.

Rigid printed circuit boards have the potential of extreme miniaturisation and circuit accuracy can be improved by using computer-aided designs. These can be used for a variety of applications. On the other hand, flexible printed wiring is custom designed to meet individual requirements. Printed circuit boards are further classified into three categories as follows:

- (i) Single sided : metal clad on one side of the laminate. These are used in simple circuits and are highly reliable.
- (ii) Double sided : metal clad on both sides of the laminate with an accuracy of 0.1 mm. The problem with such boards is poor repairability.
- (iii) Multilayer : Consists of a number of multiple layers of thin flexible or laminate system stacked together in orderly registration. Layers of conductors and insulators are adjacent to each other with interconnection usually obtained by plated through hole process.

The development of multilayer printed circuit boards has presented a solution to the problem of increased interconnection density of components. Generally, printed circuit boards have large volume production capability, exact reduction of circuitry from board to board, reduction of wiring time and elimination of miswiring.

Multilayer printed circuit boards, in addition, can handle high density of circuitry and terminal point, increased freedom of conductor routing, shorter conductor paths, integral shielding and improved environmental performance.

14.3.1. Present Status

At present, the bulk of the demand (volumewise) in the country for printed circuit boards is from the entertainment industry. The method used for production of these boards is usually screen printing. The capital investment needed to begin production of printed circuit boards is minimum. It is possible to start production with a capital outlay of Rs. 25,000 or less. Therefore, there are 20 or more independent printed circuit board manufacturers in the country producing low quality

boards to cater to the consumer electronics industry. Some of the known manufacturers are B. K. Plastics Poona, Eastern Electronics Delhi, Electronics Era Bombay, Electromin, Graphic Display Co., Hedge and Golay, Ideal Radiotronics, Kubo Corporation Bombay, Malik Electronic Corporation Delhi, Photex Electronics Products Bombay, Printo Graphics Hyderabad, Rao Insulating Co. Bangalore, R. R. Enterprises Hyderabad, Salico Electronics Delhi, United Electrical Industries Trivandrum, etc. Most of these manufacturers produce boards for radio and TV industries only and have poor facilities. Only a few manufacturers like Electromin, Hedge and Golay, Rao Insulating Co., R. R. Enterprise, etc., have facilities to produce high quality single sided boards for professional use. High quality double sided boards with plated through hole are also manufactured by Hedge and Golay. A few other manufacturers like Electromin and Rao Insulating Co., are also engaged in this field. At present, most of the production of printed circuit boards is for in-house products. The large users of printed circuit boards both in consumer and professional electronics area produce them in their captive facilities. Some of the major in-house producers of printed circuit boards are Philips (India) Limited Bombay, Telerad Pvt. Ltd. Bombay, ECIL Hyderabad, BEL Bangalore, HAL Hyderabad, LRDE Bangalore, etc.

Although the printed circuit board industry lends itself to market entry with a minimum capital investment, the types of boards that can be produced by such companies are limited. To provide multilayer printed circuit boards of high reliability, capital investment of Rs. 30 lakhs to Rs. 3.5 crores or more is required. At present, no company produces multilayer printed circuit boards and only a few units like Hedge and Golay have the capability to produce sophisticated double sided boards of high reliability.

A few industries produce double sided boards with plated through holes for captive use. The important captive producers are Bharat Electronics, and Electronics Corporation of India. These major equipment manufacturing units like to maintain in-house facilities for better maintenance and control of interface between design engineers and board manufacturing unit.

For producing printed circuit boards, two varieties of copper clad laminates are generally used in the country. In most of the consumer applications like radios and TVs, paper phenolic laminates with copper cladding on one side (1 oz/sq. ft) are used. These are produced in India by Farmic (India) Ltd. Poona and Bakelite Hylum Hyderabad. The requirement of paper phenolic copper clad laminates with 2oz/sq. ft. copper is very small. In most of the professional electronic equipment, glass epoxy copper clad laminates are used. These laminates with 1 oz. copper have been recently developed by Formica. However, the material is not flame retardant and have inferior solderability. The main bottleneck in making flame retardant material appears to be the need for importing suitable additives or an epoxy resin with inherent flame retardant characteristics. The requirement of glass epoxy copper clad laminates with 2oz. copper is also large and it is imported presently. It is learnt that Bakelite Hylum have plans to develop this material. Some glass epoxy copper clad laminates have also been developed by Defence Research Laboratories Kanpur and Indian Space Research Organisation Thumba. For some special applications, the laminates with ceramic and PTFE base is also used in the country.

14.3.2. Forecast of Requirements

Printed circuits are used in almost all types of modern electronic products. Whereas in items like radios, TVs, etc., cheaper types of boards can be used, in complex equipment the cost of printed circuits may go upto five to eight per cent

of the equipment cost. Consumer applications generally require single sided and some double sided boards. The requirements for industrial applications run the full range from single sided to double sided and multilayer boards. Defence applications also require boards of all types. However, the level of sophistication is much higher, which is reflected in the higher cost of the circuit board.

It is observed that in various countries printed circuit boards account for nearly 3 to 3.5 per cent (valuewise) of the total component consumption. For Japan this figure is nearly 2.8 per cent, for United Kingdom 3.2 per cent, for France 3.1 per cent and for USA 3 per cent. It must be mentioned here that the cost of printed circuit board vary enormously, depending on the tolerance applied, the number required, the level of inspection demanded, and the plating finishes specified as well as on some more obvious factors such as number and size of holes and board. Therefore, the above percentages give only an indication of the total requirement.

The requirement of printed circuit boards for our country is broken up in two parts. First, the demand for copper clad laminates is calculated and then the requirement for printed circuit boards is given. This breakup is necessary because the cost of printed circuit board may go from a rupee to a few thousand rupees. Moreover, for most consumer applications, cheaper laminates like paper phenolic are required, but for many professional applications, single, double and multilayer boards with glass epoxy base are used. Therefore, a demand profile for copper clad laminate is given separately.

For calculating the demand for copper clad laminates, the actual requirements (both present and future) of major users like Bharat Electronics Bangalore, Indian Telephone Industries, Electronics Corporation of India Ltd., Hyderabad and the requirement for other organisations making professional equipment are considered. Also the expected level of equipment production, both professional and consumer, during the next 10 years is taken into account. The new application areas like computers are also included in the forecast. In estimating the requirements of the consumer industry, it is assumed that approximately 50 radio sets can be made with one square metre laminate. Similarly, with one square metre nearly 7 to 8 TVs can be made. The average thickness of the board is assumed as 1/16 inch. With these assumptions, the ten year requirements of phenolic paper, and epoxy glass base copper clad laminates are given in Table 14.35. The demand for other types of laminates (i. e. Silicon, ceramic, etc.) and flexible laminates (eg. PTFE) will be quite small and consequently not included here. The total ten year requirement of copper clad laminates will be nearly 31 lakh square metres (approximate weight 75 tons) worth Rs. 50 crores. The phenolic paper accounts for nearly 58 per cent of the total requirement. However, valuewise it is only 35 per cent of the total. The demand for glass epoxy is around 42 per cent of the total requirement but valuewise it accounts for more than 65 per cent of the total. During the 10 years 1974-84, the demand for copper clad laminates is expected to register a six fold increase.

The pricing of printed circuit boards vary considerably among manufacturers and even among orders for the same board from the same manufacturer. Because of this, it is virtually impossible to assign an average price per board or even per sq. inch of board. As a rough guideline, it may be said that the cost of single-sided board range from 2 paise per sq. cm. to 10 paise per sq. cm. However, for specialised applications, it may go upto 20 paise per sq. cm. For double sided boards with plated through holes it might range from about 30 paise per sq. cm to 1 rupee per sq. cm of board. Multilayer board with about four relayers are priced at about Rs. 2 per sq. cm. This can vary greatly and the price, of course, increases with the number of layers. Considering the requirements projected by various users and assuming a suitable product mix, the ten year requirements for printed circuit

XIV

Table 14.35. Ten year demand profile of copper clad laminates.
(All figures in thousand sq. metres).

Laminate	1974-75	1975-76	1976-77	1977-78	1978-79	1983-84	Fifth Five Year Plan (1974-79)	Sixth Five Year Plan (1979-84)
Phenolic paper	75	90	110	130	150	315	559	1230
Epoxy glass	30	40	55	75	100	275	300	975
Total	105	130	165	205	250	590	859	2205

Table 14.36. Ten year demand profile of printed circuit boards.
(all figures in Rs. crores)

	1974-75	1975-76	1976-77	1977-78	1978-79	1983-84	Total During 1974-79	Total During 1979-84
Single sided	7.50	9.00	10.80	13.00	15.60	32.80	55.90	128.10
Double sided	0.25	0.45	0.75	1.30	2.20	10.00	4.95	31.25
Multi layered	Small	0.05	0.10	0.15	0.20	1.20	0.50	3.50
Total	7.75	9.50	11.65	14.45	18.00	44.00	61.35	162.85

boards are projected in Table 14.36. The bulk of the present demand is for single sided boards only. Double sided boards are used in very few applications. The present requirement of multilayer boards is negligible. It is expected that with the growth of computer industry, the demand for double sided boards will grow much faster than other types. Some use of multilayer boards will also be there. At this stage, it is very difficult to anticipate any significant use of flexible printed circuitry. It may be interesting to compare the application trends in our country with those prevailing in USA presently. In USA the demand for single layer boards is declining. In 1973, single sided boards were only 9 per cent of the total printed circuit boards whereas double sided boards formed 67 per cent, multilayer 19 per cent and flexible 5 per cent of the total consumption.

It can be seen from Table 14.36 that in 1974-75 the requirement of printed circuit boards will be nearly Rs. 7.75 crores. However, double sided boards share only 3 per cent of this requirement and the remaining will be mostly single sided boards. It is expected that the share of double sided board will increase to 12 per cent by 1978-79 and by 1983-84 this will go upto 25 per cent of the total requirement. Multilayer boards, which do not have much use today, will have 3 per cent share of the total demand. It is obvious from the table that single sided boards which account for nearly 93 per cent of the total requirement in 1974-75 will be replaced by double sided and multilayer boards. But this process will be very slow and even by 1983-84, the market share of single sided boards is expected to be 72 per cent. This situation may appear a bit surprising in view of the trends in other countries. However, in our country the existing manufacturers do not have programmes which require extensive use of double sided and multilayer boards. Also, our computer production plans are very modest as compared to USA. Presently no application using flexible printed circuit is envisaged. Nevertheless, they may find some use over these years. At this stage it is very difficult to forecast the requirement for flexible printed circuits. Areawise, the requirements for single sided boards

will be nearly 1 lakh sq. metres in 1974-75 which will increase to 2.3 lakh sq. metres by 1978-79 and to 5.4 lakh sq. metres by 1983-84. The requirement for double sided boards will be roughly 500 sq. metres in 1974-75, and 4,500 sq. metres per year by 1978-79, going upto 18,500 sq. metres by 1983-84. The use of multilayer boards will increase slowly in these years and it is expected that by 1978-79, 100 sq. metres per year will be required which will increase to 600 sq. metres per year by 1983-84.

14.3.3. Capital Equipment

The capital investment required for manufacturing printed circuit boards can vary considerably depending on the type of boards and the level of sophistication required. Whereas for ordinary consumer applications, printed circuit boards can be produced with an investment of approximately one lakh rupees, for producing high quality boards the investment may go well over Rs 30 lakhs. Most of the equipment and raw material required for the production of sophisticated boards will have to be imported.

Minimum capital equipment is required for producing plain (both single sided and double sided) boards. The manufacturing process generally followed is etched-foil process and therefore, equipment like screen printing machine, etching system, stripping machine etc., are required. For simple applications, less sophisticated and semi-automatic machines can be used. However, when high precision boards are required, larger and better facilities are needed. In some cases photoresist technique is also used. The following equipment and imported raw materials are required for ordinary single sided boards.

1. Process camera
2. Illuminated drafting bench
3. Vacuum bed single sided photoprints with ultraviolet source of wave length 3490 to 4000 AU.
4. Semi-automatic screen printing machine
5. Spray etching machine
6. High speed drilling machine
7. Blanking machine
8. Solder path
9. Lith film on a polyester base
10. Screen stencil film pre-sensitised on polyester base
11. Photoresist
12. Vinyl based printing ink
13. Etchant of proper type
14. Drill bits— solid carbide and high speed steel
15. Drafting aids
16. Bolting cloth

For switching over to double sided boards with through plated holes, additional capital equipment will be required. Due to more sophisticated and exacting requirements, generally photoresist technique is used. Also the capital equipment required in this case has better precision and high degree of automation than that used for single sided boards. For accurate drafting during the preparation of master artwork, the coordinatograph with accuracy of ± 0.001 in. is required. To meet the exacting requirements of double sided boards, the precision camera with reduction accuracies of ± 0.001 in. is used. For etching these boards, highly sophisticated etching systems are available which can perform all operations like pre-cleaning, etching, post-cleaning, resist removing and drying of holes. Also numerically controlled drilling machine is required which can give both high productivity as well as good quality holes. Now automatic punching units are available

which can be used to give drilling instructions to the numerical control of the drilling machine. The drilling instruction tap can be punched while making artwork using the coordinatograph. Deburring of the drilled holes is a very important step to give a good plated through hole. For electroless deposition of copper, a single unit capable of doing all the operations involved in through hole plating is required. The use of dry resist film called Reston film has several advantages over liquid photo resists and complete Reston System can be purchased from the same manufacturer. The equipment and imported process materials required for plated through hole facility are given below:

1. Co-ordinatograph (micro plotter) for drafting artwork accuracy ± 0.001 in.
2. Drafting aids and polyester base films
3. Process camera having reduction accuracy ± 0.001 in.
4. Lith pan and ortho films
5. Photoresist (special high quality) dry film
6. Dry film laminator and processor and/or resist coating
7. Double side photo printer with vacuum base, timer, etc.
8. High speed precision circuit board drilling machine
9. Solid carbide fast spiral drill bits
10. Complete through hole plating lines with temperature control agitation units
11. Conveyorised double sided etching and processing equipment with conveyor speed control, temperature control, and spray pressure control attachment.
12. Resist stripping machine (universal)
13. Deburring, deoxidising and cleaning machine (brushing machine)
14. Circuit board cutting machine
15. Reston system (optional)

For the fabrication of multilayer boards, all the equipment listed for double sided boards with plated through holes are required. The additional equipment required include electrically heated hydraulic press for pressing laminates, temperature sensing equipment, mount control facility, thickness measuring equipment and circuit board cleaner.

Apart from the capital equipment listed above, a good testing facility is required for all types of boards. Since the through hole plating is essentially a chemical process, a sophisticated testing laboratory is necessary to test various parameters associated with the reagent used. Other equipment like betascopes used to measure very small thickness is necessary to check the hole quality and also to measure plating thickness, etc. The following equipment are required for quality checking.

1. Travelling microscope for checking the dimensions of photo master, drilled holes, etc.
2. Go, No-Go gauge for checking the dimensions of blanked cards
3. Epidioscope for pin-hole inspection
4. Betascope for plating thickness measurement
5. Shear testing machines for testing shear strength of plated through holes
6. Low resistance measurement devices for evaluating the through holes
7. PH meters
8. Full chemical testing facilities for checking concentrations, density, etc., of chemicals

A list of important capital equipment required for a good printed circuit board production facility is given in Table 14.37. Most of these equipment will have to be imported. The cost given here is inclusive of excise duties. The total capital equipment required for the production of through hole plating and multilayer boards will be approximately Rs. 35 lakhs.

Table 14.37. Capital equipment required for through-hole plating and multilayer printed circuit boards.

Name of the equipment	Cost (Rs. in lakhs)	Function
1. 'Micro plotters' coordinatograph	0.75	For micro-accurate drafting, plotting and digitising
2. Screen printer	0.60	For component and circuit printing
3. Cutting machine	0.45	For precision and burr-free cutting, punching and/or drilling of reference and pattern holes
4. Precision camera	1.75	For producing high precision photographs of the artwork
5. Photo-resist coater	0.75	For coating copper clad laminate with a contaminant free uniform and controllable layer of photo resist or other fluid
6. Oven	0.40	For baking photo-resist coated copper clad laminate
7. Vacuum exposing unit	0.15	For exposing of photomasters
8. Photo-resist developer	0.60	For automatic developing of photosensitive layers
9. Photo-resist strippers	1.50	For complete and thorough removal of any type of photo-sensitive lacquer from holes and surface of printed circuit board
10. Etching system	3.00	For etching single and double sided printed circuit boards
11. Drilling equipment	9.00	For drilling in printed circuit boards. Usually numerically controlled machines are used for precision drilling
12. Deburring machine	1.00	For polishing, deburring, removing oxides or producing an abrasive finish
13. Electroless copper deposition	2.00	For copper deposition on plastic laminates
14. Plating system	1.20	For solder plating single and double sided boards and for copper and solder plating in through-hole processing
15. 'Riston' system	1.30	For Riston lamination and processing
16. Blanking press	0.80	For Blanking of printed circuit boards. Blanking die is used only when the volume is large enough to justify the expense of building a blanking die
17. Router	1.50	For better edge finish. Also when low volume production does not permit the expense of blanking die

18.	Electrically heated hydraulic press (only for multilayer boards)	2.00	For pressing the laminates. It should be capable of achieving controlled pressures upto 1,000 psi
19.	Temperature sensing equipmet (only for multilayer boards)	0.35	For measuring the temperature during pressing. It is essentially a potentiometer with a fine thermocouple
20.	Mount control facility (only for multilayer boards)	0.65	For holding the circuitry during pressing
21.	Thickness measurement equipment (only for multilayer boards)	1.00	For measuring and controlling the thickness of the pressed laminates
22.	Circuit board cleaner, (only for multilayer boards)	1.50	For cleaning and rolling the pressed laminates to give the final finish to the multilayer board
23.	Testing equipment	2.75	For testing printed circuit boards during various stages of production

Total capital equipment required = Rs. 35 lakhs.

14.4 DC Micromotors

The silent work force behind the rapid growth of most of the portable consumer items like hair dryers, remotely controlled toys, mixers, radio tuning devices, cassette recorders, portable tape recorders, record players and changers, film camera, etc., is the DC micromotor. Owing to the adoption of mass production technique for manufacturing DC micromotors, the prices have been reduced to a level to make it attractive for consumer applications. The recent advances in the field of design and manufacture of these motors have made them suitable for a wide range of industrial and laboratory equipment, servo systems and advanced instrumentations.

The DC micromotors can be broadly divided into uncontrolled and controlled types. The uncontrolled micromotors with voltage rating of 6V or 12V, running speed of the order of 4000 rpm and developing useful torque of 30 gm/cm are widely used for high quality toys, small household appliances, actuators in automobiles, servodrivers, high performance tape recorders and tape transporters, charts and pen driver units for portable recorders, etc. The controlled micromotors with voltage rating of 4.5 V running at a speed of 2000 rpm and developing useful torque of 10 gm/cm provide the motion power for cassette recorders, portable tape recorders, record players and changers, film and zoom lens driver in film cameras, slide projectors, domestic clocks, etc.

14.4.1. Present Status

Presently in the country there are a few small scale units making uncontrolled micromotors, for toys and display tables. However, production of controlled motors is negligible. All the manufacturers of tape recorders, cassette recorders and record players, import the motors which for 1972 was nearly 1.5 lakhs numbers. Rallis India and a few other units are known to have been involved in developing controlled micromotors. Recently Thomson Motronics Ahmedabad has marketed a few types of micromotors. A number of units both in the organised and small scale sectors have been licensed and some of them are going ahead with the implementation.

14.4.2. Forecast of Requirement

The bulk of the demand of micromotors (governed type) in electronics comes from their use in tape recorders and record players where performance requirements of the micromotor are also quite stringent. Presently all the requirement is met by import. The demand will grow as the production of tape recorders, record players, etc., picks up. It is expected that by the end of the Fifth Plan, the production of tape recorders will be around 3 lakh numbers and that of record players will be around 2.5 lakh numbers. In view of this and the requirements for other miscellaneous items and replacement, the total demand for micromotors by 1978-79 is envisaged as 10 lakh numbers. The yearly requirement of micromotors during 10 years is given in Table 14.38.

Table 14.38. Ten year demand profile for micromotors.

	1974-75	1975-76	1976-77	1977-78	1978-79	1983-84	Fifth Five Year Plan (1974-79)	Sixth Five Year Plan (1979-84)
Nos. (lakhs)	4.50	6.00	7.50	9.00	10.00	20.00	37.00	85.00
Value (Rs. crores)	1.35	1.80	2.25	2.70	3.00	6.00	11.10	26.60

14.4.3. Design and Technology Trends

Ungoverned Micromotors

An ungoverned micromotor basically consists of an armature rotating in a magnetic field. The magnetic field is usually provided by ferrite permanent magnets. The current is fed to the rotating armature by means of graphite brushes running over drum or disc commutators. The armature runs in sintered bronze bush bearings and the motor normally has an injection moulded polyacetal resin housing. Spark suppressors, sometimes built in, guarantee a good performance.

Governed Micromotors

A governed type of DC micromotor either has a built-in mechanical governor or works in conjunction with an electronic governor. The mechanical governor is a miniature centrifugal switch which regulates the speed of the motor by opening and closing the supply to the armature circuit. The electronic governors are basically voltage regulators which regulate the armature voltage of the motor. Such motors are provided with a permanent magnet system consisting of a ring magnet housed in a deep drawn steel shell. These generally have brass graphite brushes running over flat commutators. Effective interference suppression is achieved by built in spark suppressors, which also enhance the life of the commutators.

The requirement of high efficiency and high power to volume ratio drives for high speed printers, film and tape transports, solar cell operated equipment, etc., are met by improved DC micromotors. The unconventional micromotor has a double pole permanent magnet located in the centre of the motor and fixed to its front end. A self-supporting cylindrical coil is wound in a skew fashion. Such a motor provides the smallest possible rotor mass and has low rotor inertia, rapid response, low losses and very high power to volume ratio. The use of precious metals—silver alloy for the commutator, gold alloy for the brushes—together with self-lubricating sintered bronze bearings ensures high reliability and maintenance-free operation.

14.4.4. Production Facilities Required

The production process for micromotors involves pressing of sintered ceramic ring magnet or the resin bonded ring magnet into a deep drawn steel or aluminium shell. Then, dynamo grade silicon steel laminations (normally having 3 slots) are assembled over the shaft along with moulded cylindrical commutator or printed disc commutator. The armature slots are insulated with paper before winding the required number of coils in the slots. The winding ends are soldered or welded to the commutator segments before varnishing the armature. The cured armatures are assembled into the magnet frame before they are magnetised in a magnet charger with suitable fixtures.

The economic viability of manufacturing micromotors depends upon the effective utilisation of the mass production techniques. Even though the production process indicates that the standard machines and tools found in any engineering workshop would be able to do the job, special/automatic machines have been used/developed with a view to reducing the cost. Notable among these are the automatic armature slot paper inserting machine, automatic coil winding machine and automatic armature lead wire welding machine. With these machines, production rates of 400 motors/hour has been achieved. With special purpose machines, production rate of 1000 motors per hour has been achieved.

The capital equipment required for a micromotor production facility includes deep drawing presses, power presses, automats, automatic armature winding machine, magnet chargers, magnet wire tester, dynamometer, etc., besides a well laid out assembly line.

The main raw materials required for micromotors are given below :

- (i) Dynamograde silicon steel sheets for the armature laminations
- (ii) Synthetic enamelled magnet wires for winding
- (iii) Deep drawing quality steel sheets for shells
- (iv) Self lubricating sintered bronze bearings
- (v) Sintered or resin bonded ceramic magnet
- (vi) Moulded drum or disc commutators with silver bearing copper segments
- (vii) Brass graphite or silver graphite brushes
- (viii) Varistors for spark suppression
- (ix) Silver-palladium contacts and beryllium copper leaf springs for the mechanical governors.

14.5 Batteries

Batteries find a wide variety of applications in portable electronic equipment. Batteries are either primary or secondary type. In defence, industrial and consumer electronic equipment, the following types of batteries are used :

- i) Leclanche battery (primary)
- ii) Lead acid battery (Secondary)
- iii) Nickel-cadmium battery
- iv) Silver-zinc battery
- v) Zinc-mercuric oxide battery

Out of these five types, leclanches and lead acid types are most commonly used. Nickel-cadmium batteries are extensively used in defence and industrial electronic equipment. These are used in transreceiver communication sets and as standby power supplies in electronic instruments such as PH meters, digital clocks, etc., as well as in consumer items like shavers, torches and electronic photo flashes. Silver-zinc batteries find application in specialised equipment.

Production facilities for leclanche and lead acid batteries are well established in the country. There are about nine units involved in the production of dry batteries. The present licensed capacity for dry batteries is 1,230 million numbers

and the present installed capacity is 970 million numbers per annum. The present production level of dry batteries is over 600 million numbers per annum. For storage batteries, eight manufacturers have been licensed to produce 19 lakh numbers per annum. However, the present installed capacity is 14 lakh numbers. The present production capacity is over 11 lakh numbers per annum.

Recently the production of nickel-cadmium batteries has started in ECIL Hyderabad. The technical know-how developed is for making Ni-Cd batteries with sintered plates. Sintered plate construction is the latest technology in Ni-Cd batteries since it has low internal resistance, higher efficiency and rugged construction. A pilot production plant to make 50,000 batteries per annum has been started. The production is expected to go upto one million numbers per annum in the next 3 to 4 years.

The following Ni-Cd batteries are made by ECIL :

- (i) Sealed button type sintered plate construction; capacity 180 MAH
- (ii) Rectangular sintered plate, spill proof type; capacity 1AH
- (iii) Rectangular sintered plate, spill proof type; capacity 2 AH

Further development work is in progress to make 0.5 AH sealed button type and 5AH sealed (safety vent type) batteries.

Besides ECIL, LRDE Bangalore is engaged in the production of pocket type nickel cadmium cells.

The primary raw materials for Ni-Cd batteries, namely nickel powder and nickel mesh are imported. Nickel nitrate and cadmium nitrate are indigenously available but not in large quantities. Potassium hydroxide and graphite are available in the country. All mechanical parts for Ni-Cd batteries are made indigenously.

Rechargeable lead acid batteries are imported. Development work on magnesium - manganese dioxide batteries is in progress and is expected to be completed by the end of 1975.

It is estimated that during the terminal year of this Fifth Plan, the demand for dry batteries will be 1,300 million numbers. Technical advantages warrant switchover to nickel-cadmium batteries in defence and portable communication equipment. The demand for nickel-cadmium batteries is expected to be around 10 lakh numbers by 1978-79.

14.6 Guidelines for Production and R&D

The Panel on Mechanical and Electrical Components has examined the various aspects of electromechanical component industry. It is observed that the basic problems associated with the industry are broadly the following :

- (i) Wide diversity of types produced and lack of proper standardisation in the country
- (ii) Requirements of extensive tooling for production and lack of adequate tool room facilities in the country
- (iii) Nonavailability of suitable raw materials indigenously
- (iv) Nonavailability of suitable design know-how and R&D efforts indigenously

In view of these, the Panel has made a number of general recommendations for the overall growth of electromechanical components industry and specific recommendations for various types of electromechanical components. The guidelines for production and R&D suggested by the Panel are described below.

14.6.1. General Recommendations

Standardisation

It is observed that the major factor hindering the growth of electromechanical component industry in India has been the lack of standardisation. In order to promote the economic production of these components in the country, it is essential that a list of standards as recommended in section 14.2.4 are followed by equipment

designers, component manufacturers and licensing authorities. Certain modifications in this list may, however, be necessary to keep pace with future developments.

This list should be reviewed from time to time by the standing task force having representation from components manufacturers, professional equipment manufacturers, standardisation organisations, DGTD, etc. The Task Force should be given the following responsibilities.

(i) To finalise the recommended list of standard by the Panel, taking into account the comments received from existing manufacturers, prospective entrepreneurs and users. This list should be finalised by the end of 1974. The standardisation of unsealed relays including telephone type, and connectors with 75 ohms impedance should be taken up by this Task Force.

(ii) It should periodically update the list of the standards depending upon the technological developments and the future needs. As it is noticed that there is no specification existing for electromechanical components relating to consumer industry, it is recommended that ISI should take up this task on high priority basis.

Licensing

In the field of electromechanical components it is found that the present utilisation of the approved capacity is to the extent of 30 to 40 per cent. This is mainly due to the wide diversity of these components in usage and low demand for individual types. Considering the projected demand for 1978-79, it appears that sufficient approved capacity exists by way of licensed capacity and letters of intent issued. There seems to be no need for further licensing at this stage as the future requirements can be met by the units who have already set up production lines, together with a realistic implementation of the capacity possessed by holders of letters of intent. As standardisation plays a key role in the economical production of electromechanical components, the Panel is of the view that further licensing and foreign collaboration, if any, should be oriented towards production of only those types which have been recommended from the standardisation point of view. The final list of types to be produced should be prepared by the Task Force suggested earlier as quickly as possible. By the end of 1975, the actual capacity should be scrutinised by taking into account the effective steps taken by parties already approved. Further licensing may be done from 1976 onwards, keeping in view the projected demands by 1978-79 and the standard series recommended. In no case licensing should be done for units who take up components which are not recommended for standardisation.

The Panel recognised the special feature of capital intensiveness of electromechanical industry. It was also noted that the investment to turnover ratio is of the order of 1 : 1. In order to make a unit economically more viable, expansion of the existing units should be considered. Alternatively, a suitable diversification in the electromechanical area may be considered.

Rationalisation of Manufacture on Small Scale

The Panel has expressed the opinion that the production of each type of electromechanical component requires large amount of investment in tooling, manufacturing, testing and quality control. It is observed that, at present, individual small scale manufacturers are attempting to manufacture a wide spectrum of types of connectors, relays, and switches. This is posing problems to the professional users because the products generally do not conform to professional requirements, as the necessary standardisation and quality aspects have not been built in the design and manufacture of these components due to limitations of investment. The Panel feels that so far as the areas of connectors, relays and switches are

concerned, each unit in the small scale sector should try to limit its production to some specific varieties only. In other words, there should be individual small scale units concentrating on connectors like coaxial, circular, rectangular, etc. It is not necessary that individual unit should manufacture the total range of coaxial connectors, but it should try to concentrate around a few types so that it is capable of manufacturing within the limited investment. This will go a long way in making available acceptable products to the professional users.

Tool Rooms

At present there are several tool rooms existing in the country but only a very few of them can cater to the requirements of precision electromechanical sub-components. Tool room facilities for punch press parts, moulding parts and special types of assembling and fixtures are required for the manufacture of electromechanical components. Special types of machines which can handle small components and facilities like spark erosion, chemical milling and precision machining are required for the production of tools for electromechanical components. The machines are expensive and the outlay required would be quite considerable. More number of tool rooms should be set up immediately so that production of these components can progress satisfactorily. While some of the equipment and component manufacturers do have tool room facilities, these are not adequately equipped to take up the fabrication of all varieties of tools that would be required in the manufacture of electromechanical components. The few specialised tool rooms which can handle these are heavily booked.

Research and Development

The research and development effort in respect of electromechanical components is almost nonexistent in the various research laboratories. A limited R&D is being made by a few industries. In this area, the R&D effort should be carried out intensively by the associated industries rather than by research laboratories, since actual requirements of bulk production can best be appreciated by manufacturing agencies. It would be appropriate to encourage these activities in industries by allocation of funds for specific development projects. It is also considered that those organisations who have foreign collaboration should utilise the technical collaboration agreements to the maximum extent to bring in know-how documents required to manufacture components recommended in the list of standardisation. Norms as to which industry should be given assistance for research and future development should cover the existing manufacturing facility, existing engineering facility, quality management facility and existing potential to develop new products.

Material

There are many special types of materials required in the manufacture of electromechanical components. These include ferrous and non-ferrous metals and alloys, various types of plastics and other insulating materials. Many of these are not available in the country nor do they attract manufacturers of materials as the total requirement is too small for economic production and the quality has to be of high grade. Some of these materials can be manufactured on a pilot scale in national laboratories.

The existing material manufacturers should be encouraged with technical/financial assistance, if necessary, to produce special grade materials required for electronics industry. Specific R&D projects should be identified and given to existing material manufacturers to take up development of special types of materials required by these industries. As the requirements of individual indenter are small, foreign suppliers are not willing to supply in these quantities. It is, therefore,

recommended that all such requirements should be pooled and procurement action be taken by a centralised agency. The problem of raw materials is not confined to electromechanical components, but is equally applicable to passive and active components also. The requirement of materials should be pooled for the component industry as a whole.

14.6.2. Some Specific Recommendations

Connectors

General recommendations given earlier basically pertain to professional components. The requirements of connectors for consumer electronics also need standardisation. Standardisation organisation should play a primary role in standardising these components, e.g., audio connectors, plugs, sockets, etc. There is also a need for standardisation in the field of plugs, sockets, jacks, etc., in so far as professional equipment are concerned.

Relays

(a) Telephone Type Relays

As far as telephone type relays (BPO 3000 and 600 type and pentaconta) are concerned, they are produced at present for captive use by ITI, Bangalore. The present approved capacity is estimated to be nearly two million numbers per year. The Projected demand by 1978-79 will be of the order of 3.5 million numbers. Additional capacity has to be created for production of about 1.5 million numbers of such type of relays.

(b) Reed Relays

Due to changing patterns in some of the systems using reed relays, the earlier estimates for the requirement of reed relays appear to be on the higher side. The Panel has estimated an annual requirement of about 6 lakhs numbers towards the end of the Fifth Plan. In view of this and the capacity already approved, there is no need for further licensing during the Fifth Plan unless it is for 100 per cent export or decided on special merits.

Switches

(a) Pushbutton Switches

The illuminated type of pushbutton switches for control panels, computers, etc., are not manufactured at present in the country and the production of these should be taken up.

(b) Toggle Switches

At present sealed and miniature switches of approved quality are not available in the country. The manufacturers should be given due encouragement to set up facilities for the production of these types.

(c) Sensitive (Micro) Switches

The quality of sensitive switches available in the country should be upgraded to meet the professional requirements. Technical and/or financial assistance should be provided for indigenous development and production of microswitches.

While the requirement of switches for consumer electronics is by and large met from production within the country, a few types like miniature rotary and miniature slide switches are still being imported. Efforts should be put in to

produce them in the country. Steps may be taken by standardisation organisation to prescribe standards and indicate the types to be produced.

Printed Circuit Boards

At present, most of the production of printed circuit boards is for in-house applications. There are a few independent manufacturers both in the organised and small scale sectors, who are catering to the overall needs of the country. There is, in general, a need for creating additional capacity in this area, specially for double sided boards, keeping in view the projected requirements. Also, proper types of raw materials required for making copper clad laminates should be developed indigenously. At present, glass epoxy copper clad laminates with 2-oz copper, which has a large requirement, is being imported. Some R&D efforts should be made in developing flame retardant epoxy resin.

Micromotors

A number of units are engaged in the development of DC micromotors for tape recorders and record players and have made a significant progress in this direction. Therefore, import of technology for DC micromotors is not necessary. At present, most of the firms are developing micromotors with mechanical speed governors.

However, switching to electronic governors would be advantageous, as it provides better speed control characteristics and no component needs to be imported. The only limiting factor at present is the cost of electronic components which works out to be higher than the cost of mechanical governors. Development of hysteresis synchronous motors needed for reel to reel tape recorders and also DC motors for use in control systems, should be encouraged.

Batteries

In the case of dry cells, the production is almost entirely based on foreign know-how and, therefore, attempts should be made for their indigenous production. Development of various new electrochemical systems should be taken up. The primary materials required for various types of batteries are covered in the chapter on materials.

Materials

15.1. Introduction

Raw materials play a significant role in any industry and this is especially so in the electronic components industry. Selection of material for making a particular component depends upon the performance of the material with respect to the functional specifications and simplicity of fabrication of the component along with economic viability of the process. The specifications of materials and the quality of components made from them are, thus, interdependent. In view of this, the electronics materials have become an integral part of the electronics industry. Although, valuewise they contribute about only 10 per cent of the total equipment cost, the development of these materials is vital for the growth of electronics industry. Specifically for our country, where the import of raw materials is significant, greater emphasis is needed on their development. Research and development in almost all of these materials have brought out new and superior materials with almost tailored properties required for the fabrication of a variety of components and have helped in a very significant way towards achieving the progress of the electronics industry today. The advances in the materials area, specifically in solid state device materials, are so rapid, that long term predictions are beset with considerable uncertainties requiring continuous updating of the scope of these materials.

Table 15.1. The total annual requirement of materials envisaged by Bhabha Committee for the year 1975.
(in Rs. lakhs).

Primary materials	Primary materials which are available	Primary materials which can be obtained by special treatment of available materials	Primary materials vital to the electronics industry, required in relatively small quantities	Primary materials unavailable in adequate quantities	Primary materials for which indigenous sources are not known	Total
1. Metals	80.000	83.150	108.250	495.000	78.250	844.650
2. Alloys	170.000	220.000	113.000	15.000	15.000	533.000
3. Ceramics & glasses	—	216.000	36.000	—	—	252.000
4. Minerals & similar compounds	181.105	22.200	55.000	—	—	258.305
5. Plastics	155.000	82.000	81.000	—	—	318.000
6. Process chemicals	37.300	20.000	17.400	—	—	74.700
7. Paints	102.000	—	2.000	—	—	104.000
8. Others	94.700	275.000	36.000	—	—	405.700
Total	820.105	918.350	448.650	510.000	93.250	2,790.335

Table 15.2. Classification of materials for electronics industry.

No.	Class	Remarks	Materials
1.	Metals and alloys	Used for functional requirements with respect to electrical, thermal and mechanical properties. The production technology involves mainly metallurgical operations; ultra high purity is not essential; used in other industries in large quantities	Metals : Al, Cu, Ni, Mo, W, Hg, Zn, etc. Alloys : Steel, aluminium alloys, brass, phosphor-bronze, copper-beryllium, manganin, constantan, nickel-silver, kovar, invar, iron-nickel, dumet, mumetal, nichrome, kanthal, etc.
2.	Ultrapure materials	These materials require ultra high purity (better than 99.999%) and are special to electronics industry. The purification generally involves, chemical purification followed by electrolytic refining, vacuum melting, zone refining, etc.	Semiconductors : Si, Ge, GaAs, GaP, Se, etc. Metals, semimetals and compounds: Al, Ta, Ga, In, Zn, Au, Ag, B, Sb, As, BBr ₃ , POCl ₃ , etc. Alloys for bonding wires, solders and brazing compositions Others : Dopant gases, oxidic crystals and related oxides
3.	Chemicals and plastics	Chemicals : Required in different grades of purity depending upon their use; standard chemical and physical techniques for purification are used Plastics : Required as encapsulants, sealing-fixing agents, moulding, coatings, applications, etc., mechanical, physical and electrical properties are important; used in large quantities in other industries	Lapping and polishing compounds, solvents, and cleaning agents, etchants, gases, plating chemicals, photomask materials, chemicals for batteries, and other chemicals Lacquers, DAP, polystyrene, polyester, polycarbonate, PTFE, epoxies, silicones, paints, varnishes, phenolics, ABS, ion exchange resins, rubber, etc.
4.	Glasses, ceramics and others	Used for structural and electrical applications, substrates, insulators, etc., physical and electrical properties are important considerations	Soft glasses for bulbs, TV shells, etc., sealing glass for glass-to-metal seals, quartz, alumina steatite, forsterite, mica, ferrites, paper, etc.

Annual requirement of materials was estimated by the Bhabha Committee to be around Rs. 28 crores by the end of 1975, to sustain the electronics industry of the size envisaged in the Committee's Report. The Committee grouped the various materials into different categories based on their availability within the country. The details are given in Table 15.1. Considering the importance of the materials for the growth of the electronics industry, the Committee stressed a need for establishing self-reliance in this area. However, during the National Conference on Electronics held at Bombay in 1970, it was brought out that although the component industry had grown significantly, the production in the area of materials

was only marginal and more intensified and planned efforts are needed in this sector. Again in 1973, during the National Seminar on R&D Policy in Electronics, it was stated that while know-how for quite a few of these materials seemed to have been developed, the knowledge has not been exploited for production in many cases. Some of the bottlenecks involved in indigenisation efforts were highlighted and some possible remedial measures were suggested. As a follow-up of these developments, Department of Electronics/Electronics Commission set up technical panels to study the problems associated with the indigenisation and to suggest guidelines, so that self-reliance could be achieved within a minimum period of time. National Committee on Science and Technology (NCST) has also set up a Panel on Special Materials which covers some of these materials.

While many of these materials are required in quantities as several or several hundreds of tonnes, there are some materials used in quantities as small as few kilograms. Further, these materials are of a wide variety, ranging from gases to solids on one hand and metals to insulators on the other. In addition to this, they have to satisfy a range of technical specifications. Because of this diversity in the nature of these materials, their classification into different categories is difficult.

A classification can be arrived at on the basis of availability of individual items, nature of the development efforts needed, etc. However, such classifications would need frequent revision to incorporate changes brought about by factors like continuous indigenisation of materials production, development of newer and better materials, change of trend in components industry, etc. One of the more convenient ways of classification would be the one that takes into account the technology/discipline involved in the production of these materials and is given in Table 15.2. The table also gives the basic production technology involved and the spectrum of materials that they cover. In this classification ferrites, as production of these basically involves ceramic technology, are included under ceramics. Similarly, ultrapure materials, production of which involves very special techniques of purification, are grouped under a separate class. However, process chemicals like solvents, cleaning agents, etchants, photomask chemicals, etc., which are also required in the ultrapurity grade for some applications, are not included in this class as the technology underlined in the purification differs from that used for, say, semiconductor materials.

15.2 Current Status

Although the importance of availability of raw materials for the growth of electronics industry has been stressed upon time and again, we are still importing a number of primary materials for the industry. This dependence on import of materials poses problems for the component manufacturers, especially for professional grade components. Assessment of current status with respect to individual items would be a difficult task, as the available data regarding present requirements, the production figures, import bills, etc., are not easily available. However, it has been estimated that over 50 to 60 per cent of the total requirement of electronics materials is presently being met through imports. Major contribution to this import comes from the materials which are special to electronics industry, and required to the extent of about 40 per cent of the total materials demand. Present status regarding production and development for various classes of materials is discussed below in brief.

15.2.1. Metals and Alloys

Metals and alloys used in the electronics industry contribute roughly over 40 per cent of the total materials requirement. Although, some of these items are very special to electronics industry, this class of materials are required in other industries in large quantities and a broad production base exists for some of these

metals and alloys. For example, routinely available standard materials like zinc, aluminium, copper, brass, steel, silicon steel laminations, nichrome, etc., satisfy a part of the requirement of the industry, but a wide variety of special metals and alloys like kanthal, manganin, constantan for resistor elements and heating elements; beryllium-copper springs and strips; mumetal shields; soft iron for relays; OFHC copper, nickel and molybdenum parts for electron tubes; kovar for glass-to-metal seals; special types of phosphor bronzes, etc., are still being imported.

Table 15.3. Manufacturing programme for special metals and alloys proposed by DMRL.

No.	Type	Alloys	Form/shape	Annual capacity in tonnes
1.	Nickel and special nickel alloys	Vacuum tube grade nickel metal, manganese nickel, nickel-iron	Sheets, tubes, wires	100
2.	High temperature nickel base alloys	Nemomic, nimocast Inconels	Castings, forgings, hot rolled, extruded sections, sheets, wires, etc. -do-	100 100
3.	High temperature iron base alloys	Maraging ausforming grade, etc.	Castings, forgings, bars, sections, sheets, etc.	500
4.	Controlled expansion alloys	Fernico, invar, dumet	Rods, sheets, strips, wires	200
5.	Thermocouple alloys	Chromel, alumel, constantan, compensating lead wires	Strips and wires	10
6.	Bi-metals and clad sheets	—	—	15
7.	Heating element alloys	Nichrome, Kanthal	Wires, and strips,	200
8.	Soft magnetic alloys	Mumetal, radio metal, grain-oriented Ni-Fe alloy, perminvar permendur Armco ingot iron	Rods, sheets, foils Ingots, rods, sheets, wires	200 1000
9.	Permanent magnet alloys	Alnico, semi-columnar and columnar alnico	Castings	50
10.	Other metals	Tungsten and molybdenum	Rods, sheets, strips, wires	10

Other facilities : Facilities for powder metallurgy, which include powder making, compacting, sintering, etc., for small components as well as for semis for further hot and cold working.

Efforts have been put in to develop some of the important items mentioned above especially for which demand has been established. At Bhabha Atomic Research Centre (BARC) Bombay, efforts are being put on the development of alloys like copper-beryllium, kovar, iron-nickel alloys for glass-to-metal seals, dumet wires, etc. Some of these products now are ready for exploitation for production. In addition to this, work on some refractory metals and alloys has been initiated at BARC. Considerable amount of development work in respect of other special metals and their alloys is being carried out at organisations like Defence Metallurgical Research Laboratory (DMRL) Hyderabad, National Metallurgical Research Laboratory (NML) Jamshedpur, Central Electrochemical Research Institute (CECRI) Karaikudi, etc., and quite a few of these programmes have matured to a stage of production. Another outcome of this R&D exercise is that a good deal of expertise has been built up in mining and processing of underground low grade ores and also necessary infrastructure has been created for production of metals and alloys involving similar types of manufacturing and processing technologies. Work on rare earth metals which is being carried out at Indian Rare Earth Plant at Alwaye is in progress. In addition to this, projects like development of various rare earth cobalt magnets as substitutes for platinum-cobalt magnets, rare earth phosphors, etc., have also been undertaken in order to explore the application potential for some of these rare earth metals. Regarding beryllium and its alloys, adequate stockpile of this mineral has already been built up by Atomic Minerals Division of the Department of Atomic Energy (DAE). Activities at NML include mainly development of mumetal; and substitute for kanthal. They are also working on extraction of nickel from Orissa and Jaduguda uranium mines.

Regarding special metals and alloys like nickel and cobalt base alloys, high strength steels, tungsten and molybdenum, etc., DMRL has been engaged in R&D work on several of these alloys and have achieved both experience and competence in the production technology. Recently, they have proposed a production plant, the manufacturing programme of which covers materials involving similar production technology. The proposed programme is summarised in Table 15.3. The capital outlay has been estimated at Rs. 26 crores (with FE at Rs. 18.5 crores). The annual sale proceeds are estimated at Rs. 16 crores and a recurring foreign exchange saving of about Rs. 12 crores. It is expected that the production will commence from 1978. Tungsten is being produced a pilot plant scale at DMRL and some other private agencies. Tungsten filament fabrication facilities have been established in the country.

15.2.2 Ultrapure Materials

Ultrapure materials contribute about 6 per cent of the total materials requirement of the industry. The only major production activity in this area is at the Special Materials Plant (SMP) in Nuclear Fuel Complex (NFC) at Hyderabad. This plant which is the outcome of the know-how generated at BARC was started in around 1969. The plant was envisaged to require a capital outlay of about Rs. 40 lakhs (Rs. 7 lakhs in FE) and an annual turnover of about Rs. 76 lakhs with about Rs. 52 lakhs (about Rs. 9 lakhs in FE) of production cost. The plant has already started production of a good number of materials as indicated in Table 15.4. This schedule itself would involve about Rs. 38 lakhs as the production cost. Besides the items mentioned in Table 15.4, SMP is considering to take up production of high purity niobium and optical grade sodium iodide. In addition to the plant at Hyderabad, another production unit in the private sector, Pihani Ultrapure Materials Corporation at Ghaziabad is being started recently.

Besides the materials mentioned above, various other materials like semiconductors, dopants, bonding wires, high purity soldering alloys, etc., are required for

Table 15.4. Present production schedule of the special materials plant.

Sr. no.	Material	Purity (percentage)	Shapes	Quantity (in kgs)
1.	Antimony	99.999	Zone refined (ZR) ingots of 25 mm × 25mm cross section and up to 500 mm long	20
2.	Arsenic	99.999	Sublimed granules; powder	10
3.	Bismuth	99.999	ZR ingots of 25 mm × 25 mm cross-section and upto 500 mm long	500
4.	Boron tribromide	99.990	Liquid in ampules of customer's specifications	75
5.	Cadmium	99.990 & 99.999	Vacuum distilled cast ingots (99.99+%) or ZR ingots	200
6.	Gallium	99.999	Liquid in ampules of customer's specification or their standard packing	6
7.	Gold	99.999	Gold potassium cyanide, gold wire and sponge	10
8.	Indium	99.999	Sheet, rod, punched discs	200
9.	Lead	99.999	Vacuum refined or ZR cast ingots	500
10.	Phosphorous oxychloride	99.990	Liquid in ampules of customer's specifications	75
11.	Selenium	99.999	Vacuum distilled cast ingots	1000
12.	Silver	99.999	Ingots, rods, wires	20
13.	Tin	99.999	ZR ingots	500
14.	Tantalum	Capacitor grade	Porous tantalum anodes for electrolytic capacitors; rods, wire, sheets	1000
15.	Tellurium	99.999	ZR ingots	100
16.	Zinc	99.999	Bars or ingots	20
17.	Zirconium	Detonator grade	Powder	1000

the industry and most of them are being imported. Work is being carried out at a few places on the development of some of these products. BARC, for example, has been working on ultrapure aluminium, boron nitride, etc. Regarding polycrystalline silicon, considerable efforts have been put into its development since about a decade at National Chemical Laboratory (NCL), Poona, Solid State Physics Laboratory (SPL), Delhi, National Physical Laboratory (NPL), Delhi, and BARC. NPL and BARC are continuing their work and are capable of producing polysilicon of only about 10 ohm/cm resistivity, which however, is not acceptable to the electronics industry.

BARC is intending to improve its facilities by way of providing a separate clean working space and procuring equipment like float zone melting unit, hydrogen purifying unit, etc., which would involve an expenditure of about Rs. 4 lakhs, mostly in foreign exchange. Recent investigations by BARC and Central Fuel Research Institute (CFRI), Dhanbad have shown that germanium content in the sources available in India is very low. The requirement of germanium is met through import of germanium oxide which is further processed in the country for pure germanium acceptable for the industry. Regarding gallium arsenide and other III-V group compounds, development work is being carried out at a few places. SPL is working on single crystal growth and epitaxial processes for gallium arsenide and also on gallium phosphide and related compounds. Efforts at Tata Institute of Fundamental Research (TIFR) Bombay, are mainly concentrated on the development of epitaxial techniques for gallium arsenide. Regarding bonding wires, solders and brazing alloys, the requirement of almost all of these alloys is met through im-

ports. It is to be noted that SMP is making the majority of the constituent metals required for these alloys. However, the processing facilities and expertise have not yet been developed. Various oxides and related oxides used for piezoelectric, optoelectronic and other applications are required in small quantities and are imported. Work on some of these strategically important crystals has been initiated at a few laboratories. Development work on thick and thin film materials is being carried out at laboratories like NPL, NCL, CECRI, etc., and some compositions, have been developed and being evaluated by the user industry. Work on laser crystals and related materials is being carried out to a very limited extent.

15.2.3. Chemicals and Plastics

Chemical industry is one of the well established industries in India and has achieved competence and experience in production of various chemicals. The plastics industry, though relatively recent, has been progressing fast as elsewhere in the world. Although the requirement of chemicals and plastics for electronics industry forms a very small fraction of the total requirement of the country, this class of materials contributes roughly about 30 to 35 per cent of the total materials used in the electronics industry.

The materials industry is capable of supplying chemicals, especially for which ultra-high purity and strict quality control are not prime requirements. The existing production base can cater to the requirement of most of the solvents and cleaning agents. Electronic grade solvents like methyl alcohol, trichloroethylene, etc., are presently being imported. Recently, some chemical manufacturers have started production of some of these items. Presently, the prices of these products are relatively higher than those of imported ones but likely to come down if large demand is established. In the case of etchants and lapping and polishing compounds, only electronic grade materials such as hydrogen peroxide, hydrofluoric acid, ammonium fluoride, etc., are being imported. High purity gases do not pose a serious problem except for a technical difficulty, namely, compressing the purified gas back into the cylinders. However, this can be partially overcome by setting up purification plants at the respective places of work. Small requirements of gases for x-ray tubes and other special purpose tubes are being met through import. Most of the materials used for high quality photolithography, e. g., for integrated circuits, are being imported. Recently, substitutes for some of these products are locally available. Except for special chemicals, which are required in small quantities, most of the plating chemicals are available locally. Regarding other chemicals, considerable number of them are being imported. Amongst the imported ones, various grades of graphite, electronic grade oxide powders, barium-strontium-calcium carbonates, some high purity silicates, phosphors for TV tubes; etc., require considerable amount of foreign exchange.

Extensive research and development efforts are being put in by respective private agencies to improve their products. This is so especially for solvents, cleaning agents, etchants, etc. In addition to this, laboratories like NCL, BARC, CECRI, etc., have established competence and have necessary infrastructure to take development work in this area. Regarding ultra-high purity gases, BARC has adequate expertise to take up this work. Regarding photomask materials, development is in progress at Defence Research Laboratory (Materials) (DRL (M)), Kanpur. R&D groups at some private firms are also working on the development of some of these items. Development work on special plating chemicals is being carried out at CECRI, National Aeronautical Laboratory (NAL), Bangalore, and at a few private firms. Regarding other chemicals which are presently being imported, Regional Research Laboratory (RRL), Hyderabad and Jorhat, NCL, etc., are working on the development of aluminium oxide. RRL Bhubaneswar is working on

the development of graphite. BARC has been working on nickel nitrate, cadmium nitrate, diboro trioxide, phosphors, etc., and work is in the advanced stage of development in a number of cases. R&D capabilities also exist at other laboratories like NCL, CECRI, etc.

Among the various plastic materials which are being imported, special types of lacquers, diallyl phthalate, high quality polystyrene/polyesters/silicones, etc., are the major ones. Some of the products like ABS plastics, a few types of epoxy laminating resins, some silicone compounds, superior grade phenolics, nitrite rubber, etc., will be indigenously available in the near future.

A number of R&D groups are working on the development of some of these products both in private production agencies and national and Defence laboratories. R&D laboratories, where considerable research and development work has been carried out and considerable amount of expertise has been attained, are NCL, DRL (M), Shriram Institute for Industrial Research (SIIR) Delhi, University Department of Chemical Technology (UDCT) Bombay, Polymer Division at IIT Delhi, and Madras.

15.2.4. Glasses, Ceramics and Others

This class of materials contributes roughly about 19 per cent of the total requirement of materials. The ceramics industry in India has established strong production base only in a few items like mica and some of the special glasses. However, most of the requirement of TV shells, sealing glasses for kovar, compression seals, high purity fused quartz, quartz crystals, steatite, forsterite, alumina ceramics for integrated circuit applications, etc., is met through import. Regarding raw materials for these products, the basic ingredients are available in India in most of the cases.

Considerable amount of development activity has been initiated in the country recently. High purity alumina ceramics has become very important because of its use in semiconductor industry, as substrates for resistors and alumina bodies for various applications. NPL has already put forward a proposal to produce electronic ceramics on a commercial basis. DMRL has developed a process for steatite. Work on some ferroelectric and piezoelectric ceramics is being pursued at laboratories like, NPL, NCL and Indian Institute of Science (IISc) Bangalore. NCL has produced PZT on a laboratory scale. In general, there exists a technology base for the production of these types of materials. Work on high purity fused silica is being carried out at IISc. Work on quartz crystals is being carried out at CGCRI where the process technology seems to have been completed.

Ferrites which are included in this class deserve a special mention. Total annual requirement of ferrites would be around 1200 tonnes by the end of 1978-79, out of which, soft ferrites would be required to the tune of 600 tonnes annually. Regarding soft ferrites for radios, the entire demand for the Fifth Plan would be met through indigenous production. However, the requirement of TV ferrites, telecommunication pot cores, memory core ferrites and special microwave ferrites is met through imports. Production of hard ferrites has also been well established in the country and a firm production capacity of about 700 tonnes per annum of hard ferrites would be available in the country against an estimated demand of about 600 tonnes in 1978-79. It should be noted here that although, competence and infrastructure already exist in the country, the products developed and manufactured in the country have not met the requirement of the professional grade components, in some cases. For example, substantial imports are being incurred to meet the requirement of MnZn ferrite pot cores and TV components. The raw materials like beneficiated ore, lowgrade ferric oxide, manganese carbonate, barium carbonate, gamma ferric oxide (development has been completed), etc., required for the ferrite

industry are available in the country, while superior grade ferric oxide and manganese dioxide, nickel carbonate, strontium carbonate, etc., are being imported presently. Amongst the laboratories which are engaged in the development of ferrites NPL, NCL and RRL Hyderabad, are the major ones. NPL has been active in the area of professional ferrites, specially TV ferrites, pot core ferrites and square loop ferrite. Development activities at NCL include work on isotropic hard ferrites, gamma ferric oxide and wet chemical methods. In addition to this, work on microwave ferrites is being carried out at SPL and RRL Hyderabad. DMRL is doing some work on anisotropic hard ferrites, plastic magnets and gamma ferric oxide. IIT Kanpur has done some work on permanent magnets based on strontium ferrites.

15.3 Demand Forecast

The total requirement of materials is assumed to be around 25-30 per cent of the total components cost. Further, as mentioned earlier, the metals and alloys, ultrapure materials, chemicals and plastics, and glasses, ceramics and others contribute roughly about 43-45, 5-6, 30-35 and 17-20 per cent, respectively, of the total cost of materials required for the components industry. Therefore, from the envisaged production of components, the materials requirement under each class has been computed and is given in Table 15.5.

Table 15.5. Demand projection for electronics materials.

Class	1974-75	1975-76	1976-77	1977-78	1978-79	1974-79	1979-84	1974-84
Metals and alloys	8.0	12.0	15.5	20.5	27.0	83.0	207.0	290.0
Ultrapure materials	1.0	1.5	2.0	3.0	4.0	11.5	44.0	55.5
Chemicals and plastics	7.5	9.5	12.5	17.0	22.0	68.5	151.0	219.5
Glasses ceramics and others	3.5	5.0	7.0	9.5	12.0	37.0	98.0	135.0
Total	20.0	28.0	37.0	50.0	65.0	200.0	500.0	700.0

One of the methods to arrive at itemwise demand forecast for various materials would be based on the normalised demand profile—the average requirement of each of the materials per piece or so of each component—and the production profile (quantitywise) for different components. The accuracy of such a forecast depends on the accuracy of both of these factors. The diversity in the materials used in a particular type of component makes it difficult to work out an accurate normalised demand profile. This is quite an involved process, since estimating the quantity of each of the materials for each component would require an exact knowledge of not only the process employed but also the wastage of materials from spillover and component rejection.

Because of the difficulties mentioned above in the process of computing the yearwise requirement for individual items, the estimated requirement only for 1978-79 is given here. These estimates are based on the envisaged production of various components in 1978-79 as given in Table 15.7. Tables 15.8 to 15.12 list the items required along with their technical specifications, important appli-

cations, and requirements in both quantity and value. These tables also include the remarks regarding present development and production status as well as suggested course of action, if any, for their development. It should be noted here that this compilation gives only the indicative list of items required for the envisaged production of the components. This list has to be updated from time to time, in order to accommodate development of new materials, better substitutions, change in trend in component industry, change in prices, etc.

15.4 Analysis of Gaps

Although the importance of self-reliance in the electronics materials has been stressed upon often and considerable amount of development efforts have been initiated, many of these materials are still being imported. After looking at the progress of the electronics materials industry, it appears that, in order to achieve self-reliance, the Indian materials industry has a long way to go in terms of refinement, variety, cost, techniques, etc. Many of these materials are required to perform a variety of special functions and therefore, have to satisfy some stringent specifications and a high level of performance. Therefore, although similar products are manufactured by the materials industry for the use of other industries, these special items are not taken up for production as this involves extra efforts. Additional investment would be necessary in order to reprocess and upgrade their products so as to make them suitable for use in the electronics industry. This, however, may not be an economically attractive proposition for the manufacturers, especially for items with very modest requirements. In addition, there are certain problems associated with the respective classes of materials, which have to be solved in establishing a viable materials industry.

15.4.1. Metals and Alloys

One of the major problems in this class of materials is the scarcity of indigenous resources, for example, in the case of nickel, copper, zinc, etc. For some materials, however, the know-how seems to have been successfully developed but the materials await production, the likely reason being that the prospective manufacturers are not sure that the product would be lifted. Kovar and invar, perhaps can be quoted as examples of this case. Materials like aluminium, steel, copper, brass, phosphor-bronze, etc., are available locally, but satisfy only part of the need of the electronics industry. This is because they do not satisfy the specific electrical and structural properties, which invariably require varying and controlled compositions to achieve these desired properties. Further, many of the metals and alloys are required in the form of fine wires, ultra thin foils, etc., and these special configurations are yet to become available as the special skills and tooling facilities have not been established in the country. Because of the small requirement in some cases, no production or development activity exists in the country. Constantan, manganin, etc., could be included in this category.

Some of the important metals and alloys which need attention are special steels, nickel-silver, phosphor-bronze compositions, beryllium-copper, OFHC copper, brass compositions, manganin, constantan, copper-chromium, very thin wires and foils of various metals and alloys, etc.

15.4.2. Ultrapure Materials

Besides the special technology involved in the production, these materials are required in small quantities and therefore, production in quite a few cases, is not economically viable. Further, some of them are available with the required purity but have not been productionised because the industry requires them in a specific form or a shape. For example, BARC is understood to have the know-how for production of ultrapure aluminium, but because of the lack of necessary infrastructure as well as competence for foil making and etching, it is

not being productionised in the form which is needed for the capacitor industry. Boron nitride is required in the form of thin slices; the bonding wires are required in a variety of compositions as well as in diameters ranging from 0.0012 to 0.05 cms; the soldering alloys including those of gold, lead, indium, etc., are required as foils, strips, pellets, rings, etc., and these items have not been productionised because of the reason mentioned above. Although, the high purity gases, like phosphene in hydrogen and nitrogen, silane in hydrogen, etc., which are used in semiconductor diffusion processes, can be developed, the nonavailability of appropriate cylinders appears to be the major bottleneck in taking up their production. Regarding thin and thick film materials, although the present requirement is not large, it will be substantial by the end of 1978-79, so that production can be started on an economically viable basis. Regarding polycrystalline silicon, the material developed so far has not come up to the specifications of the industry. Failure to develop the required grade silicon in the country seems to be due to lack of concentrated efforts and proper planning.

Some of the items from this class which need attention include silicon, gallium arsenide/phosphide, silicon tetrachloride, various soldering, doping and brazing alloys in the required compositions as well as shapes and forms, high purity aluminium foils, metals such as nickel, gold, silver, gallium, etc., and their alloys, high purity oxidic crystals and related oxides. Besides this, R&D should be initiated in establishing required infrastructure for the production of various alloys, mentioned above.

15.4.3. Chemicals and Plastics

With a few exceptions like electronic grade process chemicals, photomask materials, and some special plastics for electronics, many of the materials included in this class are used in other industries in very large quantities. However, it appears that a number of these are being imported at present, as the available products are not acceptable to the electronics industry. In many such cases, the lack of availability may be due to the fact that some of these items are required in quantities such that the production of these may not be an economically attractive proposition for the existing materials industry. Such items include photomask materials, electronic grade ammonium chloride, cerium sulphate, ammonium nitrate, indium oxide, etc., as well as PTFE, special rubbers, some special lacquers, resins, hardeners, fixers, etc. In some cases, although, the development or production agency is ready to take up the work, the exact specifications required by the user industry with regard to the purity, electrical and mechanical properties, particle size, etc., have not been brought out clearly. Chemicals used for plating and polishing, graphite, electronic grade aluminium oxide and magnesium oxide powders, lacquers, coating and sealing compounds, paints, resins, etc., can be cited as examples in this category. In certain cases, although the know-how could be made available and also an economically viable production can be taken up, the raw materials/constituent materials are not available indigenously and the production suffers because of irregular supply. Some times this is true even for indigenously available raw materials. This may reflect in the higher prices for the indigenous products. Lack of adequate testing facilities also have contributed, to a certain extent, towards this slow process of indigenisation.

The items where efforts are needed include some electronic grade solvents and process chemicals, photomask materials, special plating chemicals, various types of graphite and carbon products, diallyl phthalate, polyester, polycarbonate, nylon, PTFE, epoxy, silicones, etc., amongst others.

15.4.4. Glasses, Ceramics and Others

In spite of the fact that most of the basic raw materials for various types of

ceramics are available in India. considerable amount of foreign exchange expenditure is incurred in importing these electronic ceramics. The basic problems for this class of materials are more or less of a nature common to other classes mentioned in earlier paragraphs.

The existing production activity in ceramics is suitable for large scale manufacturing and as the requirement of electronic ceramics is quite modest, these plants are not suitable to take up the production. Further, in cases like alumina, steatite, etc., detailed specifications like size, exact physical, mechanical and electrical properties, etc., are not readily available. Some of the products like sealing glasses have to go as component parts and hence they have to be developed in close co-ordination with the users as well as the R&D groups which are involved in the development of the respective alloys. Such an effective coordination is lacking in some cases. In certain cases, for example TV glass shells, demand is smaller than the minimum which can be produced on an economically viable basis.

Although, good production base for ferrites exists in the country, the import bill for ferrites is estimated to be around Rs. 1.25 crores by 1978-79, mostly for professional grade components. Although the basic raw materials are available in adequate quantities, they are not acceptable for manufacturing special grade ferrites because they do not meet certain specific requirements regarding physical and chemical properties. Some amount of standardisation has been thought necessary regarding the raw materials as the subsequent processing technology depends upon the properties of these starting materials. This is especially true for ferrites for microwave and TV applications.

Some of the important areas to be developed include various types of sealing glasses, high purity alumina, high purity quartz, various piezoelectric ceramics, ferrites for professional grade components, paper for loudspeakers, etc.

15.5 Production and Investment

As pointed out earlier, the materials which are special to electronics contribute only to the extent of around 40 per cent of the total materials requirement. The production activities are distributed amongst large number of manufacturing units mostly in private sector which include both large scale and small scale units. This makes it difficult to arrive at a detailed estimate regarding production and investment in this sector of the electronics industry. However, a brief outline is presented here which highlights some important aspects.

15.5.1. Production

Production of metals and alloys is likely to increase considerably in the later part of the Fifth Plan, when the special metals and alloys plant proposed by DMRL will start its production activity. Production at SMP as envisaged in their future plan and from other agencies will contribute substantially towards the requirement of ultrapure materials. Most of the solvents and process chemicals would be produced locally. Regarding general purpose plastics, the production base has already been established and it is expected that the production of some special plastics, especially where substantial quantum of requirement has been established, would be started by the end of the Fifth Plan. It is envisaged that a number of products which fall under the class of glasses, ceramics and others would be manufactured indigenously by the end of the Fifth Plan. It is expected that by the end of 1978-79 about 70 to 75 per cent of the materials for electronics would be made available indigenously. The production is expected to grow further, during the Sixth Plan. However, some special materials, to the extent of about 10 per cent of the total requirement, will still have to be imported. The production profile for materials is given in Table 15.6.

Table 15.6. Production and investment profile for materials (in Rs. crores).

	1974-79	1979-84	Total during 1974-84
Requirement	200	500	700
Production	125	385	500
Investment	17.3	37.0	54.3

15.5.2. Investment

Because of the diversified nature of the products, it is difficult to forecast the investment breakup in this sector. Most of the production activities are in private sector and the agencies are producing materials required in other industries in large quantities. Therefore, to arrive at the investment necessary, exclusively for the production of electronics materials, would be a difficult task. A rough estimate of the investments necessary to meet the production targets, envisaged earlier, is given in Table 15.6.

15.6 Proposed Guidelines

It is clear from the earlier sections that considerable expertise has been achieved and sizeable infrastructure and competence have been established in the production of the electronics materials. However, the import of materials constitute around 50 per cent of the total requirement of the electronics industry. Although, some materials seem to present the problem of non-availability or scarcity of resources in the country, there are a number of items which could very well be developed in India. Some of the problems faced by the materials industry have been highlighted earlier. Some general guidelines, so as to achieve self-reliance in the materials area, are listed below.

(i) Although the materials contribute to a small fraction of the turnover of the electronics industry, the production of components very much depends on the ability to produce the materials within the country. This calls for a need to give greater emphasis on the indigenisation programme for materials.

(ii) As the materials requirement, both in quantity and quality, is dictated by the user industry, it is necessary that the user industry should specify their requirements quite in advance with detailed specifications and quantity of each of the product required. Such data should be compiled and updated from time to time by Electronics Commission/Department of Electronics. This is a very important task and should get priority.

(iii) In order to achieve maximum benefits within minimum period of time, the efforts should be concentrated only on important items properly selected. Selection of the priority areas should be based on (a) import substitution, (b) monetary value and total industry requirement, (c) its strategic importance, (d) export possibility, and (e) available infrastructure for production.

(iv) In addition to the above criteria, R&D projects should be chosen so as to tie up with the future plans of the electronics industry. The projects should be specific and time bound and should be monitored periodically.

(v) In deciding the scope of the production/development efforts, the philosophy should be to combine to a maximum extent, the production/development of items involving similar technologies.

(vi) Immediate steps should be taken to establish the production of items which are used extensively, if necessary, with technical know-how from abroad, so that the take-off point for indigenous development is raised. In such cases, however,

while taking the decision, National Research and Development Corporation (NRDC), an appropriate R&D organisation, DGTD, etc., should be consulted.

(vii) In cases where nonavailability or scarcity of their sources in the country exists, while we make exhaustive surveys for finding the sources we may import the materials in the raw form and do the further processing in the country. This is being done with respect to germanium. This type of approach offers an advantage of saving foreign exchange, the processing cost, by not importing the item in the finished form. Further, once the sources are found, complete indigenisation would be simple as the necessary infrastructure already exists within the country. In order to safeguard against continued escalation of prices of raw materials, for example nickel, stockpiling of these is recommended.

(viii) For the items for which the know-how and technical competence in manufacturing similar items seem to exist in the country, intensive promotional efforts must be put in to start the production at the respective places. The following situations will arise :

(a) If the products which are being produced do not meet the specifications of the electronics industry, it is in the national interest, that the manufacturers be encouraged to upgrade these products to the required specifications. There should be an initiative from the user agency by giving detailed specifications with samples of the imported item if possible. An R&D organisation should be involved, if the need calls for it. In some cases the matter should be pursued by arranging for trial orders, etc.

(b) If the production could not be taken up as it would not be economically viable, although a modest demand exists, the production can be entrusted to an appropriate R&D organisation where the cost could be subsidised. If the demand picks up later the know-how can be transferred to a production organisation.

(ix) Import should be allowed in cases where the material is required in small quantity and the production would require considerably large investment. However, for strategic items efforts should also be put in to make the item on a laboratory scale. Appropriate R&D laboratory should be consulted before liberalising the import of the respective materials.

(x) Regular supply of the raw materials (constituents) is very essential and immediate steps should be taken to help the production agency in this regard.

(xi) In order to facilitate the materials programme, it is extremely necessary to have standardisation in electronics materials. Necessary steps should be taken to set up a group which will lay down specifications and procedures for testing the materials.

(xii) Regarding testing facilities, the users as well as the materials manufacturing agencies should be encouraged to set up their own testing facilities or quality control laboratories for routine testing. In addition to this, a test laboratory where standardisation and certification for electronics materials could be undertaken, should be set up. This laboratory should have all the testing facilities for electronics materials and these facilities should be available on a commercial basis to the materials industry as well as user agencies and R&D organisations. In addition to this, the existing facilities at other places should be augmented on case to case basis.

Table 15.7. Production of components envisaged by 1978-79.

Components	Nos. in lakhs
1. Electron Tubes	
Receiving tubes	150.000

XV

Transmitting tubes	8.200
VHF & UHF output tubes	1.000
Microwave tubes	0.045
X-ray tubes	0.030
TV picture tubes	4.000
CR tubes	0.070
Photo & image tubes	0.155
Gas filled tubes	1.500
2. Semiconductor Devices	
Germanium signal diode	120.000
Germanium small signal transistors	140.000
Silicon signal diodes	40.000
Silicon small signal transistors	370.000
Zener diodes	50.000
High current rectifiers	101.500
Low current rectifiers	98.500
Thyristors (high power)	0.500
Germanium power transistors	36.000
Silicon power transistors	60.000
Microwave diodes	0.750
Microwave transistors	0.070
Diode lamps	10.000
Digits	5.000
Linear integrated circuits	20.000
SSI/MSI	95.000
LSI/IC subsystems	5.000
Hybrid circuit	5.000
3. Resistors	
Carbon film (fixed) (carbon composition)	3000.000
Metal/metal oxide film	5.000
Wire wound (fixed)	150.000
Thermistors & varistors	25.000
Carbon track potentiometers	300.000
Wire wound/cermet (variable)	250.000
4. Capacitors	
Paper	125.000
Plastic film	100.000
Electrolytic (Al)	700.00
Electrolytic (Ta)	10.000
Ceramic	1900.000
Mica/silver mica	175.000

Gang (variable)	1000.000
Trimmers	300.000
5. Connectors	
Coaxial	13.000
Printed circuit	35.000
Cylindrical	8.000
Rack and panel	7.500
Miscellaneous	35.000
6. Relays	
Armature type	38.000
Reed	6.000
Miscellaneous	1.000
7. Switches	
Rotary	13.000
Push button	20.000
Toggle	25.000
Sensitive	2.500
Slide	40.000
Lever	2.500
Reed	15.000
Miscellaneous	7.500
8. Others	
TV deflection components	6.000
IFTs and coils	750.000
IP/OP transformers	220.000
Loudspeakers	120.000
Microphones	6.000
Crystals	10.000
Magnetic heads	7.000
Cartridges	6.000
Stylis	10.000
Magnetic tape (metres)	500.000
Telephones	8.000
Dry cells	1000.000
Ni-Cd cells	10.000
Permanent magnets (in tonnes)	3400.00
Printed circuit boards	
phenolic (value in Rs. millions)	400.00
epoxy (value in Rs. millions)	100.000

Table 15.8. Demand forecast for metals and alloys for the year 1978-79.

No.	Materials	Specifications	Applications	Requirement		Remarks
				Quantity	Value (in Rs. lakhs)	
1.	Aluminium	(i) Foil—99.9% purity, free from particles, uniform size foil	Plastic and paper capacities	150 tonnes	37.50	Although aluminium up to purity 99.95% seems to have been developed in the country, most of the requirements under (i) and (ii) seem to be met through imports as the material in the required form is not available in the country. Other requirements can be met by indigenously available materials. In addition to this, some special aluminium alloys are imported, e.g. ITI presently imports these alloys to the tune of about 35 tonnes worth Rs. 4,00,000. Some promotional efforts are needed.
		(ii) Sheet—99.5% and 99.9% purity, uniform in size 0.3 to 6.5 mm thick	For vanes in gang condensers, cans for electrolytic capacitors and IF transformers	100 tonnes	20.00	
		(iii) Rod—dent free 3 to 6 mm in diameter	Shafts for potentiometers	50 tonnes	10.00	
		(iv) Sheets, castings, etc., 98% pure	Chasis, cabinets, cases for servo-components, etc.	1500 tonnes	150.00	
2.	Beryllium copper	2 to 4% beryllium and rest copper, mostly in strip form (approximate thickness 0.1 mm)	For contacts in connectors, relays, potentiometers, variable capacitors and gyros	10 tonnes	40.00	Presently being imported. The raw material for beryllium presents no problem. BARC has already developed the master alloys and the dilution can be taken up. Heat treatment procedures of this alloy are not yet very well known. Adequate data are available to set up a large scale production unit which will cater to the need of the country.
3.	Brass	Free cutting and spring tamper, in the form of strips, thin tubes, etc.	Small parts such as bushes, screws, caps, etc., for resistors, potentiometers, connectors, and miscellaneous parts for components	1000 tonnes	200.00	These alloys are required in other industries and the requirement for electronics industry is much small. The 'free cutting' type of the alloys are available in India. However, the requirement of spring tamper, close tolerance tubes, dent-free rods with small diameters, etc., used mainly by ITI, is met through

4.	Constantan	57% copper and 43% nickel, rods and wires	Support in tubes and incandescent lamps, thermocouples	60 tonnes	60.00
5.	Constantan/manganin/karma/evanohm	Wires, 20 to 50 SWG	For high and low valve wire wound precision resistors and potentiometers	10 tonnes	25.00
6.	Copper	Electrolytic copper 99.99% pure	For flashing and electroplating, for leads in resistors, capacitors and rectifiers	400 tonnes	200.00
		OFHC copper	Semiconductor devices, waveguides and other microwave components, vacuum tube structures, etc.	250 tonnes	200.00
		Foil—continuous, uniform thickness 20 to 250 microns	Printed circuit boards	5 tonnes	2.00

import. These types of alloys are being produced by Indian metal industries and the useability of these should be explored.

The estimates are approximate. The items are presently being imported. There seems to be no development activity.

The estimates are approximate. The items are being imported presently. There seems to be no development activity for these items.

Requirement for wires and cables has not been considered here. Requirement only for tinned copper wire as hookup connections is given. Requirement of copper for leads with dimensions thinner than 44 SWG, OFHC copper and foils for printed circuit applications is met through import. There is a scarcity of copper ores. NML, BARC, etc., are working on the reclamation of the ores available in the country. DMRL has been working on production of copper from Indian ores. CECRI seems to have developed the process for electrolytic copper on a bench scale. Further work on these lines is to be carried out. Regarding OFHC copper, DMRL is known to have produced the material to the required specifications. Work on the development of copper foils and screens by electroforming techniques appears to have been completed on a laboratory scale at CECRI. Continuous foils upto width of 100 cms and thickness 20 to 250 microns has to be taken up.

7.	Dumet wire	Alloy of Ni 40% and Fe 60%, coated with copper	For leads in point contact diodes, relays, pilot lamps	10 tonnes	17.00	The requirement, which is met through import, is only a small fraction of the lamp industry's needs. BARC is known to have developed the technology of production.
8.	Kanthal	Patent alloy containing approximately Cr — 25%, Fe — 70%, Al — 3%, Co — 2%	Heating element for high temperature furnaces	30 tonnes	25.00	Presently being imported. The estimate given is only approximate. Kanthal India Ltd., Calcutta is known to draw wires from imported kanthal. NML has developed a substitute for this alloy. DMRL seems to have plans to produce it to cater to the needs of electronics industry.
9.	Kovar, and Iron-nickel alloys	Kovar : Ni — 29%, Co — 17%, Fe — 54%, Al, Mg, Zr, Ti each less than 0.1%, and together less than 0.2%, Mn less than 0.5%, Si less than 0.2%, required in the form of strips upto 0.6 mm thick, 50-100 mm wide, tubes of 1.5 mm diameter and above 0.35 mm thick Iron-nickel alloys : Fe : Ni — about 50 : 50; mostly required in wire form of 1 mm diameter, thicker wires up to 3 mm are also required. Cylinders and plates for microwave applications are required in thickness of about 10 mm	Glass-to-metal seals for tubes, semiconductor devices and semiconductor device packages, relays, etc.	200 tonnes	200.00	BARC and DMRL seem to have developed the technology and have established the production process on a small scale, of the order of 10 kg per melt, basis. Fabrication of rods, wires, strips, etc., is being carried out to suit the need of the industry. The products seem to be satisfactory and are being used by some of the user agencies. The proposed special metals and alloys plant at DMRL would be able to produce these alloys to meet the requirements of electronics industry.
10.	Mercury	99.9% pure	Amalgams, relays, contacts, rectifier	25 tonnes	75.00	The estimate given includes the requirement only for relays and batteries.

		tubes, mercury actuated controllers, batteries, manometers, etc.			Quantitywise, the requirement will be very small compared to the requirement for other industrial applications like electrolytic purification of metals, etc. The purification presents no problem, however, there is scarcity of indigenous resources.	
11.	Molybdenum	99.99% pure, it is used in the form of wires, rods, tapes, plates, sheets, tubes, etc.	Used in vacuum tubes as grids, electrodes, heat shields, support structures, etc.; in point contact diodes; as heat sinks in semiconductor devices, etc.,	8.0 tonnes	16.00	Estimate given are for semiconductor and tube industries only. Requirement for other applications like furnace heaters, is not included. This metal is also used in steel industry in the form of its oxide. Jaduguda uranium ore contains significant amount of molybdenum. Possibility of recovery from this ore has been worked out. Extensive development work is being carried out at BARC and DMRL. In addition to this, DMRL have plans to start its production from metal powders. The further facilities for wire drawing seems to be available within the country. Other organisation involved in the development effort is IIT, Kharagpur.
12.	Mumetal	Patent items, consisting of Ni 75%, Fe 16%, Ca 5% and Mo 4%, required in the form of rods, sheets and foil	Magnetic shields and cores in cathode ray tubes, choppers and low level transformers, laminations for magnetic head input transformers for special applications	22 tonnes	22.00	DMRL has developed the know-how and has plans to productionise this item in the required form. IIT, Kanpur also seems to be working on this point.
13.	Nichrome	Ni-80%, Cr-20%, wires of 18 to 50 SWG	Wire wound potentiometer and resistor metal film	10 tonnes	15.00	Presents no problem. Requirement for heating elements is not included. Also used for other industrial applications in

		resistor, heating elements, etc.			
14.	Nickel	(i) Semiconductor grade in the form of wires and foils; metallic impurities less than 100 ppm	In semiconductor devices as electrodes	50 tonnes	50.00
		(ii) Vacuum tube grade in the form of wires, tubes, sheets, etc., maximum impurity limits : C 0.08%, Cu 0.25%, Fe 0.3%, Mn 0.35%, S 0.008%, Si 0.2%, for general purpose tubes. For cathode cores and special tubes these are C 0.05%, Mg 0.01% Mn 0.02%, S 0.005% Si 0.01%	In vacuum tubes as supports and other component parts		
		(iii) Metallic impurities less than 100 ppm	Electroplating	—	18.00
		(iv) Battery grade porous nickel plaques	Ni-Cd batteries and other applications	—	20.00
		(v) Wire of 20 to 24 SWG, annealed	For tantalum capacitors and defence grade wire wound resistors	2 tonnes	2.00
15.	Nickel silver	In sheet form, typical composition : Cu 60%, Ni 20%, Zn 20%	Used as slip ring and slides in general purpose wire wound potentiometers	3 tonnes	5.00
		As strips—say 0.3 × 42 mm and 0.3 × 33 mm size	For cans in germanium devices	40 tonnes	8.00

large quantities. DMRL has plans to productionise this to cater the special needs of the electronics industry.

The indigenous sources are very limited and almost all the requirements of nickel are met through import. Development for nickel for Ni-Cd batteries has been complete. The nickel for anodes in electroplating is available in India. The nickel wires, foils, tubes, etc., used in electron tubes and semiconductor devices are imported. NML has been working on the extraction of nickel from indigenous ores. DMRL has plans to undertake production of some of these items in their proposed special metals and alloys plant.

16.	Permanent magnet alloys	High energy special alloys, most of them are patented items; they contain Al, Co, Ni, Mo, etc., as major constituents, various types available are Alnico (with Al), Cumico (with copper), etc.	For loudspeakers, meters, microphones, telephones, magnetrons, etc.	1,25,00,000 pieces	125.00 (cost of materials)
17.	Phosphor bronze	Commercial grade, in sheet form, and special grade for specific applications like telecommunication equipment	Relays, connectors, band switches, carbon potentiometers, and air gang capacitors, valve sockets, etc.	150 tonnes	150.00
18.	Solders	(i) 62% tin, 36% lead 2% silver	For soldering leads to components,	20 tonnes	20.00

and zinc and suitable melting techniques with fluxes and deoxidising agents are required. NAL has successfully produced this in kg quantities. NAL also has necessary facilities to take up alloy development work. However, Nickel would still have to be imported. It should be noted here that some Indian copper foundries seem to be producing a variety of these alloys and suitability of these products should be explored.

Because of the special manufacturing technology involved, these magnets are generally expensive and the raw materials for these are mostly being imported. NML and DMRL are working on the development. DMRL has plans to productionise these alloys. Substitution by ceramic magnets is effective. Substitution by rare earth cobalt magnets could be possible. Misch metal has been developed by CEERI and could also be used. Some work on misch metal cobalt magnets has been initiated at IIT Kanpur.

Partially imported. The requirement for carbon potentiometer and air gang capacitors only is around 24 tonnes. The requirement estimated does not include the requirement of ITI which would be around 200 tonnes most of which is met through import at present. These alloys are being produced at some production agencies in the country. Specific requirements of electronics industry should be referred to them. Some promotional efforts are needed.

Presents no problem; except that there is scarcity of raw material resources for

			and for sealing sealed capacitors, etc.			tin and lead.
		(ii) 70% tin, 30% lead		15 tonnes	10.00	
19.	Steels and iron	(i) Cold rolled grain oriented silicon steel laminations low loss, burr free, silicon 2 to 4%	Power transformers, chokes	2000 tonnes	300.00	Requirement of structural steel which does not pose any problem has not been included. The requirement of electronics is negligible as compared to the other industrial applications. There is no problem regarding raw materials. However, conversion into special steels and in the required form/shape poses a problem. Most of the requirement of steel mentioned here is met through import. IIT, Kanpur, seems to be engaged in this type of development work. If they could develop the product, the production can be taken up at HSL, Rourkela for quick implementation. DMRL is also well advanced in this area and have plans to undertake production of some of these alloys.
		(ii) Cold rolled close annealed sheets, 20 to 30 gauge, uniform in thickness, good surface finish for tin plating	Resistor caps, cans for sealed capacitors, covers for potentiometers, etc.	100 tonnes	5.00	
		(iii) Steel sheets	Loudspeakers, magnetic head covers for transformers	850 tonnes	25.00	
		(iv) Bright steel, SS rods, 3 to 6 mm diameter with good surface finish	Shafts for professional potentiometers	10 tonnes	5.00	
		(v) Steel DPDD	Silicon power transistors and other semiconductor devices	3000 tonnes	150.00	
		(vi) Mild steel and various other grades	For electron tubes	—	20.00	
		(vii) Iron as pure powder	As core material	—	—	
20.	Tin*	Commercial grade	Tinning copper wire, for electric solders	—	—	Requirement is considered under solders. All the requirement of tin is met through import. Purification does not pose any problem.
21.	Tungsten	Better than 99.9%, split free, thin wires, rods, sheets, etc.	For tubes as heaters cathodes, grids, support structure,	700 kgs.	3.50	Requirement in other industrial applications is large. Requirements for electron tubes (50 kgs) and semiconductor

			etc., in point contact diodes, heat sinks, etc.			industry (700 kgs) have been given here.
22.	Zinc	High purity grade purity better than 99.9%	Primary batteries, silver/zinc batteries, diecast parts, constituent as tin-brass	2,000 tonnes	100.00	This is a scarce metal in India. However the requirement of the electronics industry being small, should not pose any special difficulty. Requirement only for dry-cells is given here. Diecasting zinc of purity 99.99%, is not being produced commercially in India. However, SMP (NFC) is able to produce the product of 99.999% purity and therefore, there should be no problem in this regard.

*Owing to either their type diversity or uncertainty in the demand of the components where they are used, no definite demand could be arrived at.

Table 15.9. Demand forecast of ultrapure materials for the year 1978-79.

No.	Materials	Specifications	Applications	Requirement		Remarks
				Quantity	Value (in Rs. lakhs)	
1.	Aluminium	(i) Foil—99.99% pure, free from particles, uniform size foil (ii) Slugs/powder 99.999% pure, maximum level of impurities in ppm : Cu 0.1, Mn 0.2, Mg and Ca 0.1	Electrolytic aluminium capacitors Metallisation; bonding wire compositions	250 tonnes 300 kg	60.00	Foils for electrolytic capacitors are being imported mostly as etched foils. Although BARC is understood to have the know-how for producing ultrapure aluminium, the infrastructure and the competence for making and etching the foils and wire drawing have not been established in the country. The requirement may continue to be met through imports till these facilities are created—CECRI karaikudi is working on the development of etched foils.

2.	Antimony	99.999% pure; maximum level of impurities : Pb, Cu, Fe and Si less than 0.5 ppm, halogen, Se and S together less than 1 ppm	Dopant; bonding wire and solder compositions, compounds like $SbCl_3$	60 kg	0.54	ECIL is known to have found the product supplied by SMP satisfactory. BEL and other semiconductor device manufacturers should try this product. Alloys of antimony with germanium and silicon and compounds like $SbCl_3$ that are also invariably used by the device manufacturers may also be developed by SMP with the help of BARC.
3.	Arsenic	99.999% pure; maximum level of impurities : Si, Fe, Pb, Mg less than 1ppm each, Cu less than 0.5 ppm; halogen, Se and S together less than 1 ppm	Dopant; constituent element in GaAs; compounds like $AsCl_3$ and AsH_3	60 kg	3.00	SMP has an annual production capacity of about 10 kgs and should be able to scale up its production in order to meet the additional requirement. SMP should, in consultation with BARC, also try to produce some arsenic compounds like arsine, arsenic trichloride, arsenic oxide and arseno silica emulsion that will be required in small quantities.
4.	Barium/ strontium	99.999% pure; filled in thin metallic (Ni/Cu/Fe) tubes	Gettering in electron tubes	800 kg	2.50	The technology involved in producing these materials in the forms in which they can be easily handled is rather difficult owing to their high affinity for oxygen. Owing to the technology being involved and the requirement being small, these materials may continue to be imported.
5.	Bismuth*	99.999% pure; maximum level of impurities : Pb, Fe 1 ppm each; Cu, Ag 2 ppm each; also 99.99% pure	Constituent element in Bi_2Te_3 ; solder compositions	—	—	ECIL uses bismuth from SMP for thermoelectric cooling elements. SMP has the production capacity to meet the requirements.
6.	Boron	99.999% pure, powder	Dopant	5 kg	0.30	BARC is known to be working on it and is expected to transfer the know-how to SMP for production. In the meanwhile it could be continued to be imported particularly when the requirement is not large.

7.	Boron nitride	99.999% pure; wafers of say, 2 inch diameter and 10 mil. thickness (wt.~ 3 gm/wafer)	Dopant	30 kg	4.00	Production of boron nitride involves ceramic technology. BARC is known to be in the process of developing it. While BARC needs to be encouraged to intensify their efforts in developing it, it would have to continue to be imported for the present.
8.	Boron tribromide	99.999% pure	Dopant	100 kg	4.50	The product produced at SMP is known to be satisfactory and SMP has the capacity to meet the requirement. The import may be banned.
9.	Boron trichloride	99.999% pure	Dopant	5 kg	—	It is in the gaseous form at room temperature, therefore involves the problem of compressing it into cylinders. Even if the facilities were to be set up, the cylinders would have to be imported. It may, therefore continue to be imported as the requirement is small.
10.	Chromium		Chromium cladding of glass plates in photolithography	3 kg	0.27	The requirement being small it can continue to be imported.
11.	Diborane in hydrogen		Dopant	20 cylinders	0.30	Non-availability of cylinders being the major bottleneck it may continue to be imported.
12.	Gallium	99.999% and 99.99% pure	Constituent element in GaAs/GaP, solder compositions	180 kg	35.00	The present annual capacity at SMP is about 6 kg but SMP should be able to scale up its production. There is a worldwide shortage of gallium. The bauxite in India is relatively rich in gallium. Gallium is one of the few materials which is expected to have a good export potential. In view of this a positive step should be taken to set up plants for extracting gallium which

13.	Gallium arsenide/ gallium phosphide	99.999% pure polycrystalline	GaAs/GaP based devices	200 kg	168.00	could be purified at SMP. The technology for extracting is known to be available with BARC and CECRI. Major requirement of GaAs/GaP is for making LEDs. The entire range of equipment for producing LEDs, starting from the synthesis of GaP from gallium and phosphorous is expected to cost only about Rs. 70 lakhs. In order to minimise the time lag the complete plant may be installed in the proposed semiconductor complex. The present R&D efforts in the area of gallium arsenide growth should continue.
14.	Germanium dioxide	—	Germanium devices; bismuth germanate for electro-acoustic delay lines	3,000 kg	24.00	Owing to the non-availability of the germanium ore in the country the material is imported and processed further to meet the needs of the industry. Until such time, as suitable source material for germanium is found in the country, the oxide may continue to be imported.
15.	Gold	—	Metallisation; conductive pastes, preforms, bonding	small	—	The requirement of pure gold can be met by SMP.
16.	Indium	99.999 % and 99.99 % pure; pellets	Dopant; solder compositions	900 kg	4.00	The present annual production of indium at SMP is of the order of 200 kg. SMP should eventually be able to meet all the requirements of indium.
17.	Lead	99.999 % and 99.99 % pure	Dopant; solder compositions	2.5 tonnes	—	SMP should be able to meet all the requirements of lead.
18.	Phosphorous oxychloride	99.999% pure	Dopant	200 litres	0.08	Phosphorous oxychloride produced at SMP is of satisfactory quality and as SMP can meet its requirement the import may be banned.

19.	Phosphorous pentoxide	99.999% pure	Dopant	5 kg	—	Requirement is small and it may continue to be imported. Possibility of producing on a laboratory scale should be explored.
20.	Phosphene in hydrogen	—	Dopant; making GaP and GaAsP	25 cylinders	0.38	Nonavailability of cylinders being the major bottleneck, they may continue to be imported for the present.
21.	Phosphene in nitrogen	—	Dopant	20 cylinders	0.30	—do—
22.	Silane in hydrogen	—	Dopant	100 cylinders	6.00	—do -
23.	Selenium	99.999% pure	Selenium rectifiers	1000 kg	—	SMP has developed the material which could be used for xeroxing. It seems that the rectifier industry requires doped selenium which seems to be not available in the country. Efforts should be put in for its development.
24.	Silver	99.99% pure	Conductive pastes, soldering and brazing compositions		—	SMP can meet its demand.
25.	Silicon	99.999% pure; polycrystalline, semiconductor grade	Silicon devices	5000 kg	40.00	NPL and BARC are capable of producing polysilicon of only 10 ohm cm., resistivity. BARC is intending to improve upon its facilities which would involve an expenditure of about Rs. 4 lakhs mostly in foreign exchange. In view of the marginal success achieved by these organisations and the urgent requirement of this material, the Semiconductor Committee set up by Department of Electronics in 1972 has recommended that the technology for producing polysilicon should be imported. It

26.	Silicon tetra- chloride	Semiconductor grade	For epitaxy in silicon semicon- ductor devices	1,000 kg	3.00
27.	Tantalum	Better than 99.9% pure, slugs	Solid tantalum electrolytic capa- citors	3,000 kg	—

is, however, understood that the minimum economical scale of production of polysilicon is about 10 tonnes, so that it is economical to set up a plant for producing polycrystalline silicon unless export of silicon is envisaged. Owing to the worldwide shortage of silicon, the export would be commercially viable. However, the present requirement of polycrystalline silicon may continue to be met through imports. The R&D should also be encouraged to be continued in the organisation that is still pursuing this activity. The expertise gained by the R&D organisation could prove useful when the technology is to be imported.

The conversion of 5 tonnes of polysilicon into single crystal silicon (about 3.6 tonnes) would need import of additional equipment for crystal growth. Present annual capacity for the single crystal conversion is only about a tonne.

Semiconductor grade product can continue to be imported for the present. Meanwhile, an R&D group should be identified to undertake the purification of commercial grade silicon tetrachloride that is available in the country. IISc Bangalore, NCL, and BARC are the organisations which can take up this purification.

SMP has been supplying this product to ECIL for use in their solid tantalum capacitors. SMP should be able to step up the present production, by about a tonne a year, to meet the entire requirement.

28.	Tellurium*	99.999% pure	Constituent element in Bi_2Te_3	—	—	SMP is supplying this to ECIL and should be able to take care of the total requirement.
29.	Zinc	99.999% pure	Dopant	Small	—	SMP is capable of meeting the requirement.
30.	Zirconium	Powder, suspension	Shield coating in magnetrons	60 litres	0.04	SMP produces zirconium powder of detonator grade. They should explore the possibility of making the required type of suspension after consulting with BEL who is its main user.
31.	Zirconium hydride		Getter in electron tubes	100 kg	0.25	SMP should explore the possibility of producing it after consulting BEL who is its main user. It seems that some steps in this direction have been taken up.
32.	Special Alloys*					
	Bonding wires*	Diameters ranging from 0.0005 inches to 0.02 inches	—	—	20.00	The requirement of all these alloys is being met through imports. There seems to be no local effort to produce them. The total foreign exchange requirement is significant and there is a distinct need to start an intensive R&D activity in this area. Most of the constituent elements have been developed at SMP. It appears that DMRL has some infrastructure to take up these development activities.
	Solders*	As strips, pellets, discs, rings, foils of, say, 1 inch width and 0.001 inch length, 0.005 inch thickness	—	10 tonnes (appro)	15.00	
	Brazing alloys*	—	—	112 kg	4.35	
33.	Oxidic crystals*	High purity	Various	—	—	Some of the oxides like lead oxide, gallium oxide, boric oxide, bismuth oxide, tantalum oxide, etc., can be supplied by SMP. Work on other oxides is being carried out at BARC.
34.	Thick film materials	Various conducting and contacting materials	Various	—	—	NPL, NCL, and CECRI have been working on thick film materials and has already developed some compositions which could be used.

*Owing to either their type diversity or uncertainty in demand of components where they are used, no definite demand could be arrived at.

Table 15.10. Demand forecast for chemicals for the year 1978-79.

No.	Materials	Specifications	Applications	Requirement		Remarks
				Quantity	Value (in Rs. lakhs)	
1.	Acetates					
	Barium acetate	G. R. grade	TV and CR tubes	4.5 tonnes	1.80	Available indigenously and presents no problem.
	Butyl acetate	—	For germanium devices	800 litres	0.10	—do—
	Ethyl acetate	High purity grade	For cathode material suspension in receiving tubes	1 tonne	0.03	—do—
	Methyl-glycol acetate	High purity grade	For receiving tubes	15 tonnes	0.10	The requirement is small and presently being imported. Development can be taken up at places like BARC, NCL, etc.
2.	Acetic acid	i) Pure	For Germanium devices for pickling	3 tonnes	0.14	The types (i) and (ii) pose no problem as they are available indigenously. The electronic grade is presently being imported.
		ii) High purity grade	For silicon semiconductor devices for plating	50 litres	0.08	BDH and SMC have listed this on their latest catalogue which seems to have been approved by user industry. The
		iii) Glacial, electronic grade	For silicon semiconductor devices	12 tonnes	0.75 (3.60)**	cost seems to be very high as compared to the imported one.
3.	Acetone	i) High purity grade	For cleaning germanium devices and receiving tubes.	60 tonnes	1.75	Both the products are indigenously available and present no problem.
		ii) Electronic grade— Assay 99.5%, residue after evaporation 0.0003%, acidity 0.002% alkalinity	For silicon semiconductor devices	10 tonnes	2.80	

(as NH_3) none, aldehyde pass ACS test, methanol 0.025%, substances including KMnO_4 pass ACS test; Pb, Cu, Fe, Ni less than 0.000004% of each, H_2O 0.31%, non-volatile matter 0.001%

4.	Acetylene black	75% compressed	Dry cells	300 tonnes	18.00	Presents no problem, as it is available indigenously. However, the present production has to be increased to meet the future requirement.
5.	Aluminium oxide/hydroxide	i) High purity aluminium oxide powder	For heater in receiving tubes	2 tonnes	1.35	Electronic grade aluminium oxide powder seems to be available indigenously. RRL Hyderabad, is understood to be making Al_2O_3 which is being used by BEL. RRL Joharat and IIP are also working on similar types of materials. BDH, SMC, etc., are manufacturing special grade powders, but possibly they do not satisfy the requirement of the electronics industry. The suspensions are being imported.
		ii) High purity grade activated powder, particle size 10 microns	For can filling in germanium devices	4.8 tonnes	116.00	
		iii) High purity grade suspension	For heater coating in magnetrons	120 litres	0.03	
		iv) Aluminium hydroxide suspension	For mica spraying in receiving tubes	3000 litres	0.65	
6.	Aluminium—calcium silicate	High purity grade	For can filling in germanium devices	300 kg	0.25	Presently being imported. Some work is being carried out at CECRI on calcium silicate.
7.	Ammonium fluoride	Electronic grade—Assay (NH_4F) 95.0%; maximum level of impurities : ammonium bifluoride (NH_4HF_2) 1.5%, H_2SiF_6 0.3%, residue after ignition 0.005%, Ca and NO_2 0.002%, of each, SO_4 0.005%, Cl, Fe and heavy metals (as Pb) 0.0005% of each	As an etchant for silicon semiconductor devices	6 tonnes	1.00	Presently being imported. However, if electronic grade hydrofluoric acid is made available, it would not be difficult to produce this material indigenously as high purity ammonia gas would very easily be available. As the quantity required is very small this can be taken up on a pilot plant scale by firms manufacturing other fluorides.

8.	Ammonium chloride	i) Pure	Dry cells	600 tonnes	7.00	Products (i) and (ii) are available in the country at present. The small requirement of electronic grade product is met through import. However, this can be developed at laboratories like NCL/ BARC. Until then, the product may be imported.
		ii) High purity grade	For polishing in silicon semiconductor devices	2 tonnes	0.15	
		iii) Electronic grade	For gold plating in silicon semiconductor devices	120 kgs	0.03	
9.	Ammonium hydroxide	Electronic grade	For plating in integrated circuits	10 tonnes	0.75 (2.00)**	Presently being imported. However, there should not be any technical problem for its development.
10.	Argon	Oxygen free (less than 10 ppm) other gases in ppb range	For semiconductor industry	10,000 cubic metres	3.00	Estimates given only for semiconductor industry. The required quality product seems to be available in the country and presents no problem. The requirements for mtz tubes seem to be imported.
			For nixie tubes				0.06
11.	Ba—Sr—Ca carbonates	Purity better than 99.9%, particle size approximately in the range 3 microns	For cathode coating in receiving tubes	3.7 tonnes	0.90	Presently being imported. It is understood that BDH is working on making the dicarbonates. The production should be taken up when the development is complete. Till then, it should be allowed to import. It should be noted that the requirement of barium carbonate as ceramics is quite large.
12.	Boric acid	Plating grade	For nickel plating in germanium and transmitting tubes	300 kgs	0.02	Indigenously available.
13.	Bromine*	Maximum impurities allowed Cl 0.05%, I 0.0001%, SO ₄ 0.005%, As 0.0001%, non-volatile matter 0.01%, organic impurities no reaction	As etchant for semiconductor devices	—	—	The present practice is not to use bromine but hydrogen peroxide as etchant.
14.	Cadmium nitrate	GR grade	Ni-Cd cells	2.5 tonnes	3.38	Indigenously available and presents no problem.

15.	Cadmium sulphide*	Luminescent grade	Optoelectronic application	Small		R&D work is being carried out at CECRI, NPL, NCL, etc. CECRI seems to have developed know-how. If the product developed at these laboratories is acceptable the laboratories would be able to cater to the needs of the electronics industry.
16.	Calcium sulphate	High purity grade	For can filling in germanium devices	300 kg	0.25	Available indigenously and presents no problem.
17.	Carbon	i) Pulverised : ash content 0.001 to 0.003% maximum, by weight depending upon the application ii) Collidal graphite iii) Acqua-dag suspension iv) High density, semiconductor grade v) As pressed graphite rods	Carbon composition resistance and telephone Non-wire wound potentiometers TV tubes For boats, jigs Dry cells	28 tonnes 15 tonnes 6.5 tonnes Estimates not available 500 tonnes	9.00 3.00 1.50 — 16.00	Except graphite used for dry cells the requirement is met through import. Some crystalline variety of graphite used for batteries also is being imported. Only place where some R&D work is being carried out is RRL Bhubaneshwar and have reported graphite of purity 99.9%. These efforts should be encouraged. The total requirement of graphite considering that for other industries, is enormous and therefore, concentrated efforts should be put in the development of this item. Regarding semiconductor grade product, BARC seems to have been working on its development.
18.	Chlorine*	Very pure	For recovery of scrap germanium	—	—	Presents no problem as it is available indigenously.
19.	Citric acid/ ammonium citrate	Plating grade	For gold plating in semiconductor devices	1.5 tonnes	0.60	Citric acid is available indigenously. However, ammonium citrate (worth Rs. 3000) seems to have been imported. However, it should not pose any technical difficulty in producing it on a laboratory scale at any of the established R&D laboratories.

20.	Ethyl alcohol	High purity grade, denatured	For cleaning in germanium devices	45 tonnes	1.70	Available indigenously and presents no problem.
21.	Forming gas*	Nonexplosive mixture of nitrogen and hydrogen. Nitrogen percentage to be greater than 75; other gases in ppb range	Reducing atmosphere in the electron tube and for semiconductor industry			Available indigenously and presents no problem.
22.	Hydrocarbons heptane/xylene	High purity grade – acidity 0.02 N/1%, alkalinity 0.21 N/1%, organic impurities to pass acid wash test, thiophene 0.0002%, sulphur compounds (CS ₂) 0.0003%, nonvolatile matter 0.002%	For carbonising in carbon film resistors	45 tonnes	2.70	Indigenously available and presents no problem.
	Xylene	Electronic grade – Maximum impurities allowed; residue after evaporation, 0.001%, acidity (as HCl) 0.001%, substances darkened by H ₂ SO ₄ passes ACS test, water 0.02%, sulphur compounds (as CS ₂) 0.003%, Ca, Ni and Fe 0.00001% of each, Heavy metals (as Pb) 0.0001%	As cleaning agent for integrated circuits	10 tonnes	0.80	Presently being imported. Special purification facilities are needed. Production can be taken up on a small scale plant by established manufacturers or at R&D centres
	Benzene	High purity grade	For carbonising of nickel parts in transmitting tubes	80 litres	0.02	Indigenously available and presents no problem.
	Cyclohexane	Electronic grade	Cleaning agent for silicon small signal devices	200 litres	0.10	Indigenously available and presents no problem.
	Toluene	i) High purity grade	Cleaning agent for TV and CR tubes	60 tonnes	2.00	High purity grade toluene is indigenously available while the electronic grade product is presently being imported. Special purification facilities are needed. Production can be taken up on a small scale at established manufacturing firms or at R&D laboratories.
		ii) Electronic grade	Cleaning agent for integrated circuits	10 tonnes	0.50	

23.	Hydrochloric acid	i) Liquid, 36%, high purity grade ii) Gas—electronic grade	As etchant for germanium For epitaxial process in silicon semiconductor devices	14 tonnes 0.56 600 cylinders 12.00
24.	Hydrogen	Oxygen free (less than 10 ppm) both other gases in ppb range	For semiconductor devices	25,00,000 cu. metres 125.00
25.	Hydrogen peroxide	i) High purity grade—Assay 29.0 to 32.0%, maximum allowed impurities—residue after evaporation 0.002%, H ₂ SO ₄ 0.003%, Cl, NO ₂ , SO ₂ and NH ₄ 0.0005% of each, PO ₄ 0.00025%, Pb 0.0001%, Fe 0.00005%, pH 2.5 to 3.5 ii) Electronic grade	As etchant for germanium devices As etchant for integrated circuits	200 tonnes 8.00 5.2 tonnes 3.00
26.	Indium oxide	High purity grade suspension	For grids in receiving tubes	30 kgs 3.18

High purity grade acid available in the country.

Although electronic grade aqueous HCL is available, the gas is not available in the country and is being imported. As considerable amount of foreign exchange is involved, steps should be taken to start indigenisation of the production. BARC could be one of the organisations to take up the work.

Part of the requirement is met by indigenously available product. The requirement for epitaxy for integrated circuit fabrication seems to be being imported. But this is small.

The high purity grade seems to be available in the country. However, this is being imported at a cheaper rate (of about Rs. 2.5 per litre). The electronic grade product is being imported. National Peroxide Ltd., has plans to improve the quality of the high purity grade product. This plant with a capacity of 6000 tonnes of 35 per cent H₂O₂ per year is going to be established within a few years. If this product is acceptable to the industry and available at reasonable cost, the import should be banned.

Presently being imported. SMP has developed ultrapure indium and the oxide would not pose any problem. Further, Rohuk Industries Ltd. Bombay also supply the high purity product. However, the oxide suspension has to be developed according to the industry, requirements.

27.	Isopropyl alcohol	High purity grade	As cleaning agent for germanium devices	35 tonnes	1.70	Available in the country and presents no problem.
28.	Lead sulphide*	Photoconducting grade	Opto-electronic applications	Small	—	Presently being imported R&D work is being carried out at CECRI, SPL, NCL, etc. CECRI has obtained a patent for electronic grade product. As the requirement is small, the production can be taken up at appropriate laboratory.
29.	Magnesium oxide	a) High purity grade, homogenised powder	For base and mica spraying in receiving tubes.	24 tonnes	0.90	Presently both the types are imported. CECRI has developed a pure grade oxide. BDH and SMC have plans to produce high purity oxide. Both physical as well chemical specifications should be made available to these agencies. As the requirement is small, production can be taken up on a pilot plant scale
		b) Electronic grade powder	For masking during diffusion in germanium devices	60 kgs	0.10	
30.	Manganese dioxide	a) Electrolytic	For dry cells	650 tonnes	26.00	Indigenously available. However, the production capacity is not adequate at present. CECRI has been working on electrolytic grade. NML is working on the gamma type oxide.
		b) Gamma type		1600 tonnes	19.00	
31.	Manganese nitrate	Purity better than 99.9%	For solid tantalum capacitors	400 kgs	0.24	Indigenously available. It is also required in ferrite industry. SMP is producing for the capacitor requirement.
32.	Methyl alcohol	i) High purity grade—Solubility in water (to pass ACS test); maximum impurities allowed—residue after evaporation 0.001%, acetone and aldehyde (as acetone) to pass ACS	As cleaning agent in germanium devices and receiving tubes	22.5 tonnes	0.35	The high purity grade product is indigenously available. The electronic grade alcohol is presently being imported (at a rate of about Rs. 35 per litre) although it has been listed on the catalogue of some chemical manufacturers. The price of the indigenous product is very high.

		test, acidity (asHCO-OH) 0.002%, alkalinity (as NH ₃) 0.003%, Pb and Ni 0.0001% of each, Ca 0.00001%, of each, Ca 0.00001%, H ₂ O 0.1%				
		ii) Electronic grade	As cleaning agent for silicon semiconductor devices	100 tonnes	50.00	
33.	Methyl ethyl ketone	High purity grade	For coating formulation in magnetic tapes	5 tonnes	0.64	Indigenously available and presents no problem.
34.	Sodium gluconate	High purity grade	As a drying agent for germanium devices	1.2 tonnes	0.12	Presently being imported. As the requirement is small, the production can be taken up at R&D organisations like BARC, NCL, etc. The exact specifications should be made available.
35.	Nickel salts	i) Nickel chloride—Plating grade and LR grade	For nickel plating for germanium devices and in transmitting tubes	330 kgs	0.26	All these salts are indigenously available and present no problem.
		ii) Nickel nitrate -- AR grade	For Ni-Cd cells	3 tonnes	4.50	
		iii) Nickel sulphur—Plating grade and LR grade	For nickel plating for germanium devices and in transmitting tubes	660 kgs	0.20	
36.	Nitric acid	i) High purity grade—Assay 70–71%, residue after ignition 0.0002%, maximum limit of impurities—Cl, SO ₄ , and Al 0.00001%	As etchant for germanium devices and receiving tubes	9 tonnes	0.15	The high purity grade acid is available in the country and presents no problem. As regards the electronic grade acid it is being supplied by SMP on a small scale (know-how developed at BARC). The problem of scaling up has to be

		of each, Fe and Pb 0.00002% of each.				
		ii) Electronic grade, 65%	As etchant for silicon semicon- ductor devices	35 tonnes	9.00	
		iii) Electronic grade, 99%, fuming	As etchant for silicon semicon- ductor devices	25 tonnes	6.00	
37.	Nitrogen	Oxygen free (less than 10 ppm), other gases in ppb range	For semicon- ductor devices	55,00,000 cubic metres	110.00	
38.	Oxygen	Nitrogen in ppm range, other gases in ppb range	For semicondu- ctor devices	7,00,000 cubic metres	17.50	
39.	Phosphoric acid	i) High purity grade	For solid tant- alum capacitors and as etchant for germanium	1.5 tonnes	0.10	
		ii) Electronic grade	As etchant for silicon semicon- ductor devices	5 tonnes	0.40	

taken up and can be done. This product has already been included in the catalogues of some of the manufactures but the prices are high as compared to that of imported item (about Rs. 5.75 per litre). Therefore the requirement is met through import. The fuming grade acid is imported at present and no R&D activity exists in the country. As BARC has worked and established its competence, this work can be taken up at BARC in consultation with user industry. Imports of these products should not be allowed if the products developed are satisfactory and available at reasonable cost.

Most of the requirement is met through import. The know-how for laboratory scale purification seems to be available with BARC. Scale-up operations are to be carried out. There seems to be a problem regarding recompressing the purified gas into cylinders.

Most of the requirement is met through import. The know-how for laboratory scale purification seems to be available at BARC, Scale-up operations are to be carried out. There seems to be a problem regarding recompressing the purified gas into cylinders.

The high purity grade acid is available indigenously. The electronic grade product is being imported presently. Excel industries Ltd., is producing AR grade which can further be processed to obtain electronic grade material. BDH and SMC have indicated that they have plans to take up the production in the next few years.

40.	Phosphors	i) P ₄	For TV tubes	3 tonnes	3.25
		ii) P ₁ , P ₇ , P ₁₁ , P ₄ , P ₁₀ , P ₃₁ and P ₃₂	For CR tubes	90 kgs	0.38
		iii) Low voltage	For fluorescent display tubes	45 kgs	0.20
41.	Photomask materials:				
	i) Photoresists	Positive and negative	For silicon semiconductor devices	5,000 litres	25.00
	ii) Photoresist thinner		—do—	9,000 litres	5.00
	iii) Photoresist stripper		—do—	35,000 litres	4.25
	iv) Kodak HRP developer		—do—	10,000 litres	1.25
	v) Photoresist developer		—do—	10,000 litres	4.50
	vi) Kodak acid fixing salt		—do—	10,000 litres	10.00
	vii) Unifix Kodak 603 PA		—do—	400 litres	0.42
	viii) Cerium sulphate	High purity	For silicon small signal devices	210 kgs	0.37
	ix) Potassium ferrocyanide	High purity	For silicon small signal devices	55 litres	0.55
	x) RBS solution	—	—do—	260 litres	0.27
xi) Ultra high resolution photographic plates	—	For silicon semiconductor devices	—	16.00	

Most of these materials are presently being imported. Considerable development work is being carried out amongst other places at NPL and BARC. Phosphors suitable for black and white TV tubes as well as CR tubes (e. g. P₃₁) seem to have been developed at NPL and there were some proposals to undertake production of these in collaboration with BEL. The requirement is likely to be fulfilled within a few years, if the joint project comes through. It seems that there is a need to establish a laboratory where these products could be evaluated.

Except for Kodak acid fixing salt and low quality cerium sulphate (worth about Rs. 12,000) all these items are being imported. However, substantial amount of development efforts are being carried out in the country. DRL (M) has developed photoresist, photoresist thinner, developer, Kodak 910 cement, etc., which seem to be satisfactory. Although, these products are required in small quantities they are very vital for the silicon semiconductor industry. The production can be taken up at appropriate laboratory or a production unit. The products developed by the R&D organisations or manufacturing agencies should be tried out by silicon semiconductor device manufacturers. Amongst the laboratories where the development work can be taken up BARC, DMR (L), NCL, IITs, etc., are the major ones. Regarding items like glass plates, CGCRI should also be contacted and technical collaboration for selected

	xii) Optically plane glass plates	(i) Electronic grade —	Monolithic ICs	10,000 nos	2.00	items should be sought on case to case basis, if needed.
	xiii) Chrome clad glass plates	—	Monolithic ICs	10,000 nos	5.00	
21	xiv) Cut N ^o strips	(i) High purity grade —	Monolithic ICs	12,000 nos	4.50	
	xv) Pyrometallic di-unhydroxide	—	Monolithic ICs	1,200 kgs	4.00	
42.	Polythene glycol	Plating grade ii) Electronic grade	For gold plating in semiconductor devices	1,200 litres	0.06	Presently being imported.
43.	Potassium cyanide	Plating grade i) High purity grade	For gold plating in semiconductor devices	1,300 litres	2.60	Indigenously available and presents no problem.
44.	Potassium hydroxide	i) High purity grade— assay 85% maximum allowed impurities Cl, and SiO ₂ 0.01% of each, PO ₄ , Fe, P ₂ and NH ₄ OH 0.001% of each, NO ₃ and Zn 0.002% of each, SO ₄ and Al 0.005% of each, As 0.0001% and CO ₃ (K ₂ CO ₃) 2% ii) Electronic grade	For etching and plating in germanium devices	5 tonnes	0.20	Both available in the country and present no problem.
				75 kgs	0.04	
45.	Potassium silicate	i) High purity grade ii) —	As a binder in screen coating for CR tubes As a binder in screen coating for TV tubes	2.4 tonnes	0.04	Presently being imported. No development effort seems to be carried out in the country.
				360 tonnes	8.00	
46.	Potassium stannate	Plating grade	For plating in germanium devices	2 tonnes	0.90	Indigenously available and presents no problem.

47.	Sodium hydroxide	i) High purity grade— assay 97%, maximum allowed impurities—Cl and SiO ₂ 0.01% of each, SO ₄ and Al 0.005% of each, NO ₃ and Zn 0.002% of each, PO ₄ , Fe, Pb and NH ₄ , 0.001% of each; K 0.05%, As 0.0001%, and CO ₃ (Na ₂ CO ₃) 2%.	For etching and plating in germanium devices	1 tonne	0.10	Both available in the country and present no problem.
		ii) Ultra high purity grade	For plating in silicon small signal devices	1 tonne	0.21	
48.	Sodium hypophosphite	Plating grade	For electroless nickel plating in germanium devices	750 kgs	0.16	Presently being imported. However, it seems that a laboratory production has been completed by Rohuk Industries Ltd. This product should be evaluated for its use in the device manufacturing.
49.	Soldering fluxes	i) Blue solder	All required for germanium devices	750 litres	0.16	Presently these are being imported. Although they are required in small quantities, substitution efforts should be encouraged at the R&D laboratories like NCL, BARC, CECRI, etc.
		ii) Soldering liquid 29		400 litres	0.12	
		iii) Flosol		1.5 tonnes	0.14	
50.	Special solvents	i) Clean solvent (coben spray)	For integrated circuits	75 tonnes	16.00	All these are proprietary items and are imported. They involve considerable amount of foreign exchange and therefore development efforts towards substitution should be undertaken at the R&D laboratories where the competence exists.
		ii) Ectusolve acetate	—do—	23 tonnes	1.40	
		iii) Transene	—do—	2.5 tonnes	1.40	
51.	Sulphuric acid	i) High purity grade	As etchant for germanium devices and receiving tubes	9 tonnes	0.06	Both types are available in the country. However the electronic grade is imported presently as it is available at low rate (about Rs. 2.5 per litre). The import should be allowed if this product is made available at reasonable cost.
		ii) Electronic grade — residue on ignition	As etchant for silicon semicon-	5 tonnes	1.50	

		0.0005%, maximum allowed impurities; Cl 0.00006%, NO ₃ and Pb 0.0002% of each, PO ₄ 0.0005%, Si and NH ₃ 0.0003%, of each Fe 0.001%, and As 0.000001%	ductor devices			
52.	Tin chloride	i) Plating grade	For chemical tinning in germanium devices	45 kgs	0.05	The plating grade tin chloride is indigenously available. The high purity product seems to be being imported at present. However, this will be available from SMP within a year's time and presents no problem.
		ii) High purity grade	For metal oxide film resistors and receiving tubes	500 kgs	0.25	
53.	Trichloroethylene	i) High purity grade—residue after evaporation 0.001%, acidity (as HCl) 0.0003%, alkalinity (as NaOH) 0.001%, maximum allowed impurities Pb 0.0001%, Ca, Fe and Ni 0.00001% of each, and resistivity minimum 105 ohm cm.	As cleaning agent for germanium devices and receiving tubes	72 tonnes	2.75	Both types are available in the country. However, the electronic grade is being imported at present as it is available at low rate (about Rs. 8 per litre). The import should not be allowed if this product is made available at reasonable cost.
		ii) Electronic grade—residue after evaporation 0.0005% maximum acidity (as HCl) 0.0005%, alkalinity (as NaOH) 0.001%, phosphate (PO ₄) 0.0001%, As 0.0001%, Cu, Fe and Ni 0.00001% of each Pb 0.00005%	As cleaning agent for silicon semiconductor devices	105 tonnes	60.00	

* Owing to either their type diversity or uncertainty in the demand of components where they are used, no definite demand could be arrived at.

* Prices of the indigenously available equivalents.

Table 15.11. Demand forecast of plastics for the year 1978-79.

No.	Materials	Specifications	Applications	Requirement		Remarks
				Quantity	Value (in Rs. lakhs)	
1.	Acrylonitrile butadien styrene (ABS)	Moulding powder; tough, high impact strength over wide temperature range; excellent resistance to sur- face scratching, required in the form of coloured granules	Telephones, ins- trument panels, portable radio cabinets, electro- nic typewriter frames, electronic calculator bodies	300 tonnes	18.00	Requirement given is only for the coloured telephone. Shri Ram Institute for Industrial Research has developed a process and taken over Synthetics and Chemicals for pilot plant trials. Poly- Chem Ltd., also have plans to produc- tionise this. Thus, although, presently being imported, it will be available locally in near future. Work on other varieties may also be taken up.
2.	Adhesive tapes*	Foil, tape, double sided/ single sided	Various		4.00 (approx- imately)	Some varieties are being imported. The basic polyurathane and its ingredients will be available with one of the produc- tion agencies. The production facilities are adequate if the know-how is dev- eloped.
3.	Diallyl phthal- ate (DAP)	Should have good electri- cal insulation, high im- pact strength and chemi- cal resistance; should be superior in performance particularly with respect to electrical insulation, water absorption, dielec- tric losses and dielectric strength	For printed cir- cuit connectors, rack and panel connectors and multipin connec- tors; moulding powder for hous- ing or bodies for professional type potentiometers, deflection yokes, etc.	120 tonnes	12.00	Presently being imported. R&D work on monomer and prepolymer upto labo- ratory stage has been done by DRL(M). SSTC has developed a process based on imported allyl alcohol and indigenous phthalic unhydried. The requirement in other industries is estimated to be large. The material is of strategic im- portance. R&D efforts should be emphasised. Private agencies manufac- turing thermosetting resins should be encouraged to take up its production.

4.	Epoxy	(i) Moulding powder	For metal and metal oxide film and wire-wound resistors; Defence grade inductors, coils and mylar/mica capacitors, tantalum capacitors, etc.	15 tonnes	6.00
		(ii) Superior grade moulding powder; after curing the material should have low water absorption (less than 1 %) low loss factor (less than 0.003 in MHz range), high binding strength, good adhesive properties, and very high surface and volume resistivity	For silicon semiconductor devices	150 tonnes	75.00
		(iii) Laminates, properties same as above, in addition to this the material should not warp or develop blisters due to long time climatic effects	For printed circuit boards	80 tonnes	30.00
5.	Fixers	(i) Resins	For fixing germanium and silicon bars for slicing	15 tonnes	5.00
		(ii) Apiezon lute	For fixing slices for silicon semi-	3 tonnes	2.00

The products under (i) and (ii) are mostly imported at present. Formica Ltd., claims to be marketing some of the laminates. The production is based on imported know-how. DRL(M) seems to have developed some laminates which have been approved by some of the user agencies. Ciba of India and Dr. Beck and Co., produce epoxy resins for general purpose applications and they may be in a position to take up production of moulding grade if the production could be economically viable. R&D work, if needed, can be taken up at NCL, RRL, Hyderabad and also at the above agencies.

Mostly imported except the wax of the type (iii). Most of these items are proprietary items. Substitutes should be developed by the earliest as considerable foreign exchange is being spent for their import.

			conductor devices			
		(iii) Wax, Sticky (50°C)	For fixing slices for germanium devices	100 kgs	0.06	
		(iv) Resins (e.g. kimcode)	For TV tubes	14 tonnes	3.60	
6.	Grease	Special type	For use during epitaxy for silicon semiconductor devices	40 kgs	0.75	Required in small quantity and is presently imported.
7.	Hardener	Special type	For TV tubes	10 tonnes	3.00	Present requirement is met through import. Attempts should be made to develop suitable substitute as import of this involves considerable amount of foreign exchange.
8.	Ion exchange* resins	Cation and anion type capable of giving 7.5 M ohm/cm resistivity	For use in de-ionising the water for semiconductor device processing	—	—	Most of the requirement seems to be met through indigenous production. However, other special products needed for electronics industry could be made available with little R&D effort.
9.	Lacquers	(i) Coating and sealing type	For sealing in plastic film, ceramic and mica capacitors	125 tonnes	28.00	These general purpose type lacquers are available in the country.
		(ii) Red lacquer	For germanium devices	250 kgs	0.07	Seems to be available indigenously.
		(iii) Purple, copying	For silicon small signal devices	150 kgs	0.60	Being imported presently.
		(iv) Aluminising, acrylate resin, liquid	For CR and TV tubes	13 tonnes	1.25	Presently being imported. R&D, towards finding out substitutes, should be taken up. As the quantity required is small, these can be produced on a pilot plant scale, perhaps, at R&D laboratory.

10.	Nitrocellulose	Dopes	For receiving tubes in manufacturing cathodes	6000 litres	0.56	Indigenously available and presents no problem.
11.	Nylon	Glass filled moulding powder (e.g. rilsan)	For plugs of printed circuit connectors	3.5 tonnes	3.50	<p>The estimates given do not include other requirement. For example, the present requirement of ITI is around 25 tonnes.</p> <p>The whole of the requirement is met through import. There appears to be no R&D effort. It would be better to select two or three important types of nylons at places like UDCT Bombay, SRI Delhi, NCL etc. As the starting materials would be available soon, the development of nylon should be given priority. In addition to this, possibility of using PTFE in the place of nylon should be explored.</p>
12.	Oil	Special type	For lapping wafers for silicon devices	7000 litres	0.3	Seems to be imported.
13.	Paints and inks	(i) Paints stoving/epoxy/phenolic, low moisture absorption, quick drying and hard after drying	For carbon film resistors	15,000 litres	2.05	Most of the requirement, especially for (i) is met through indigenously available products. The requirement of this type for equipment panels, which is fairly large, is not included here. The other requirement of types (i) and (ii) is met through import.
(ii) Special type, white masking		For making components		0.3		
(iii) Special ink, blue		For dotting crystals in semiconductor devices	300 litres	0.2		
14.	Phenolic	(i) Moulding powder; general purpose, similar properties	For radio cabinets, knobs, telephones and	6,000 tonnes	60.00	The types (i) and (ii) are available indigenously and present no problem. The type (iii) is partly imported. Few

		as mentioned for diallyl phthalate	general purpose plugs and sockets			
		(ii) Moulding powder; superior grade after moulding; the properties should be superior than those for general purpose powder; the material should have low dielectric strength at high frequencies and should be capable of working at high temperatures	For potentiometers, carbon composition resistors, valve bases, etc.	900 tonnes	90.00	
		(iii) Laminates, better performance with respect to the electrical properties; should not warp	For potentiometers and printed circuit boards	850 tonnes	127.00	
15.	Polycarbonate/polyester/polystyrene/nylon/styroxflex	Uniform thickness; free from metal particles; thickness 0.25 to 0.5 mil; high dielectric constant; low loss, dimensional stability	As dielectric films in plastic capacitors	75 tonnes	85.00	
16.	Polycarbonate	(i) Moulding powder (markelon)	For receptacles of a printed circuit connector	15 tonnes	7.50	

firms in organised sector like, Bakelyte Hylum Ltd., India Plastics, etc. are manufacturing phenolics. If sizeable demand exists to sustain an economically viable production of the imported product, production can be taken up within the country. It appears that technical know-how would be made available with very little efforts.

The present requirement is met through import. It seems that although the basic polyester is available the facilities for making the films are not available. It is learnt that Lamine Industries at Indore is working with biaxially oriented polystyrene films and have produced films which are very much near to the imported quality. Further, the possibility of using DAP monomer developed at SSTC should be explored for suitability.

The present requirement is met through import. Bisphenol 'A' which is one of the constituents, is being produced while the other constituent is likely to be produced within two to three years.

		(ii) Thin laminates	For variable condensers	25 tonnes	25.00	Some R&D is being carried out at SRI Delhi.
17.	Polyester	(i) Moulding powder; properties similar to those mentioned for DAP but in addition to this, it should have better dimensional stability and electrical properties	For silicon small signal devices	13 tonnes	1.80	The requirement is being met through import. The film blowing facility exists in the country. Promotional efforts are called for. Possibility of production on a pilot plant scale should be explored.
		(ii) Film for magnetic tape; in addition to the above properties, it should have better tensile strength and uniform thickness	For magnetic tapes	165 tonnes	68.00	
18.	Polystyrene	Moulding powder	For variable (PVC) condenser	400 tonnes	7.00	Indigenously available and presents no problem.
19.	Polythene*	Same as phenolic powder; in addition, it should have resistance for chemical reactions and good abrasion properties, very low loss factor (0.001 at 1 Mc/s), high dielectric strength (2 to 3 times that of phenolic)	Coaxial and other cables	—	75.00 (approximate)	Presently available indigenously and seems to present no problem.
20.	Polyvinyl chloride*	Same as phenolic powder but should have better fire resistance, chemical resistance properties and good abrasion properties	PVC wires, cables and sleeves	—	40.00 (approximate)	Presently available indigenously and seems to present no problem.

21	PTFE*	In the form of rounds/tubes, good chemical resistance dielectric strength, low dielectric loss and capable of high temperature and high frequency operation	For coaxial (PTFE) connectors, band switches, washers, seals, special cables, etc.	100 tonnes (approximate)	50.00	The estimate for connector industry would be around 9 tonnes. The total requirement of the electronics industry is of the order of 100 tonnes. Presently imported in the form of powder. Navin Fluorine Ltd., is known to be manufacturing the basic component. The development at the firm's R&D group with close co-operation with R&D laboratory like NCL should be initiated. Possibility of import of know-how should be explored. IIT Kanpur, seems to have undertaken a project to develop PTFE. There is a possibility of export market for this product.
22.	Resins	(i) Special type	As binder for carbon composition resistors	8 tonnes	0.30	The products (ii) and (iii) are being imported. The requirements of these products are small. R&D should be taken up for some of these products.
		(ii) Base cement	As adhesive for TV tubes	500 kgs	0.76	
		(iii) Vinylitic (VA/VC Copolymer)	For magnetic tapes	17 tonnes	2.00	
23.	Rubber*	(i) Nitrile rubber granules, (BF, Goodrich)	For magnetic tapes	5 tonnes	0.60	Mostly imported. Regarding nitrile rubber, development of this product has been initiated at NCL and could be persuaded. Complete know-how for the 'O' rings manufacture is available with DRL(M) Kanpur. The production can be established if the exact demand with respect to size and quantity is worked out.
		(ii) 'O' rings	For various applications			
24.	Silicons*	Grease				
		(i) High vacuum grease, very low vapour pressure	For leak proofing in vacuum tube devices	10 tonnes (approximate)	40.00	

	(ii) Special grade	For can filling in germanium devices	800 kgs	0.90	
Resins	(iii) Other types Various types	Various	2.4 tonnes	3.80	Most of these silicon products are being imported. In some cases the compounded forms, in which these are required, are being made from imported basic silanes. There is a definite demand for these products. They are of considerable strategic importance and therefore every effort is needed to develop indigenous technology. It appears that basic work has been completed at DRL(M), Kanpur. Some work has been initiated at NCL and UDCT, Bombay. BARC seems to have developed diffusion oils. Most of the basic components are available. Some of the products developed at the above places have been proved to be satisfactory and a scale up operation has to be taken up. There is a possibility to earn considerable foreign exchange from Asian and African countries.
		For germanium devices, and silicon power transistors for junction coating for TV and receiving tubes	2.2 tonnes	7.55	
Lacquers	—	For junction coating in germanium devices	800 kgs	0.16	
Varnish	Good high temperature properties and low humidity absorption properties	For metal oxide resistors	12,000 litres	1.50	
Oil	(i) High dielectric strength	For paper capacitors	25 tonnes	1.05	
	(ii) Special types	For silicon small signal and germanium devices	2 tonnes	1.15	
	(iii) Low vapour pressure	For diffusion	10 tonnes (approximate)	5.0	
Rubber	(i) Same as synthetic rubber; in addition, it should withstand high temperatures	For silicon small signal devices	150 kgs	0.27	
	(ii) N-9161	For solid tantalum capacitors	600 kgs		
25. Thinners	Special type	For use with paints for carbon film resistors and lacquers for germanium devices	12,000 litres	0.12	Mostly available indigenously. Thinners will be required in fairly large quantities in paints for equipment panels. Any special requirement can be met by R&D base and there seems to be no problem.

*Owing to either their type diversity or uncertainty in the demand of the components where they are used, no definite demand could be arrived at.

Table 15.12. Demand forecast for glasses, ceramics and other insulators for the year 1978-79.

No.	Materials	Specifications	Applications	Requirement		Remarks
				Quantity	Value (in Rs. lakhs)	
1.	Abrasives*	Silicon carbide (corundum) diamond powder (as suspension) aluminium silicate and ceric oxide	Grinding and polishing	—	—	Silicon carbide is being produced at RRL, Hyderabad on a 3 tonnes/batch operation. This product is useful for other industrial applications and has to be evaluated for use in electronics industry.
2.	Alumina	(i) Powders—for optical polishing, particle size 0.03 and 0.05 microns Al_2O_3 content more than 99%	Abrasive powders for lapping and polishing for semiconductor wafers and other applications	30 tonnes	10.00	Controlled grain size alumina for abrasives and for can filling is being imported. Attempts to prepare powders are being made at IIP, RRL, Jorhat, Hindalco and Sarabhai M. chemicals. Efforts are needed to develop high purity fine alumina powder by techniques such as pyro-gel and cryochemical methods.
		(ii) Substrates, tubes, rods; 95% Al_2O_3 , free iron particles, surface finish 0.6 to 1, parallelism of the surfaces —50 micron, flatness 40 micron/cm; tolerance of surface dimension $\pm 1\%$ tolerance of thickness $\pm 5\%$	For micromodules (thick film circuit packages) for cermet trim pots; vacuum tube parts etc.	20 lakh nos.	12.00	Work on alumina substrates is being carried out at NPL, DMRL and CGCRI. While conventional fabrication techniques have been tried, efforts need to be put in for techniques like isostatic pressing and hot pressing.

3.	Ceramics, special					
	(i) Mullite/forsterites/steatites	In the form of rods and tubes; required with low alkali content, zero water porosity and less than 15 microinches surface finish	Used for high stability and precision resistors	200 lakh nos.	6.00	NPL has made and supplied from its pilot plant facility, ceramic substrates for resistors; steatite, alumina and wollastonite bodies for valve electrode spacers, insulating tubes, trimmer bases, coil formers, alumina sleeves, etc.,
	(ii) Porcelain/mullite/steatite	In the form of rods and tubes; low alkali content, low porosity and surface finish better than 30 to 40 microinches	General purpose film and wire wound resistors	3,000 lakh nos.	35.00	Some production agencies in private sector make the ceramic bodies for various types of resistors and capacitors for their captive use.
	(iii) Steatite/porcelain/alumina glazed	Non-porous, low loss and dimensional accuracy $\pm 1\%$ in diameter and $\pm 2\%$ in length	Gang condensers and high voltage capacitors	120 lakh nos.	18.00	There is at present no production of forsterite though some laboratories have been working on it.
	(iv) Low loss, steatite	Loss factor 0.002 at high frequency	Small tablets or pressing for trimmers, padders, coils, valve bases, and band switches		4.00	The low loss steatite is being imported.
	(v) Metallised ceramics	Non-porous, low loss and good adherence for metalisation	Used for ceramic to metal seals for high voltage industrial and defence grade sealed capacitors	40,00,000 nos.	12.00	
4.	Ferrite materials					
	(i) Beneficated ore	—	For radio ferrites	550,000 tonnes	3.30	The beneficated ore, manganese carbonate and zinc carbonate are locally available. In the case of ferric oxide
	(ii) Ferric oxide	Low grade	Hard ferrites	850 tonnes	17.00	

(iii) Ferric oxide	Fe ₂ O ₃ weight percentage 99.2 to 99.6% SiO ₂ weight percentage 0.005 to 0.03%, sodium and potassium oxide weight percentage below 0.05%; mean size of particles varies from 0.1 to 0.8 depending upon the type, specific surface (m ² g ⁻¹) varies from 27 to 5 depending upon the type	TV ferrites, pot cores, special ferrites	300 tonnes	15.00
(iv) Gamma ferric oxide	High quality	Magnetic tapes	20 tonnes	10.00
(v) Manganese carbonate	CR	Radio ferrites	100 tonnes	2.00
(vi) Manganese dioxide	Manganese weight percentage 71%, SiO ₂ weight percentage between 0.02 and 0.005% depending upon the type, sodium and potassium oxide weight percentage 0.004 to 0.05% depending upon the type, particle shape mostly spherical, specific surface (m ² g ⁻¹) around 20	TV ferrites, pot cores, special ferrites	100 tonnes	40.00
(vii) Nickel carbonate	—	Radio ferrite	50 tonnes	40.00
(viii) Strontium carbonate	—	Hard ferrites	100 tonnes	30.00
(ix) Barium carbonate	—	Hard ferrites	100 tonnes	1.10

for hard ferrites, since the chemical purity requirements are not so stringent and traces of silica are recommended, beneficiated ore may be used. Regarding ferric oxide for TV ferrites and pot cores, which is being imported presently, NPL has been producing it on a pilot plant scale starting from ferrous sulphate of pharmaceutical grade. Work needs to be done on production of this grade of ferric oxide, starting from cheaper raw materials such as the pickling solution from steel plants. The suitability of manganese dioxide developed by CECRI may be evaluated. Work also needs to be done on the production of suitable grade of manganese dioxide. Regarding gamma ferric oxide, although the material is not being produced in the country at the present time the technology for making it in appreciable quantity is in advanced stage of development at NCL. It appears possible to produce batch quantities of 1 kg per day at NCL. In addition to the materials listed in the table small quantities of lithium carbonate, cobalt carbonate and chromium dioxide are also required for ferrite industry and are presently being imported.

(x) Zinc carbonate	—	Radio ferrites, TV ferrites, pot cores, special ferrites	120 tonnes	4.80	
5. Fibre glass*	Very low water absorption (0.01%), very low loss factors (0.003 at 1 MHz), high dielectric strength (1000 V) good mechanical strength and very high surface and volume resistivity; this is alkali-free aluminosilicate type glass	Used as filler for many plotting and moulding materials such as, phenolic, melamine, DAP, epoxy and as thermal insulation in ovens; also used with silicon varnish and epoxy for moulding cases, cabinets and laminates; one of its major applications is in the manufacture of antennae	—	—	Among the re-enforcements, 'A' and 'E' glass fibres with imported basic glass compositions are produced in the country. These types of products are used in chemical industry in large quantities.
6. Glasses, sealing					
(i) Compression sealing	Glass to be used under compression with low carbon steel (e.g. Corning 1990, 1991)	For transistor headers, hermetically sealed relays, connectors, modules, crystals, etc.	20 tonnes	4.00	The requirement of dumet sealing glass in the electronics industry is a small fraction of its requirement in the lamp industry. Both compression sealing and kovar sealing glass are presently imported, though CGCRI is understood to have developed them. BEL is also understood to have developed glass frit for kovar seals.
(ii) Dumet sealing	Glass to match the thermal expansion of dumet (e. g. Corning 0080, 0120, 7570)	As glass enclosures for point contact diodes, pilot lamps, etc.	12 tonnes	0.60	
(iii) Kovar sealing	Borosilicate glass to match thermal expansion of kovar (e. g. Corning 7052, 7056, 7040, etc.)	For glass-to-metal seals for semiconductor devices, electron tubes, crystal housing etc.	40 tonnes	12.00	

7.	Glasses, special	Soda lime, tubing	Receiving tube bulbs	20 tonnes	2.00	Both soda lime and lead glasses for receiving tube envelopes are indigenously available. Glass shells for TV picture tubes as well as CRTs are imported. Bulbs for transmitting tubes are also imported at the present time.
		Lead glass	(a) Receiving tube bases and stems	140 tonnes	12.00	
			(b) TV picture tube shells	4,00,000 nos.	4.00	
			(c) CR tube bulbs	5,000 nos.	2.00	
		borosilicate/ aluminosilicate	Transmitting tube envelopes	20,000 nos.	4.00	
8.	Mica*	Natural—Mica powder free from metal and other conductive particles	Mica powder as filler in moulding powders	—	—	Presents no problem. However, the use of mica powder as indigenous filling material should be encouraged in high quality electrical mouldings. Any specific requirement for this application should clearly be brought out and development, if necessary, should be taken up.
		Laminates — Thin mica laminates, free from conductive particles, high dielectric strength, low dielectric loss, low water absorption properties	Fabricated mica used for mica capacitors, coil interlayer insulation, resistance and potentiometer cards, bridges and spacers in vacuum tubes, transformers, etc., manufactured mica mainly used for mica capacitors			Fabricated mica presents no problem. The mica for capacitor is indigenously available. However, silvering medium is not available. There is a possibility of considerable export for this material and some special tool room facilities for fabrication and maintenance of high precision dies and punches may be required. CGCRI is one of the laboratories where development work can be taken up.
9.	Other materials					
		Barium carbonate 99% pure	Ceramic capacitors	100 tonnes	4.00	Presents no problem.

Titanium dioxide	—	Ceramic capacitors	30 tonnes	3.00	Presents no problem.
Lead zirconate/ lead zirconate titanate/lithium neobate	In various shapes (e.g. discs, pellets, etc.)	For ultrasonic cleaners, microphones, transducers for various applications			Regarding Ferroelectric materials, production base exists in the country. NCL, and NPL are the major organisations who have developed considerable amount of competence in these types of materials. In some cases batch-production has been initiated to meet limited demand for some organisations.
10. Quartz*					
Fused quartz (transparent)	Low grade in the form of tubes	For furnace tubes	—	5.00	The requirement of electronics industry is small as compared to the total requirement. Production of opaque and translucent variety of fused silica has been established in the country. The high quality transparent fused silica tubing is imported. The process know-how and machinery are not easily available but the material is strategically important. Further, the raw material, in the form of high purity quartzite required for the purpose, is available. In case the available good quality quartzite is not sufficient, this can be imported from Brazil with a fraction of the cost of the finished product. IISc, Bangalore is understood to be working on the development of fused quartz.
	High purity, quartz tubes crucibles, boats etc.	For reactor tubes, furnaces for diffusion purposes in semiconductor industry	—	3.00	
Crystals	Flawless quartz single crystals	For oscillators, filters and transducers	10,00,000 nos.	460.00	The natural quartz available in the country is not suitable for direct application and intensive efforts should be undertaken to prepare synthetic quartz. Such crystals of suitable size and quality have been synthesised

at CGCRI on a batch-production scale in five feet autoclaves. It is reported that BEL, the main user of such crystals, is negotiating with CGCRI about setting up of a plant in Bangalore for growing quartz crystal by hydrothermal method. Estimates are given for the raw crystalline quartz (25% of the cost of crystals).

11.	Vitreous enamel powder	Finely ground frit, stable	For wire-wound resistor	120 tonnes	12.00	Mostly available indigenously.
-----	------------------------	----------------------------	-------------------------	------------	-------	--------------------------------

*Owing to either their type diversity or uncertainty in the demand of the components where they are used, no definite demand could be arrived at.

Standardisation, Testing and Evaluation

16.1 Introduction

Standardisation activities in other countries closely followed industrial development while in India standardisation was necessary as a preamble to industrial growth for providing direction, control and guidance. Standardisation and its implementation envisage four basic activities, namely, (a) research in environmental and life testing, failure modelling, reliability prediction, etc., (b) preparation of standards, (c) testing to standards and preparation of test reports, and (d) certification based on the test reports.

Preparation of one unified series of standards will minimise the diversity of items to be produced and optimise the scale of production. Even in advanced countries like UK, only one series of standards is being brought out (BS 9000 series) with this objective. Once the areas of standardisation and gaps in these areas are identified, unified and harmonised standards can be established to cater to various applications. One sure step to achieve the ultimate goal of economic production of reliable components in India will be to persuade the professional users of components to accept the recommended standards. In order to ensure reliability of components, a continuous testing, not only of the finished product but also at the earlier stages, is necessary. In some cases, as in MIL (US military) specifications, it would be necessary to test the materials also. While it may be impracticable to immediately take up such a thorough scheme with the present state of industry in India, all efforts should be made to ultimately aim at BS 9000 schemes of inspection.

Progress of standardisation is not possible without a scheme for unified inspection and testing. The testing of materials, components and equipment to the standards requires provision of elaborate and detailed test facilities. It may not be possible for all the production units, particularly in the small scale sector, to provide such a facility for themselves. Therefore, it was recommended by the Bhabha Committee that test facilities should be available as early as possible in various centres such as Bangalore, Bombay, Calcutta and Delhi, where the electronics industry is established. The Committee recommended that "to begin with

- (a) the Atomic Energy Establishment of Trombay be asked to set up test facilities for the Bombay region;
- (b) the National Physical Laboratory, New Delhi, be asked to augment the existing facilities to cater to the needs of the Delhi region;
- (c) the Defence Research & Development Organisation and the Defence Production Organisation at Bangalore be asked to augment the existing facilities to meet the requirements of the southern region; and
- (d) similar facilities be set up in Calcutta or elsewhere in the eastern region.

Also, one of the functions of the National Physical Laboratory, New Delhi,

should be to maintain national standards for all parameters of interest in electronics". In pursuance of these recommendations, BARC was asked to set up Reliability Evaluation Laboratory and NPL was asked to enhance its test facilities and to establish a Test and Evaluation Centre. Similarly, the facilities at CIL were made available to the industry by the Ministry of Defence. The National Test House, Calcutta also started its electronics division with this objective. In order to assess the present status of standardisation, testing and evaluation activities in the country and to suggest future course of action, the Electronics Commission has set up a Panel on Guidelines for Standardisation in Electronics. The various details presented here have emerged from the discussions of the above Panel. In Section 16.2 of this chapter, the present activities towards standardisation and the guidelines for future standardisation are discussed. Section 16.3 presents a detailed account of the existing facilities for calibration, testing, and evaluation in the country. This section also outlines the plans of various laboratories regarding expansion and augmentation of the existing facilities during the Fifth Plan period. Since, the reliability and failure rate information play a vital role in the design of equipment, it is discussed in Section 16.4 of this chapter. Finally, an implementation structure is suggested taking an integrated view of all the aspects of standardisation, inspection and approval.

16.2 Standardisation

16.2.1. Current Status

At present, there are two organisations, viz., Indian Standards Institution (ISI) and Electronics Components Standardisation Organisation (LCSO), dealing with the standardisation work.

Indian Standards Institution is the national standards body responsible for the preparation of standards covering all end uses. It is the national committee of the corresponding international standards body in the electrotechnical field, namely the International Electro-technical Commission (IEC). In the preparation of Indian standards the various standards available both at the national and international level like IEC (International), MIL (American), BSS and DEF (UK), JSS (Ministry of Defence, Govt. of India), are taken into account. In all the committees of ISI, various user and manufacturing agencies are represented and their interests are taken into consideration while formulating the Indian standards. The technical committees also keep track of the developments all over the world and the documents available from other countries and IEC. During the past several years, ISI has brought out several hundred specifications which mainly deal with test methods. But the task of standardisation, i.e., evolving standards dealing with exact mechanical/electrical rating, stability, etc., has not progressed correspondingly.

Electronic Components Standardisation Organisation was created at Bangalore to produce Joint Service Specifications (JSS) for different types of electronic components and to effect standardisation of defence electronic components in accordance with these JSS. This organisation has completed most of the specifications and a large number of components of indigenous origin are now being tested for type approval in accordance with the JSS brought out by them. During the last three years, LCSO has brought out 167 specifications, about 1,000 standards and has given 227 approvals. The Joint Services Guide 50102 gives the details of the components already approved.

The LCSO has adopted the MIL components and the MIL method of testing during type approval and inspection. Certain factors peculiar to India, however, preclude the possibility of adopting the MIL specification in their entirety and these factors have led to the modification of the MIL specification in the JSS. For example, the MIL specifications in several cases invoke testing of materials and processes which must have been done in their very early stages of production. In several instances, the end electrical parameters have also not been included in the MIL tests because these parameters have been taken care of during the testing of the materials which go into the production of the components. Unfortunately, this is not possible in our country and JSS have, therefore, taken into account all the important electrical and mechanical factors which must be checked both during type approval and acceptance tests. Again, the MIL specifications are based on a time schedule rather than on the quantities required in each order. For example, the Group A, B, C and D tests of the MIL are based on the lots of production and then certain tests are conducted at fixed periods. Continuous inspection is possible only if there is continuous production which in turn depends on continuous demand. Such a situation again does not exist in this country and in order to make type approval and inspection more practical to suit the Indian scene, the JSS have adopted two separate schemes of tests—one for type approval and the other for acceptance tests. In the case of acceptance, Group A, B tests have been so devised that they could be conducted on the individual supplies. Again, in the case of MIL specifications there is an accept/reject basis as, for example, if the component does not meet the required specification, it will be completely rejected and no intermediate quality is acceptable even though the item may be suitable for their final requirements. Such a stipulation is not viable if component production in the country is to be encouraged. The JSS have, therefore, adopted the philosophy of former DEF specifications of testing for various severities for which they are specified so that even if components cannot pass the highest specified severity, they could be tested for the lower severity and a limited approval given to encourage their use in indigenous production of equipment.

The JSS already provide for preferred lists and have the necessary structure for continued updating of the lists. Regarding the suitability of LCSO standards for other professional users like P&T, Railways, Civil Aviation, etc., it has been pointed out at various discussions that these departments also prefer components approved for defence use by LCSO. In certain cases, these users needed still higher stringencies. However, all professional components must be viewed under one canopy and all requirements including those of P&T, Defence and Railways should fall in the same category.

In the absence of adequate national standards, the large users of professional grade components have to rely on their own resources to draw up the standards. This is one of the reasons why major public sector units producing professional electronic equipment have attempted to formulate inter-company standards through inter-company standardisation panels. Some public sector organisations have drawn up a number of company specifications/standards and also have a list of their own approved manufacturers, who are able to supply to their respective company specifications/standards. These companies are also active participants in the compilation of JSS by LCSO.

16.2.2. BS 9000 Scheme

The Indian standards drawn up on the pattern of BS 9000 scheme may

be useful for the necessary categorisation on the basis of application. The BS 9000 scheme is based on three important basic principles, namely, (a) harmonisation of various categories of components, (b) unified inspection and (c) manufacturers' responsibility for quality assurance of the components supplied by them.

Under the present scheme for acceptance of components by users in the UK, the former procedure of inspection on ad hoc orders has now been replaced by the quality assurance scheme envisaged in BS 9000. This quality assurance is implemented through a series of A, B, C and D tests of which A and B are conducted on weekly lots produced, C tests once in three months and D tests once in a year or two years or three years as the case may be. The essence of the scheme is based on a continuous, systematic basis and it provides for sufficient feedback to ensure that the required activities for quality assurance take place during the process of manufacture at the appropriate stages.

The BS 9000 scheme could also be considered while formulating the national specifications/standards with certain practical modifications which may be necessary to accommodate the conditions existing in India.

16.2.3. Guidelines for Future Standardisation

(a) Field of Activity

Equipment: It is necessary for assuring the quality and reliability and or improving the maintainability of all electronic equipment, that standard components should be used to the maximum extent. However, as regards the standardisation of equipment themselves, the agencies concerned can examine the details as to what extent this can be achieved.

Components: There is an urgent need for standardisation in the field of electronic components to provide guidance to the industry in the production of components and to the equipment designers in the choice of components.

Materials: For indigenous development and production of electronic grade materials, it is essential to draw up specifications/standards for these materials on the same lines as for the components.

(b) Requirements of Components

The requirements of electronic components can be classified under three categories as follows:

S: For special application

P: For professional application, and

C: For commercial application.

The requirements of 'S' category being relatively small at present, there is no immediate need for preparing national standards. The individual users may take care of their interests on the basis of their own special requirements.

'P' category covers requirements of all the professional users including Defence, P&T, Railways, AIR, Civil Aviation, Police Wireless, Atomic Energy and most of the space applications. This is the area where immediate action is required.

'C' category is required for lower degree of assurance or stress levels as compared to 'P' category. Specifications in the category should closely follow the 'P' category specification.

(c) Standardisation Programme

'P' Category

In order to guide the production and use of professional grade components, national standards must be made available without any further delay. It has been observed that a number of indigenously produced components have already been tested and approved in accordance with the Joint Services Specifications prepared by the LCSO. The capability to produce components conforming to JSS is fast developing in the country and, therefore, JSS are considered as suitable for the 'P' category applications. JSS could form the basis of standardisation in the field of professional electronic components. However, for a standard to have nation-wide acceptance it is necessary that it is finally brought out by the ISI. For this purpose the Panel on Guidelines for Standardisation in Electronics has made the following suggestions.

(i) To meet the immediate requirements, (JSS) standards prepared by the LCSO should be the operating standards for 'P' category components till the Indian standards are issued.

(ii) JSS should be processed through the ISI committee in which LCSO should be represented and issued as Indian Standards.

(iii) In case ISI or any organisation through ISI wishes to take up preparation of any standards for 'P' category components, this should be done in consultation with LCSO, wherever JSS are under preparation with a view to maintaining uniformity of approach.

(iv) Similar procedure should be followed for the issue of amendments or revisions to such specifications.

The ISI standards/specifications brought out as a result of the above procedure should be the ultimate standards/specifications to be quoted wherever applicable. LCSO and other departments should take necessary steps to withdraw the corresponding JSS and their respective department standards.

'C' Category

ISI should continue to prepare specifications for 'C' category components. As and when 'P' category specifications are made available, the 'C' category specifications, for the sake of harmonisation, should be aligned to the 'P' category specifications with suitable modification on stress and performance levels.

For export purposes the Indian standards prepared in accordance with the scheme recommended above should be followed by the authorities concerned, e.g., the Export Inspection Council. This will, of course, be applicable only in the absence of user specifications.

Materials

Although some work has been done for laying down standard specifications for certain materials, it has been carried out essentially for materials required for general applications. The materials used in electronics industry are invariably required to satisfy more stringent specifications than needed for other industries and therefore, separate standard specifications are needed for these. Hence, this aspect should be looked into after getting the requirements of various user organisations. The specifications/standards for materials can be drawn on the same lines as for components, i.e., covering the three categories as given in BS 9000 scheme.

The existing testing facilities for raw materials in the various establish-

ments in the country e.g., Defence R&D and Inspection Organisations laboratories, CSIR laboratories, etc., should be surveyed and suitably augmented. Also, setting up new laboratories in those regions where none of the above mentioned laboratories already exist, may be necessary. For raw materials of electronic grade required exclusively for the electronics industry, facilities for testing could also be established at the Central Test Laboratories.

16.3 Testing and Evaluation

16.3.1. Current Status

A large number of testing and evaluation facilities are available with NPL, BARC, CIL and NTH (Calcutta) and these are being utilised by various manufacturers for testing/evaluation of their products. Certain testing/evaluation facilities are also available with other Defence R&D/DGI and CSIR laboratories, ISRO and major public and private sector companies to meet their individual requirements.

(a) Controllerate of Inspection Electronics (CIL)

Among the various functions and responsibilities of CIL, one of the important ones is to carry out testing/evaluation of components and equipment manufactured indigenously against the defence requirements. For this purpose, a considerable infrastructure of testing facilities and expertise has been built up at CIL in the last decade or so. Even though the test facilities at CIL are meant primarily for defence use, the testing/evaluation of components and equipment and calibration of equipment for non-defence applications are also carried out on nominal payment. A compendium published by CIL gives a summary of the various standards held and facilities available for calibration and measurement of various electronic and electrical parameters. The achievable degree of accuracy has been indicated against each range of measurement. The calibration facilities available at CIL include parameters like resistance, capacitance and inductance and also various other parameters like current, voltage and power—both AC and DC, frequency attenuation, impedance, waveform, etc., from DC, to microwave frequencies. The components laboratories in CIL have played a major role in the import substitution and indigenous development and testing of electronic components. These laboratories are equipped with facilities for comprehensive tests on components such as resistors, capacitors, semiconductors, electronic tubes, crystals, connectors, cables, inductors/transformers and electro-mechanical and electro-acoustic components. The facilities include switching parameter measurements of the order of 10^{-9} seconds, noise in resistors, immittance bridge for transfer function measurement, incremental inductance upto 12 Amps, temperature run on crystals with recording facility, sealing measurement up to 10^{-11} torr litres per second. Limited test facilities for integrated circuits also exist. CIL is also equipped with facilities for measurement of microwave parameters like power, frequency, noise figure, attenuation and SWR, in S and X bands at spot as well as swept frequencies. Facilities are also available for accurate spectral analysis of signals. The electro-medical facilities in CIL cover accurate measurements on medical lamps, X-ray machines, electrocardiographs, etc.

CIL has sophisticated and modern facilities for climatic and durability testing of components and equipment. Climatic hazards of high altitude, low

temperature, desert conditions, tropical conditions and a combination of these, are simulated with the help of equipment like dry heat, cold, dust, tropical, mould growth, corrosion, rain and combined environmental chambers. The mechanical hazards likely to be encountered by the equipment during transportation and usage are simulated with the help of equipment like vibration generators, centrifuges bump machines, impact machines, shock testers, transportation simulators and free drop facilities, etc. Facilities also exist for testing the effectiveness of different types of packages to withstand hazards encountered during transportation, storage and usage. Limited facilities for material testing such as bursting/tearing strength of papers and tapes, pressure, bending and brittleness tests on rubber and plastics, per sulphate tests, pH measurements, penetration tests on bitumen, tar, wax and asphalt and some mechanical test facilities for tensile strength, compression, shearing and bending also exist in CIL.

CIL has a wide-based documentation and data centre. Facilities exist for dissemination, to the electronics industry on request, of upto date information on specifications and test methods on components and equipment. Limited facilities also exist for failure analysis and failure rate assessment on components. The information gained is fed back to the manufacturers for product improvement. A feed-back card system also exists to obtain data on failures/defects noticed on equipment during usage by Army units. The analysis of this data helps in taking corrective measures to increase the reliability of equipment in conjunction with the design authorities and manufacturers.

CIL has under its technical control a number of regional inspectorates of electronics at Bombay, Calcutta, Delhi, Hyderabad, Jabalpur and Madras which are also being progressively equipped with certain test facilities. This has provided direct communication/liaison between these inspectorates and the local manufacturers and has resulted in reducing the time-schedule of testing and approval.

(b) National Physical Laboratory (NPL)

NPL maintains national electronic standards, and renders assistance to electronics industry and other R&D organisations and government agencies by undertaking the work of calibration and type testing of electronic instruments and components. The primary DC standards for 'ampere' and EMF are maintained in the form of weston cadmium cells and stable manganin coils. The accuracy of standard maintained is 1 in 10^6 . A galvanometer has also been designed to have AC/DC transfer standard. Some work has been done to set up high-frequency voltage and power standards. Working standard for the measurement of microwave power has been established upto 10 GHz with an accuracy of ± 2 per cent. The time and frequency standard is being maintained through quartz crystal clock. The accuracy of the standard is 1 in 10^8 . The time/frequency signals are broadcast 4 hours daily. NPL also provides test and calibration services to the electronics industry for a variety of equipment and components. It has established a good environmental test set up. The first phase of the 'calibration, testing and evaluation' programme covering primarily the environmental testing and calibration has already been completed. The second phase of this programme, being taken up during this plan includes measurement and calibration laboratory, reliability and field exposure stations.

(c) Reliability Evaluation Laboratory (REL)

The Reliability Evaluation Laboratory set up at Trombay on the recommendations of the Bhabha Committee is equipped to evaluate electronic and allied components equipment. The facilities have already been provided to PPED, BARC, TIFR, P&T and Navy in addition to the industries around Bombay. Besides testing, it has also developed (a) various mathematical and computer methods for reliability and availability prediction, (b) step stress model for accelerated testing, (c) methods for planning and evaluation of electronic equipment and systems projects, (d) procurement specifications for electronic components, (e) floating potential specifications for electronic components and (f) floating potential method for screening semiconductor devices.

(d) National Test House (NTH)

The National Test House in the eastern region started electronics activity in 1963, and has now built up five laboratories namely, Electronics Components Laboratory, Equipment Laboratory, Reference Standard and Measurement Laboratory, Acoustic and Audio Visual Laboratory and Environmental Testing Laboratory.

At present, all these laboratories are equipped with limited facilities. Material testing facilities also exist at NTH. However, they are located in different laboratories for their respective purposes. In the electronics division also, specialised material testing equipment exist. The general infrastructure existing at NTH is excellent as it has, besides electronics division, such major divisions as chemical, electrical, oil-petroleum products, high polymer, etc.

(e) Others

The Indian Space Research Organization (ISRO) has certain experimental test facilities in the Space Centre at Trivandrum for prototype development. However, for the Indian Scientific Satellite Project the facilities at BEL could be utilised.

The large production units such as BEL, ECIL, etc., have in-house facilities for component testing. Other public sector units also have limited test facilities. However, an extensive use of CIL facilities is made for more sophisticated work. BEL has a separate quality and reliability division. In addition, it has plans to equip this laboratory with standard facilities for environmental testing, steady state acceleration equipment electrodynamic vibration system and shock testing machine.

Many private units have their own test facilities, but these are more for process/quality control than for environmental testing. Some specialised facilities are also available at R&D laboratories.

16.3.2. Augmentation and Expansion of the Existing Facilities

(a) Controllerate of Inspection Electronics

To meet the growing requirements of the electronics industry, CIL has formulated plans to augment its existing facilities. It is proposed to have additional facilities for comprehensive testing of integrated circuits, ferrites, opto-electronic devices and light sources, tape and cassette recording stores, high voltage and high current measurement on solid state devices, cables,

dielectrics, switches and transformers. It is also proposed to augment and expand facilities for testing microwave components in G, L, Ku and J bands, microwave integrated circuits and antennae, servo components such as synchros, gyros, servomotors, etc., VT fuses and IR devices. It is also planned to have some facilities for automatic testing systems for components. Facilities are also being created for measurement of various parameters of transmitters and receivers in the UHF range. The plans for augmentation of calibration facilities include additional standards for resistance, capacitance and inductance measurement and reference standards/equipment for evaluation and calibration of signal sources involving frequency (including microwaves), waveform and magnitude, and facilities for evaluation and calibration of oscilloscopes, cathode ray tubes, thermocouples and temperature measurement devices, etc.

With the increased awareness of need for quality control and reliability and to meet the growing requirements of various electronic industries, CIL has plans to add latest climatic and dynamic test facilities like bump and shock test machines, chambers for high altitude tests including a walk-in cold chamber (down to -40°C), and corrosion, dust and sand tests for larger and heavier equipment; chamber for simulation of solar radiation; dry heat chambers; explosion chamber; additional vibration machines to handle an increased volume of work and extend testing parameters including random vibration testing facilities; endurance test machines and centrifuges for equipment; and additional test facilities for packages and packing materials.

Automatic test system for recording of failures in burn-in tests at high temperature, and failure analysis is planned for assessing the failure rates on a large number of components so as to obtain meaningful results. Establishing the failure mode and identifying the failure mechanism has become a necessity with the development of components of very low failure rates. This will involve setting up of radiographic equipment, infrared scanner and other related equipment. A computerised data centre to collate, analyse and disseminate this information as well as field failure data obtained from user units/establishments is being planned. This would assist in improving reliability of equipment and make a realistic prediction of MTBF, etc.

(b) National Physical Laboratory

Maintenance of primary standards being the statutory obligation of NPL, during the Fifth Plan it wants to augment the existing facilities to establish a good primary standards facility for electronics. These standards include (i) DC standards for EMF, resistance, AC/DC transformer standards, (ii) high frequency standards for voltage power, impedance, and attenuation, (iii) audio frequency standards for frequency, voltage, power and attenuation, and (iv) microwave standards for power, impedance, attenuation, phase shift and noise. In addition to this, NPL also plans to augment its existing facilities of time and frequency dissemination and monitoring. For this purpose it has proposed to acquire two more caesium beam atomic clocks to provide a three-clock system for interpolating on atomic scale to improve the accuracy to 1 in 10^{11} . At present, time and frequency dissemination services are provided on a frequency of 10 MHz only for 4 hrs, per day.

In addition to the primary standards facility, NPL has one test and evaluation centre. The first phase of its development has already been com-

pleted. During the second phase, NPL plans to augment these facilities to meet the growing needs of the electronics industry and to provide calibration service with higher accuracy and wider range. The second phase programme envisages (i) enlarging the environmental test facilities to cover the complete test facilities for electronic equipment and components, (ii) secondary standards and calibration facilities for AC, HF, VHF, UHF and field strength standards, (iii) facilities for testing antennas such as those used in HF, TV and mobile communications, (iv) general test facilities for equipment and components including ICs, (v) setting up of field exposure stations for correlation of actual environmental results with accelerated laboratory tests, (vi) carrying out studies of tropicalisation of components and equipment and (vii) carrying out failure analysis, reliability and model studies of performance and failure of electronic components and equipment.

(c) Reliability Evaluation Laboratory

REL at BARC has been organised to give reliability evaluation support to manufacturers, users and designers of electronic and allied products. Apart from the existing facilities like environmental simulation, physics of failure, etc., the thrust area in the next ten years will be organising advance level reliability training and computer based field equipment failure and basic part failure data collection. The programme output will have the information like (i) basic failure rate, (ii) stress factors such as temperature, use and environment and (iii) mean time to repair in case of maintained equipment. This information based on field performance of equipment would be very useful towards developing simulated laboratory tests. The culmination of this effort would result in a Parts Reliability Information Centre on the pattern of the one in NASA in U.S.A. Without this data, it is not possible for any designer of electronic equipment to attempt to design his equipment to satisfy the user's requirements of MTBF.

(d) National Test House

National Test House, Calcutta caters to the needs of electronics industries in the eastern region. Though at present only limited facilities are available, NTH plans to augment its capabilities in synchronisation with the industrial development in the eastern region. For material testing, it has good infrastructure and now by reorganising the existing facilities and providing specialised equipment, it can have material evaluation laboratory for electronic grade materials. It also has plans to expand and augment the existing environmental and reliability testing facilities. It is proposed to have four divisions namely, Testing Division, Research and Development Division, Standardisation and Measurement Division and Information and Data Processing Division.

16.3.3. New Activities During the Fifth Plan

Apart from the existing test houses augmenting and enlarging their existing facilities, the Electronics Commission has plans to start a few more test and development facilities mainly to help small-scale manufacturers. During the Fifth Plan the following projects are included:

Electronics Test and Development Facilities for Small Scale Units

The number of small scale units which have started manufacturing acti-

vities, or are in the process of starting it, find it extremely difficult to arrange for their own independent test and development facilities because of their limited resources. This is seriously hampering their progress. Considering that the various State Governments have shown initiative and are coming up with functional electronic industrial estates, the need for centralised testing facilities has become even greater.

To tackle this problem it is suggested to set up State Government owned centralised test and development facilities in all States as and when growth of electronics industry in small scale sector becomes substantial. The main function of such centres will be testing, quality certification, calibration and product development.

Twelve such centres are envisaged in the Plan period in which the total capital cost would be of the order of Rs. 3 crores—Rs. 2 crores to be given as grant by the Department of Electronics and the remaining Rs. 1 crore as outlay by the State Governments. It was further decided by the Electronics Commission that the grant-in-aid to the State Government will be limited to 75 per cent of the capital cost of the centre, subject to a maximum of Rs. 25 lakhs per centre. The recurring expenditure will be borne by the respective State Government.

The testing and maintenance of the medical electronics equipment (MEE) is an important aspect of the health care programme. It has been found that a large number of medical electronic instruments have been rendered useless due to the lack of maintenance and calibration. The need for such a maintenance and the requirements of a typical MEE maintenance have been highlighted in chapter 9 on Medical Electronics. In view of the similarity of the testing and maintenance equipment, it is planned that State-run test and development centres should also provide the maintenance support to hospitals and other MEE users. The type of special instruments and equipment required for MEE maintenance have been discussed in chapter 9. Extra financial requirements will have to be worked out in details for such a combined test and maintenance centre.

The plan for such centres in different States is already underway. In the following, the status of such centres in different States is briefly described.

Andhra Pradesh

A functional estate is being set up by the State Government in Moula Ali near ECIL. The Government has been advised to set up another functional electronic estate at Vishakhapatnam. The Government has also sent a scheme for setting up a T&D centre near the functional electronic estate.

Chandigarh

The Administration of the Union Territory of Chandigarh is taking steps to allocate land for T&D centre and for a few units in electronics.

Gujarat

A T&D centre at Makarpura Industrial Estate, Baroda has been commissioned and has started functioning. The centre is expected to expand its activities next year after acquiring the specialised equipment. A second T&D centre at Ahmedabad has been proposed.

Haryana

The location of a functional electronic estate and T&D centre is under active consideration of the State Government.

Himachal Pradesh

It has been decided to set up a T&D centre at Solan, near the site of the proposed electronic estate. The State Government is preparing a detailed proposal for getting financial assistance from the Government of India.

Kerala

The Kerala State Electronics Development Corporation (KSEDC) has proposed a T&D centre. A functional electronic estate is being set up by the Government of Kerala at Karakulam near Trivandrum.

Maharashtra

The Government of Maharashtra has proposed the setting up of a T&D centre to be run in close cooperation with the Poona Engineering College. It is expected that the centre will start functioning shortly.

Orissa

A T&D centre is proposed at Bhubaneswar where already some of the electronic units are under production.

Punjab

A T&D centre is proposed to be established near the proposed Functional Electronic Estate at Mohali near Chandigarh. A detailed scheme is under review.

Rajasthan

The State Government is proposing to establish functional electronic estates near Jaipur and at Pilani.

Tamil Nadu

The State has set up a functional estate for electronics and instruments at Adyar near Madras. The proposal of the State Government for setting up a T&D centre at Madras has been approved and financial sanction for the first phase given.

Uttar Pradesh

The State Electronics Development Corporation has set up a T&D centre at the Electronic Estate at Kanpur. The first phase of the project has been approved for purchase of indigenous equipment.

West Bengal

The Electronics Development Corporation has been set up as a subsidiary of the State Industrial Development Corporation. A functional electronic estate is planned near Calcutta along with a T&D centre.

Centralised Facility for Material Testing

The quality and reliability of electronic devices depend upon the quality of materials which go into the devices. Industries like chemicals, plas-

tics, metallurgy, etc., would be in a better position to supply electronic grade materials, provided appropriate testing facilities for electronic grade materials exist. In order to provide the needed facilities, a centre, where materials testing and characterisation of material on a commercial basis can be carried out, is proposed to be set up.

An outlay of Rs. 70 lakhs (Rs. 50 lakhs in foreign exchange) is the estimated requirement of this centre. The centre will prove useful to a variety of industries.

16.4 Reliability

16.4.1. Introduction

With the ever increasing complexity of electronic equipment and their application in almost every professional activity, there has naturally been greater demands on reliability. It is accepted that the reliability can never be a post mortem activity—it has to be engineered in the system right from the conceptual stage and augmented during the subsequent stages of development so that the ultimate production meets the requirement of reliability compatible with the cost.

In order to secure the degree of reliability required in the ultimate product, all concerned agencies, designers, production agencies, users and maintenance agencies must work in a concert. To begin with, for the designers, the need for the reliable components is paramount. When components with known failure rates become available it would be possible for them to design equipment or systems to meet the specified MTBF with the help of other disciplines, namely circuit design, sound construction practices, environmental and packaging considerations. This part of the report deals with the steps necessary for the establishment of the infrastructure required for the manufacture and certification of reliable components in the country.

16.4.2. Established Reliability Components

It should be our ultimate aim to organise the production of components with known failure rate levels, similar to the "Established Reliability" (ER) components currently being marketed in USA.

However, considering the present state of component industry in the country and its relatively very low volume of production, the immediate realisation of this aim does not appear feasible. Even in UK, where the volume of production is much higher, the BS 9000 series of components' specifications, even for professional application, do not specify the failure rate.

One of the inhibiting factors in the production of ER components is the excessive cost of testing involved to give the necessary assurance. For example, to be 90 per cent certain that a component will have a failure rate no worse than 0.1 per cent per 1000 hrs, it is necessary to conduct 2.3 million unit hours of testing with no failures permitted. (The corresponding figures with 4 failures permitted is 8 million unit hours). The better failure rates required for very complex equipment necessitate proportionately more testing to give this assurance. Thus 0.001 per cent per 1000 hrs would require 230 million unit hours testing without failure for 90 per cent confidence.

The cost of test facilities, manpower and the samples are to be taken into account. The volume of production of components in the country at present does not justify this high cost for testing. Unless large requirements

for a few varieties of components are built up through the process of standardisation, it would be difficult to bear the cost of samples alone. It is, however, envisaged that with the implementation of Part I of this report on standardisation, the requirements of components for the standard range will increase, paving the way for economic production of such components. It would then be possible to stipulate the failure rate levels in our specifications for 'P' category components. Establishment of ER component standards in the 'P' category should, therefore, be our long term objective for which planning should start immediately.

16.4.3. Immediate Requirements

Non-availability of valid failure rate data for approved indigenous components is one of the major problems facing the designers of electronic equipment of specified MTBF. Therefore, there is an immediate need for providing failure rate data for the approved 'P' category indigenous components. This information should be published in the form of a handbook and made available to the designers on priority. Laboratory life tests which include 'accelerated tests' can yield the necessary failure rate data quickly.

16.4.4. Feed-back Data From Field

Field failure rate data is not as reliable as laboratory data, due to the fact that the conditions of usage of the various types of equipment in which the failures are reported in the field cannot be controlled. Similarly, field data does not take into account various designs, the differences in quality control systems between various manufacturers, etc.

However, field failure data collection is also considered necessary for the following reasons:

- (i) To derive application K factors
- (ii) To analyse failure modes, so that steps necessary to prevent their future recurrence can be taken
- (iii) To identify high failure rate components
- (iv) To identify mis-applications
- (v) To predict maintenance requirements
- (vi) To update specifications and design and manufacturing processes.

16.4.5. Data Bank

Thus, it is seen that field failure data collection is not an objective in itself; it is an essential link in the chain of events leading to the ultimate objective of product improvement. If this exercise is to serve the declared objectives, the first and perhaps most important task is to evolve a system for data collection, involving all users of professional grade equipment in this country. This is a formidable task which requires agreement and cooperation between diversified users.

However, a Component Information Centre at Central Test Laboratories with limited objectives such as collection and dissemination of data on component availability, screening test data, qualification test reports, information on standards, vendor capability, failure analysis reports, reports on changes in manufacturing methods and component description with qualification status can usefully contribute information on these aspects and could form a nucleus for the future.

16.4.6. Reliability Programme

Planning for and preparation of an Indian equipment to MIL-DHBK-217 should be immediately taken up. A programme should be started at Central Test Laboratories/component manufacturers to generate failure rate data through laboratory life tests with manufacturers' active participation in the programme by way of providing free samples and ensuring prompt corrective action in their production whenever required. Progressively, manufacturers should be helped to acquire facilities for reliability testing and building up competence for such tests. This will ensure smooth change over to production of ER components at a later date.

16.5 Implementation Structure

For coordinating the task of standardisation and testing, the Panel on "Guidelines for Standardisation in Electronics", has suggested a governing body with two-tier structure, consisting of an apex body and two executive committees. The studies and responsibilities of the apex body should be the following.

- (i) To guide the preparation and implementation of national standards for electronic components, equipment and materials
- (ii) To prepare guidelines and policies for approval, certification, inspection and quality assurance of the components used in electronic equipment
- (iii) To formulate policies for approval of all test laboratories
- (iv) To encourage development of indigenous environmental test equipment industry
- (v) To encourage components manufacturers to accept responsibility for the quality and reliability of their products
- (vi) To plan for the production of reliable components in the country
- (vii) To coordinate the activities and administration of the two executive committees mentioned below.

The two executive committees under the apex body should be (a) Electronic Standards Committee and (b) Product Assurance Committee. The major duties and responsibilities of these committees are detailed below.

(a) Electronics Standards Committee

- (i) Implementation of the guidelines decided by the LSPAB and coordination of standardisation activity in order to ensure expeditious preparation and issue of national standards
- (ii) Coordination and assigning of investigational tasks to test laboratories, industries or universities for the sake of establishing improved techniques of testing, inspection and production of components
- (iii) Formulation of reliability policies and priorities
- (iv) Organisation of standardisation in respect of reliability, environmental (including shock and vibration mounts) and packaging disciplines
- (v) Organisation of the development of design and workmanship standards and reliability test standards for equipment.

(b) Product Assurance Committee

- (i) Approval of test laboratories for conducting qualification approval tests

- (ii) Allocation of qualification approval testing and other tasks to the various test laboratories
- (iii) Surveillance of test laboratories with respect to the progress and other details of the tasks allotted to them
- (iv) Consideration of the test reports submitted by test laboratories and granting of qualification approval or limited approval
- (v) Preparation and publication of qualified products list indicating the details of the components and the concerned manufacturers
- (vi) Fixing the test charges in consultation with test laboratories
- (vii) Approval of manufacturers' production facilities and quality control systems including the inspection staff for assessing the capability of the manufacturer to produce quality components. This will be a consideration for the granting of qualification approval.
- (viii) To plan for developing an Indian Handbook such as MIL-HDBK-217A.

16.6 Testing and Production Equipment Manufacture

It is increasingly felt that because of import of capital equipment for testing and production from numerous sources, it is becoming difficult to economically cope with spare parts, maintenance and standardisation requirements. It has been recommended by the Panel on Capital Equipment constituted by the Electronics Commission, that a beginning may be made for the custom manufacture of capital equipment for testing and production which have sufficient demand so that some degree of standardisation can be attained through a coordinated manufacturing programme. In addition, this Panel has also made the following recommendations:

In the first instance, indigenisation efforts should be concentrated on a few already identified items of capital equipment that are of higher priority. The Panel has identified established organisations who have the necessary competence to design, develop and fabricate these items of capital equipment.

A central agency should be given the task of coordinating, promoting, and monitoring indigenisation efforts for development and production of capital equipment for the electronics industry. This proposed agency will have specialised project teams consisting of experts in areas of materials, components, systems, equipment and manufacturing processes.

XVII

Defence Electronics

17.1 Introduction

Not so long ago, in the First World War practically no electronics was in use barring primitive methods of telecommunication. That war was fought by men equipped with bayonets and guns of all sizes in the Army and Navy. The boost came during the Second World War, with the advent of radars and significant wideflung telecommunication systems. Even so, what was in use then, only 3 decades ago, was entirely based on vacuum tube technique and would be regarded as primitive now. Today's environment is one of satellites, supersonic aircrafts, helicopters and guided missiles, or radars and sonars, of computer controlled weapon systems, electronics for surveillance and reconnaissance, electronic counter measures (ECM) and electronic counter counter measures (ECCM), and communication systems with channel capacity, mobility and speed to work in such an environment. A large part of the cost of a modern military aircraft lies in electronics and instrumentation (radars, electronic counter measures, navigational aids, guidance and control, on-board computers, communication sets, etc.). A gun can pinpoint a target, using laser techniques, to plus or minus a few metres at a distance of a mile using image intensifiers and infrared techniques. Man and vehicles can move in pitch darkness and through these optical systems "see" military formations ahead. These are but a few wide ranging examples to focus on the increasing role of electronics in modern warfare. The armed forces, as time goes on, will have more and more equipment (sensors, communication systems and weapon systems) of increasing sophistication. Successful use of this equipment will largely depend on electronics which is permeating all these systems to an ever-increasing degree. There are clear cut areas like communications which are entirely electronic in character. And there are major systems like aircraft, ships and missiles where electronics is an intimate part of the configuration for navigation guidance, control, sensors, etc. A significant pattern of modern electronics is the rate at which major technological changes are taking place in this field and the resulting obsolescence. In these circumstances, it is important to have a major effort in electronics to ensure that the country is abreast of contemporary developments in the field.

17.2 Requirements of Defence Electronics

As mentioned earlier, Defence Services use an ever-increasing variety of electronic equipment, both as such and those forming part of major weapon systems/equipment systems. The range, the intensity and the variety are constantly on the increase and very few weapon systems/equipment systems are being designed without having some element of electronics built in them. The major areas in which electronics play a key role are communications, radars and other sensing devices of all types, computers and EDP based

command and control systems, simulators, weapons systems' guidance and control sub-systems, navigational guidance and control systems, etc.

The Services formulate their quantitative requirements/operational requirements based on their appreciation of future threats and the manner in which they can be most appropriately met with. In formulating these requirements, R&D units and production agencies are consulted so that the requirements so formulated are realistic, taking into account the technological possibilities existing at any given time and the capabilities that are already available or are being built up in the country. The requirements thus formulated in turn provide an orientation to research and development projects which may be carried out in the Defence research and development organisations laboratories, research and development groups of the electronics industry and/or in specialised institutions like TIFR, CEERI, PRL, BARC, etc.

The competence, the facilities and the capabilities which already exist in the country in the field of electronics are considerable and it is, therefore, possible for the Services to meet a significant portion of their requirements from purely indigenous sources. Nevertheless from time to time need arises for import of limited quantities of equipment which may be required either for meeting urgent short-term requirements or for meeting small requirements of specialised equipment which cannot await the normal development and production effort. Electronic equipment are also often imported as part of major weapon systems that are being imported in the country to meet specific urgent needs. In all these cases, a conscious effort is being made to build up capabilities to meet the requirements from indigenous sources.

17.3 The Approach Towards Indigenisation of Defence Electronics

In view of the strategic importance defence electronics play in the national security, the dependence on the foreign sources for the supply of vital electronic element in the warfare systems is not desirable and, therefore, it is imperative to establish indigenous design, development and production capability in this area. This task involves (a) setting up of our own production units to manufacture these professional equipment, (b) to provide R&D back up in a coordinated manner for developing more efficient systems and to keep track of the present state-of-the-art and likely electronic threats, (c) to liaise with other R&D institutions not directly engaged in defence electronics to harness their capabilities and (d) to plan and implement system engineering approach for integrated defence system.

A significant defence electronics indigenisation base has been built up in the country in order to meet the above task. In the following sections, the various elements of this integrated approach have been described.

17.3.1. Production Base

The establishment of defence electronics production dates back to 1952 when Bharat Electronics Limited, Bangalore, was set up to meet the requirements of the Defence Services for electronic equipment and for civil uses such as communications, broadcasting, etc. Thereafter some more production units such as HAL and BDL at Hyderabad and second unit of BEL at Ghaziabad have been added to meet the ever increasing requirements of defence electronics which are described below.

XVII

Bharat Electronics Limited, Bangalore

Starting with a modest production of Rs. 10 lakhs during 1955-56, BEL, Bangalore, has made rapid progress and was able to achieve production of Rs. 45 crores during 1973-74 out of which about Rs. 28 crores were for Defence use. While production in BEL was undertaken initially on the basis of know-how obtained from foreign firms, a department of research and development was also created and during the last ten years the expenditure on R&D activities has been progressively stepped up by the company and development of a large number of new types of equipment and components undertaken. A large number of them have already gone into production. It is expected that within a few years most of the equipment required by the Defence Services in VHF and HF range would be entirely based on indigenous design. The import contents of the equipment manufactured are also being brought down progressively. The equipment manufactured by BEL include HF to UHF communication equipment required by Defence Services, by the Home Ministry as well as by other users; HF communication equipment and broadcast equipment (including studio and transmitter equipment for sound broadcasting and television) for All India Radio; various types of radars like surveillance radars, field artillery radars, fire control radars, radars for frigates, radars for meteorological applications; items like gun control equipment for tanks, amplifiers for field artillery guns; digital and peripheral equipment for computers, etc. Apart from manufacturing equipment, BEL is also producing for sale to other users a number of sophisticated electronic components such as electron tubes (receiving tubes, transmitting tubes, microwave tubes, cathode ray tubes, display indicators, TV picture tubes and X-ray tubes), semiconductor devices (germanium and silicon devices, integrated circuits and hybrid circuits). The company also manufactures piezo-electric crystals, crystal filters, mica and ceramic capacitors.

Bharat Electronics Limited, Ghaziabad

In order to meet the requirements of the Indian Air Force, BEL has set up a new unit at Ghaziabad. Apart from manufacturing these equipment, this unit also undertakes 'turn-key' projects in the area of communication systems.

Hindustan Aeronautics Limited, Hyderabad

HAL, Hyderabad division is currently manufacturing various sophisticated electronic equipment under collaboration for use in the aircraft. In addition, the production of certain other equipment by the Services as also civil users are undertaken.

The manufacture of a variety of gyros and accelerometers has been planned at HAL, Lucknow under licence agreements. This division has also taken up some design and development projects associated with gyros. Another public sector undertaking namely Mishradhatu Nigam Limited, Hyderabad under the administrative control of Ministry of Defence has been set up. This unit will produce a variety of special and super alloys required for the aeronautics, electronics and instruments industries.

Besides the above electronics manufacturing units, Ministry of Defence is also processing their requirements, from certain other public sector units

in the areas in which they have specialised capabilities. For example, ECIL, Hyderabad will be supplying computer based systems for various applications and ITI, Bangalore, have been supplying equipment for different communication purposes. Where necessary, the capability available in private sector for manufacture of electronic equipment and professional grade components is also being made use of.

17.3.2. R&D Base

Ministry of Defence under Defence Research and Development Organisation (DRDO) has set up a number of laboratories to carry out the development of major electronic systems:

(a) Electronics & Radar Development Establishment (LRDE), Bangalore is the oldest of all these laboratories. Its primary effort is oriented towards developing hardware required for different types of radar and communication systems, and power sources. Recently, LRDE has been developing, in addition, computer based data processors in the above areas, including the necessary software. It has also facilities to productionise items required in small quantities.

(b) Defence Electronics Research Laboratory (DLRL), a major laboratory located at Hyderabad is primarily concerned with the development of various kinds of receivers, transmitters and antennas as well as different types of coding practices for telegraph transmission. It has also developed secondary surveillance radar interrogator as well as a variety of microwave and high frequency passive components used in these systems.

(c) Solid State Physics Laboratory (SSPL), Delhi has been set up primarily to develop semiconductor materials and solid state devices. It has also made significant contribution to the development of proximity fuses for the Services. In the coming years, SSPL will be concerned with the development of potential materials such as gallium arsenide, mercury cadmium telluride, indium antimonide, lead selenide, etc.

(d) Himalayan Radio Propagation Unit (HRPU) located at Dehradun was basically set up to carry out propagation studies to provide back up to the three Services in their communication setups, but it has lately entered the field of development of troposcatter communication equipment.

Besides the above four laboratories which are exclusively created for working on defence electronics, there are other laboratories under DRDO which are doing research and development in electronics as a part of their programme.

Defence Research and Development Laboratory (DRDL), Hyderabad has been working to develop electronic equipment installed in rockets and missiles such as proximity fuses, homing heads, autopilots, etc., and their ground based counterparts.

Instruments Research Development Establishment, (IRDE), Dehradun has been working in various areas of instrumentation related to IR applications, shipborne instruments, etc.

Defence Metallurgical Research Laboratory, (DMRL), Hyderabad is primarily concerned with development of electronics materials especially in the area of metals, alloys and electronic ceramics. Defence Research Laboratory (Materials), Kanpur, on the other hand is trying to develop other materials used in electronic equipment and systems such as dies, paints,

epoxy resins, etc.

Naval Physical & Oceanographic Laboratory (NPOL), Cochin has been concerned with the studies of physical characteristics of the ocean and also the development of sonar systems and transducers.

In the field of avionics, the development effort in the DRDO is carried out at the Aeronautical Development Establishment (ADE), Bangalore. ADE has plans to take up work in a significant way in the field of airborne communication, fast computation, guidance, electro-optical and allied systems.

DRDO is also engaged in work in the field of rockets and missiles. Electronics plays an important part in the functioning of missile systems. Considerable work is being carried out in various DRDO laboratories on development activities on the control, guidance, instrumentation and ground environment systems for missiles.

In addition to the above laboratories, some specific tasks are also given to the national laboratories in the civil sector, viz. TIFR, CEERI, BARC, PRL, etc., and academic institutions to meet the needs of defence electronics.

17.3.3. Systems Engineering Approach

In order to implement a felt activity, the Ministry of Defence has been following system engineering approach integrating the entire chain of activities from planning, procuring and commissioning of the project with a conscious effort to use indigenous design, development and manufacture capability to the maximum. Some of the major activities in this regard in the recent years are as follows:

17.3.3.1. ADGES Project

One of the major programmes which Ministry of Defence has undertaken in recent years has been the strengthening the air-ground defence which includes the integration of the network of radars, air defence control centres, anti-aircraft gun defences, air and missile bases and necessary communication systems. This project titled Air Defence Ground Environment Scheme (ADGES) is being executed by the Radar and Communications Project Office (RCPO) under the guidance of high level Steering Committee and under the control of the Radar and Communication Board (RCB) presided over by the Prime Minister. This systems engineering group has been charged with the responsibility of systems engineering, procurement, installation and commissioning of an integrated Air Defence Ground Environment Scheme. The approach has been to harness, build up and utilise the indigenous capability to the maximum extent possible. Besides meeting the above objective, the organisation aims at building competence to tackle such tasks in future for the defence and non-defence users in the country.

To provide the necessary technological infrastructure and scientific support to the above scheme, a Research and Training Scheme has also been organised at nine selected places viz., Indian Institutes of Technology, Indian Institute of Science, Bangalore, National Physical Laboratory, Delhi, the University of Roorkee and the University of Jadavpur. At these centres, short and long term technical courses in specific areas in the communication and the radar field are organised for Service and civilian students with a view to their being utilised thereafter in the Services, systems engineering group, research and development establishments and industry. The centres also

undertake research and development in forward thinking areas in the defence electronics.

17.3.3.2. AREN Project

The second systems engineering group is the Project Management Organisation for the Army Radio Engineering Network which aims at providing an integrated area grid network communication system for the field mobile army. The main thrust of this organisation is to system engineer and get developed a family of sophisticated electronic equipment including automatic electronic switch boards, radio trunk extensions, radio line extension, etc., in addition to the normal types of radio relay equipment and transreceiver equipment. The work is being executed utilising the research and development capabilities available in the Defence R&D laboratories, TIFR, the production units such as BEL, ITI, ECIL, etc. It may be noted here that the entire series of equipment required for this purpose is expected to be designed, developed and produced in the country and that this would provide the Army with an advanced field communication system contemporary with the techniques and systems available from abroad.

17.3.3.3. Naval Projects

On warships constructed in the country, a considerable amount of electronics by way of radars, sonars, communication equipment, control systems, data processors and displays is installed. Their system engineering is being handled by special project groups set up within the Navy and many of the equipment are being manufactured by Bharat Electronics Ltd., (Bangalore) and Hindustan Aeronautics Ltd., (Hyderabad). Recently, Bharat Electronics have set up a system engineering group, with a view to design, develop and commission an integrated network of the equipment being designed and manufactured in Bharat Electronics, not only for the new warships, but also for modernisation of old warships. Likewise, a special group has been set up for system-engineering, computer based data processing and display systems, both for anti-aircraft and anti-submarine warfares.

As and when the need arises similar system engineering groups will be set up in other areas of electronic equipment required by the three Services so that the project management techniques can be fully applied to these difficult tasks.

17.3.4. Coordinating Efforts

To ensure that the defence electronics requirements are coordinated and indigenisation is effected to the maximum, various coordinating agencies at the national level have been set up.

17.3.4.1. Defence Electronics Committee

In order to maintain a continuous two way communication and exchange of views and information between the Department of Electronics and the Defence setup, a Defence Electronics Committee (DEC) has been constituted under the chairmanship of the Chairman, Electronics Commission. Through DEC, defence needs are thus known to Electronics Commission so as to ensure that the efforts of the Electronics Commission on a national scale and in the civilian sector cater to these demands to the maximum possible extent.

17.3.4.2. National Radar Council

To ensure proper coordination of various activities in the field of radar so as to meet the Defence and Civilian requirements in an integrated manner and on the basis of maximum self-reliance, the Government of India has set up National Radar Council (NRC) under the chairmanship of the Chairman, Electronics Commission. The council associates in its work all the major agencies concerned with the development, production and use of radars. The defence requirements of radars are being coordinated by the Defence Radar Requirements Plan Committee of the NRC.

17.3.4.3. Electronic Data Processing Advisory Group

Defence Services use, in a significant degree, electronics data processing equipment, both for the normal type of applications, e.g., inventory management, personnel management, production planning and schedule, etc., but also for the specialised military functions such as command and control systems, automatic data handling for air defence, weapon control systems, autopiloting systems, military intelligence applications and design and development of sophisticated equipment. To promote and coordinate the growing use of EDP techniques and equipment in the Services, a high level EDP Advisory Group has been set up under the chairmanship of Scientific Advisor to Raksha Mantri. This group is not only coordinating the induction of new EDP systems in the Defence setup, but also laying down the guidelines and the priorities for future growth. Arrangements for the training of EDP personnel in adequate depth are also being made by the Services. The maintenance of the EDP systems in the field has necessarily to be carried out by the Services themselves and the competence is being built for the purpose. A study team has been set up by the Group to examine the requirements of the minicomputer for Defence applications and to determine the extent to which indigenous production of ruggedised minicomputers for field applications has to be resorted to.

17.3.4.4. Electronics Wings of Defence Inspection Organisations

The Directorate of Production and Inspection Electronics (DPIL) of Defence Inspection Organisation has made substantial contribution towards the quality and reliability of defence equipment and exploiting potential in the indigenous industry for productionising electronic equipment and components to meet defence needs. A Technical Committee for Electronics and Electrical Stores (under the chairmanship of the Director of Production and Inspection Electronics) assists the Department of Defence Supplies for developing indigenous sources for the production of equipment hitherto imported. The Committee has been able to indigenise the production of several thousand components, sub-systems and ancillary items for such electronic equipment thus reducing dependence on foreign sources. Similar efforts on specialised electronic equipment are undertaken also by DTD&P (Air) for Air Force and DPIN for Navy.

17.3.4.5. Coordination of Development and Production

The development and production efforts of the electronic equipment required by the Defence Services are coordinated by special committees, set up within the Ministry of Defence, for reviewing their progress periodically.

An overall coordination is effected by the Electronics Development Panel (LDP) with the participation of the Ministry of Defence, the Department of Defence Production, Defence Services, Defence R&D Organisations, R&D organisations working in similar electronic discipline in civil sector and the Department of Electronics.

17.3.4.6. Rationalisation and Standardisation of Electronic Components

It is generally observed that the professional grade components required for defence electronics equipment are not easily available in the country. The problem is aggravated by the vast mixture of imported technology from varied sources presently used for manufacturing defence equipment and consequently the diversity of specifications involved in these components make them uneconomical for indigenous production. Therefore, the need for standardisation particularly in view of our emphasis to build up indigenous capability, assumes considerable significance. The standardisation work for defence applications is done by Electronics Components Standardisation Organisation (LCSO). LCSO has so far brought out over 170 specifications, 1000 standards and has given out 250 approvals for various types of components. LCSO standards (styled as Joint Service Specification (JSS)) are directly implemented through 'Type Approval' or 'Limited Approval' accorded by LCSO. From the growing list of approved components it may be inferred that the indigenous capability to produce components conforming to JSS is developing in the country.

Electronics Commission has given considerable attention to the problems of standardisation in electronics in the country. Panels on 'Guidelines for Standardisation in Electronics' and on 'Electrical and Mechanical Components' set up by the Electronics Commission have discussed various aspects related to the rationalisation and standardisation of electronic components. Some specific problems related to defence applications are also being looked into by the Electronics Development Panel set up by Ministry of Defence, where the Department of Electronics and LCSO are also participating. The general problems associated with standardisation are dealt with in a separate chapter in this report.

17.4 Conclusion

In the preceding sections, an attempt has been made to describe the various elements involved in defence electronics and cross-section of the conscious efforts going on in the country in order to achieve self-reliance in defence electronics. It may be seen that in DRDO as well as in the other national development and production agencies, considerable expertise has been built up in the strategic areas of sophisticated systems relating to communication, radar, missiles and computer based systems. The future plans envisage contemporary development activity in all spheres of defence electronics and by the end of Fifth Plan a high level of self-reliance is expected to be achieved.

XVIII

Exports and Export Facilities

18.1 Introduction

Electronics industry being intensive in engineering and skilled labour, provides ample scope for exports by utilising the comparatively lower cost of such skills in the country. Starting with almost a negligible amount in 1968-69, the export of electronic goods had reached Rs. 3 crores in 1970-71. The first significant step in broadbasing and strengthening electronics exports was taken in 1971-72, which resulted in an increased export worth Rs. 5.27 crores in 1971-72. The electronics export in 1973-74 and 1974-75 amounted to Rs. 9.3 and Rs. 11.6 crores, respectively, the break-up of which is given below :

	1973-74	1974-75
	(Value in Rs. crores)	
Data processing equipment	4.2	5.1
Radio parts and electronic components	4.0	4.9
PA equipment	0.8	0.9
Telephone and Teleprinters	0.3	0.7
Total	9.3	11.6

The number of significant exporters of electronic items has increased more than 10 fold in the last decade. The private sector has been playing a predominant role in exports. Of the public sector undertakings, Bharat Electronics Limited has shown considerable progress in their export activities as reflected by the increase in export from Rs. 6.34 lakhs in 1971-72 to about Rs. 2 crores in 1974-75. Indian Telephone Industries has more than doubled their exports, from about Rs. 44 lakhs in 1973-74 to about Rs. 1 crore in 1974-75. Both the organised and the small scale sectors have shown export growth side by side.

The country's export at present is confined to the major areas like :

- a. Data processing equipment
- b. Amplifier systems and components
- c. Car radios

XVIII

- d. Radios from small scale consortiums and large houses
- e. Laboratory instruments
- f. Plastic film capacitors
- g. Electrolytic film capacitors
- h. Mica capacitors and silvered mica plates
- i. Resistors
- j. Printed circuit boards
- k. Vacuum tubes
- l. Small exchange equipment and teleprinters.

Status of Indian Trade with East European Countries and USSR

In the field of electronics industry, the trade with East European countries has been less as compared to that with West European counterpart. The low volume of trade can be attributed to some special problems encountered while building up trade with East European countries. The normal interaction and successful communications which are possible by contacts through trading firms and agencies as in the case of West European countries, are difficult with East European countries as the latter work in a total planned economy.

The Government of India has entered into trade, cultural and scientific protocols with these countries from time to time. During 1974-75, in view of the anticipated increase in trade and technological cooperation in the field of electronics, protocols on electronics were signed with the East European countries like Bulgaria, Hungary, Czechoslovakia, USSR and Poland under the auspices of the various Joint Commissions/Committees for economic, scientific and technical cooperation. A similar protocol has been signed with USSR as well.

Status of Trade with West European Countries, USA and Japan

The West European countries, USA and Japan by virtue of their technological lead and the infrastructure necessary for production of engineering goods, share among themselves, a major part of world electronics production. Till recently, India has been importing from these countries virtually all types of electronic products ranging from semiconductor chips to electronic computers, professional telecommunication equipment and highly sophisticated radars. Exports from India have been centred around statistical machines and passive components. However, in view of rising labour costs coupled with shortage of technical manpower in these countries, opportunities in exports of labour intensive, simple electronic products exist. Opportunities can also be explored to work as sub-contractors for manufacturing sophisticated communication systems and for turn key projects.

Status of Trade with the Developing Countries

A significant portion of Indian export trade in entertainment electronic products has been carried out with developing countries in Middle-East Asia,

XVIII

Africa and South-East Asia. The major export items to these countries are radios, radio parts, components, telegraphic and telephone equipment.

Developing countries offer prospects for both capital goods, and consumer goods export. The nature of demand varies from country to country, depending upon the state of their engineering and technical development, foreign exchange position, etc. Export trade can be increased by meeting the existing demand and creating new markets for finished products, and by offering industrial plants and machinery on turn key basis. However, these exports would have to be done on face of stiff competition from other countries.

Scope for Expansion of Electronics Export

The changing international trade structure in electronics favours India to promote electronics exports. For example :

- a) Developed countries have achieved maturity in the electronics field and are concentrating on sophisticated research based items as future areas of domestic investment.
- b) Owing to rising wages of industrial workers, the developed countries are adopting the policy to farm out production of low technology content electronic items to some of the developing countries.

As compared to other Asian countries, India is better placed in carrying out accelerated electronics exports due to the ready availability of skilled labour and a sizeable internal market to provide a base.

Although India has, on an average, a 25 per cent annual growth rate in electronics export, the overall percentage of export with respect to production is insignificant. India presently manufactures about Rs. 300 crores worth of electronic items but exports only about Rs. 11 crores worth of items. The industry has developed primarily on import substitution basis. The present export therefore accounts for less than 4 per cent of the total production. Many of the Asian countries, although late starters in the field of electronics as compared to India, are exporting much more than us.

Some of the reasons, apart from the stiff international competition, for the low export performance in the past are given below :

- a) Existence of wide awareness gap in terms of structure of foreign markets and products
- b) Lack of faster and continuous product development plans oriented towards export production
- c) Absence of modern technologies and fast production methods
- d) Under-utilisation of the licensed capacity

Planned efforts are underway to remove some of the above mentioned bottle-necks. Setting up of Electronics Trade and Technology Development Corporation and Technology Development Council are some of the major steps towards this.

Steps are being taken to boost the export of electronic goods, by increased production by utilising existing idle capacity and also by giving incentives like,

relaxed import of raw materials and equipment for export oriented production.

An Export Working Group constituted by the Ministry of Commerce and convened by the Department of Electronics submitted its report to Government of India in April 1974. This Working Group, apart from a number of policy recommendations (for boosting the electronics export), had identified a number of items having export potential within the area of technical managerial expertise which can now be readily made available. These are listed below :

1. Capacitors
 - a) Electrolytic
 - b) Ceramic
 - c) Paper
 - d) Plastic
 - e) Tantalum
 2. Variable capacitors
 3. Fixed resistors
 4. Variable resistors
 5. Connectors, plugs and sockets
 6. Relays
 7. Printed circuit boards
 8. Receiving valves
 9. Crystals
 10. Semiconductor devices including integrated circuits
 11. Transformers, coils and chokes
 12. Loudspeakers and microphones
 13. Electronic calculators, desk top and pocket size
 14. Transistor radios AM/FM
 15. Automobile radios
 16. Cassette tape recorders
 17. PA and Hi-Fi equipment
 18. TV receivers, including portable ones
 19. Oscilloscopes
-

XVIII

20. Digital instruments
21. Battery eliminators
22. Power supplies
23. Antenna and antenna hardware

Some of the major areas which are not indicated above, but have export potential are discussed below :

Computer Software

Computer software has been recognised as an area having considerable export potential, as large number of qualified and competent personnel in the field of software and system engineering are available in the country. An encouraging beginning in this area has already been made by consultancy organisations in private sector by carrying out software export to developed countries. The setting up of the National Centre for Software Development and Computing Techniques is a major step in this direction.

Communication and Other Systems

During the last ten years, India has made remarkable progress in the area of production of communication and radar equipment. This is amply reflected by the product mix of narrow band/wide band microwave line of sight communication systems, troposcatter communication systems, satellite communication receive and transmit chains, digital data modems, and various radar systems and associated signal processing equipment. Capability also exists within the country in the area of communication systems planning and implementation as illustrated by commissioning of extensive communication systems for P&T, Railways, etc.

With the near term availability of some of the vital components from indigenous sources coupled with a favourable environment being created for export awareness in the area of communication equipment, (as reflected in the recommendation of the Telecommunication Planning Committee to consider export of 5 per cent of total production during the Fifth Plan period and 10 per cent during the next Plan period) and the available skill and expertise in the country in this field, the export production can be successfully be geared up.

The export drive, particularly in the field of communications, has to be properly coordinated, as this would have to be carried out in competition with the major established consortia of the multinational companies. There has been a long-felt need to bring together the various manufacturers and development organisations in the country, so as to effectively utilise the manpower and other resources available at these organisations and to plan long term export strategies.

18.2 Santacruz Electronics Export Processing Zone (SEEPZ)

The Santacruz Electronics Export Processing Zone was established in Bombay, in 1973, by Ministry of Commerce, for the manufacture of electronic equipment and components for exports. Similar free trade and export processing zones have already contributed in a big way to electronics exports in the countries like, Taiwan, Korea, Phillipines, and Malaysia. There are plans to import foreign technology to SEEPZ, in areas such as high priced entertainment equipment, assemblies and subassemblies of professional and industrial equipment, and high quality compo-

XVIII

nents. The SEEPZ has a capacity to accommodate between 80 and 100 units and is expected to provide employment for about 15,000 personnel.

Some of the special concessions and incentives offered to units in SEEPZ are as follows :

1. Concessional rents/lease rents for flatted space accommodation as well as for leased land
2. Duty free imports of capital goods and equipment
3. Exemption from customs and additional (countervailing) duty on the raw materials, components, spares, consumables, tooling and packaging materials as are imported
4. Exemption from central excise duties and other levies on products manufactured within the Zone
5. Supply of capital goods, equipment, raw materials, components, spares, tooling and packaging material supplied to the Zone from the rest of the country will be treated as exports and will be eligible for cash assistance and other duty concessions. However, these concessions will be admissible only in respect of such goods as are eligible under the normal rules for similar export concessions
6. Advance import licence for raw materials equal to twelve months' requirements
7. Expeditious disposal and liberal treatment of applications for industrial licences, capital goods licences and foreign collaboration approvals.
8. Blanket permissions for foreign exchange needed for business visits abroad
9. Liberal treatment in regard to import of technical know-how.

SEEPZ has approved a number of applications for setting up manufacturing operations. A few units have already started production covering areas such as entertainment electronics, professional measuring instruments, computer software and components. It is envisaged that by the middle of 1976, SEEPZ will have an export capacity of about Rs. 22 crores worth of electronic goods. By the end of the Fifth Five Year Plan the annual exports from SEEPZ is expected to reach Rs. 50 crores.

18.3 Electronics Trade and Technology Development Corporation

The main difficulty in increasing trade with East European countries has been the lack of communication. This, coupled with insufficient information in India concerning development in Soviet Union and East European countries, details of their products and performance, and language barrier have resulted in poor implementation of trade provisions. Two Delegations of Electronics and Computer Experts visited these countries in 1972 to investigate trade possibilities. The reports of these Delegations have indicated that a wide variety of electronic items could be considered for trade with socialist countries. It was emphasised that continuous marketing and technical monitoring efforts are needed to enhance this trade. A separate Electronics Trade and Technology Development Corporation (ETTDC)

has been set up to achieve these and to continuously foster the foreign trade in electronics with an initial thrust in East European countries.

18.3.1. Tasks Before ETTDC

The main task before this Corporation is to convert import from hard currency areas in Western countries to soft currency areas in East European countries. At present, those imports which may necessarily have to be obtained from hard currency areas are not always obtained on the best possible terms. Such items are being imported in small quantities by a number of users from different sources, with the result that high unit prices are being paid to foreign suppliers. The extensive market survey in the socialist countries can help to divert these imports and also acquire goods on better terms.

There are some special problems encountered while building up trade with East European countries. These socialist countries always work on planned programme of production and any change in these programmes to meet ad hoc requests for supplies are not possible to be accommodated in their yearly or long range plans. The normal interaction and successful communications which are possible by correspondence through agents, as in the case of West European countries, are not possible with East European countries, since their trade channels are not oriented purely on sales and profitability basis and it is necessary to have negotiations normally at Governmental levels. It was thought that a special organisation to deal with the import trade in electronics is necessary to avoid the delays in processing the orders. Specialised skills and knowledge are required to effectively build up trade in this field which has high rate of growth and obsolescence. In the recent years, considerable delay in procuring some raw materials like nonferrous metals, etc., from East European countries have seriously affected growth of production in electronic component industry and has also increased the demand for imports from hard currency areas. Constant liaison is required with manufacturing, trading and design organisations in East European countries as they do not have as yet any effective means for fast disposal of commercial and sales transactions, nor do they have a system of fast dissemination of information by way of updated catalogues and necessary publications in English.

A detailed field work needs to be done on a continuing basis with appropriate feedback given to the manufacturing units in the country with regard to quality, volume of production and pricing. The Corporation will perform the function of product identification, and product development (where necessary). It is of prime importance to make our electronics industry export oriented through the efforts of this organisation. It will be possible to ensure that promotional and long term tasks are taken by organisations in East European and other countries and organisations in India jointly.

Another important function of this Corporation will be to help the transfer of technology from the countries abroad to different Indian manufacturers. This agency would form a technically knowledgeable interface for this transfer. It will act as an information base about the available technologies abroad. The suitability of a particular technology to be imported will be decided on its cost effectiveness in the context of the Indian economy and the gaps existing in technology in the elective field. Such studies will be conducted from time to time by experts in relevant fields. Many of the items, which are presently imported by different Government departments and national laboratories are available in the East European countries.

XVIII

A typical and representative list of such items is given in Table 18.1. The Delegation that visited many East European countries indicated the items for import/export trade with these countries which are shown in Table 18.2. The list is only illustrative and it is felt that constant marketing and monitoring efforts would be required to realise the possibilities in practice.

Table 18.1. A typical, representative list of items which are presently being imported and available in the East European countries.

I. DGCA, Home Ministry and I & B Ministry

1. Air-field surveillance radars
2. Precision approach radars
3. VHF/UHF direction finders
4. Beacons
5. VHF/UHF transreceivers
6. Transponders
7. Spectrum analysers
8. Frequency deviation meters, etc.
9. 2 inch-video-tape recorders

II. Meteorological Department

1. Cyclone warning radars
2. Skopographs
3. Ceilographs
4. Power meters
5. Frequency converters
6. Magnetic tapes
7. Equipment for investigational aid, ground and airborne equipment for observation

III. P&T and Railways

1. Microwave equipment
2. UHF and HF
3. Coaxial cables, etc.
4. Components for V/UHF transreceivers
5. Components for automatic train-control system and signalling relays, etc.

IV. Research Laboratories

1. Microwave sweep oscillators
 2. Resistor trimming units with accessories
 3. Microwave circulators and isolators
 4. Oscilloscopes (general purpose, portable and storage)
 5. Silicon slices
 6. IC testers and programming units
 7. Instrumentation tape recorders
-

XVIII

8. Signal generators
9. Data logging systems
10. Digital printers
11. Multichannel magnetic tape recorders
12. Platinum-resistance temperature sensors
13. Opto-electronic devices, etc.

Table 18.2. Possibilities of import from and export to rupee trade areas.

Country	Possibilities of import	Possibilities of export
1	2	3
GDR	Components : Passive and active components for entertainment, some professional components for defence, reed relays, wafer switches, coaxial straight and bent connectors, trimmers, etc. Mechanical filters, ferrite cores, dust iron cores, ceramic high voltage capacitors and trimmers, liquid crystal displays, microscopes required for semiconductor industry, magtape units, etc.	Cores, relays, microwave antennae, multiturn, servo, sine cosine posts (At present being imported from Hungary).
Rumania	<ol style="list-style-type: none"> 1. Ferrites of all varieties (They are offering to help to set up a plant in India for the production of large quantities of ferrites (say 1000 tons/year) 2. Glass technology and TV tubes making (they are in collaboration with Corning Glass of USA and Standard Electric Lorenz of West Germany) 3. Immediate needs of glass shells or picture tubes 4. Jelly filled telephone cables utilising very latest technology 5. TV deflection components (Philips know-how). varactor type TV VHF tuners 	<ol style="list-style-type: none"> (a) Quartz crystals (b) All types of rectangular multipin connectors (c) Miniature rotary switches (d) PC boards (e) Relays (f) PTFE cables & sleeves (g) Some types of transistors, ICs (h) Microammeter, ammeters, voltmeters, All professional equipment (i) Receiving and transmitting tubes, cassette tape recorders, some sophisticated measuring instruments, etc. are not being manufactured in Rumania

XVIII

1	2	3
Poland	<ol style="list-style-type: none"> 1. Beryllium copper, and high permeability magnetic material, chip capacitors, ceramic trimmers, feed through capacitors, high voltage capacitors for TV, piezo electric elements, ceramic filters and monolithic chip capacitors 2. TV equipment, mobile outside broadcasting equipment, video tape recorders, production equipment for ceramic capacitors, selective nano voltmeter, transistorised wide band oscilloscope, digital panel meter 	<p>Connectors, PTFE wires, coaxial cables and sleeves, rotary switches, all type of connector multiturn potentiometer with dial, relays, switches, wave guide components, semiconductor of all types, power cables of aluminium core (15 to 30 KV variety), communication cable, teflon insulated coaxial connectors, telephone cables, telecomm equipment for railways, cross bar telephone exchanges, telephone relays, resistors and capacitors.</p>
USSR	<ol style="list-style-type: none"> 1. Materials: Magnetic materials, special alloys like kovar, invar, beryllium copper OFHC copper, tungsten molybdenum. Iron, special ceramics, Ga Si for semiconductor devices, high purity chemicals 2. Components : Wide range of resistors, capacitors, TV deflection components, connectors, electronic valves, ferrites ceramics trimmers, high voltage capacitors, circular and multipin connectors, semiconductor devices, varactors, TV transistor, ICs 3. Professional equipment : TV studio and lighting equipment, TV cameras, audio and video mixing consoles, VTRS of high quality. Attractive range of digital types of measuring instruments and wide range of test equipment 4. Process control instruments : Electronics unit for controlling the even temp within $\pm 0.5^{\circ}\text{C}$, in 1600°C, servo systems transducers, 2 position regulators 5. Plant & machinery : Plants for production of aluminium foil plastic 	<ol style="list-style-type: none"> a) Connectors b) PTFE insulated wires, cables and sleeves c) Rotary switches and relays d) Tantalum capacitors, metal glaze trimmers, multiturn potentiometers with dial e) MW WG twists f) Semiconductors of certain types

XVIII

1	2	3
	<p>film, metallised paper carbonisation plant, complete production line for resistors, furnaces, die bonders, lead bonders, semiautomatic machine for plastic encapsulation of semiconductors, etc.</p>	
Hungary	<ol style="list-style-type: none"> 1. Phosphor bronze, beryllium copper, permalloy high purity aluminium substrate. Microwave components and MW ferrite components. Ceramic tubular and disc capacitors, ceramic feed through capacitors, ceramic trimmers, metal film trimming potentiometers, carbon potentiometers, ceramic to metal sealed metallised polyester and poly-carbonate capacitors, electrolytic capacitors (-40°C to $\pm 70^{\circ}\text{C}$) 2. Professional equipment : 12 channel taperecorders for use in the airports. VHF communication equipment, 400 MW walkie talkies 3. Test equipment : Whole range of test equipment for TV, transistorised digital multimeters, signal generators (1200 MW and 5 band 2 watts), etc. 4. Plant & machinery : Aluminium foil etching and forming plant (approximate cost \$ 20,000), grinding machines for RF and IF screw cores, tape controlled PCB inking and drilling machines for R&D, automatic PCB testers. die bonders, lead bonders. Know-how for private automatic exchanges, microwave equipment 	<ol style="list-style-type: none"> a) Transformers b) Quartz crystals c) Microwave aluminium disc antennae including antennae towers for continuous export d) Receiving and transmitting valves e) O/E/N switches and connectors f) Telephone relays g) Calculators
Czechoslovakia	<ol style="list-style-type: none"> 1. Materials : Gallium arsenide, ferrites, both for professional and consumer industries, silicon steel, permalloy 2. Components : ICs, varicaps, switching diodes, silicon ICs 3. Equipment : Semi-electronic exchanges, radio relay stations, channelling equipment, radar equipment, medical electronic equipment, elec- 	<ol style="list-style-type: none"> a) Antenna of different types specially for PAR, etc. b) Through hole plated printed cards c) Transformers d) Relays e) Contactors f) complete sets of wave guide parts for radars

XVIII

1	2	3
	tron-microscopes, spectro-photometers	g) Equipment like radio altimeters
4.	Consumer : Loud speakers of different sizes and power microphones, components for TV	
5.	Plant & machinery : Special types of plant and machinery developed for several applications like loudspeakers, ICs, etc.	

Table 18.3. Expected production and imports of electronic items and the possible conversion to soft currency areas (Rs. crores).

Sector	Value of production		Imports		Possibility of conversion	
	Present	1980	Present	1980	Present	1980
Public sector	89.0	286.0	22.0	61.0	7.0	47.0
Entertainment	64.0	447.0	5.0	2.0	4.0	2.0
Professional items	17.0	150.0	6.0	28.0	3.0	18.0
Components	55.0	140.0	6.0	14.0	3.0	13.0
User departments (Railway, Defence, etc.)	—	—	11.0	52.0	0.5	12.0
R&D organisations	—	—	2.0	10.0	1.0	3.0
Total	225.0	1023.0	52.0	167.0	18.5	95.0

ETTDC is expected to work in close cooperation with the Department of Electronics. This will ensure the necessary coordination by the Department of Electronics in formulating policies on the technical and marketing aspects of the Corporation, functioning as well as in implementation of these policies. This will also take advantage of the existing joint cooperation agreements between the East European countries and India.

18.3.2. Structure of ETTDC

Presently, the production of electronics in the country is to the tune of approximately Rs. 225 crores out of which nearly Rs. 90 to 100 crores worth of equipment and components are being produced by public sector undertakings. To support this volume of production in public sector, more than Rs. 20 crores worth of special items, materials, etc., are imported every year. In the private sector also, there is constant drain of foreign exchange for the production of TV, tape recorders, desk calculators, etc. It is expected that by 1980-81, the total electronics production in the country would be about Rs. 1023 crores. To support this level of production, about Rs. 170 crores worth of materials, components and plant items would be

XVIII

needed from abroad, even though further indigenisation efforts in the manufacture of components and equipment would be taken up in the country during this period. Also, vigorous attempts will be made to increase the high volume of export by that time. Thus, East European countries would become main source of supply for materials, components, equipment, etc., for the continued growth of electronics in the country.

Table 18.3 gives the values of production, level of imports and possibilities of conversion to soft currency areas for the present and by 1980. Extensive information was collected by the Department of Electronics regarding the types and quantity of electronic goods imported by user organisations.

It is expected that ETTDC will be able convert a large fraction of the expected imports to the soft currency areas.

The main office of the Corporation will have under its purview the foreign based liaison cells and the subunits within the country. It is expected that there should be one foreign based liaison cell for each of the East European countries like USSR, Poland, Czechoslovakia, Rumania, GDR and Hungary. Initially the members of the liaison unit will work at the respective Indian missions abroad or in very close coordination with them. As the volume and diversity of work increases, separate office for the liaison unit may be opened in these countries. Each liaison cell is expected to keep track of the technologies developed and the import export formalities in the respective countries. The major responsibility of the subunits within India, two of which are already functioning, will be to channelise all the import of electronic materials and equipment and study the possibility of converting the hard currency imports into soft currency areas. These units will also be responsible for providing the information of the products from abroad to the end users here. Technical and marketing expertise will be built up with first hand knowledge of the conditions both in India and abroad and to link up this with the necessary regulatory powers.

Table 18.4. Anticipated turnover of ETTDC.
(in Rs. crores)

	1975-76	1976-77	1977-78	1978-79
Imports	5.0	10.0	20.0	30.0
Exports	1.0	2.0	5.0	10.0
Total	6.0	12.0	25.0	40.0

The operating income of the unit would arise from the service charges to be laid on imports and exports. Assuming average net service charges of 5 per cent and 2 per cent on imports and exports, respectively, the expected income during the first five years of the Corporation is shown in Table 18.5.

Table 18.5. Expected income of ETTDC during 1974-79.

Year	Income (in Rs. lakhs)	
	Imports	Exports
1974-75	2.5	—
1975-76	15.0	2.0
1976-77	50.0	4.0
1977-78	100.0	10.0
1978-79	150.0	20.0

XVIII

In the case of exports, the income is expected to be more as the unit undertakes direct exports and not through associates. ETTDC will require large working capital for procuring some of the equipment for display and initial import orders. It is anticipated that the major expenditure of the Corporation will be in terms of warehousing facilities, expenditure of foreign and local cells, etc. The Corporation will have to import initially some of the electronic goods, which are likely to have large demand in the country. It is anticipated that about three to four months stock of imports will be required to be stored by the Corporation to cater efficiently to the demand of users in the country and for accelerating the production in all important sectors of electronics. As the import-export trade builds up during the later period of the Fifth Plan, the Corporation is expected to become selfsustaining in its financial position. ETTDC will aim at balancing the two way trade in electronics with the rupee currency areas as early as possible.

The major benefit of the Corporation to the national economy will be that, it would be possible to convert a sizeable portion of imports from Western side to East European countries. From Table 18.3, it can be seen that the present possibilities of conversion of foreign exchange from West European source to East European source are to the tune of Rs. 20 crores per year for components and equipment. The Corporation will be able to establish constant liaison with the development and commercial agencies in the East European and other countries. This organisation can also shoulder partially the responsibility stepping up the growth of electronics in the country by arranging the transfer of advanced technologies from abroad. One of the main reasons inhibiting the build up of purchase of equipment and plant especially from East European countries for the electronics field is the inadequate and irregular supply of spares and the maintenance support from their supply organisations. The Corporation can take immediate action to rectify this position and improve the supply of spares for the stepping up of the production in different electronics sectors. Apart from converting a portion of the foreign trade to the soft currency areas, this organisation can constantly help users like DGCA, Defence, Home Ministry, I & B Ministry, Meteorological Department, P&T, Railways, etc. The present level of imports by these organisations of the order of Rs. 11 crores per year and by 1980 it may rise to Rs. 52 crores. ETTDC can make use of the availability of professional and high grade components in these countries. It will be necessary to convince the Indian users about the acceptability of East European products. In some cases, it is seen that the specifications of East European products differ only marginally as compared to Western specifications. ETTDC will hold constant technical and commercial discussions in these countries, if needed even at the Government level, to make organisations in East Europe, to suitably modify the specifications to suit our requirements. Increasing the export-oriented production will be a crucial assignment of the Corporation. With the technological advancement in our country in the production of certain components like tantalum capacitors, sophisticated switches, relays, etc., it would be possible to improve the export trade. Some of the countries abroad have acute shortage of trained manpower and they are prepared to divert labour intensive items to our country through bilateral trade agreements. The entrepreneurs in our country will be able to take advantage of the expertise existing at the Corporation in deciding the best way of transferring the advanced technologies from abroad.

Manpower

19.1 Introduction

Bhabha Committee envisaged that the average wage bill for producing electronic equipment would be 38 per cent of the sale value of which the wage bill for those engaged in direct production, engineering supervision, design and development in the plant would be about 28 per cent, while wage bill for auxiliary staff engaged in storage, purchase, administration, etc., would be about 10 per cent. The output per person employed for the manufacture of equipment in the electronics industry, including all supporting and auxiliary staff was estimated to be Rs. 9,000, against Rs. 12,000 per person directly employed in production. As the Committee envisaged a production of Rs. 300 crores worth of electronic equipment by 1975, the total manpower requirement was foreseen to be 3.3 lakhs, with the skilled workers, technical staff and engineers numbering 2.5 lakhs.

For the production of Rs. 300 crores worth of equipment, the production of roughly Rs. 84 crores worth of components was envisaged. The output per person employed in the components and other process oriented industries was assumed by the Committee to be about double of that for the equipment industry. On this basis, the total number of persons employed in the component production industry, in 1975, was estimated to be about 40,000 with skilled workers and technical engineers numbering about 32,000.

An additional manpower comprising of about 15,000 scientists and engineers and 30,000 supporting technical staff was envisaged for R&D activities in laboratories and research institutes outside the plants.

Thus it was expected that an investment of about Rs. 170 crores would provide employment in the electronics industry for about 4 lakh scientists, engineers, skilled workers and supporting staff, per capita investment being about Rs. 4,000.

Though we have to a large extent achieved the production targets set by the Bhabha Committee, this is not the case as far as the manpower employment in the industry is concerned. It is estimated that, at present, about 1.2 lakh persons are engaged as the production and supporting staff. This is only about 30 per cent of the projected figure. The main reason for the Bhabha Committee's estimates going awry, is the increase in per capita productivity. At present, the average per capita productivity at ex-factory value for the electronic equipment industry is about Rs. 30,000, while for component industry, it is 15,000, approximately. The per capita productivity estimates of Bhabha Committee at the current prices are of the order of Rs. 17,000 for equipment and Rs. 34,000 for components.

The increase in output per worker occurs primarily as a result of changes in production techniques. In view of these qualitative and quantitative changes, the Bhabha Committee estimates have been updated in this chapter.

19.2 The Experience of Developed Countries

Before going ahead with the task of projecting manpower requirements for the next decade, it is instructive to examine the existing employment and organisational structure in various sectors of the electronics industry in developed countries like UK and USA. This will also serve as a comparison between the manpower requirements of an industry, if it is labour intensive or capital intensive.

19.2.1. Employment Pattern in the UK Electronics Industry

The gross output of the electronics industry, in UK in 1970 and 1971 were £1409 and £1528 millions, respectively. The total number of employees in the industry in these two years was about 4.50 and 4.47 lakhs, respectively. Although the output of the industry increased by about 8 per cent during these two years, the employment decreased marginally. The per capita productivity in 1971 was £3400. The break up of the total production and employment in four broad sectors of electronics is given in Table 19.1. In the last column, gross per capita productivity is also included. It is maximum for capital equipment manufacturing units (see footnote to Table 19.1), being £4600, while for components, it is £2500.

Table 19.1. Gross output (in £M) and the employment (in thousands) of UK electronics industry.

Sector	1970		1971		Per capita productivity (as in 1971) (£)
	Output	Employment	Output	Employment	
Consumer equipment	169.0	57.0	214.0	62.4	3400
Components	337.0	139.9	339.0	136.1	2500
Computers	240.0	59.2	231.0	58.3	4000
Capital equipment*	432.0	99.8	445.0	97.7	4600
Telecommunication	231.0	94.2	299.0	92.1	3300
Total	1409.0	450.1	1528.0	446.6	3420(Gross)

* Capital equipment includes medical electronics, industrial electronic control, electronic measuring & testing equipment, nucleonic instruments and controls, public broadcasting, radar, navigational and radio communication equipment.

The occupational structure of the industry is given in Tables 19.2 and 19.3. It is apparent that a high proportion of the industry's manpower is engaged in administrative, technical and clerical (AT&C) occupations.

As far as the occupational structure is concerned, the electronics industry in UK can be divided into two subgroups, namely: (i) consumer electronics, telecommunication and components, and (ii) computers and capital equipment.

While in the former subgroup an average of 30 per cent of the staff is engaged in AT&C jobs and 48 per cent are semiskilled personnel (machinists, assemblers), in the latter subgroup more than 60 per cent are employed in AT&C jobs, the semiskilled personnel being bare 16 per cent of the total strength. The reduction in the demand for semiskilled personnel in the manufacture of computers and capital equipment is largely due to the high level of technology involved.

XIX

Table 19.2. Occupational structure of the UK electronics industry in 1971.*

Occupation	Staff (thousands)	Percentage
Administrative, technical & clerical	168.3	42
Manager & works supdts.	20.6	
Scientists & technologists	19.1	
Technicians & draughtsmen	48.0	
Office staff (clerical, etc.)	80.6	
Craftsman in skilled occupations	53.5	13
Machinist, assembly workers, etc.	145.9	36
Other employees	34.7	9
Total	402.4	100

* Only firms having more than 11 employees are considered.

Table 19.3. Employment pattern (%) in various disciplines of UK electronics industry (in 1971).

Occupation	Consumer equipment	Telecommunication	Components	Computers	Capital equipment
Administrative, technical and clerical	24	32	34	58	67
Craftsmen in skilled occupations	12	12	12	18	12
Machinists and assemblers	50	48	45	16	16
Other employees	14	8	9	8	5

The percentage of skilled workers which is about 12 is more or less constant in all the sectors of the industry.

Another striking feature of the employment in this industry is the high level of employment of women. It is about 48 per cent of the total. The majority of the female labour force is employed as semiskilled production workers on wiring and assembly tasks. The two sectors with a low proportion of production workers have also a considerably low percentage (about 29 per cent) of women employees.

The output per person involved in the production job is much higher than the gross per capita productivity. Sectorwise, the output per person is as follows: consumer electronics £6500, components £4000, computers £7000 and capital equipment £9000. The high level of productivity per person is due to the increased use of automation systems in the production units. On the average, male and female manual workers earn about £28 and £16, respectively, per week while male and female non-manual workers earn about £37 and £18, respectively. The wage bill amounts to about 40 per cent of the total production value.

During the year 1969-70, about £147 million was spent on scientific research and development in electronics. This is less than 10 per cent of the annual production during 1970. Within the manufacturing units, £130 million of the total expenditure was in the private industry and £13 million in public corporations. Nearly half of the expenditure was spent on salaries and wages of the R&D staff. The private industry during this period spent about 5 times more on applied research as compared to basic research and nearly 8 times as much on development as on applied research.

XIX

19.2.2. Employment Pattern in the USA Electronics Industry

The total sales of electronic equipment in USA during 1971 was \$27.1 billion. During 1971 the share of consumer, communication and industrial products (eg. computers, control, test and measuring, communication, navigational aids, medical electronics equipment) was \$5.5 and \$11.06 billion, respectively. The remaining sales represent the share of the defence, NASA and civil aviation departments. During the same year, the sales of US electronic component industry was valued at \$4.7 billion.

About 1.08 million persons were employed in electronics manufacturing and related activities at the end of 1971. The per capita productivity in terms of sale value was \$25,000. Table 19.4 lists the employment figure in four broad sectors of the industry. More than 66 per cent of the workers were engaged in the plants producing the end equipment, while the component manufacturing units were responsible for about 33 per cent of the employment. According to the US Department of Labour about half of the workers in electronics manufacturing units were in plant jobs (i.e. production, maintenance, transportation and service), while the rest were engaged in white collar jobs such as scientific, administrative, clerical and sales). In Table 19.5, the occupational structure of the industry is given. The structure is very much similar to that of the UK electronics industry given in Table 19.2. On the average about 40 per cent of the personnel are in AT&C jobs, the skilled and semi-skilled workers account for nearly 14 and 40 per cent, respectively of the total.

Another similarity of the industry in these two countries is the employment figures by sex. In USA also, they account for more than 40 per cent of the employment.

Table 19.4. Employment figures (thousands) in the four sectors of USA electronics industry (as in 1971).

Sector	Staff	Percentage
Consumer equipment	135.9	13
Communication equipment	440.1	40
Components and accessories	332.6	31
Computing machines	170.1	16
Total	1078.7	100

Table 19.5. Electronics manufacturing employment by major occupational groups and selected individual occupations (as in 1970).

Occupation	Staff (thousands)	Percentage
Administrative technical & clerical	395.1	37
Managers, officials, works supdts.	48.7	
Engineers & scientists	84.5	
Technicians & draughtsmen	70.9	
Clerical, sales, etc.	191.0	
Skilled workers	175.6	16
Machinists, assembly workers	467.8	44
Others	34.7	3
Total (of major occupational groups)	1074.2	100

The average weekly earning of production workers varies from \$120 to \$170 per week depending on whether it is in a component or computing machine manufacturing unit. The total wage bill amounts to about 35 per cent of the total production of electronics goods. For R&D activities \$2.3 billion were spent in 1970, which is about 8 per cent of the output during the year.

19.3 Indian Public Sector Experience

An idea regarding the organisational structure in the Indian electronics industry can be obtained by looking into the staffing pattern in some large scale manufacturing units like BEL and ECIL. BEL is primarily engaged in the manufacture of communication equipment, electron tubes, semiconductor devices, TV picture tubes, etc. Their production during the year 1973-74 was about Rs. 43 crores. The total number of personnel employed is around 14,000 with the per capita productivity of about Rs. 30,000. More than 75 per cent of the staff is directly employed in production units, while the remaining 25 per cent is engaged in activities like administration, accounts, etc. About 65 per cent of the employees are either scientists/engineers or skilled workers. The scientists, engineers, diploma holders and graduates account for about 8 per cent of the staff. The strength of unskilled and nontechnical staff is nearly 12 per cent of the total employment.

ECIL with an annual turnover of about Rs. 6.6 crores (1972-73) employs about 3,300 personnel. Per capita productivity during this year was Rs. 23,000, approximately. The Corporation is engaged in the production of passive components, semiconductor devices, television, computers, etc. The administrative staff accounts for more than 15 per cent of the employment. About 73 per cent are engaged as scientific and technical personnel while the remaining are in the unskilled category.

Presently the per capita investment in the electronics industry is estimated to be about Rs. 9000.

19.4 Employment Potential of the Indian Electronics Industry During the Fifth and Sixth Five Year Plans

The electronics industry in our country being predominantly labour intensive, the occupational structure is expected to be considerably different from the one in the developed countries. It has a very high employment potential for skilled and semiskilled workers as many of the manufacturing units require manual skill. At present, the semiskilled staff accounts for more than 60 per cent of the total manpower employed in the industry. The proportion of the in-plant and white collar workers differs from one sector to the other as it depends on factors like the extent of industrial automation, the usage of sub assemblies etc. From the ten year profile given by IPAG on the basis of extensive data available through the Task Force VII and other numerous analysis, information and technical panel reports, the additional manpower required by the end of the Fifth and Sixth Plan period has been estimated.

An electronic equipment production of Rs. 537 crores (base financial year 1973-74) is envisaged during the terminal year 1978-79 of the Fifth Plan period. The total value of the component production during the same period is expected to be Rs. 245 crores.

The production in these two sectors by the terminal year 1983-84 of the Sixth Plan is estimated to be about Rs. 1300 crores and Rs. 550 crores, respectively.

The present per capita productivity for electronic equipment industry

XIX

is about Rs. 30,000, while for component industry it is Rs. 15,000. During the terminal year of the Fifth Plan the productivity per person is expected to increase and go upto Rs. 35,000 for the equipment industry and about Rs. 20,000 for the components. These ratios, however, give a macro economic picture of the industry and cannot be used to give a detailed breakup of manpower requirement in each sector.

In Table 19.6, the estimate for the additional direct manpower required during the Fifth Plan period is given. The numbers given for the various sectors of the industry and the occupational structure were estimated from the existing manpower employment figures in the various public and private sector enterprises. Allowance has been made for the increase in productivity per person due to technology development. The employment potential of the industry is anticipated to be 1.86 lakhs during the Fifth Plan period. The semiskilled personnel alone account for 60 per cent of the total employment. These workers are to be engaged in jobs like assembling and machining. The demand for the scientists/engineers/diploma holders is likely to be about 14,500, while 24,500 skilled workers will be required.

The increase in employment during the Sixth Plan period is expected to be less than the corresponding increase in the output, since due to the improvements in the production techniques, per capita productivity is expected to increase further. The partial growth of mechanisation and automation of assembly line operations, the increased usage of integrated circuit technology and the associated miniaturisation will reduce the demand of semiskilled workers to some extent. The employment of engineers, scientists, skilled workers and administrative staff is expected to increase. In Table 19.7 the estimated additional direct manpower requirement for the industry, during the Sixth Plan period is given. The industry is expected to generate an additional manpower requirement of 2.14 lakhs. Table 19.6 and 19.7 reveal that the semiskilled labour will account for only 56 per cent of the additional manpower during the Sixth Plan period as compared to 60 per cent in the Fifth Plan period. It is anticipated that the demand for scientists/engineers/

Table 19.6. Estimated additional direct manpower required during the Fifth Five Year Plan.

Sector	Scientists/ engineers	Skilled	Semi skilled	Unskilled	Administrative	Total	Percentage of total
Consumer	1,000	2,000	15,000	2,000	2,500	22,500	12
Instruments & MEE	1,000	1,000	13,000	3,000	1,500	19,500	10
Computers & desk calculators	1,000	1,000	4,000	500	500	7,000	4
Control & industrial electronics	1,000	1,500	6,000	1,000	1,000	10,500	6
Telecommunication telemetry, two way com- munication, civil naviga- tion, mass communication	2,000	6,000	36,000	4,000	4,000	52,000	28
Components & materials	3,500	6,000	42,000	8,000	4,500	64,000	35
General facilities	2,000	4,000	1,000	1,000	2,000	10,000	5
Total	11,500	21,500	1,17,000	19,500	16,000	1,85,500	
Percentage of total	6	12	63	10	9		

Table 19.7. Estimated additional direct manpower required during the Sixth Five Year Plan.

	Scientists/ engineers	Skilled	Semi skilled	Unskilled	Administrative	Total	Percentage of total
Consumer	1,000	2,000	12,000	2,000	3,000	20,000	9
Instruments & MEE	1,500	1,500	14,000	3,000	3,000	23,000	11
Computers & desk calculators	2,000	2,000	6,000	5,500	1,000	11,500	5
Control & Industrial electronics	1,000	2,500	7,500	1,000	1,000	13,000	6
Telecommunication, telemetry, two way com- munication civil naviga- tion, mass communicati-	3,000	8,000	40,000	6,000	7,000	64,000	30
Components & materials	4,000	7,000	45,000	7,000	6,000	69,000	32
General facilities	3,000	6,000	2,000	1,000	2,000	14,000	7
Total	15,500	29,000	1,26,500	20,500	23,000	2,14,500	
Percentage of total	7.0	13.5	59.0	9.5	11.0		

diploma holders and skilled workers will be 18,500 and 33,000, respectively. The total wage bill by the terminal year of Sixth Plan period is expected to be 30 per cent of the production during the same period.

It is expected that the production of about Rs. 2600 crores worth of electronic equipment and components during the Fifth Plan period will provide an additional indirect employment to about 70,000 persons. This number will reach to about 100,000 by 1983-84, provided the projected production of about Rs. 6400 crores worth of electronic equipment and components is achieved. The indirect labour will mainly consist of servicemen and maintenance workers.

Hence the growth of the electronics industry is expected to generate an additional employment of 2.5 lakh and 3.1 lakh persons, respectively during the Fifth and Sixth Plan periods.

19.5 Breakup of Requirement of Production Workers

The personnel at the level of scientists/engineers are required to look after the design and manufacture of tools and products, control of production, process control, plant installation, maintenance, quality control, design and fabrication of assembly, test jigs and other R&D activities. The diploma level personnel are required for the supervision of plant, machinery and assembly line operation. They are also required for the use of sophisticated instruments and machines. The Industrial Training Institute (ITI) trained students are to be placed in the skilled workmen level to work on the tool room and other precision machines. They are also suitable for maintaining production machines and routine type of test and measuring instruments.

The semiskilled workers are required to work on the assembly line operations. The essential requirements being, (i) ability to take minor decisions, (ii) good reflexes, (iii) close coordination between hand and eyes, (iv) efficient handling of small (thin) components (wires), (v) handling of special assembly tool, etc. To become proficient in their job they require from a few weeks to a few months of training.

As ascertained by the Bhabha Committee, there is very little scope for the employment of unskilled labour in the electronics industry, except in an auxilliary capacity.

19.6 Present Status of Availability of Trained Manpower

19.6.1. Degree Courses

The number of institutions conducting the degree courses or equivalent in engineering and technology is nearly 140, with the sanctioned admission capacity of about 21,000 students. This is nearly 30 per cent less than the one existed during early sixties. The decision to curtail the admission capacity was taken as a remedial measure and to cope with the problem of unemployment among technical personnel. At present, the yearly admission is about 21,000 with an annual turnover of 16,500 students. Nearly 25 institutions are offering degree courses in electronics and communications and other related areas with an annual turnover of less than 1000 graduates.

19.6.2. Diploma Courses

At present, there are 284 polytechnics conducting diploma courses in engineering and technology. The existing admission capacity is 43,300 students. About 36,700 students are admitted every year, while the yearly outturn is 15,200 students. In addition, there are 24 women polytechnics in the country with sanctioned admission capacity of 2,500 students. The annual outturn from these institutes is about 950 students. Out of the 308 polytechnics only 42 are equipped with facilities for training in electronics field.

The share of electronics, telecommunication and other allied fields is as follows: against the total admission capacity of 1350 students, the yearly admission is about 1450, while the annual outturn is 550 students.

19.6.3. ITI and Other Apprentice Training Centres

There are 356 Industrial Training Institutes in the country conducting craftsman training programmes. Out of these, only about two dozens of them undertake training in field of electronics. The training programmes are confined only to the trade of mechanic (radio and TV) and mechanic (electronics/communication). The total number of seats available for these two trades in the country are 3,200 and 530, respectively. Besides this, there are 52 apprentice training centres conducting courses in the electronics trade. At these centres, 16-20 weeks of on-the-job training is given to the students.

Apart from this, many private training institutes conduct courses in radio/TV servicing, wiring, etc.

19.7 Anticipated Gap in the Demand and Availability of Trained Manpower

In view of the job requirements of scientists/engineers laid down earlier, only about 30 per cent of the total number of persons required in this category, need to be electronic and telecommunication engineers, the remaining being specialists in other areas like mechanical, electrical and chemical engineering, material sciences, ceramic, glass technology, metallurgy, physics and chemistry. Physicists, with post graduate degrees, provide a sizeable supply of electronics scientists. At present, more than 40 per cent of the post-graduate students in physics specialise in electronics/wireless and about 10 per cent in instruments. Majority of the students specialising in solid state/nuclear phy-

sics, which accounts nearly for 20 per cent of the total, has strong back ground of theoretical and/or experimental knowledge of electronics. Thus more than 70 per cent of the annual turn over of postgraduates in physics are suitable for absorption, either directly or after a few months of on-the-job training, in the electronics industry.

In view of the existing programmes in science, engineering and technology, it is anticipated that the demand for personnel in this category will be met with. The existing curriculum, however, needs to be modified. The future training programmes are discussed in the next section.

A shortage of skilled personnel is anticipated. This may be a bottle neck in the growth of the industry. Even the developed countries are faced with the shortage of skilled labour. In our country, we do not have adequate training facilities for tool makers as well as mechanics. It requires about 2-3 years for an ITI trained personnel to become proficient in his field. The existing admission capacity should be increased considerably in view of the future requirements. The curriculum in these institutes also needs updating.

The demand for semiskilled personnel though large is not likely to create any hinderance for the future development of the industry. These workers need about a few months of on-the-job training which can be taken up after their recruitment in the industry.

19.8 Future Training Programme

With the expansion and diversification of the electronics industry in India and the growing need for self-reliance in this field, there has been a continuing demand for electronics engineers specialised in the design and development of electronic equipment and systems. This demand is particularly pressing in the fast growing areas, such as television, computers, communications, instrumentation and industrial electronics, which are poised for major growth during the next decades. In view of the worldwide trends in electronics, it will be prudent that a few institutions conducted specialised courses in the design, development, application and use of semiconductors and integrated circuitry.

Presently, there are instances where the same subject is taught to different standards in different institutions. There is need to have a uniformity of standards. The training programmes should be constantly reviewed to include technological developments that take place in the fast growing field of electronics.

At present, the training of engineers tends to be more theoretical with less emphasis on practical work. The design and laboratory work should be oriented towards including a habit of engineering methodology such as dealing with open ended problems, decision making and innovation.

Currently there is a shortage of instrumentation engineers. The demand for these personnel is expected to increase during the next decade. Instrumentation engineers are required to undergo a broad training encompassing a number of disciplines in science and technology, as well as in technical skills of high order. In view of this, a modification and augmentation of existing courses is necessary. At least five institutions at the degree level and ten at the diploma level are required to offer programmes in process control instrumentation. The annual intake of each institute could be 25 and 40, respectively, at these two levels. The Department of Electronics is providing

XIX

technical support for the setting up of an Advanced Training Institute for electronics and process control instrumentation at the Central Training Institute for Instructors at Hyderabad.

Manpower requirement for medical electronics is of varied and diverse nature. Design and production engineers in sufficient numbers will be required to undertake the development and manufacture of these life saving equipment. This requirement can be met only if the universities and IITs offer full-fledged medical electronics programmes to students at B.Tech and M.Tech levels. The industry can also coordinate with educational institutions and hospitals in setting up training programmes and workshops. Students should be encouraged to take up summer jobs for working in hospitals. Given the need for the industry to meet the demand target as also for the hospitals to keep well maintained equipment in its repository, the necessity to train a corps of skilled technicians becomes imminent. It might be mentioned that according to the findings of a recent survey, lack of skilled personnel has been one of the factors that is responsible for nearly 60 per cent of the equipment to be out of order. Equipment operators should be trained on the job for a minimum of six months to one year so that they get acquainted with the nuances of life-saving equipment. Diploma holders should be trained in maintenance for upkeep of medical electronic equipment. They should also be given rudimentary courses in medical physiology.

Based on the demands of the semiconductor industry, curriculum for training programmes should be developed. Besides the theory courses on semiconductor devices microelectronics and computer aided design, laboratory facilities for semiconductor device technology covering oxidation, photolithography, diffusion, vacuum techniques and thick film techniques are desirable for training students.

There is, at present, lack of suitably trained manpower to build up reasonable levels of activity in sophisticated areas like that of computers. The delegations sent by the Department of Electronics to East European countries have noted that the number of people involved in the computer industry in the country is only a small percentage of the counterpart even in the smaller countries in Europe. Minicomputer networks and midcomputers with a number of intelligent terminals are planned to complement a small number of maxicomputers during the next decade. This requires development of expertise in areas of network engineering, maintenance and management. Among the wide range of minicomputer applications are process control, data communication and instrumentation control which require elaborate systems and application software for time sharing data acquisition, online control, communication and the like. This needs specialised programmers with engineering background.

Limited facilities exist for training technicians in areas of glass, ceramic and vacuum technology. There is a dearth of tool engineers and technicians. To ensure adequate progress in the electromechanical areas like printers, disc drives, etc., the training of such personnel should be taken up on priority basis. In view of the development of TV broadcasting (terrestrial and satellite), there is a need for large number of TV technicians.

At the level of highly skilled craftsmen and technicians, there is no

organised training in the various sectors of electronics industry. In order to meet this need, the Ministry of Labour is proposing to establish an Advanced Vocational Training Institute with Swedish assistance. This Institute will offer training in various disciplines such as television, communication, consumer, industrial, medical electronics and process control instrumentation.

During the formulation of the curriculum for training courses in engineering and technology, active participation from the industries is desirable. Frequent dialogue between the industry and educational institutions will help in providing the trained manpower of desired quality. In-plant training is as important as the theoretical coursework in the training programmes. At present, it is not being sufficiently emphasised in majority of institutions.

In order to have properly qualified personnel to teach in the advanced courses and overcome the obsolescence that is inevitable in the field of electronics, it is suggested that short term courses in specified advanced modern topics be organised by institutions which have the facilities for this purpose.

19.9 Reversing the Brain Drain

A scheme is being drawn up by the Department of Electronics for the return of Indian scientists and engineers in the electronics and allied fields from abroad. As on June, 1973 there were about 18,900 personnel enrolled in the Indians Abroad Section of National Register of Scientific and Technical Personnel, of which 39 per cent were engineers, 33 per cent scientists, 21 per cent medical personnel and 7 per cent technologists. About 50 per cent of the total have already returned. Of the remaining, nearly 1,760 are either mechanical, electrical or electronics communication engineers and about 590 are physicists. Particular attention is being paid to the problems peculiar to the placement of these engineering/scientific/technical personnel in organisations in India. The main thrust of the present programme would be on getting professional men who are at present at the intermediate level and are deemed to be intrinsically of higher quality in their profession. These persons who are capable of acting as nucleating centres for the development of selected areas of electronics which are crucial for future development, shall be carefully identified. In view of the paucity of suitable placement and opportunities for such persons in existing programmes in institutions/organisations, there have been difficulties in the past in getting this proposal to a practical start. With the formulation of the Fifth Five Year Plan in Electronics and Telecommunications, many new programmes will be taken up in the existing industries/organisations and many new industries/organisations will be started both by the Department of Electronics and by other Governmental and non-Governmental organisations. It should then be possible to bring in suitable qualified persons from abroad and provide them with the right kind or areas of work and working environments to enable them to accomplish time bound tasks.

An important avenue for bringing in Indian scientists/engineers from abroad would be the production of technocrat entrepreneurship. There are many highly qualified persons who would like to come back to India to start their own industries. They would have to be provided with information regarding areas in which scope exists for the starting of new industries and the relevant information on the various procedures that are involved in the initiation of new industries.

Bibliography

A. Report of the Panels set up by IPAG, Electronics Commission

1. Report of the panel on medical electronics, October 1973.
2. Report of the panel on TV test instruments, January 1974.
3. Report of the panel on control components, September 1973. This panel had, in addition, two sub-groups viz., (a) Panel on industrial drives and controls, (b) Panel on power station load despatch and telemetry.
4. Report of the panel on ultra pure materials for electronics, May 1974.
5. Report of the panel on chemicals & plastics for electronics, July 1974.
6. Report of the panel on indigenisation of microwave components manufacture, June 1974.
7. Report of the panel on passive components, February 1974.
8. Report of the panel on mechanical & electrical components for electronics, April 1974.
9. Report of the panel on special electron tubes, March 1974.
10. Report of the panel on guidelines for standardisation in electronics, January 1975.
11. Report of the panel on guidelines for evolving funding procedures for R&D projects to be funded by Electronics Commission, September 1974.

B. Report of the Technical Panels/Committees set up by Department of Electronics

1. Report of the technical panel on manufacture of TV glass shells and TV picture tubes, August 1972.
2. Report of the semiconductor committee, November 1972.
3. Report of the technical committee on ferrites, February 1973.
4. Report of the panel on minicomputers, March 1973.
5. Report of the panel on electronic desk calculators.

C. IPAG Reports

Technical Analysis Reports

1. Profile of competition with radio industry in the organised sector, April 1972.
 2. Economical scale of production for the television receiver industry under Indian conditions, April 1972.
 3. Analysis of computerisation in the Bombay-Poona region, May 1972.
 4. Some technical & regulatory problems associated with the indigenous manufacture of magnetic tapes, May 1972.
 5. Analysis of the factors governing the penetration of the rural radio market, June 1972.
 6. Economics of regional computer centres for developing countries, June 1972.
 7. Planning for indigenous production of minicomputers and programmable calculators, Part-1, Demand profile, July 1972.
-

8. Planning for indigenous production of minicomputers and programmable calculators, Part-2, Peripherals, August 1972.
 9. Planning for indigenous production of minicomputers and programmable calculators, Part-3, Level of integration, September 1972.
 10. Planning for indigenous production of minicomputers and programmable calculators, Part-4, Production Planning, September 1972.
 11. Planning for indigenous production of minicomputers and programmable calculators, Part-5, Software and manpower, September 1972.
 12. Planning for indigenous production of minicomputers and programmable calculators, Part-6, Financial analysis, September 1972.
 13. Planning for the promotion of minicomputer applications in India, Part-1, Production of capital equipments, September 1972.
 14. Planning for the promotion of minicomputer applications in India, Part-2, Telephone network, September 1972.
 15. Analysis of elasticity of urban consumers of TV receivers, September 1972.
 16. Planning for the semiconductor industry in India, November 1972.
 17. A first approximation analysis of demand and investment profile for electronics and communication during the decade 1971-1981, November 1972.
 18. An approach to standardisation in the electronics industry, December 1972.
 19. A normalised demand profile for electronic materials, January 1973.
 20. A techno-economic analysis of two-way communication equipments, January 1973.
 21. An approach to the indigenisation in the computer peripheral industry, January 1973.
 22. Electronic components industry—an analysis, February 1973.
 23. Microwave solid state devices & materials—an analysis, February 1973.
 24. An analysis of import of electronic goods during 1972-73, February 1973.
 25. Planned introduction of medical electronics to hospitals in India, Part-1, General analysis, February 1973.
 26. Optimal size of firms in the Indian electronic industry, March 1973.
 27. Techno-economic analysis of possible strategy for the analysis of penetration of rural radio market, March 1973.
 28. Process control instrumentation: Problems during the nucleation of the industry, March 1973.
 29. A strategy for antenna manufacture in India, March 1973.
 30. Potential geographical locations for setting up electronic industries in India, March 1973.
 31. Analysis of the factors governing the location of a joint real-time computer for Air India and Indian Air Lines, April 1973.
 32. Planning for the indigenous development and production of instrument control components, May 1973.
 33. Planning for the indigenous development and production of TV test instruments, June 1973.
 34. A sequential optimal decision model for the R&D plan in electronics, July 1973.
 35. Planning for the indigenous development and production of microwave test and measuring instruments, September 1973.
 36. A techno-economic analysis of waveguides manufacture, September 1973.
 37. Preliminary decision of a computer-based cultivator information system, September 1973.
 38. Analysis of technical and organisational requirements of computerisation in Indian steel plants, November 1973.
-

39. Improving yield of semiconductor devices, November 1973.
40. Capital equipment and primary material requirements for the semiconductor industry, December 1973.
41. Technological alternatives and demand profile for electronic equipment in the Indian pulp and paper industry, January 1974.
42. Energy crisis: An analysis of its impact on the Indian electronics industry, January 1974.
43. Cost benefit analysis of foreign equity participation in the Indian computer industry, December 1973.
44. Planning for the manufacture of printed circuit boards in India, February 1974.
45. Materials for electronics industry in India: An analysis, February 1974.
46. Custom manufacture of capital equipment for the electronics industry in India, March 1974.
47. An integrated approach to the system study of a broadcast satellite system, March 1974.
48. Strategy for the indigenous production of microwave tubes, March 1974.
49. A strategy for transreceiver manufacture, March 1974.
50. A preliminary analysis of export possibilities of selected electronic items, November 1974.
51. High purity alloys in electronics, December 1974.
52. Environmental pollution monitoring instrumentation: Planning and implementation strategy for India, December, 1974.
53. Connector industry in India: Problems and prospects, December 1974.
54. Materials for electronic component industry—glasses and ceramics, December 1974.
55. Materials for electronic component industry—metals and alloys, January 1975.
56. FM broadcast : The future of radio industry in India, January 1975.
57. Mining electronics—prospects for India, January 1975.
58. Agri-electronic instrumentation—its relevance to Indian agriculture, January 1975.
59. A preliminary analysis of tethered balloon communication and its application to India, February 1975.
60. A case study of computer requirements for large scale banking, February 1975.
61. Modernisation of signalling and traction facilities in Indian Railways : A perspective analysis, February 1975.
62. The March fever, February 1975.
63. A comparative study of display devices from the indigenous angle, February 1975.
64. Control and instrumentation in Indian fertiliser industry—current status and strategy for progressive indigenisation, February 1975.
65. Electronic aids to marine activities : The Indian scene, March 1975.
66. Planning for automation in semiconductor industry in India, February 1975.
67. Techno-economics of alternative power supplies for community TV reception, March 1975.
68. Maritime communication, February 1975.
69. Power semiconductor devices—their role in the industry, March 1975.
70. Indian Railway's modernisation programme in telecommunication facilities vis-a-vis indigenous capabilities, March 1975.
71. An analysis of subcontracting software on a modular basis, March 1975.

72. Low-cost peripherals : Their relevance to the Indian computer industry, March 1975.
73. Strategy for progressive indigenisation of electronic materials, March 1975.
74. Digital data communication via satellites for Defence applications, February 1975.
75. Formation of a development project for automatic finger print identification, May 1975.

Technical Information Reports

1. Structure and function of Electronics Commission and the Department of Electronics, April 1972.
2. Structure and function of IPAG, April 1972.
3. Background information for new entrepreneurs in the electronics industry, April 1972.
4. Research trends upto 1971 in data links and remote processing, May 1972.
5. Trends in the application of electronics and communication technology to railway and other transport networks, May 1972.
6. Comparison of large computer systems suitable for regional computer centres, May 1972.
7. Research trends upto 1971 in transducer technology, June 1972.
8. Technology trends upto 1971 in integrated circuit production, June 1972.
9. Statistical outline of electronics production during 1965-71, November 1972.
10. Market survey on telemetry and telecontrol systems, November 1972.
11. Government organisation for co-ordinating the electronics industry in France, November 1972.
12. Information processing at IPAG : A framework for computerisation, February 1973.
13. GaAs semiconductor technology : State-of-art and perspective technological alternatives, February 1973.
14. Navigational aids : State-of-art and perspective technological alternatives, March 1973.
15. Telecommunications : State-of-art and perspective technological alternatives, March 1973.
16. Medical electronics equipments : Information to users, June 1973.
17. Industrial electronics and control : technological trends and alternatives, July 1973.
18. A classification for the electronics industry, July 1973.
19. Product identification in the electronics industry, August 1973.
20. Energy crisis : An annotated bibliography, December 1973.
21. Potential application of remote sensing to economic development in developing countries, February 1974.
22. Computers in medicine, February 1974.
23. Analytical instruments : Technological trends and alternatives, March 1974.
24. Recent trends in international telecommunication, March 1974.
25. Agri-electronic instrumentation—an appraisal of the technique and methods, November 1974.
26. Credit facility for public sector imports, December 1974.
27. Environmental quality monitoring instrumentation : A critical appraisal of current methodologies, research trends, and future needs, December 1974.
28. Mass media of education : A comparative study of radio and television, January 1975.

Manpower Reports

1. Manpower training for the semiconductor industry, February 1974.
2. Manpower profile for implementing the Fifth Five Year Plan for electronics and communication, February 1974.
3. The role of intensive training schemes for plan implementation, March 1974.
4. Report of the Committee on Small and Medium Entrepreneurs : Implementation strategy for electronics and communication, March 1974.

Area Survey Reports

1. A perspective analysis of trade and technology cooperation in electronics with Hungary, February 1974.
2. A perspective analysis of trade and Technology cooperation in electronics with Australia, February 1974.
3. A perspective analysis of trade and technology cooperation in electronics with USSR, February 1974.
4. A perspective analysis of trade and technology cooperation in electronics with France, March 1974.
5. A perspective analysis of trade and technology cooperation in electronics with Poland, March 1974.
6. A perspective analysis of trade and technology cooperation in electronics with Japan, March 1974.
7. A perspective analysis of trade and technology cooperation in electronics with German Democratic Republic, July 1974.
8. A perspective analysis of trade and technology cooperation in electronics with Canada, July 1974.
9. A perspective analysis of trade and technology cooperation in electronics with Netherlands, July 1974.
10. A perspective analysis of trade and technology cooperation in electronics with Yugoslavia, August 1974.
11. A perspective analysis of trade and technology cooperation in electronics with Federal Republic of Germany, August 1974.
12. A perspective analysis of trade and technology cooperation in electronics with Czechoslovakia, September 1974.
13. Electronics exports to Gulf Countries : A preliminary survey, September 1974.
14. A perspective analysis of trade and technology cooperation in electronics with Denmark, September 1974.
15. A perspective analysis of trade and technology cooperation in electronics with Rumania, October 1974.
16. A perspective analysis of trade and technology cooperation in electronics with United Kingdom, October 1974.
17. A perspective analysis of trade and technology cooperation in electronics with Italy, October 1974.
18. A survey of electronics industry in the People's Republic of China, November 1974.
19. A perspective analysis of trade and technology cooperation in electronics with Latin American Countries, February 1975.
20. A perspective analysis of trade and technology cooperation in electronics with Bulgaria, February 1975.
21. A survey of electronics industry in South Korea, March 1975.

D. Special Reports

1. Advanced system for communication and mass education for India's deve-

- lopment (ACME), B. Prasada, and J. P. Singh (ed.), Indian Institute of Technology, Kanpur, June 1969 (Final Report).
2. Advanced system for communications and education in National Development (ASCENO), School of Engineering, Stanford University California, June 1967.
3. Annual statistical survey of the electronics industry, National Economic Development Office, London, 1972.
4. Annual convention, IEEE India section, Bombay 1973.
5. Annual convention of the Computer Society of India, 1972.
6. Annual report, Government of India, Department of Space, 1973-74.
7. Annual report, Government of India, Ministry of Information and Broadcasting, New Delhi, 1972-73.
8. All India Radio Fifth Plan—Shelf of Projects, Directorate General.
9. Compendium of calibration, measurement and testing facilities at CIL, Chief Inspectorate of Electronics, Bangalore.
10. Compendium of environmental test equipments in India, Society of Environmental Engineering, Bangalore.
11. Compendium of type approved electronics stores, Vol. I & II, Chief Inspectorate of Electronics, Bangalore.
12. Computer development in India, report submitted to the Atomic Energy Commission, October 1967.
13. Computers in India—Report of a Working Group on Computers submitted to the Electronics Committee, Government of India, December, 1968.
14. Computer industry for India—A proposal from Electronics Corporation of India Ltd., December 1970.
15. Computer networks, Infotech state-of-the-art report 6, Infotech Information Limited, UK, 1971.
16. Data base management : The key to long range systems development Ferguson, A., Infotech state-of-the-art report 8—Application technique, Infotech Corporation, UK, 1972.
17. Design and construction of large steerable serials, IEE publication, 1966.
18. Development and production plans draft, Bharat Electronics Limited, Bangalore, June 1972.
19. Directory of Indian instruments, All India Instrument Manufacturers and Dealers Association, Bombay, 1969.
20. Directory of Indian process control instruments, IDEMI, Bombay, 1973.
21. Economics of scale in manufacturing industry, Cambridge University Press, 1971.
22. Electronics 1985, Vol. I to IV, Electronics Industries Association, Washington, 1972.
23. Electronics in India, Report of the Electronics Committee (Chairman : H. J. Bhabha) Govt. of India, February 1966.
24. Electronics in India, S. Swaran Ed., Statistical Information Bureau, Bombay, 1973.
25. Electronic market data book, Electronics Industries Association, Washington, 1972.
26. Electronic products and instrumentation developed in the laboratories of the Department of Atomic Energy, Electronics Board of the Department of Atomic Energy, Bombay, 1972.
27. Fifth Five Year Plan—Television and broadcasting, Planning Commission (Transport Division), Planning Commission Circular No. T&C/2(40)/72 dated 23.6.1973.

28. Fifth Five Year Plan—Telecommunication and electronics, Report of the Task Force VII of the Planning Commission's Steering Committee on Engineering Industries, March 1973.
29. Final Report of Task Force on R&D relating to electrical industry and power systems, NCST, August 1973.
30. First international biomedical engineering workshop series, 1972.
31. Forecast of the integrated circuit business, Arizona : Integrated Circuit Engineering Corporation, 1972.
32. Gallium arsenide and related compounds, Institute of Physics Conference, London, 1971,
33. Gaps in technology between member countries—OECD, Paris, 1968.
34. Importing or exporting of computer software, Auerbach, A. L., Ed., Proceedings of the Jerusalem Conference on Information Technology, ILTAM Corpn. for Planning and Research, Jerusalem, 1971.
35. Indian electronics directory, Electronic Component Industries Association, 1974.
36. Infotech state-of-the-art reports, Infotech Corporation, UK, 1971.
37. RDOEI Seminar Record—Industries machines and their control, 1971.
38. Instrument industry in India, An interim report, Department of Atomic Energy, 1970.
39. LSI : The changing interface, McGraw Hill, New York, 1969.
40. Selection and evaluation of computer personnel, On the management of computer programming, Mayer, D. B. and Stalnaker, A. W., Weinwurm, G. F. (Ed.) Auerbach Publishers Inc., New York, 1970.
41. Medical Electronics—Prosthetics, Chapter 16, potential civilian markets for the military—Electronics industry, John E., (Ed.) Ullmann Praeger Publishers, New York, 1970.
42. National science and technology plan for process control instrumentation, Report of the Planning Group No. 10 of NCST Panel No. 4, October 1972.
43. Dislocation free gallium arsenide single crystals, A. Steinemann and V. Zimmarli, Proc. International Conference on Crystal Growth, Boston, 1966, Pergamon Press, Oxford, 1967.
44. Planning for advanced skills and technologies, United Nations, 1969.
45. Power semiconductor applications, Vol. I and II, IEEE Press, 1972.
46. Process control equipment market—New York, Frost and Sullivan Inc., March 1972.
47. Proceedings of the first meeting of the National Advisory Committee on Electronics, New Delhi, March 1974.
48. Proceedings of 22nd electronic components conference, Electronics Industries Association, Washington DC 1972.
49. Proceedings of the national conference on electronics, Electronics Commission, 1971.
50. Proceedings of the seminar on electronic instrumentation, Military College of Electronics and Mechanical Engineers, Secunderabad, 1971,
51. Proceedings of the symposium on electronics, Vol. I & II, Department of Atomic Energy, Hyderabad, 1972.
52. Gallium arsenide : Proceedings of the second international symposium, Dallas, 1966, C. I. Pederson (Ed.), Institute of Physics and the Physical Society, London, 1967.
53. Gallium arsenide : Proceedings of the international symposium, Reading 1966, A. C. Stickland (Ed.), the Institute of Physics and the Physical Society, London, 1967.

54. Proceedings of the symposium on electronics (Microwave technology,) Committee on Electronics, Department of Atomic Energy, Bombay, 1970.
55. Approaching the minicomputers on a silicon chip—progress and expectations for LSI circuits, H. G. Rudenberg, Proc. of AFIPS conference, Vol. 40, 1972.
56. Report of the INSAT Task Force (submitted to the Planning Commission), 1973.
57. Raby Committee report, Ministry of Technology, UK.
58. Report of the expert group on geoscientific instruments, Committee on Science & Technology, January, 1972.
59. Report of the planning group on equipment of panel on marine resources, National Committee on Science & Technology, New Delhi, 1973.
60. Report 382—International Radio Consultative Committee—XIth plenary session, October, 1966.
61. Report on science and technology plan for chemical industry, Vol. I, NCST, June, 1973.
62. Report of the Working Group on Computers, Electronics Committee, Government of India, December 1966.
63. Satellite Instructional Television Experiment, Indian Space Research Organisation (ISRO).
64. Seminar on Indian programme for space research and applications—Report on communications, Indian Space Research Organisation, Ahmedabad, August 1972.
65. Seminar on manpower for electronics, Institution of Engineers (India), Poona, 1972.
66. Communication satellites for education and development—The case of India, Schramm, W and Nelson, Vol. II, US Agency for International Development, Washington DC, August 1968.
67. Special materials—Report on the S&T plan of the NCST group, NCST August 1973.
68. Specialised common carrier communications, Report No. 68. Frost & Sullivan Inc., USA, January 1971.
69. Status of integrated circuits mid year 1971, Arizona, Integrated Circuit Engineering Corporation, 1971.
70. Symposium on reliability of electronics through environmental engineering, LRDE, Bangalore, 1971.
71. Report of the Task Force on rare metals and other special metals and alloys, The Steering Group on Metallurgical Industries, Planning Commission, New Delhi, November 1972.
72. Technical manpower bulletins, Division of Scientific and Technical Personnel, CSIR, New Delhi.
73. Telecommunication Capacity Planning Committee, Ministry of Communications, May 1973.
74. Telecommunications Research Review Committee, Working Group reports, 1972.
75. Government markets—Ten year forecast, C. A. Bean, Electronic Industries Association, Washington, 1971.
76. Various publications of the Institute for Defence Studies & Analyses.

Appendix

List of specialists who assisted in the preparation of the report

This report was made possible by the direct or indirect contributions of a large number of specialists representing almost all the important organisations including national laboratories, university departments, public sector industries, defence electronics establishments, Ministries concerned with electronics, associations promoting electronics, etc.

A. The report was prepared by a Committee consisting of the Chairman, Electronics Commission, as Chairman, Director (IPAG) as Member Secretary, and all the Officers of the Information, Planning and Analysis Group as members. Composition of the Committee is given below:

Professor M. G. K. Menon (*Chairman*) Dr. N. Seshagiri (*Member Secretary*)
Chairman, Electronics Commission Director (IPAG), Electronics Commission

Policy Planning & Analysis Division, IPAG

Dr. A. P. Agnihotry
Senior Scientific Officer

Shri. Pradeep Kumar
Senior Project Analyst

Dr. V. P. Bhatkar
Senior Scientific Officer

Dr. S. L. Sarnot
Senior Scientific Officer

Dr. R. C. Chopra
Senior Scientific Officer

Dr. R. Srinivasan
Senior Scientific Officer

Dr. R. Devanathan
Senior Scientific Officer

Shri. M. S. Vasudeva
Senior Scientific Officer

Dr. V. K. Misra
Senior Scientific Officer

Dr. M. J. Zarabi
Senior Scientific Officer

Dr. S. G. Patil
Senior Technical Officer

Technology Development and Implementation Division, IPAG

Dr. A. K. Chakravarty
Senior Scientific Officer

Shri. E. R. Ramachandran
Senior Scientific Officer

Dr. S. M. Goklaney
Senior Scientific Officer

Dr. K. S. Srinivas
Senior Scientific Officer

Data Bank and Informatics Division, IPAG

Dr. P. Chandrasekhar
Senior Systems Scientist

Dr. N. Vijayaditya
Senior Scientific Officer

Dr. K. K. Krishnan Kutty
Senior Systems Scientist

Publications and Entrepreneur Guidance Division, IPAG

Shri S. Adiga
Senior Technical Publication Officer

Western Regional Cell, IPAG

Shri G. S. Rao
Senior Scientific Officer

Eastern Regional Cell, IPAG

Shri S. N. Chakravarty
Information Research Officer

Northern Regional Cell, IPAG

Shri Satish Kumar
Information Research Officer

Southern Regional Cell, IPAG

Shri R. T. Narendra
Senior Market Analyst.

B. The Planning Commission set up a Task Force on Electronics and Telecommunication. This Task Force prepared extensive report which formed the basis for the Fifth Five Year Plan Profile of the Department of Electronics. The Task Force report also reflects the shelf of projects of the Ministry of Communications, Ministry of Information & Broadcasting, Ministry of Defence, Ministry of Tourism and Civil Aviation, Ministry of Industrial Development, Department of Atomic Energy and the Department of Space. The information content of the Task Force report was significantly updated and presented concisely in this report. The Task Force composition is given below as its members have significantly contributed to the preparation of this report.

Professor M. G. K. Menon *Chairman*
Secretary
Department of Electronics

Dr. Amarjit Singh
Director, CEERI,
Pilani

Shri P. R. Latey
Chief Engineer, Planning Commission
New Delhi

Shri A. Banerjee
Post and Telegraph Directorate
New Delhi

Shri C. R. Subramanian
Managing Director, BEL
Bangalore

Shri B. Bhanot
Development officer (Electronics)
DGTD, New Delhi

Shri T. S. Subramanian
Director, TRC
New Delhi

Shri I. K. Gupta
Chairman, ITI Ltd, Bangalore

Shri N. T. Taskar
Director (Tech), Dept. of Electronics

Shri B. L. Jain
Joint Secretary (P&C)
Ministry of Defence, New Delhi

Shri Y. Venkatramiah
Chief Engineer, All India Radio
New Delhi

Shri H. B. Lal
Joint Secretary, Dept. of Defence Supply
Ministry of Defence, New Delhi

Shri S. R. Vijayakar
General Manager, ECIL
Hyderabad

Shri Laljee Singh
Director, Ministry of Railways
New Delhi

Dr. N. Seshagiri *Convener*
Director, IPAG
Electronics Commission

The Task Force set up seven working groups with the following members:

1. Working Group on Consumer Electronics

Dr. Ram K. Vepa
Joint Secretary
Dept. of Electronics

Coordinator

Shri S. C. Bhattacharjee
Director (R&D), AIR
Delhi

Shri R. K. Arora
Joint Director, DCSSI
Delhi

Dr. P. Chandrasekhar
Senior Systems Scientist
IPAG, Electronics Commission

Shri B. Bhanot
Development Officer (Electronics)
DGTD, Delhi

2. Working Group on Mass Communication

Shri D. V. Phatak
Asst. Chief Engineer, AIR,
Delhi

Coordinator

Shri C. V. Ramachandran
Manager (Projects), BEL
Bangalore

Shri B. Bhanot
Development officer (Electronics)
DGTD, Delhi

3. Working Group on Telecommunication

Shri C. S. S. Rao
Manager (Production), ITI Ltd
Bangalore

Coordinator

Shri T. S. Subramanian
Director, TRC
Delhi

Shri A. Banerjee
Post & Telegraph Directorate
Delhi

Shri N. T. Taskar
Director (Tech.)
Department of Electronics

Shri R. G. Deodhar
Development Officer (Electronics)
DGTD, Delhi

Shri G. S. Rao
Senior Scientific Officer
IPAG, Electronics Commission

Shri C. V. Ramachandran
Manager (Projects), BEL, Bangalore

4. Working Group on Aerospace Electronics and Communication

Shri H. B. Lal Joint Secretary, Dept. of Defence Supply Ministry of Defence, Delhi	<i>Coordinator</i>	Shri C. R. Thirumalai Director (Comm), DGCA Delhi
Shri R. G. Deodhar Development Officer (Electronics) DGTD, Delhi		Dr. R. Srinivasan Senior Scientific Officer IPAG, Electronics Commission

5. Working Group on Radar and Defence Systems

Shri H. B. Lal Joint Secretary, Dept. of Defence Supply Ministry of Defence, Delhi	<i>Coordinator</i>	Dr. N. W. Nerurkar Director (Tech) Department of Electronics
Shri I. C. Bansal Deputy Secretary, Ministry of Defence Delhi		Dr. R. P. Shenoy Chief Technical Officer BEL, Ghaziabad
Brig. S. Misra Director of Research and Training Ministry of Defence, Delhi		Shri S. N. Chakravarty Information Research Officer IPAG, Electronics Commission

6. Working Group on Computers, Control & Industrial Electronics

Dr. N. Seshagiri Director, IPAG Electronics Commission	<i>Coordinator</i>	Shri A. N. Rajabhadur Instrumentation Ltd Kota
Col. A. Balasubramanian OSD (Computers) Department of Electronics		Dr. S. Srikantan Head, Computer Division ECIL, Hyderabad
Shri R. G. Deodhar Development Officer (Electronics) DGTD, Delhi		Dr. K. K. Krishnan Kutty Senior Systems Scientist IPAG, Electronics Commission

7. Working Group on Instruments and Instrumentation

Shri S. R. Vijayakar General Manager, ECIL, Hyderabad	<i>coordinator</i>	Dr. S. K. Mangal Head, Medical Electronics Division CSIO, Chandigarh
Shri K. R. Banerjee Head, (R&D) Instrumentation Ltd, Kota		Shri E. R. Ramachandran Junior Scientific Officer IPAG, Electronics Commission
Shri B. Bhanot Development Officer (Electronics) DGTD, Delhi		

Based on the system requirements arrived at by the above Working Groups, the components requirement was worked out by the following members of IPAG, Electronics Commission :

Dr. S. L. Sarnot Senior Scientific Officer	Dr. K. S. Srinivas Senior Scientific Officer
Dr. M. J. Zarabi Senior Scientific Officer	

C. The material of the report is partly based on the information and guidelines given in the various panels constituted by the Electronics Commission. The members of these panels and the organisations they represented have, therefore, made significant contribution to the information content of this report.

1. Panel on Medical Electronics

Dr. K. G. Nair Head of Dept. of Cardiology KEM Hospital, Bombay	<i>Chairman</i>	Dr. S. K. Mangal Head, Medical Electronics Divn. CSIO, Chandigarh
Dr. R. S. Chawla Assistant Director General Directorate General of Health Services, Delhi		Dr. A. K. Mukherjee Nuclear & Allied Instrumentation Division ECIL, Hyderabad
Dr. S. K. Guha Head, Biomedical Engineering Group Indian Institute of Technology & All India Institute of Medical Sciences Delhi		Professor B. Ramamurthi Director Institute of Neurology Madras
Dr. J. D. Henderson Maintenance Engineer CMC Hospital Vellore		Dr. M. K. Vaidya Chief Medical Officer KHI Hospital Ghataprabha
Shri T. G. Krishnamurthy Consultant for Associated Electronic Engineers Bangalore		Shri E. R. Ramachandran <i>Convener</i> Senior Scientific Officer IPAG, Electronics Commission

2. Panel on TV Test Instruments

Dr. Ram K. Vepa Joint Secretary Dept. of Electronics	<i>Chairman</i>	Prof. M. Murugesan IIT Bombay
Dr. G. N. Acharya Deputy Director CEERI, Pilani		Shri R. S. Prakasam ECIL, Hyderabad
Shri Pramod P. Kale Electronics Systems Division Space Application Centre ISRO, Ahmedabad		Shri P. N. Rangole Scientist, CEERI Pilani
Shri M. S. Kathuria Eskay Electronics Pvt. Ltd. New Delhi		Shri P. Sandell President, IMDA Regional Council, Bombay
Shri C. K. Krishnamurthy Directorate General of AIR New Delhi		Shri P. K. Venkatasubramanian Deputy General Manager BEL, Bangalore
Shri S. C. Mazumdar (alternate) Directorate General of AIR New Delhi		Shri Satish Kumar <i>Convener</i> Information Research Officer, IPAG, Electronics Commission

3. Panel on Control Components

Dr. S. V. Kasargod Head, Servo Components Division ECIL, Hyderabad	<i>Chairman</i>	Prof. A. K. Mahalanabis Head, Electrical Engineering Department IIT, Delhi
Shri K. R. Banerjee Manager, (D&D) IL, Kota		Shri C. S. Srinivasan Head, Power Reactor Instrumentation Division ECIL, Hyderabad
Prof. B. L. Deekshatulu School of Automation IISc, Bangalore		Shri K. N. Tiwari Officer-in-Charge LCSO, Bangalore
Dr. S. C. Gupta Head, Control, Guidance and Instrumentation Division VSSC, Trivandrum		Dr. V. P. Bhatkar Senior Scientific Officer IPAG, Electronics Commission <i>Convener</i>

(a) Study Group on Industrial Drives and Control

Prof. B. L. Deekshatulu School of Automation IISc, Bangalore	<i>Coordinator</i>	Shri S. J. Kumar Assistant Director (Electronics) CMTI, Bangalore
Dr. J. Ansari Asstt. Professor School of Automation IISc, Bangalore		Dr. N. Jagan Mohan Rao Asstt. Professor School of Automation, IISc Bangalore
Shri S. Balakrishna Scientist NAL, Bangalore		Prof. Joseph Vithayathil Head, Electrical Engineering Department IISc, Bangalore
Prof. M. R. Chidambara School of Automation IISc, Bangalore		

(b) Study Group on Power Station Load Despatch and Telemetry

Prof. A. K. Mahalanabis Head, Electrical Engineering Department IIT, Delhi	<i>Coordinator</i>	Prof. J. Nanda Electrical Engineering Department IIT, Delhi
Dr. H. S. Kang Assistant Professor Electrical Engineering Department IIT, Delhi		

4. Panel on Ultrapure Materials

Shri K. V. Ramanathan Head, Solid State Electronics Group TIFR, Bombay	<i>Chairman</i>	Dr. J. Shankar Emeritus Scientist BARC, Bombay
--	-----------------	--

Dr. A. D. Damodaran
Scientist-in-Charge
SMP, NFC, Hyderabad

Shri G. Soni
Senior Scientific Officer
Dept. of Electronics

Dr. S. G. Patil
Senior Technical Officer
IPAG, Electronics Commission

Dr. A. K. Sreedhar
Deputy Director
SPL, Delhi

Shri P. S. Raju
Head, Semiconductors Division
ECIL, Hyderabad

Dr. M. J. Zarabi *Convener*
Senior Scientific Officer
IPAG, Electronics Commission

5. Panel on Chemicals and Plastics

Prof. S. P. Potnis *Chairman*
Professor of Polymer Chemistry
UDCT, Bombay University

Dr. S. Ramaseshan
Deputy Director & Head
Materials Division
NAL, Bangalore

Dr. K. J. Balakrishna
DCSO, DRL (M)
Kanpur

Dr. C. V. Suryanarayana
Scientist, CECRI
Karaikudi

Dr. M. D. Karkhanavala
Head, Chemistry Division
BARC, Bombay

Dr. M. J. Zarabi
Senior Scientific Officer
IPAG, Electronics Commission

Dr. R. B. Mitra
Deputy Director
NCL, Poona

Dr. S. G. Patil *Convener*
Senior Technical Officer
IPAG, Electronics Commission

6. Panel on Indigenisation of Microwave Components Manufacture

Shri R. V. S. Sitaram *Chairman*
Head, Microwave Engg. Group
TIFR, Bombay

Shri H. J. Mirchandani
Deputy Director General
P&T Department, New Delhi

Col. M. L. Anand
Planning Officer (L)
Ministry of Defence, Delhi

Shri D. K. Sachdev
Chief Engineer (Transmission Research)
ITI, Bangalore

Shri S. S. Bhawe
Radio Astronomy Group
TIFR, Bombay

Shri P. S. Saran
Deputy Director
TRC, New Delhi

Shri O. P. N. Calla
Head, Microwave Division
ISRO, Ahmedabad

Dr. R. P. Shenoy
Chief Technical Officer
BEL, Ghaziabad

Dr. Kailash Chandra
Scientist, NPL
New Delhi

Dr. A. K. Chakravarti *Convener*
Senior Scientific Officer
IPAG, Electronics Commission

Shri K. C. Gawrishankar
Junior Scientific Officer
Dept. of Electronics

7. Panel on Passive Components

Shri U. Venkateswarlu Head, RCD/NID ECIL, Hyderabad	<i>Chairman</i>	Shri R. T. Narendra Senior Market Analyst IPAG, Electronics Commission
Shri B. Bhanot Development Officer (Electronics) DGTD, Delhi		Shri T. R. Raman Director (Tech.) Dept. of Electronics
Shri P. A. Bhat Member, ELCINA Bombay		Shri N. S. Sathyanarayanan Deputy Chief Engineer ITI, Bangalore
Col. N. Dayal Ministry of Defence Delhi		Shri R. Somasekhara Deputy Engineer BEL, Bangalore
Dr. G. C. Jain Deputy Director NPL, New Delhi		Shri C. G. Subramanyam Chief Engineer (Electronics) NRDC, Delhi
Shri V. P. Luthra President ELCINA, Delhi		Dr. K. S. Srinivas Senior Scientific Officer IPAG, Electronics Commission

8. Panel on Mechanical and Electrical Components

Shri B. Bhanot Development Officer (Electronics) DGTD, Delhi		Shri G. R. Pai Technical Manager Power Reactor Instrumentation Division, ECIL, Hyderabad
Shri K. Gururaja Standards Engineer BEL, Bangalore		Shri M. S. B. K. Rao Technical Manager HTL, Madras
Dr. S. K. Hajela Chief Engineer (R&D) ITI, Bangalore		Shri K. N. Tiwari Officer-in-Charge LCSO, Bangalore
Col. M. S. Nagarajan Chief Executive Amphetronix Ltd., Poona		Dr. S. L. Sarnot Senior Scientific Officer IPAG, Electronics Commission
Shri R. T. Narendra Senior Market Analyst IPAG, Electronics Commission		

9. Panel on Special Electron Tubes

Dr. C. Ambasankaran Director, Electronics and Instrumentation Group BARC, Bombay	<i>Chairman</i>	Shri V. P. Kulkarni Engineer-in-Charge OCS, Bombay
---	-----------------	--

Dr. S. S. S. Agarwala
Scientist
CEERI, Pilani

Dr. E. Bhagirath Rao
Director, Himalayan
Radio Propagation Unit
Dehradun

Shri G. K. Bhide
Head, Opto Electronics Division
BARC, Bombay

Dr. K. A. George
Senior Research Scientist
TIFR, Bombay

Shri R. A. P. Iyengar
Deputy Chief Engineer
AIR, Delhi

Shri P. K. Rao
Principal Scientific Officer, CIL
Bangalore

Prof. M. Satyam
Dept. of Electrical Communication
Engineering
IISc, Bangalore

Dr. R. P. Wadhwa
Deputy General Manager
BEL, Bangalore

Dr. K. S. Srinivas *Convener*
Senior Scientific Officer
IPAG, Electronics Commission

10. Panel on Guidelines for Standardisation in Electronics

Brig. D. Swaroop, AVSM *Chairman*
Managing Director
IL, Kota

Brig. B. Bhasin
Director of Production &
Inspection Electronics
New Delhi

Shri B. P. Ghosh
Deputy Director (Electronics)
National Test House
Calcutta

Shri K. Gururaja
Standards Engineer
BEL, Bangalore

Dr. V. S. Kulkarni
Department of Electronics Production
VSSC, ISRO, Trivandrum

Shri S. Mukhopadhyay
Joint Director
Dept. of Electronics

Shri D. V. Petkar
Officer-in-Charge
Reliability Evaluation Laboratory
BARC, Bombay

Shri T. R. Raman
Director (Tech.)
Dept. of Electronics

Dr. Y. R. Somayajulu
Officer-in-Charge
TEC, NPL, New Delhi

Shri K. N. Tiwari
Officer-in-Charge, LCSO
Min. of Defence, Bangalore

Shri Y. S. Venkateswaran
Deputy Director General
ISI, New Delhi

Shri H. R. Babu Seetharam
Dy. General Manager
(Quality Assurance)
BEL, Bangalore

Dr. R. P. Shenoy
Director
LRDE, Bangalore

Shri S. N. Chakravarty *Convener*
Information Research Officer, IPAG
Electronics Commission

11. Panel on Guidelines for Evolving Funding Procedures for R&D Projects to be Funded by Electronics Commission

Shri P. M. Abraham
Director
Dept. of Electronics

Shri K. Raghupathy Rao
Deputy Secretary/IFA
Dept. of Electronics

Shri A. Balasubramanian
Under Secretary
Min. of Finance
New Delhi

Shri M. R. Raman
Joint Director
Planning Commission
New Delhi

Shri J. Innocent
Director
Dept. of Personnel &
Administrative Reforms
New Delhi

Dr. P. V. S. Rao
Senior Research Scientist
TIFR, Bombay

Shri Prem Nath
Joint Secretary
Ministry of Finance
New Delhi

Dr. P. Chandrasekhar *Convener*
Senior Systems Scientist
IPAG, Electronics Commission

12. Panel on TV Glass Shells and TV Picture Tubes

Shri C. R. Subramanian *Chairman*
Managing Director
BEL, Bangalore

Dr. K. D. Sharma
Director
CGCRI, Calcutta

Shri Keshav Chandra
Chief Engineer
AIR, New Delhi

Dr. S. P. Verma
Industrial Adviser
DGTD, New Delhi

Shri M. D. Godbole
Deputy Secretary
Min. of Finance, New Delhi

Dr. Ram K. Vepa *Member Secretary*
Director
Dept. of Electronics

Dr. M. K. Sen Gupta
Ophthalmic Glass Plant
Durgapur

13. Semiconductor Committee

Shri C. R. Subramanian *Chairman*
Managing Director
BEL, Bangalore

Dr. P. V. S. Rao
Senior Research Scientist
TIFR, Bombay

Dr. N. R. Mantena
Technical Manager (Semiconductor
Divn.)
ECIL, Hyderabad

Prof. S. Sampath
Deputy Director
IIT, Madras

Dr. B. R. Marathe
Scientist, CEERI
Pilani

Dr. A. K. Sreedhar
Deputy Director
SPL, Delhi

Shri H. J. Mirchandani
Deputy Director General
P&T Department, Delhi

Shri T. R. Raman *Member Secretary*
Director (Tech.)
Dept. of Electronics

Shri K. V. Ramanathan
Head, Solid State Electronics Group
TIFR, Bombay

14. Panel on Ferrites

Prof. E. C. Subbarao
Metallurgical Engg.
IIT, Kanpur

Chairman

Shri D. K. Sachdev
Chief Engineer (R&D)
ITI, Bangalore

Shri John Francis
Deputy Director
TRC, Delhi

Dr. B. V. S. Subbarao
Assistant Director
DMRL, Hyderabad

Prof. D. Y. Phadke
Adviser
TIFR, Bombay

Dr. B. H. Wadia
Behram Wadia & Associates
Poona

Shri T. V. Ramamurti
Deputy Director
NPL, Delhi

Shri T. R. Raman *Member Secretary*
Director (Tech.)
Dept. of Electronics

15. Panel on Minicomputers

Dr. P. V. S. Rao
Senior Research Scientist
TIFR, Bombay

Chairman

Dr. R. Sankaranarayanan
Manager, Computer Services
HAL, Bangalore

Col. A. Balasubramanian
OSD (Computers)
Dept. of Electronics

Dr. N. P. Sastry
Fellow, TIFR
Bombay

Dr. S. Krishnan
Scientist
NAL, Bangalore

Dr. N. Seshagiri
Director, IPAG
Electronics Commission

Professor B. Nag
Department of Electrical Engg
Jadhavpur University
Calcutta

Prof. G. Srikantiah
IIT, Kanpur

Col. G. K. Rao
Addl. General Manager
BEL, Bangalore

Study Group

Dr. P. Chandrasekhar
Senior Systems Scientist
IPAG, Electronics Commission

Dr. K. K. Krishnan Kutty
Senior Systems Scientist
IPAG, Electronics Commission

Shri S. Govindarajan
Senior Technical Officer
ECIL, Hyderabad

Shri M. S. B. K. Rao
Technical Manager
HTL, Madras

16. Panel on Desk Calculator

Prof. B. Nag *Chairman*
Dept. Electrical Engineering
Jadhavpur University
Calcutta

Shri K. V. Ramanathan
Head, Solid State
Electronics Group
TIFR, Bombay

Dr. S. S. Agarwal
CSIO
Chandigarh

Col. G. K. Rao
Addl. General Manager
BEL, Bangalore

Col. A. Balasubramanian
R&D, Dept. of Defence Production
New Delhi

Dr. N. P. Sastry
Fellow, TIFR
Bombay

Dr. S. Krishnan
NAL
Bangalore

Dr. S. Srikantan
Head, Computer Division
ECIL, Hyderabad

Shri S. Malhotra
Director (Tech.)
Dept. of Electronics

D. The Technology Development Council and its six Working Groups constituted by the Electronics Commission indirectly assisted in the preparation of this report by contributing ideas for developing the electronics technology on predominantly indigenous basis. Each Working Group has also prepared a Technology Development Plan, the contents of which are partly reflected in this report. The members of the council and its Working Groups are as follows :

Technology Development Council

Prof. M. G. K. Menon *Chairman*
Chairman
Electronics commission
New Delhi

Dr. Amarjit Singh
Director
CEERI
Pilani

Shri G. U. Menon
Chairman & Managing Director
HTL, Madras

Prof. E. C. Subbarao
Metallurgical Engineering
IIT, Kanpur

Dr. N. W. Nerurkar
Director (Tech.)
Dept. of Electronics
New Delhi

Shri T. S. Subramanian
Director
TRC
New Delhi

Dr. P. V. S. Rao
Senior Research Scientist
TIFR
Bombay

Dr. N. Seshagiri
Director
IPAG
Electronics Commission

*Member
Secretary*

Dr. R. P. Shenoy
Director
LRDE, Bangalore

Working Group on Materials and Components

Prof. E. C. Subbarao Metallurgical Engg IIT, Kanpur	<i>Chairman</i>	Dr. Amarjit Singh Director CEERI, Pilani
Dr. V. G. Bhide Deputy Director NPL, New Delhi		Shri U. Venkateswarlu Managing Director CEL., New Delhi
Dr. S. Ramaseshan Deputy Director NAL, Bangalore		Dr. R. P. Wadhwa Deputy General Manager BEL, Bangalore
Shri K. V. Ramanathan Head, Solid State Electronics Group TIFR, Bombay		Dr. M. J. Zarabi <i>Member</i> Senior Scientific Officer <i>Secretary</i> IPAG, Electronics Commission

Working Group on Consumer Electronics

Dr. Amarjit Singh Director CEERI, Pilani	<i>Chairman</i>	Shri Babu Seetharam Deputy General Manager (QA) BEL, Bangalore
Shri D. C. Bhattacharjee Chief Engineer AIR, New Delhi		Shri U. Venkateswarlu Managing Director CEL, New Delhi
Surg. Cdr. A. K. Deb Head, Medical Engineering Divn LRDE, Bangalore		Shri T. R. Raman Director (Tech.) Dept. of Electronics
Dr. S. K. Mangal Assistant Director CSIO, Chandigarh		Dr. K. S. Srinivas <i>Member</i> Senior Scientific Officer <i>Secretary</i> IPAG, Electronics Commission

Working Group on Computers, Control and Industrial Electronics

Dr. P. V. S. Rao Senior Research Scientist TIFR, Bombay	<i>Chairman</i>	Prof. I. G. Sarma Prof-in-Charge School of Automation IISc, Bangalore
Col. A. Balasubramanian Officer on Special Duty Dept. of Electronics		Dr. S. Srikantan Head, Computer Division ECIL, Hyderabad
Prof. P. Duggal Adviser Govt. of Assam, Gauhatti		Shri M. K. Tewari Manager (R&D) IL, Kota
Shri H. P. Jaiswal DCSO LRDE, Bangalore		Dr. P. Chandrasekhar <i>Member</i> Senior Systems Scientist <i>Secretary</i> IPAG, Electronics Commission

Prof. B. Nag
 Head, Dept. of Electronics
 and Communication Engg
 Jadavpur University
 Calcutta

Working Group on Radars, Sonars and Navigation Aids

Dr. R. P. Shenoy
 Director
 LRDE, Bangalore

Chairman

Dr. V. P. Kodali
 Director (Tech.)
 Dept. of Electronics

Shri R. Aravamudan
 Head, TERLS
 VSSC, Trivandrum

Dr. D. Srinivasan
 Director
 Naval Physical & Oceanographic
 Lab, Cochin

Shri M. N. Gadre
 OCSO, LRDE
 Bangalore

Shri C. R. Thirumalai
 Director (Communications)
 DGCA., New Delhi

Dr. K. V. Gopalakrishna
 Manager
 Radar Equipment Dev.
 Department
 BEL, Bangalore

Dr. A. K. Chakravarti
 Senior Scientific Officer
 IPAG, Electronics Commission

*Member
 Secretary*

Prof. P. V. Indiresan
 Head, School of Radar Studies
 IIT, New Delhi

Working Group on Communication and Broadcasting

Shri T. S. Subramanian
 Director
 TRC, New Delhi

Chairman

Dr. E. Bhagirath Rao
 Director
 Himalayan Radio Propagation Unit
 Raipur, Dehradun

Col. N. Pant
 Director
 Experimental Satellite
 Communication Earth Station
 Ahmedabad

Shri D. K. Sachdev
 Chief Engineer (Transmission
 Research)
 ITI, Bangalore

Shri N. C. Nath
 Deputy Director (Communications)
 DGCA, New Delhi

Shri N. T. Taskar
 Director (Tech.)
 Dept. of Electronics

Dr. C. G. Khot
 Joint Director
 RDSO, Lucknow

Dr. R. Srinivasan
 Senior Scientific Officer
 IPAG, Electronics Commission

Member Secretary

Col. G. K. Rao
 General Manager
 BEL, Bangalore

Working Group on Electro-Mechanical Components and Equipment

Shri G. U. Menon Chairman & Managing Director HTL, Madras	<i>Chairman</i>	Shri N. L. Krishnan General Manager BEL, Ghaziabad
Shri S. S. Bhave TIFR, Bombay		Shri S. Jayant Kumar CMTI, Bangalore
Shri N. Ethirajalu Divisional Manager ITI, Bangalore		Shri R. M. Nayar Managing Director ETTDC, New Delhi
Dr. S. C. Gupta Head, Control Guidance & Instrumentation Division VSSC, ISRO, Trivandrum		Dr. K. K. Krishnan Kutty Senior Systems Scientist IPAG, Electronics Commission
E. The draft of the report was improved by eliciting comments from the following specialists :		
Dr. Amarjit Singh Director CEERI, Pilani		Col. A. Balasubramanian O S D (Computers) Dept. of Electronics
Shri I.C. Bansal Deputy Secretary Ministry of Defence New Delhi		Shri K. C. Gawrishankar Senior Scientific Officer Dept. of Electronics
Brig. B. Bhasin Director, DP & IE Dept. of Defence Production (DGI) New Delhi		Shri P. N. Krishnamurthy Director (Tech.) Dept. of Electronics
Shri D. C. Bhattacharjee Addl. Chief Engineer AIR, New Delhi		Dr. V. P. Kodali Director (Tech.) Dept. of Electronics
Shri Jai P. Singh Scientific Staff-Officer to Chairman ISRO, Bangalore		Dr. N. W. Nerurkar Director (Tech.) Dept. of Electronics
Shri B. L. Jain Joint Secretary (P&C) Ministry of Defence New Delhi		Shri A. Parthasarathi Secretary (EC) Electronics Commission
Shri R. M. Nayar Managing Director ETTDC New Delhi		Shri T. R. Raman Director (Tech.) Dept. of Electronics

Shri S. N. Ranganathan
Senior Member (Telecom Devpt.)
P&T Board, Ministry of
Communication
New Delhi

Shri S. Ranganathan
Senior Scientific Officer
Dept. of Electronics

Shri A. S. Rao
Managing Director, ECIL
Hyderabad

Shri G. Soni
Joint Director (Tech.)
Dept. of Electronics

Shri C. R. Subramanian
Chairman & Managing Director
BEL, Bangalore

Shri N. T. Taskar
Director (Tech.)
Dept. of Electronics

Shri U. Venkateswarlu
Managing Director
CEL, New Delhi

Dr. Ram K. Vepa
Joint Secretary
Dept. of Electronics

F. Portions of the draft of the report were sent for information/comments to the members of the Electronics Commission :

Professor P.N. Dhar
Secretary to Prime Minister

Shri A. S. Rao
Managing Director
Electronics Corporation of India Ltd
Hyderabad

Dr. B.D. Nag Chaudhuri
Vice-Chancellor
Jawaharlal Nehru University
New Delhi

Shri H.N. Ray
Secretary, Ministry of Finance

The extensive and thorough review of the entire manuscript made by Shri Ashok Parthasarathi, Secretary to the Electronics Commission, is specially recorded.

G. The logistics of production of the report including layout design, general and technical editing, proof reading, choice and layout of photographs and supervision of printing was taken care of by Dr. K. K. Krishnan Kutty, Officer on Special Duty (R&D) of IPAG. He was assisted during the initial stages by Shri Srinivasa Adiga, Senior Technical Publication Officer of IPAG. He was also given excellent support by the Recorder Press of New Delhi which, though is a relatively small press, took up the challenge of the massive and quality printing called for by the production of this report.

INDEX

Index

AIR	105-107
Adges project	637-638
Agri-electronic instruments	341-347
Applications	341-342
Classification	343
Current status	344-345
Guidelines	345-347
Requirements	343-344
All India Radio	
See	
AIR	
Antennae	
R&D Policy Seminar, 1973, New Delhi	50-52
Applications	
Agri-electronic instruments	341-342
Ceramics	610-616
Dielectric heating	327, 329-330
Metals & alloys	575-582
Batteries	553-554
Bhabha Committee Report	
See	
Electronics Committee Report	
Bibliography	667-674
Capacitors	475-505
Capital equipment	
Printed circuit boards	548-551
Cartridges	475-505
Ceramics	559-616
Applications	610-616
Requirements	610-616
Specifications	610-616
Characteristics	
Electronics industry	71-73
Chemicals (electronics)	559-616
Applications	589-601
Requirements	589-601
Specifications	589-601
Classification	
Agri-electronic instruments	343
Electronics materials	560
Industrial drives	306-309
Instruments	380-385
Medical electronic equipment	348-352

Microwave components	505-507
Process control instruments	267-276
Servo mechanisms	256-257
Computer peripheral equipment	89, 221, 225, 230-239
Fifth Plan	221
Requirements	89
Sixth Plan	225
Specifications	230-235
Computer peripherals	
R&D Policy Seminar, 1973, New Delhi	54-55
Computers	208-253
Current status	209-211
Fifth Plan	219-220
Fourth Plan	219
Gaps in technology	225-229
Guidelines	229-238, 245-246
Indigenous manufacturing	229-238
Investments	90, 251-253
Licensing	240-246
Market survey	228-229
National Conference on Electronics, 1970, Bombay	34-37
Output	211-212
Output projection	90, 251-253
Sixth Plan	224, 226
Standardisation	246-251
Technological trends	212-217
Ten-year profile	88-91, 218-225
Connectors	516-517, 524-534
Specifications	524-534
Consumer electronics	84-86, 139-150
Current status	140-144
Estimates Committee Report 1973-74	65-66
Gaps in technology	146-147
Guidelines	147-149
Investments	85, 149
Output	139
Output projection	85
R&D Policy Seminar, 1973, New Delhi	44-45
Requirements	144-146
Ten-year profile	84-86
Control equipment	91-94, 254-304
Applications	92
Fifth Plan	93
Investments	92-93
Output projection	92-93
Requirements	92
Sixth Plan	93-94
Ten-year profile	91-94
Crystals	475-505
Current status	
Agri-electronic instruments	344-345

Computers	209-211
Consumer electronics	140-144
DC micromotors	551
Dielectric heating	327
Electromechanical components	516-529
Electronics materials	561-567
Electron tubes	413-415
Industrial drives	317-318
Instruments	385-397
Manpower	662
Mass communication	105-107
Medical electronic equipment	352-360
Medical electronics	352-360
Microwave components	509-510
Mining electronics	330-333
Navigational aids (civil aviation)	197
Navigational aids (maritime)	201-202
Numerical control	324-325
Passive components	475-485
Pollution detection & control instruments	336-338
Printed circuit boards	544-545
Process control instruments	279-289
Radio communication	188
Semiconductor devices	428-436
Servo mechanisms	257-258
Space communication	119-122, 129-138
Standardisation	618-619
Telecommunication equipment	153
Telecontrol	193-195
Telemetry	193-195
Testing centres	622-624
DC micromotors	551-553
Current status	551
Requirements	552
Technological trends	552
Data processing systems	
R&D Policy Seminar, 1973, New Delhi	43-44
Defence electronic equipment	633-640
Indigenous manufacturing	634-636
R&D	636-637
Requirements	633-634
Defence electronics	633-640
Projects	637-638
Public sector units	634-636
Department of Electronics	39-42
Dielectric heating	327-330
Applications	327, 329-330
Current status	327
Guidelines	327
Requirements	327
ETTDC	104, 646-654
Exports	649-652

Imports	648-652
Electromechanical components	515-558
Current status	516-520
Guidelines	554-558
Investments	543-544
Output	516
Requirements	520-522
Standardisation	520-543
Electronic components	98-102
Electronics Committee Report 1966	9
Estimates Committee Report 1973-74	66-67
Fifth Plan	100-102
Output	99
Output projection	101
R&D Policy Seminar, 1973, New Delhi	58-59
Requirements	100
Sixth Plan	102
Ten-year profile	98-102
Electronic equipment	
Electronics Committee Report 1966	7
Electronics Commission	39-42
Electronics Commission, Panels	679-686
Electronics Committee Report 1966	3-14
Electronic components	9
Electronic equipment	7
Electronics materials	10
Guidelines	7
Investment pattern	10
Manpower	6
R&D	11
Radio receivers	9
Requirements 1965-75	4
Electronics (Dept. of), panel reports	667
Electronics industry	
Brain drain	665
Characteristics	1, 71-73
Employment potential	659-661
Fifth Plan	79-82
Growth invariant	74
Growth projection: India	78
Growth trends: India	74
History	14-20
Japan	75
Manpower	655-665
Problems (1966)	13-14
Sixth Plan	81
Ten-year profile	79-104
Electronics in India	
History	1-2, 14-20, 39-42
Electronics materials	102-103, 559-616
Classification	560
Current status	561-567
Electronics Committee Report 1966	10

Fifth Plan	103
Gaps in technology	568-570
Guidelines	571
Investments	570-571
National Conference on Electronics, 1970, Bombay	32-34
Output	570-571
R&D Policy Seminar, 1973, New Delhi	47-50
Requirements	559, 567-568, 575-616
Sixth Plan	103
Ten-year profile	102-103
Electronics Trade and Technology Development Corporation	
See	
ETTDC	
Electronic switches	
R&D Policy Seminar, 1973, New Delhi	55-56
Electron optics	
R&D Policy Seminar, 1973, New Delhi	58-59
Electron tubes	412-426
Current status	413-415
Guidelines	418-426
Output	413-414
R&D	414-415, 424-426
Raw materials	415
Requirements	415-418
Technological trends	418
Estimates Committee Report 1973-74	64-70
Consumer electronics	65-66
Electronic components	66-67
Electronics materials	66-67
Exports	69-70
Licensing	68-69
Professional equipment	66
R&D	67-68
Exports	641-654
ETTDC	649-652
Estimate Committee Report 1973-74	69-70
Ferrites	475-505
Fifth Plan	
Computer peripheral equipment	221
Computers	219-220
Control equipment	93
Electronic components	100-102
Electronics industry	79-82
Electronics materials	103
General facilities	104
Health services	352
Instruments	98, 409
Manpower	659-611
Mass communication	83
Navigational aids (civil aviation)	198
Testing centres	626-629

Foreign collaboration	
National Conference on Electronics, 1970, Bombay	25-27
Fourth Plan	
Computers	219
Health services	352
Gaps in technology	
Consumer electronics	146-147
Electronics materials	568-570
Industrial drives	318-323
Instruments	399-404
Microwave components	510-514
Passive components	488-489
Semiconductor devices	461-467
General facilities	103-104
Fifth Plan	104
Glasses	559-616
Applications	610-616
Requirements	610-616
Specifications	610-616
Guidelines	
Agri-electronic instruments	345-347
Consumer electronics	147-149
Dielectric heating	327
Electromechanical components	554-558
Electronics Committee Report 1966	7
Electronics materials	571
Electron tubes	418-426
Industrial drives	318-323
Instruments	404-408
Mass communication	111, 117-118
Medical electronic equipment	367-368
Medical electronics	367-368
Microwave components	510-514
Mining electronics	333-334
Navigational aids (maritime)	202-204
Numerical control	325-327
Passive components	489-505
Pollution detection & control instruments	338-341
Process control instruments	294-302
Radio communication	190-193
Semiconductor devices	468-474
Servomechanisms	263-265
Space communication	127-128
Standardisation	620-622
Telecommunication equipment	169-173
General facilities	
Ten-year profile	103-104
Health services	352-353
Fifth Plan	352
Fourth Plan	352
Manpower	353
History	
Electronics in India	1-2, 14-20, 39-42
INSAT	125-127

Cost estimates	127
INSAT Plan	
Mass communication	84
IPAG	42
IPAG panel reports	667
IPAG reports	667-671
Imports	
ETTDC	648-652
Process control instruments	277-279
Telecommunication equipment	154
India Meteorological Department	
See	
IMD	
Indian National Satellite	
See	
INSAT	
Indian Space Research Organisation	
See	
ISRO	
Indigenous capabilities	
Instruments	388-390
Process control instruments	289-292
Space communication	127-138
Indigenous manufacturing	
Defence electronic equipment	634-636
Mining electronics	333
Process control instruments	280-283, 295-296
Induction heating	327-330
Industrial drives	305-323
Classification	306-309
Current status	317-318
Gaps in technology	318-323
Guidelines	318-323
Requirements	309-317
Information, Planning and Analysis Group	
See	
IPAG	
Installed capacity	
Semiconductor devices	461-467
Instruments	97-98, 379-411
Classification	380-385
Current status	385-397
Fifth Plan	98, 409
Gaps in technology	399-404
Guidelines	404-408
Indigenous capabilities	388-390
Investments	98, 408-411
Output	387
Output projection	98
R&D	390-397
R&D Policy Seminar, 1973, New Delhi	46-47
Requirements	397-399
Ten-year profile	97-98

International communication	183-187
Investment pattern	
Electronics Committee Report 1966	10
Investments	
Computers	90, 251-253
Consumer electronics	149
Control equipment	92-93
Electromechanical components	543-544
Electronics materials	570-571
Instruments	98, 408-411
Mass communication	84, 118-119
Medical electronic equipment	368-369
Medical electronics	96
Navigational aids	88
Process control instruments	302-304
Radio communication	88
Semiconductor devices	474
Servo mechanisms	265-266
Telecommunication	87
Telecommunication equipment	180-183
Telecontrol	88
Telemetry	88
Japan	
Electronics industry	75
Licences (ownership)	
Radio receivers	140
TV receivers	143
Licensing	
Computers	240-246
Estimates Committee Report 1973-74	68-69
National Conference on Electronics, 1970, Bombay	22-25
Loudspeakers	475-505
Magnetic heads	475-505
Magnetic tapes	475-505
Manpower	655-665
Brain drain	665
Current status	662
Electronics Committee Report 1966	6
Fifth Plan	659-661
Health services	353
Medical electronics	364, 377-378
Public sector	659
Sixth Plan	659-661
Training programmes	663-665
UK	656-657
USA	658-659
Mass communication	82-84, 105-138
Current status	105-107
Fifth Plan	83
Guidelines	111, 117-118
INSAT plan	84
Investments	84, 118-119
Output projection	84

Requirements	108-111, 112-117
Technological trends	107-108
Ten-year profile	82-84
Medical electronic equipment	348-378
Classification	348-352
Current status	352-360
Exports	360
Gaps in technology	363-365
Guidelines	367-368
Imports	360
Investments	368-369
Output	354
R&D	355-359
Requirements	360-363
Technological trends	365-367
Testing centres	369-376
Medical electronics	94-97, 348-378
Current status	352-360
Guidelines	367-368
Investments	96
Manpower	364, 377-378
Requirements	95
Sixth Plan	96
Ten-year profile	94-97
Metals and alloys	559-616
Applications	575-582
Requirements	575-582
Specifications	575-582
Micro electronics	
National Conference on Electronics, 1970, Bombay	37-38
Microphones	475-505
Microwave components	505-514
Classification	505-507
Current status	509-510
Gaps in technology	510-514
Guidelines	510-514
R&D Policy Seminar, 1973, New Delhi	50-52
Requirements	507-509
Mining electronics	330-334
Current status	330-333
Guidelines	333-334
Indigenous manufacturing	333
Requirements	330-333
NACE	62-63
National Advisory Committee on Electronics	
See	
NACE	
National Automation and Control Agency	301, 304
National Conference on Electronics, Bombay, 1970	20-39
Computers	34-37
Electronics materials	32-34
Foreign collaboration	25-27
Licensing	22-25

Micro-electronics	37-38
R&D	27-29
Small scale sector	30-31
TV receivers	38-39
National Radar Council	63-64
National Seminar on R&D Policy, 1973, New Delhi	
See	
R&D Policy Seminar, 1973, New Delhi	
Navigational aids	88, 196-204
Investments	88
Output projection	88
Navigational aids (civil aviation)	196-199
Current status	197
Fifth Plan	198
R&D	197-199
Requirements	197
Navigational aids (maritime)	200-204
Current status	201-202
Guidelines	202-204
Requirements	201-202, 204
Navigational equipment	
R&D Policy Seminar, 1973, New Delhi	52-53
Numerical control	323-327
Current status	324-325
Gaps in technology	325-327
Guidelines	325-327
Requirements	324-325
Output	
Computers	211-212
Consumer electronics	139
Electromechanical components	516
Electronic components	99
Electronics materials	570-571
Electron tubes	413-414
Instruments	387
Medical electronic equipment	354
Passive components	476, 478-479
Process control instruments	280
Radio receivers	141-142
Semiconductor devices	427-434
TV receivers	143
Telecommunication equipment	153-154
Output projection	
Computers	90, 251-253
Control equipment	92-93
Electronic components	101
Instruments	98
Mass communication	84
Navigational aids	88
Process control instruments	302-304
Radio communications	88
Telecommunication	87
Telecontrol	88

Telemetry	88
Overseas communication	183-187
Passive components	475-505
Capital equipment	501-503
Current status	475-485
Gaps in technology	488-489
Guidelines	489-505
Investments	505
Output	476, 478-479
R&D	489-505
R&D Policy Seminar, 1973, New Delhi	57-58
Requirements	485-488
Plastics	559-616
Applications	602-609
Requirements	602-609
Specifications	602-609
Pollution detection & control instruments	334-341
Current status	336-338
Guidelines	338-341
Requirements	335-336
Printed circuit boards	544-551
Capital equipment	548-551
Current status	544-545
Requirements	545-548
Process control instruments	266-304
Classification	267-276
Current status	279-289
Gaps in technology	289-294
Guidelines	294-302
Imports	277-279
Indigenous capabilities	289-292
Indigenous manufacturing	280-283, 295-296
Investments	302-304
Output	280
Output projection	302-304
R&D	283-289, 303
Requirements	276-279
Production planning	
Telecommunication equipment	173-183
Professional equipment	
Estimates Committee Report 1973-74	66
Public sector	
Manpower	659
Public sector units	
Defence electronics	634-636
R&D	
Defence electronic equipment	636-637
Electronics Committee Report 1966	11
Electron tubes	414-415, 424-426
Estimates Committee Report 1973-74	67-68
Instruments	390-397
Medical electronic equipment	355-359
National Conference on Electronics, 1970, Bombay	27-29

Navigational aids (civil aviation)	197-199
Passive components	489-505
Process control instruments	283-289, 303
Semiconductor devices	434-436
Telecommunication equipment	155
R&D Policy Seminar, 1973, New Delhi	42-59
Antennae	50-52
Computer peripherals	54-55
Consumer electronics	44-45
Data processing systems	43-44
Electronic components	58-59
Electronics materials	47-50
Electronic switches	55-56
Electron optics	58-59
Instruments	46-47
Microwave components	50-52
Navigational equipment	52-53
Passive components	57-58
Radar	54
Radio broadcasting	44-45
Relays	55-56
Servo components	56
Sonar	53-54
Television broadcasting	45-46
Tools	56
Radars	204-207
IMD	204-205
ISRO	207
R&D Policy Seminar, 1973, New Delhi	54
Requirements	205
Space (Department of)	206-207
Radio broadcasting	
R&D Policy Seminar, 1973, New Delhi	44-45
Radio communication	88, 187-193
Current status	188
Guidelines	190-193
Investments	88
Output projection	88
Requirements	188-190
Radio receivers	
Electronics Committee Report 1966	9
Licences (ownership)	140
Output	141-142
Requirements	144
Raw materials	
Electron tubes	415
Servo mechanisms	260-262
Relays	518, 535-536
R&D Policy Seminar, 1973, New Delhi	55-56
Specifications	535-536
Reliability	629-631
Requirements	
Agri-electronic instruments	343-344

Computer peripheral equipment	89
Consumer electronics	144-146
Control equipment	92
DC micromotors	552
Defence electronic equipment	633-634
Dielectric heating	327
Electromechanical components	520-522
Electronic components	100
Electronics materials	559, 567-568, 575-616
Electron tubes	415-418
Industrial drives	309-317
Mass communications	108-111, 112-117
Medical electronic equipment	360-363
Medical electronics	95
Metals and alloys	575-582
Microwave components	507-509
Mining electronics	330-333
Navigational aids (civil aviation)	197
Navigational aids (maritime)	201-202, 204
Numerical control	324-325
Passive components	485-488
Pollution detection & control instruments	335-336
Printed circuit boards	545-548
Process control instruments	276-279
Radars	205
Radio communication	188-190
Radio receivers	144
Semiconductor devices	460-461
Servo mechanisms	257-258
Space communication	125-127
TV receivers	145
Telecommunication	86
Telecommunication equipment	155-168
Telecontrol	196
Telemetry	196
Requirements 1965-75	
Electronics Committee Report 1966	4
Resistors	475-505
SEEPZ	645-646
SITE	121-122
Santacruz Electronics Export Processing Zone	
See	
SEEPZ	
Satellite Instructional Television Experiment	
See	
SITE	
Semiconductor Complex	472-473
Semiconductor devices	427-474
Current status	428-436
Gaps in technology	461-467
Guidelines	468-474
Indigenous capability	461-467
Installed capacity	461-467

Investments	474
Output	427-434
R&D	434-436
Requirements	460-461
Technological trends	436-459
Servo components	
R&D Policy Seminar, 1973, New Delhi	56
Servo mechanisms	255-266
Classification	256-257
Current status	257-258
Guidelines	263-265
Investments	265-266
Raw materials	260-262
Requirements	257-258
Sixth Plan	
Computer peripheral equipment	225
Computers	224, 226
Control equipment	93-94
Electronic components	102
Electronics industry	81
Electronics materials	103
Manpower	659-661
Medical electronics	96
Small scale sector	
National Conference on Electronics, 1970, Bombay	30-31
Sonar	
R&D Policy Seminar, 1973, New Delhi	53-54
Space Communication	119-138
Current status	119-122, 129-138
Guidelines	127-128
Indigenous capabilities	127-138
Requirements	125-127
Technological trends	122-125, 129-138
Specifications	
Connectors	524-534
Metals and alloys	575-582
Relays	535-536
Switches	537-543
Standardisation	103-104, 617-622, 631-632
Computers	246-251
Current status	618-619
Electromechanical components	520-543
Guidelines	620-622
Stylii	475-505
Switches	519, 537-543
Specifications	537-543
TV receivers	
Licences (ownership)	143
National Conference on Electronics, 1970, Bombay	38-39
Output	143
Requirements	145
Task force on Electronics & Telecommunication, Planning Commission	676-678

Technological trends	
Electron tubes	418
Mass communication	107-108
Medical electronic equipment	365-367
Semiconductor devices	436-459
Space communication	122-125, 129-138
Technology Development Council	60-62, 686-689
Telecommunication	86-88, 151-183
Investments	87
Output projection	87
Requirements	86
Ten-year profile	86-88
Telecommunication equipment	153-183
Current status	153
Guidelines	169-173
Imports	154
Investments	180-183
Output	153-154
Production planning	173-183
R&D	155
Requirements	155-168
Telecommunication traffic	183-187
Telecontrol	88, 193-196
Current status	193-195
Investments	88
Output projection	88
Requirements	196
Telemetry	88, 193-196
Current status	193-195
Investments	88
Output projection	88
Requirements	196
Teleprinters	230-234
Television broadcasting	
R&D Policy Seminar, 1973, New Delhi	45-46
Ten-year profile	
Computers	88-91, 218-225
Control equipment	91-94
Electronic components	98-102
Electronics industry	79-104
Electronics materials	102-103
General facilities	103-104
Instruments	97-98
Mass communication	82-84
Medical electronics	94-97
Telecommunication	86-88
Testing centres	103-104, 617, 622-629, 631-632
Current status	622-624
Fifth Plan	626-629
Medical electronic equipment	369-376
Tooling facilities	
See	
Tools	

Tools	
R&D Policy Seminar, 1973, New Delhi	56
Transformers	475-505
UK	
Manpower	656-657
USA	
Manpower	658-659
Ultrapure materials	559-616
Applications	582-588
Requirements	582-588
Specifications	582-588