



REPORT ON
POSTGRADUATE EDUCATION
LEADING TO A Ph. D. DEGREE

AT
INDIAN INSTITUTE OF TECHNOLOGY, BOMBAY

SUBMITTED BY THE
Ph. D. REVIEW COMMITTEE
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A THOUGHT

Although this may seem a paradox, all exact science is dominated by the idea of approximation. When a man tells you he knows the exact truth about anything, you are safe in inferring that he is an inexact man.

Bertrand Russell

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CHAPTER I

INTRODUCTION

The academic programme leading to the degree of Doctor of Philosophy has been in operation in the Departments of Science, Engineering and Humanities and Social Sciences almost since the beginning of the Institute. It has made some worthwhile progress over these years. Nevertheless the present technical and social environment prevailing in the country shows some mismatch between the kind of Ph. Ds produced in Engineering and Sciences and the kind required by the Industry or Educational and Research Institutions. In view of the above, the Senate of this Institute felt it advisable to make a reappraisal of the existing Ph. D. programme and suggest ways and means of improving the same so as to be generally consistent with the requirements of a developing economy without losing the requisite academic bias. A Senate Committee was accordingly constituted comprising the following members :

1. Prof. Y. N. Bapat (Aeronautical Engg. Dept.)
2. Prof. R. E. Bedford (Elec. Engg. Dept.)
3. Prof. A. B. Biswas (Chemistry Dept.) (Convener)
4. Prof. P. H. Prabhu (Humanities and Social Sciences Dept.)
5. Prof. C. K. Ramesh (Civil Engg. Dept.)
6. Prof. R. P. Singh, Dean of Research and Development
(by invitation)
7. Prof. C. M. Srivastava (Physics Dept.)
8. Prof. P. D. Sunavala (Chem. Engg. Dept.)

The Terms of reference assigned are 'The Committee to go into Ph. D. programme in this Institute and is expected to go into all aspects of the question and make appropriate recommendations. The Committee is also to examine the question regarding the desirability or otherwise of the institution of D.Sc. degree and make appropriate recommendations in this behalf'.

The Committee discussed in detail the basic philosophy of Ph. D. education. It seems imperative that to keep pace with the ever expanding frontiers of the knowledge in Science, Engineering and H & SS and also to adapt to the changing panorama of the technological and social mileau, it is necessary to introduce a dynamic system with scope for flexibility and innovation. With this background an attempt has been made here to make some recommendations which are of a

fundamental character In the formulation of these recommendations, considerable help has been received from the replies received to the questionnaire which the Committee sent to a large number of academicians, industrial managers, past Ph. D. students, present Ph. D. students and faculty members of the Institute. The Committee had a series of meetings with faculty members, technical and research assistants and research scholars of the Institute and was greatly benefitted by the discussions. Invaluable help was also received from the reports of several distinguished Committees on Ph. D. education. On the basis of our study of the problem, it is felt that a radical change of the present programme is needed. However, commensurate with the strength and ability of the faculty and the facilities available, we have pruned our ambition to a point where a realizable goal is in sight.

Currently an entry to the Ph. D. programme is permitted to a Bachelor or Master of Technology and Engineering, or to a Master of Science or Arts. In Engineering, candidates with B. Tech./B. E. degree seeking direct admission to the Ph. D. programme has been rare, although there is provision for any candidate of proven ability to seek direct admission. By and large, only the candidates with M. Tech. degree in Engineering, M. Sc. degree in Science and M. A. degree in H & SS have been the main entrants to the Ph. D. Programme.

Experience over these years of running Ph. D. programmes has shown that there is a significant gap between the levels of attainment at the end of B. Tech. / M.Sc. / M. A. and that required at the beginning of a Ph. D. programme. This gap is widening because of the expanding frontiers of knowledge in all these areas. Any dynamic programme of education at the Ph. D. level will have to take cognizance of this and formulate a workable programme to reduce the gap to a minimum. This is one of the important questions which the Committee has examined in detail and suggested ways and means to achieve the same.

Due to the multiplicity of disciplines in various Departments, there are considerable constraints in formulating a common programme for the Ph. D. education. The proposed programme will have to take note of the overall requirements of these disciplines and at the same time give due recognition to the unique problems facing each discipline.

The problem of reconciling a Ph. D. programme, especially in Engineering, with the requirements of the Industry is well-known as the Academic Institutions and the Industrial Organisations are apparently at conflict with each other with regard to the objectives of training at the Ph. D. level. Suggestions have been made for evolving programmes that may meet the requirements of both.

The basic philosophy of postgraduate education and its relevance to social and national needs is discussed in Chapter 2. As the success of the programme ultimately depends on the active participation of the

faculty and the students, their aspirations and problems have been examined with a view to optimising the working of the system. The special educational needs of scientists-engineers and teachers under the Ph. D. programme have also been discussed.

In Chapter 3, the existing system for the award of the Ph. D. degree has been discussed. The admission procedure, the selection of the research project and the present status of the interaction with Industry and other Research and Development Organisations have been described. The present pre-registration programme and its effectiveness have been critically examined.

In Chapter 4, some of the possible solutions to the existing problems and recommendations for a modified system involving a course programme have been made. Guide-lines regarding the course credit requirements, the evaluation procedure for the course and thesis work and the admission procedure have been given.

For a proper implementation of the recommendations, additional inputs and reforms in the present structure of academic bodies have been discussed in Chapter 5. Creation of additional central facilities for workshop, instrumentation, analytical and engineering testing facilities, computer centre, library etc., have been suggested. Ways and means of strengthening the interaction between this Institute and Industry as well as other Research Organisations, have been discussed. Finally, some recommendations have been made for improving the facilities for students and faculty members.

A brief summary of the recommendations is presented in Chapter 6.

The report has necessarily been limited to problems of this Institute. The Committee feels that there is a need for a much broader and detailed study of the entire Ph. D. education in the country which could possibly be undertaken by a national agency on lines somewhat similar to those carried out by the Royal Society, London.

The Reviewing Committee of the Institute has recently examined the post-graduate education and research and developmental activities of this Institute and has suggested several measures for improvements in the existing programme.

The Committee acknowledges with pleasures the considerable help it received from Prof. P. K. Kelkar, Director, who initiated the work with a comprehensive discussion on the various relevant issues involved. The report of the Royal Society, London on 'Post-graduate Training in the United Kingdom (1967-69)' and also report of the Massachusetts Institute of Technology on 'Creative Renewal in a Time of Crisis', U.S.A., have been of great source of inspiration in formulating the philosophy of the Ph. D. education by this Committee. The faculty and the students of this Institute have also contributed immensely by their effective and

meaningful discussions during the various stages of the work of this Committee. The replies received from the leaders in Industry, academicians from other Institutions and past Ph. D. students have thrown further light on various issues that came up before the Committee, particularly, with regard to the formulation of a new dynamic Ph. D. programme for this Institute.

CHAPTER 2

POSTGRADUATE EDUCATION AND ITS RELEVANCE TO NATIONAL NEEDS

Higher education in science and technology, in the last quarter century has received great impetus in this country in anticipation that it would be helpful for its rapid industrialisation. The large investment already made in this sphere is the reason for call from many quarters for its accountability in performance.

The goal of higher education even in the present context must remain close to the traditionally accepted aim of developing originality and creative thinking in the student. However, the methodology and the programme of education have to be modified so as to yield best results in this age of knowledge-explosion and in the context of developing a scientific and industrial base in the country. This demands establishment of new organizational structures in the departments to cater to the need for well-coordinated educational and research policy. Suitable steps to achieve this both within and between departments have been discussed later.

2.1 Postgraduate Education :

1) Engineering :

Engineering education in the past few decades has undergone radical changes; primarily to meet the demands arising from the rapid obsolescence of technical knowledge and skills, environmental problems associated with industrialization and the stresses generated in man and society in the wake of rapid progress in science and technology. Before World War II, engineering education was primarily practice-oriented. This was so because changes occurring in design and construction of engineering systems were so gradual that the university education based on practice, proved adequate for the entire working life of an engineering graduate. After the war the rapid advances in science and technology have led to major innovations in design and construction of systems which occurred so frequently that the engineering education during the past two decades has perforce become principle-oriented. Furthermore, because of the man-machine interface the engineer to-day has to tackle not only problems of machines but also of complex human affairs and it is now accepted that an engineer's training is incomplete without the latter.

The postgraduate engineering programme, generally speaking, should fulfil the need for training engineers for design-development and research

This is specially imperative in the context of countries like ours for producing the much needed entrepreneurs, whose approach to engineering problems differs somewhat from that of a research-trained engineer. Being primarily concerned with a time-bound and economical solution, the emphasis of an entrepreneur would be to obtain a solution regardless of the means adopted. In contrast, the aim of a research engineer is to enlarge the frontiers of knowledge with emphasis on advanced study leading to original research. This in turn creates attitudes entirely different from those whose main objective is to exploit ideas for practical utilization.

Postgraduate engineering education should thus provide training facilities with emphasis on the processes of design, and development on the one hand and research on the other. For the former, it is necessary to build sufficient background, through a formal course education and practical experience, to appreciate the contributions of the pioneers in the area of one's interest with an ability to evaluate the real worth and significance to hardware production. This could possibly be fulfilled through the Master's degree programme by providing appropriate blending of understanding with mature practical experience, needed for this type of work. On the other hand, a research engineer works and develops a habit of critical thinking in order to be able to extend the frontiers of knowledge. This is achieved usually through a doctoral programme.

(ii) Science :

Postgraduate science education in the country is modelled somewhat differently from engineering education. The undergraduate programme in sciences extends to three years after school, while that in engineering spreads over five years. The Master's programme generally extends for two years after graduation and has to be devoted mostly to broad-based training. Any further postgraduate education involving specialisation is traditionally made available only under a doctoral programme. The employment opportunities to science graduates have been fulfilled probably with this type of training. However, as there are some signs that science graduates are now finding increasing job opportunities in research and development organizations, it will be necessary in future to plan a system of postgraduate education similar to the engineering one. Doctorate programmes in sciences should have goals similar to those in engineering discussed, earlier.

(iii) Humanities and Social Sciences (H. & SS) :

The relevance of postgraduate studies in H & SS including the doctoral programme, with emphasis on the inter-relationship between science and technology and society is now well recognized in the Institute. It has been rightly pointed out by the Reviewing Committee of our Institute that 'A systematic and cumulative study of major behavioural

sciences emphasizing the inter-disciplinary approach towards an understanding of the nature and problems of contemporary society in a developing country should be the guiding theme of the Humanities and Social Science Department'.

The postgraduate programme of studies should be offered with the object of making the engineering/science student perform his professional duties satisfying the needs and demands of the society of which he is a part. Concomitantly, this should also make him aware of the Nature's imbalances and the consequent environmental problems created as a result of ever-increasing scientific and technological progress. Furthermore, this education should offer opportunities for postgraduate management studies as a means for a professional career. Finally, attempts should be made to introduce special areas such as experimental linguistics which offer vast scope for original contributions and is clearly useful in the context of our multi-lingual society.

2.2 Aspirations of Students :

The motivation of students for postgraduate education arises on account of three primary reasons :

- (i) advancement of knowledge
- (ii) betterment of career, status, and employment opportunities, and
- (iii) stimulation of creative thinking.

All the three occur to some extent in each student and the system should be so organised as to offer them suitable opportunities for the fulfilment of these basic urges. Only then, it is possible to achieve their complete involvement in the educational programme and make it a success.

In planning a doctoral programme, the maturity and capacity of the students to stand on their own feet should be recognized at the outset. The programme should offer scope to develop an attitude of independent and original thinking and self-confidence to tackle sophisticated experimental work.

The urge for advancement of knowledge should be fulfilled through offering a wide variety of advanced lecture programmes to suit the individual aptitude and need. Similar programmes should also be provided for training in experimental techniques. Self-study, literature survey and seminars should be introduced as early as possible. These should aim at developing a habit of critical analysis of the published work and its presentation in a logical and consistent manner.

In the present national context, career and employment play a dominant role with most students in selecting an area of specialisation for postgraduate studies. This is also responsible for students gravitating to some well established, reputed faculty members for guidance of their research project. This urge on the part of the students is natural.

However, ways and means may have to be devised to promote the interests of large number of faculty members. One solution would be the formation of research schools with more than one faculty member for jointly guiding students in the group. The other advantages of the formation of viable research schools are discussed elsewhere.

The stimulus for creative thinking is a rich and exciting experience to the student. This part of his experience during the doctoral programme usually shapes his attitude and approach to tackling problems at all levels later in his career. This has therefore to be organised carefully in a manner so as to develop originality and self-confidence in the student. Having assigned the problem for the research project, the student may be allowed to work out in some detail the various possible methods of obtaining solution and in consultation with the guide, to pursue the one he thinks would yield the best result. In this exercise the student should feel happy that most of the planning and execution carried out by him has led to a successful completion. Such an experience would fulfil the primary objective of developing originality and capacity for independent work in the student.

2.3 Involvement of Faculty :

A faculty member is generally deeply involved in postgraduate activities particularly in the research programmes to achieve academic distinctions on which his career largely depends. He is therefore keen to get facilities for furthering his interest in research. A worthwhile output is likely to emerge only when potentially capable research students participate in the programme under his supervision. On the other hand, students would be willing to accept the guidance and put their best only if they are assured of a satisfactory outcome leading to a good and remunerative career.

In a teaching organization like ours, the faculty has to devote part of its time to teaching functions. Teaching and research are inherently intertwined, co-equal and mutually promote each other. The propagation of new ideas and concepts takes place through proper communication to others, which one acquires through teaching. For good teaching function, it is necessary to be relatively broad both in knowledge as well as in intellectual sympathies, while for dedicated research work one has to be highly specialized. For the conflict to be resolved and to achieve excellence both in research and teaching, the two have to be balanced. Further, it is refreshing to be in a teaching-cum-research profession because of the opportunity of association with young and inquisitive minds who continuously keep flowing.

The residential character of the Institute requires participation of the faculty in activities which may not have a direct relevance to academic pursuits but may be important for a happy and harmonious student-

faculty relationship. In addition, to plan and to implement our academic programmes, it is often necessary to participate in committees consuming a lot of time and effort. This has given rise to a general feeling in the faculty that sufficient time is not left for doing worthwhile research work and this is the reason in some cases for poor supervision at the master's and doctoral levels.

As the status of an Institute amongst the national and international community of academic organizations depends primarily on the quality of its original contributions, every attempt should be made to reduce the difficulties that come in the way of faculty's effort in this direction. The problems discussed above can to some extent be solved by the rationalisation of the research programmes in the Departments and formation of research groups, involvement of research scholars as part-time teaching assistants and lessening of committees work. These are discussed elsewhere in the report.

2.4 Training of Scientist-Engineer :

The industrial research to-day is of an extremely complex character and has led to the belief that only a new type of scientist-cum-inventor-cum-engineer holds today the key to the progress of technology. This is so because the knowledge needed in this field is made of layers, a question at any one level is dependent upon information contained in the next lower layer, the answer to these in turn can be applied to a layer just above. Hence, there is need for scientists and engineers with multi-disciplinary background. The emergence of such a class of scientist-engineers has reduced significantly the gap between scientific discoveries and technological applications. It took only three years between the invention in 1948 and the sale of the first transistor and almost the same period elapsed between the invention and the production of the solar battery (1953-55) and stereospecific rubbers and plastics (1955-58).

The training of scientist-engineers required for manning industrial research organisations which have led in the establishment of improved technology, often with rapid economic returns, is a major responsibility of institutes of higher learning. Such a training programme requires active cooperation between science and engineering departments having competent faculty and requisite facilities. The collaboration is most fruitful when, despite specialisations in the distinct areas of science and engineering, the faculty has the desire and motivation to provide significant overlap in their research and teaching programmes. What has been said above is also valid for inter-departmental programmes within engineering as well as science faculties. It should be the special responsibility of a body like the proposed Institute Postgraduate Committee to identify the areas in which such programmes can be effectively introduced based on the facilities available at the Institute and the demands of the industry.

2.5 Training of Teachers :

One aspect of professional responsibility too often neglected is the training of teachers. To produce a trained body of competent and adaptable teachers and to meet the rapid changes in education, it is necessary that a well organised programme for training of teachers extending upto the Ph. D. level, is adopted by the Institutes of higher learning. It may be a matter of some controversy whether postgraduate training at the Ph.D. level is necessary for good teaching functions, but there is no doubt that involvement in a piece of original investigation leads to inspiring and creative teaching. Further, this helps the teaching faculty to be sensitive to changing patterns of advanced knowledge and to suitably adopt their curricula.

CHAPTER 3

THE EXISTING SYSTEM

In this Chapter, we describe the existing system for the award of the Ph. D. degree and some of its shortcomings. In the next Chapter, we shall discuss the solutions to the existing problems.

The Institute offers facilities for work leading to the degree of Doctor of Philosophy to a candidate who has obtained the Master's degree of this Institute or an equivalent qualification by virtue of an examination. The degree of Ph. D. is conferred upon the candidate on the basis of research work carried out at the Institute under the guidance of a teacher for a period of at least two calendar years following his registration, on the merits of a thesis duly approved by the Senate. A candidate is also permitted to carry out a part of his research work outside the Institute in a factory, laboratory, workshop or worksite duly approved for the purpose.

The thesis submitted for the degree of Ph. D. should contain an account of research work carried out by the candidate leading to the discovery of new facts or techniques or new correlations of scientific facts already known, the work being of such quality that it makes a definite contribution to the advancement of knowledge. As a pre-requisite for the submission of the thesis, a candidate is required to pass a foreign language test in any one of the languages approved by the Senate. The thesis is assessed by two referees appointed by the Senate for examination and report. The two referees are from outside the Institute chosen from a panel of examiners recommended by the departmental Academic Committee. The Senate may also consider the registration for Ph. D. degree of a candidate who has obtained Bachelor's degree of this Institute or equivalent qualification by virtue of an examination in a subject duly approved by the Senate and has furnished evidence of proven capacity for research or has satisfactorily pursued an approved programme of studies extending for a period of not less than nine months, under a teacher of this Institute.

The registration to the Ph. D. degree of the Institute is also open to an *external* candidate who has obtained a Master's degree at any one of the Indian Institutes of Technology and who has carried out research at a recognized institution under the supervision of a recognized guide, provided the candidate fulfills all the qualifications required for admission to the course and submits the thesis not earlier than three years after the date of registration. Such a candidate needs to be sponsored by a member of the faculty of this Institute. The sponsor also acts as an internal examiner on the panel

constituted to examine the candidate's thesis. The candidate is required to give at least two seminars on the progress of his work every year.

A teacher of the Institute, other than an associate lecturer, pursuing research on his own or under the guidance of another teacher of the Institute may submit his work in the form of a thesis for the degree of Doctor of Philosophy, if permitted to register for the degree by the Senate at least three years prior to the submission of the thesis. An associate lecturer, research assistant, technical assistant or any other category of the staff may be registered for Ph. D. degree provided he registers under a faculty member of the Institute and submits his thesis not earlier than three years after his registration.

The registration programme is usually drawn up by the guide and on the recommendation of the departmental Academic Committee is submitted to the Senate for its approval. The Academic Committee also recommends the panel of examiners and the mode of assessment for the pre-registration programme which may include one or more of the following

1. Written examination
2. Oral examination
3. Seminar talks on assigned topics

The period of the pre-registration programme varies from nine to fifteen months.

A candidate with a Master's degree can be registered without undergoing the pre-registration programme provided the guide recommends, and a panel of examiners assesses and approves the suitability of the candidate for direct registration.

3.1. Admission Procedure :

The candidates are selected on the basis of a comprehensive viva-voce examination at the beginning of the first semester of each academic year. They are assigned to the guides immediately on joining the Institute depending on their preference of the subject and the acceptability by the guide. The pre-registration programme is recommended by the academic committee and approved by the Senate and this usually consists of some course programme at the M. Tech./M.Sc. level, self study courses and/or seminars.

Over the years, considerable difficulties have been experienced by the faculty as well as the students on account of the existing admission and registration procedures. The admission procedure does not permit the students to make a mature decision regarding the choice of the area of research as they are aware of the facilities in the Department only in a very superficial manner. Similarly, the faculty member does not get any opportunity to assess the capability and aptitude of the candidate in a few minutes of his contact at the interview time.

The registration programme is intended for preparing the candidate for his research project as well as for filling up of the gaps which he may have had in his earlier education and training in order to make him better prepared for the work in the area of his specialization. This has often been not effective, possibly for two main reasons. The candidate does not really get deeply involved in the programme as he views it merely as a hurdle to cross the Ph.D. degree without appreciating much the need for it to form a part of the Ph.D. degree requirement and secondly, as the programme is not strictly time bound, the student often adopts a leisurely pace so that sometimes it extends beyond any reasonable time limit.

In view of the ineffectiveness of the existing pre-registration programme, the Committee feels that it is now necessary to introduce formal course requirements for the degree of Ph.D. in Engineering, Science and H & SS. The requirement for the Ph. D. degree should consist of the satisfactory completion of an original investigation as well as of the prescribed courses of study through a definite period. The details of the credit requirements are discussed in the next Chapter.

3.2 The Research Project :

As the research project is the primary requirement of the Ph.D. degree, the proper choice of topics has to be carefully made. This choice, at present, is distorted on account of (a) lack of contact with industrial establishments, (b) eagerness to achieve distinction through easy and quick publications and (c) concern regarding the duration of students fellowships. The selection of the research projects has often been carried out in a manner which reflects our concern with science and technology but ignores the background in which these could be applied. Such a situation has arisen partly on account of our unawareness of national objectives and priorities in the field of scientific and technological advances. Several agencies such as the National Committee for Science and Technology, Council of Scientific and Industrial Research, Department of Atomic Energy and R & D Organization of the Ministry of Defence are now attempting to identify the short- and long-range problems facing our country and it may now be possible to reorient our policy regarding the areas of research activity towards achieving greater social and national relevance.

3.3 Interaction with Industry :

The method of interaction between our Institute and Industry has so far been on the traditional lines. A particular department takes on a specific project or task with the cost borne by the industry; fellowships or grants from the industry are given to the Institute with little commitments whatsoever. Also, formal consultative services are sought from the faculty to provide expert advice on day-to-day problems,

which are normally termed as 'troubleshooting'. So far as the Ph.D. programme is concerned, it is probably necessary to have well-defined objectives, both long and short term, so that the problems for research can be clearly formulated with a meaningful participation by the Institute for the growth of industry. The ways for doing it have been outlined in the next Chapter.

3.4 Collaboration with R & D Organisations and other Academic Institutions :

Our location in the proximity of research and development organisations such as T. I. F. R. and B. A. R. C. has offered us excellent opportunities for collaboration with them. During the fifteen years of our existence, some joint projects with these organisations have been undertaken and successfully completed by us. However, there is need for further improvement in this sphere. The specific measures which may be taken in this direction has been discussed in the next Chapter.

One of the responsibilities of the Institutes of higher learning is to extend facilities for teachers of other academic institutes to advance their knowledge and to specialise in areas of their interest. This eventually is expected to help them to improve the quality of their teaching and research in their own organisations. A Quality Improvement Programme with emphasis on full-time Ph.D. level training, but limited only to teachers of engineering colleges has been in operation for sometime. This programme needs further strengthening and extension to teachers of other institutions and has been discussed later.

CHAPTER 4

SOLUTIONS TO EXISTING PROBLEMS

4.1 Requirements for Ph. D. Degree :

We discuss now some possible solutions to the existing problems facing Ph. D. education in our Institute. In the opinion of the Committee, the aim of the postgraduate training is to achieve intellectual broadening and maturing of the graduate and to inculcate the ability to evaluate evidence, discuss new knowledge and discover new principles by intelligent application of upto-date research tools.

The present programme with too much emphasis on research projects without offering any breadth of background education is narrow overspecialized and possibly isolated. Such a training is not a good preparation for later work in engineering and science where imagination and capacity to understand and appreciate a complex problem as a whole is required. It is especially true in our context where it is difficult for a candidate with Ph. D. degree to choose a career entirely in research in the very field of his specialization. It may require making a transition to an entirely different area of science and engineering. The capacity for adaptability which the present employment opportunities demand, requires acquisition of related knowledge and skills in wider aspects of the candidate's field of specialization. Such a preparation can be imparted only through a coherent scheme of lecture courses and experimental techniques and establishment of research schools. The Committee therefore recommends that the degree of Ph. D. should be conferred in recognition of an investigation done by the student together with the completion of prescribed courses of study in a specified period. The details of the course programme and the research projects are discussed below.

4.2. Course Programme :

In the past, it was assumed that a good B. Tech./M. Sc./ M. A. was an adequate formal education for admission as a Ph. D. candidate. It is now becoming widely felt that, with the recent explosion of knowledge and complexity of modern experimental methods, this is no longer true. Therefore, the introduction of formal courses is strongly recommended to bridge this gap between education at the above-mentioned degree levels and start of a research project. This is also the almost unanimous opinion of all academicians, industrial managers and students consulted by us.

The pattern of courses offered should be designed on the basis of the student's background and experience and should help him to acquire under-

standing necessary to pursue and complete his investigation effectively. Course work in related areas may be included to provide wider knowledge to equip the student to adapt himself to rapidly changing scientific and technological fields of activity. To achieve these objectives, the course programme may be organised along the following lines.

(a) Basic postgraduate courses – These could be offered at post – B. Tech./M. Sc./M. A. levels and could also include M. Tech. courses.

(b) Intensive short term courses.

The Departmental post-graduate committee may advise a student to take a supervised self-study course, but such courses should not be more than one for a candidate in science and engineering faculties. For H & SS this restriction may be relaxed, if required. Such a course would carry 4 credits only.

In special cases, a few courses even from the undergraduate programme may be offered if the candidate did not have previous exposure in a subject. Such courses could be offered upto a maximum of 8 credits only.

The basic philosophy of post – B. Tech./M. Sc./M. A. courses should be to prepare the students for higher level of competence in modern Engineering, Science and Humanities and Social Sciences.

The objective of the intensive short term courses should be to acquaint the student with the latest development in some areas of research. These should normally be of ten to fifteen contact hours. Such a programme would offer opportunities for greater participation from amongst the faculty members. Further, it will enable many eminent scientists/engineers/technologists from outside the Institute to participate in this programme. As such persons may not normally be able to spare one whole semester for offering advanced courses, they can easily participate in the programme by spending one or two weeks in the Institute to conduct these courses and do the necessary evaluation as required. Through these courses, it would be possible to generate active interaction between the Institute and research laboratories and industrial research centres.

4.3 Credits for Courses :

The assignment of credits to a course is often based on either contact hours or contact hours plus the estimated preparation time of the student. The Institute should follow an uniform procedure for the same. The present recommendations are based on contact hours, which has been adopted for our undergraduate courses and also suggested by the M. Tech. Review committee for the Master's degree programme in Engineering.

For a theory course one lecture hour or tutorial per week for a full semester would carry two credits. The intensive short term courses, however, will carry two credits irrespective of the duration of the course. For a

laboratory course, one hour per week for a full semester would carry one credit.

Each seminar will carry four credits.

4.4 Foreign Language Requirements

A foreign language study has its own merits. However, a study of the present system existing in the Institute has revealed that it has not produced the desired results. Further, with the increasing possibility of obtaining translations of many original researches published in other foreign languages, the compulsory language requirement may not be that essential. It is, therefore, recommended that the foreign language be made an optional and noncredit course. Even in the existing system, some motivated candidates have derived benefits from this programme. It is therefore recommended that facilities should be continued for the study of foreign languages. A student successfully completing such a course should be awarded a certificate and mention of it should be made in the transcript.

4.5 Course Credit Requirements:

The following course credit requirements are recommended for the candidates in various faculties :

i) Science Faculty :

Entrants to this stream would normally have a Master's degree in Sciences. The minimum course credit requirements proposed here are based on the general background of such candidates and the level of competence required to pursue the research project at the end of the course programme. If the advisory panel feels that the background of the candidate is such that more courses are needed, the credit requirements may be increased.

Minimum credit requirements – 38

These credits may be earned in the following manner :

- a) Course Programme – Credit requirements – 30 §
- b) Seminars – Not less than 8 credits.

(ii) Engineering Faculty :

In engineering departments, the courses leading to the Master's degree require two years of work after the Bachelor's degree and prepare the students for professional career of an advanced nature. This generally provides the student with sufficient experience to embark on a programme of

§ If during initial screening, the Departmental Postgraduate Committee finds that a candidate has adequate proficiency in the basic post-B. Tech./M. Sc. level courses, it may recommend to the Institute Postgraduate Committee for reduced credit requirements. However, in no case, the credits could be less than 20. Adequate care should be taken so that it is not used as an escape clause.

advanced study for the degree of Doctor of Philosophy. It is therefore recommended that the course credit requirements should be less for a candidate with M. Tech.

a) Candidates with M. Tech. degree—Minimum credit requirements – 8.

These can be earned through courses or seminars or both. In case the postgraduate committee finds that a candidate has the potentialities for pursuing the Ph. D. degree programme but needs additional knowledge in some areas of direct relevance to his field of research, it may prescribe suitable course credits over and above the prescribed minimum of 8 credits.

b) Candidates entering with B. Tech./M. Sc. degree.

Admission of B. Tech. and M. Sc. degree holders would be considered for candidates with good academic record and distinct aptitude for research.

The credit requirements for this stream would be the same as that for candidates entering the science faculty.

iii) Humanities and Social Sciences Faculty :

On account of the diversified interests of the faculty members of the Humanities and Social Sciences Department and the present limited strength of the faculty, it is proposed that the student may be permitted to undertake supervised self-study courses along with the formal courses which the Department may offer at the Post-M. A. level.

Minimum credit requirements – 38

(a) Course programme – 26§

(b) Seminars – 12

4.6 Method of Evaluation :

It is recommended that grades should be awarded for the course work and seminars. The following grades as recommended by the M. Tech. Committee may be awarded for the course work :

Letter Grade	Quality Grade	Grade Points
A	Excellent	10
B	Good	8
C	Satisfactory	6
F	Failure	Zero
Au	Audit	No grade
I	Incomplete	No grade
W	Withdrawal	No grade

§ 11 during initial screening, the Departmental Postgraduate Committee finds that a candidate has adequate proficiency in the basic post-M. A. level courses, it may be recommended to the Institute Postgraduate Committee for reduced credit requirements. However, in no case, the credits could be less than 16. Adequate care should be taken so that it is not used as an escape clause.

The last three grades would not be applicable for the evaluation of the performance in the seminar.

A transcript giving the complete record of the courses and seminars taken by a candidate along with the grades obtained by him will be given at the completion of the Ph. D. degree programme or earlier if he discontinues the studies for reasons beyond his control.

4.7 Academic Performance Requirement :

The following is the requirement for the eligibility of a candidate to continue the Ph. D. degree programme. A student seeking registration for the Ph. D. degree should have SPI (Semester Performance Index or grade point average) of not less than six for each semester. However, CPI (Cumulative Performance Index) should not be less than seven at the completion of the course programme.

If CPI falls below seven, he is advised to discontinue his studies for the Ph. D. degree. However, such cases may be reviewed by the Departmental Postgraduate Committee which may recommend deserving cases for transfer to a suitable DIIT programme, if available. The method of calculation of SPI and CPI is as per the recommendation of the M. Tech. Review Committee.

4.8 Selection of Research Projects :

The selection of a research project needs considerable care and planning. Fundamental research must be respected and encouraged as an instrument providing fertile educational background. But it does not mean that it is by itself a healthy diet. The emphasis on research has to be oriented towards useful projects and fulfilling specific needs which have relevance to social and national objectives. Such problems are now being brought to our notice through several agencies mentioned earlier. It may be noted in this connection that work on applied projects is expected to generate a number of fundamental research problems and raise demand for basic data. As a result, there will always be enough scope for identification and pursuance of relevant fundamental research.

The research project may consist of one or more of the following types of investigations :

- (a) Theoretical
- (b) Experimental
- (c) Developmental.

and should form part of a well co-ordinated programme, having a clearly defined objective.

Sophisticated and challenging developmental projects, though not of original nature could constitute a research project for the Ph. D. degree. In such cases, however, it should be ensured at the end that better design with

primarily indigeneous components was not possible and data obtained are reliable and reproducible within the limits of accuracies quoted by the candidate. The thesis should contain a comparison of the performance of the newly developed model with the best available in order to clearly indicate the degree of accomplishment by the candidate.

4.9 Supervisory System :

The present practice of students working with a supervisor on a project which is often isolated from the rest of the other projects, does not lead to an experience where attitudes for collaboration could develop. Further the research experience acquired is in a very narrow and isolated environment. A much broader experience could be gained if the student forms part of a group; he will then be able to appreciate the different facets of the problem and would realize the need for tackling the problem in its totality. Such working conditions can only be created through the formation of research groups consisting of a minimum of four faculty members. The other advantages of the formation of research groups have further been discussed in Chapter 5.

As indicated earlier, there is considerable pressure from students to work with some of the eminent faculty members. This has resulted in large concentration of the students under a single faculty member, with the result that adequate attention to the student cannot be given. This has also partly resulted in some faculty members being left out from the research activities of the department. In an Institute devoted to advanced teaching and research, every effort has to be made to get the maximum involvement of the faculty in research activities in some way or other. It is therefore recommended that a faculty member should not normally undertake to supervise more than six students at a time. This limitation of number should be viewed as a measure of self-control by the supervisor.

The contact limited to one supervisor only is often an undesirable source of narrowness in education. A supervisor is bound to have gaps in his knowledge and skills and hence regular discussion with others, providing valuable broadening experience is desirable. The Committee is therefore in favour of encouraging 'joint supervisor' system, both within the department and in interdisciplinary and interdepartmental projects, wherever this is feasible.

4.10 Categories of candidates for registration :

We envisage three different categories of candidates who may seek registration for the Ph. D. degree at the Institute :

- i) Full time candidate
- ii) Staff member of the Institute and sponsored candidate from other institutes.
- iii) External candidate.

The following are recommended to be the requirements of registration for candidates in the above categories:

i) Full Time Candidate :

A full time candidate with B. Tech./M. Sc./M. A. degree seeking registration should complete within one calendar year all the course credit requirements prescribed by the Postgraduate Committee of the department. An M. Tech. candidate would normally complete the prescribed course credit requirements within one semester. The date of registration would be from the date of successful completion of the prescribed course credits.

In case a full time candidate is unable to complete the prescribed credits within one calendar year, he may be advised to discontinue his programme for the Ph. D. degree.

ii) Staff Member of the Institute and Sponsored Candidate :

A staff member of the Institute or sponsored teachers from other institutions may be permitted on the recommendations of the Institute Postgraduate Committee to extend the period of completing the prescribed course credits for registration. In case a staff member or a sponsored candidate fails to complete all the course credit requirements within the prescribed period, he may be advised to discontinue his programme for the Ph. D. degree.

iii) External Candidate :

The present Ph. D. regulation, OD-7, permits external registration only to a candidate who has received M. Tech./B. Tech./M. Sc. degree of any of the Indian Institutes of Technology. He is permitted to carry out his research work in a recognized institution under the guidance of a recognized supervisor. His application has to be sponsored by a member of the faculty of this Institute.

Research primarily signifies an intense form of creative intellectual activity wherein an individual or a group and the environment as a whole, form an organic entity. The doctoral thesis and the research publications would be a reflection of the kind and the level of research work done at the Institute. Research initiated and carried out entirely in a different set up would not present the same image. At the same time we cannot live in complete isolation. The requirement that the candidate has to be a graduate of an IIT only needs reappraisal. Further, the sponsor from this Institute has academically no significant role to play. For these reasons, OD-7 needs revision.

The real benefit to the Institute in permitting external registration should be to enhance the interaction between the Institute and the existing well-developed centres of research. This will promote the growth of collaborative research and developmental work including research effort on more relevant problems of national importance than is often the case at present. A member of the faculty may be able to initiate and get associated with more

challenging research projects which it may not be possible for him to undertake at the Institute all by himself. The candidate is also likely to get better experience by being exposed to different environments. This would broaden his outlook and bring confidence in facing challenging problems.

We have obligation to other institutions and colleges to offer facilities for improving the quality of teaching and fostering growth of research activities. Such a programme is already in operation for teachers in engineering colleges, under the Quality Improvement Programme (QIP).

In view of the above, the Committee makes the following recommendations :

- (1) External registration of a candidate who has the same entry qualifications as those prescribed for a full time candidate, may be permitted.
- (2) The application in prescribed form should be sponsored by the employer and submitted alongwith a certificate that facilities available in the sponsor's laboratory can be made use of by the candidate under the supervision of the supervisor. Such an application will be considered by the Institute Postgraduate Committee on it's merit.
- (3) A qualified staff member of the sponsoring organisation, willing to supervise the work of the candidate in his own laboratory, may become the joint supervisor with a faculty member of this Institute. If there is no staff member who can supervise in the sponsor's organisation, a senior person in the organization can sponsor the application, and an appropriate faculty member(s) of the Institute will act as the supervisor(s).
- (4) The candidate should be required to pass the same number of advanced level courses as are required by a full-time candidate for registration.

In case a candidate has acquired some course credits elsewhere of a standard equivalent to those of the Ph.D. credits of the Institute, these could be counted towards fulfilment of a part of the credit requirement. The completion of the course requirements may, if desired, be spread over a period of 3 to 4 semesters.

- (5) A properly documented research programme for such a degree would be drawn by the candidate in consultation with his research supervisors. It is understood that such a programme should be related to the broad-based interests of the Institute and that of the sponsoring organisation.
- (6) It is expected that the candidate would contribute to the growth of academic and research programme of the Institute with a sense of belonging, during the period of his work for the research degree, by carrying out a part of the work in this Institute.
- (7) For the above, a certain minimum period of full time attendance for study and research work at the Institute is required. This shall be

prescribed by the Institute Postgraduate Committee in each individual case, but in no case it shall be less than one semester.

The external registration facilities can be taken advantage of not only by persons who are working in well equipped scientific institutions, laboratories, R and D establishments and industrial organizations engaged in science-based activities, but also by persons working in institutions and colleges where facilities for research are available.

4.11 Admission Procedure :

We have earlier discussed some of the disadvantages of the present procedure of admitting students for the Ph. D. programme and immediately assigning them to a supervisor. This often leads to students accepting the choice of the specialization on superficial and inadequate information, while supervisors accepting the responsibility without being aware of the intrinsic interest, aptitude and skill of the candidates. Based on these considerations some modifications in the admission procedure have been recommended :

(i) Minimum Qualifications :

A candidate seeking registration for the Ph-D. degree at this Institute should satisfy the following minimum qualifications.

Engineering Faculty :

Candidates having good second class (or equivalent grade) M.Tech./ M.E. degree are eligible for admission. Candidates having first class B. E/B. Tech./B.Sc. engineering degree or first class Master's degree in an approved branch of science with a distinct aptitude for research may also be considered for admission.

Science Faculty :

Candidates having good second class (or equivalent grade) M.Sc. M. A. degree in an appropriate subject or allied discipline are eligible for admission. Candidates having first class B.E./B.Tech./B.Sc. engineering degree with distinct aptitude for research may also be considered for admission:

Humanities and Social Sciences Faculty :

Candidates having good second class (or equivalent grade) M.A. degree in an appropriate subject or allied discipline are eligible for admission.

Notwithstanding the above, if a Departmental P. G. Committee finds the qualifications and training of a candidate particularly suitable for admission to some area of research, it can recommend to the Institute P.G. Committee for consideration of his admission.

The admission to interdisciplinary/interdepartmental programmes may be considered by the Institute P. G. Committee.

(ii) Procedure to be followed before registration :

(1) Admissions may be allowed twice a year at the beginning of each semester in July and January. The admission may be on the basis of a comprehensive viva-voce examination. However, if it is deemed necessary, the viva-voce examination may be supplemented with a written test.

(2) A successful candidate may first be admitted to a broad area of research available in a department. He will not be assigned to a supervisor during the first semester of his stay in the Institute.

(3) The candidate will undergo a programme of studies recommended by the Departmental Postgraduate Committee. The supervisor would be decided at the end of the first semester through mutual consultation between the candidate and the Departmental Postgraduate Committee. In case a candidate wishes to change the area of his research, he can do so with the approval of the Departmental Postgraduate Committee which may specify further course work, if any, before he completes his registration programme.

(4) A faculty member, other than an associate lecturer, can register on his own or under the supervision of another teacher of the Institute. The course and seminar programme in each such case will be decided by the Institute Postgraduate Committee. The supervisor, if required, will have to be decided before the registration programme is completed.

(5) An associate lecturer, research assistant, technical assistant or any other category of staff of the Institute will be required to register under the supervision of a faculty member of the Institute. The course and seminar programme in each such case will be decided by the Departmental Postgraduate Committee. The supervisor may be decided at the time of admission itself.

(6) In the case of candidates joining under sponsored schemes (like QIP) or as an external candidate, the supervisor will be appointed at the time of the admission. The course and seminar programme will be decided by the Departmental and Institute Postgraduate Committees on specific recommendations of the supervisor.

4.12 Method of Evaluation : Thesis :

The procedure for assessment of research projects would consist of three different stages, namely (i) Internal Assessment, (ii) External Assessment and (iii) Viva-voce examination. These are discussed below :

(i) Internal Assessment :

For attaining a consistently good standard for the Ph. D. degree by each individual candidate, it is sometimes argued whether it should be left to the responsibility of the supervisor alone to confirm the same, or careful joint discussion among the members of the research school staff is desirable. However, it is now realised that regular attention by more than one faculty member helps to reduce undesirable variability in both research and student.

According to the present regulations (RD-6), 'A viva-voce defence shall be an open defence'. The merits and demerits of the system were examined. It may be considered a part of good training and a way of creating self-confidence and clarity of expression that the candidate is asked to present and defend his work before a gathering of experts and knowledgeable persons. However, he is often under great stress during the time of an open defence and sometimes is put to embarrassment due to awkward question and may feel slighted before a large gathering. Further, these comments and criticisms on the work given at the final defence stage, improves neither the quality nor the method of presentation of the work.

If a detailed criticism of the work by a group of competent persons is made available soon after the completion of the experimental work but prior to the submission of the synopsis of the thesis, the candidate can take note of useful hints and suggestions and even do some more critical experiments to clarify any controversial points raised during the discussion. In this way both the quality of work and method of presentation of the thesis will improve.

In view of the above, an Internal Assessment System may be introduced on the following lines:

- (a) A panel for assessment of the quality of the work and attainment of the candidate, be appointed by the Departmental Postgraduate Committee in consultation with the supervisor(s). The candidate is required to present his work in one or two seminars before the submission of the synopsis of the thesis.
- (b) The panel will consist of his course instructors, two or three experts conversant with the work and the supervisor. If desired, some experts from nearby institutes or research laboratories may be invited to attend the seminar(s). In addition, all interested staff members and students may be invited to attend, through a circular by the Department.
- (c) The main objective of this assessment committee will be to offer constructive criticisms and comments on the quality of the work by pointing out any weaknesses and giving suggestions for improving the quality of the thesis.

It is to be understood that the purpose of this open forum, comments and suggestions would be of an advisory nature only.

(ii) External Assessment : Thesis Evaluation :

In the present system of the appointment of external examiners, the Academic Committee of the Department sends to the Chairman of the Senate a panel of six names which includes both Foreign and Indian experts. The Chairman selects any two names from this panel. This procedure may continue.

According to the existing system of reporting on the thesis. the following guidelines are mentioned :

“The referees should be requested to clearly state whether the research work carried out by the candidate has led to the discovery of new facts or techniques, or to the new correlations of scientific facts already known, the work being of such quality that it makes a definite contribution to the advancement of knowledge.

A referee need not necessarily make a firm recommendation for the acceptance or rejection of the thesis which is the exclusive prerogative of the Senate as per RD-6.2”.

The Committee is of the opinion that instructions given above need modification and suggests the following :

The examiners appointed to assess a thesis be requested to send their reports within two to three months from the date of receipt of the thesis. Such a report should include :

- (a) a critical survey and evaluation of the quality and quantity of the work of the candidate as embodied in the thesis,
- (b) questions, if any, to be asked or points to be clarified at the oral examination,
- (c) a definite recommendation as to whether the thesis has attained the standard for the Ph. D. degree or not.

If the examiners are not in a position to make a definite recommendation for the award of the degree, they should assist the Senate in deciding whether the candidate should be required to make :

- (1) minor revisions—e.g. detailed corrections not involving retyping of thesis,
- (2) substantial revisions – e.g. rewriting one or more chapters, not involving much, if any, further research, and
- (3) complete rewriting – if a thesis is not acceptable but reveals sufficient quality and quantity of work to warrant the candidate being given an opportunity to do further research or re-interpretation of data and to rewrite it.

(iii) Viva-voce Examination :

Normally the viva-voce examination will be conducted at the Institute after the receipt of satisfactory reports from examiners. This examination may be conducted jointly by one of the external examiners who has examined the thesis, an internal examiner, the research supervisor (s) and a Chairman. The Chairman of the Institute Postgraduate Committee, the convener of the Departmental Postgraduate Committee and the supervisor(s) may invite a few more interested faculty members to be present during the examination.

The viva-voce examination may primarily be designed to test the understanding of the candidate on the subject matter of the thesis and his competence in the general field of his study.

4.13 Remuneration to External Examiners :

The payment of an honorium of Rs. 200/- to the thesis examiner has recently been approved by the Board of Governors of this Institute. We further recommend an additional honorium of Rs. 100/- be paid to the thesis examiner if he conducts also the viva-voce examination. In case he is not a thesis examiner, an honorium of Rs. 200/- be paid to him for conducting this examination.

4.14 Institution of other Postgraduate Degrees :

The Committee discussed the question of instituting other postgraduate degrees like M. Phil and D. Sc. in Science and Humanities and Social Sciences faculties. At present, the M. Sc./M. A. programme can offer only general training, since candidates enter these programmes after three years of their leaving the school. Thus, the only postgraduate programme available in these faculties for specialization is the doctorate programme for which all the candidates seeking admission may not have the right aptitude and capacity. Instituting a two year degree programme similar to the M. Tech. programme in engineering faculties may possibly be a solution. However, a detailed discussion led us to the conclusion that the present employment opportunities for candidates in Science and Humanities and Social Sciences Departments are not favourable for starting such a programme. To some extent the requirements of these Departments in this respect can be met by instituting a one year diploma (DIIT) programme.

The Committee also discussed in detail the question of instituting a higher degree than Ph. D. like the D. Sc. (Doctor of Science). An examination of the activities under the Ph. D. programme led us to the conclusion that in the brief span of fifteen years of our existence, although we have been slowly moving towards achieving the standards normally expected of Institutes of higher learning, we have still to reach our objective. Instituting a still higher degree would only mean lowering the standards for both the degrees. The Committee therefore recommends that the question of instituting the D. Sc. degree be postponed to a later date.

CHAPTER 5

IMPLEMENTATION OF THE RECOMMENDATIONS

For an effective implementation of the recommendations, it is necessary to introduce some additional inputs in the existing facilities and some reforms in the present structure of the academic bodies. These could be on the lines suggested below :

5.1 Creation of Institute and Departmental Postgraduate Committees :

To ensure proper implementation of the proposed course and seminar requirements for candidates seeking registration for the Ph. D. degree, it is necessary to constitute Institute and Departmental Postgraduate Committees as recommended by the M. Tech. Review Committee recently.

The Institute Postgraduate Committee should be responsible for developing an integrated programme for the post-graduate education and research in the Institute and accelerating the growth of interdisciplinary programmes. The following composition is suggested for this Committee.

- 1) The Dean of Research and Development (Convener)
- 2) The Chairmen of Departmental Post-graduate Committees (Members)

The Committee may be authorised to coopt any other member, if necessary.

The Departmental Postgraduate Committee should be responsible for developing and organizing both broad-based and intensive courses. This Committee will also assign to each candidate an appropriate course and seminar programme and finally, a supervisor (s). It will make constant effort to recognize and promote interdisciplinary activities in the areas where the departments can collaborate with each other, in a significant manner. The following composition is suggested for the Committee.

- 1) The Convener (appointed by the Senate and need not necessarily be the Head of the Department).
- 2) Two Faculty members from other departments.
- 3) Three to five faculty members from the department.

The Committee may be authorised to coopt any other member, if necessary. A faculty member registered for any degree or diploma, will not be eligible for its membership.

It is suggested that the Departmental Postgraduate Committee should meet the Ph. D. students and the supervisors once or twice a year to review

the progress of work. It may also examine the difficulties experienced by them and take suitable remedial step. Likewise, the Institute Postgraduate Committee should meet particularly the persons involved in interdisciplinary/ interdepartmental programmes once or twice a year.

5.2 Formation of Research Groups :

As discussed earlier, the Committee attaches great importance to the existence within the Institute, of strong research schools in a few selected areas within each department and also at interdepartmental levels.

A research school would be the most effective medium for postgraduate education. The existence of strong research schools can help greatly the staff members to inspire the students by teaching the subjects both in breadth and depth, and also by high-lighting the practical aspects, giving live examples so that teaching does not become too much divorced from realities.

When a research degree is taken in major research school, the student sees his research problem in relation to a wide range of problems of other research workers in the same field. A new entrant to a team benefits considerably from the work of his predecessors while an isolated student would have to construct his own apparatuses, computer programme and other supporting facilities. It becomes possible for him to spend a much greater part of his time in regular study and useful work than would have been otherwise possible. This avoids the dangers of excessive concentration in a narrow topic when very few people in the department, apart from the student and his supervisor, are interested in the topic of his research. For example, seminars held on such a narrow subject receive poor response while those organised by the members of a research group would be well attended and give rise to benefits to a larger number, as the state of current research trend, its aim and results are discussed by several members. Furthermore, limited resources might be better utilized by being channelled to research groups than being thinly equipartitioned.

In areas like Materials Science and Systems Engineering, there is hardly an alternative as these are highly interdisciplinary areas and would demand participation by members of more than one department. This activity should further be extended to develop strongly coupled interactions and close relations with other institutes, universities, government laboratories and industry.

The major research schools at departmental and interdepartmental levels should be developed in areas which are of interdisciplinary character or have a wide base. This will be of considerable benefit to the research workers in the departments of engineering and science, as more experimental facilities could be pooled in these schools. Collaborative effort can be promoted by assigning with priority, research students and technical staff to such projects. Joint faculty appointments would also effectively foster close relationships

5.3 Central Facilities

The growth and reputation of well coordinated research and developmental activities of an institution depend heavily on the ancillary facilities as Library, Workshop, Precision Instrumentation, Analytical Equipment, Computational Aids, Typing, Photo-copying and Duplicating aids. Some of these facilities do exist in the Institute at present but they need considerable strengthening and changes in their organisational structure. With the exception of library, institutional advisory bodies are not organised to advise and to audit the proper functioning of these central facilities. It is time for us to give an adequate thought and work out the organisational procedures for all central facilities through the formation of users' advisory committees. Formation of such committees will create a sense of common possession of the equipment and proper sharing and utilisation according to the need.

(i) Library :

The library should be one of the most important centres of attraction for the students and the staff in an academic institution. In view of the present stage of growth, and envisaged expansion of the Institute, the library urgently requires many functional values to be added. Considering all the factors it may turn out that the present structure, including its location, is inadequate to play its due role in the life arteries of the Institute. With the explosion of available information it is necessary that the library should have increased recurring grants for buying journals, periodicals, reports and reprints.

Some of the facilities which should be acquired and located in the library are : (i) Facilities for micro-filming, (ii) A good microfilm reader (iii) Zero reduction duplicator, (iv) Duplication facility, (v) Computer aided cataloguing and information retrieval facilities. A qualified and experienced person at the Professorial level should be appointed as Librarian to cater to the needs of expanded Library and its associated facilities.

The Institute has an active collaboration with the USSR for obtaining scientific information, periodicals, reports and books. A large number of staff

members know the Russian language. However, for persons not knowing this language, it is a big handicap, as efficient translation facilities are not available in the country. It is therefore suggested that a Language Translation Centre may be started on a small scale, in the Library, in the long run this service can seek recognition from INSDOC as a National Centre for Russian Scientific Translation. If found necessary, the centre can have additional facilities for translation of other languages.

For increasing the functional value of the Library, it is recommended that a sub-Library be started in the ground floor of the (old) Aeronautical Engineering Building for the benefit of the staff and students of the adjoining departments. This may, for the present, function as a reference (non-issuing) library by keeping duplicate copies of text and reference books and recent issues of journal, of direct interest to the nearby departments. This sub-Library is envisaged to serve a much better purpose than having separate departmental libraries in this area.

(ii) Equipment Facilities :

The standard and quality of research work, especially experimental, being carried out at an institute can be judged to some extent by the type and quality of equipment possessed by the institute. It must be of utmost concern to develop sophisticated and specialized research and investigation facilities for the institute as a whole.

It is well-known that this Institute is not well-equipped. A number of modern instruments are essentially required to improve the quality of our postgraduate research programmes. The presence of well equipped and active laboratories, operated by dynamic and competent faculty, will motivate the students to think and do creative work.

For encouraging a lively growth of, and establishing fruitful relationship between our research activities with those of other institutes, universities, government R and D organisations and industry, we urgently need establishment of good central, analytical laboratory equipped with sufficiently sophisticated instruments, normally required for precision analysis. Some of these are : (i) Electron Microscope, (ii) X-ray equipment, (iii) Spectrometers (NMR, ESR, UV and IR etc.), (iv) Instron Machine, (v) Electronic calculators, (vi) Hotwire anemometers, (vii) Vibration and sound measuring equipment, (viii) Oscilloscopes, (ix) Solid State device fabrication facilities, etc. We envisage that this laboratory, if established, will be, heavily used by industry located in and around Bombay. The payment of nominal charges by them could self-sustain its running and maintenance expenditure. This activity will generate cross-currents of ideas and collaborative activities as mentioned before.

In the recent past the Institute has already initiated steps for procuring a few of the most urgently required equipment as a central facility of the Institute. The Review Committee of the Institute has also recommended the

purchase of several such equipment for central facilities and also to meet the specific needs of the departments. These equipment are urgently needed for the sustenance of worthwhile research activity, growth of the Ph. D. programme of the Institute and opening of avenues for collaboration with other research and teaching organisations. We urge upon the authorities for making a concerted effort to procure these equipment at an early date.

(iii) Developmental Facilities (Workshop, Instrumentation and Glass blowing)

Imported equipment alone cannot go too far in the growth of experimental research and developmental activities at the Institute. We must have expertise not only for efficient maintenance and operation of these facilities but also an attitude of self-reliance and confidence to modify these to suit our requirement, improvise new instruments and devices, through design and fabrication activities within indigeneous resources. For the above purpose we must have an adequate workshop, precision instrumentation and glass-blowing facilities as a central service. Departments with their limited staff cannot be expected individually to provide the varied requirement of talent, skill and the facilities demanded for undertaking such work. While the department may be permitted to have such facilities to the extent of meeting their day to day need, it is most urgent to pool the resources to undertake design, construction, standardization and maintenance work as a centralized facility. This will require the formation of well-formed inter-disciplinary teams to identify common needs and undertake their design and fabrication.

With the decreased academic load of the central workshop (located in Mechanical Engineering Department) in the new UG programme, the central workshop should be able to play an increasing role as a central fabrication facility. It can help in fabrication from full scale models to small prototypes of mechanical machines and structures. If necessary, it may be further equipped with more sophisticated fabrication facilities. It may be made clear here that the committee fully understands the necessity of retaining basic workshop facilities existing in most of the departments but advocates the pooling of the large scale facilities which are not required for day to day use of the departments.

The Central Instruments Repairs Organisation has to be revamped in such a fashion that it can actively contribute in the development and fabrication of sophisticated instrumentation systems required by other departments. In the long run, it can also undertake to meet some of the needs of the adjoining academic and industrial enterprises

(iv) Computational Facilities :

Computers are bound to play a key role in most of the large scale and sophisticated research and design work undertaken in this Institute. At present, the Institute has very limited digital computer facility primarily designed for educational purposes and most of the serious computational

work is being referred to the TIFR Computer Centre. However, the facilities at the TIFR Centre are becoming unavailable day by day due to the increasing load of the Centre. Therefore, there is an urgent necessity of upgrading the existing installation at this Institute. This has been fortunately realised and an effort is being made seriously to acquire a third generation large scale digital computer. Besides the large scale computational requirement of the R and D work, the Institute is initiating a number of systems oriented investigations such as aerospace control systems studies and hydrologic systems studies. These will involve large scale simulation studies to be undertaken on Analog and Hybrid computer systems. At present, the Institute has a reasonable Analog computational facility but no Hybrid Computer facility. It is therefore recommended that, (i) A large scale general purpose digital computer of the third generation with time sharing facility may be acquired, (ii) A large scale Hybrid Computer facility may be developed on an institutional basis integrating the presently available analog and digital computer facilities, (iii) A process control computer may be acquired to serve the process control studies which will form an important element of R and D work for industry.

(v) **Development of Personnel for Central Services:**

No faculty member can be expected to give total devotion to the work in central services. A few joint appointments on an inter-disciplinary, inter-departmental basis may be made to encourage such group activities on an institutional level. In addition, the Institute will have to seek the support, expertise and collaboration of other R and D organisations in Bombay for the development of central facilities.

In the areas of computation, instrumentation and workshop, it is difficult to attract and retain skilled technical personnel on the salary scales that exist in the Institute. It will, therefore, be necessary to have some technical posts with higher emoluments unrelated to academic qualifications. Periodic evaluation of the involvement of the existing staff in the inter-departmental activities should be made and necessary training facilities provided for upgrading their skill and knowledge by deputing them for practical training outside the institute.

The Committee realizes the great importance of giving training in Instrumentation (electronic) as a part of the Ph.D. course programme, particularly to those students who are not having any background and are going to make their career in experimental research. The Institute may design a suitable theory-cum-laboratory course for this purpose. Sufficient encouragement and facilities may be given for design and fabrication of instruments and devices required by the students themselves.

5.4 Cooperation with other Institutions/Industry :

A successful application of applied research is very difficult without a close and continuous interaction between those who are doing research

and those who are expected to use the results of research. The post-graduate education should be viewed as a cooperative task between an institute, research school and industry and - R and D organisations.

This Institute is ideally situated for collaboration with other institutes and industry. The western region has been, over the past half century, providing inspiration to the nation and process of rapid transformation of our country to an industrialized society. Over the past three decades, several centres of research and development have come into existence in Bombay, which have been pioneers in the country in some of the new areas of science and technology. Such an environment provides excellent possibilities for active and meaningful cooperative research and developmental programmes with industry and other institutions. Our Institute has taken advantage of this and over the past decade there has been continuous increase in the number of consultation services rendered by us in various forms to industry. Our efforts at meaningful collaboration with other institutions like Bhabha Atomic Research Centre and Tata Institute of Fundamental Research has led to the completion of some projects with improved quality of work on account of better experimental facilities available at these centres. Despite these positive results which we have achieved so far, the Committee feels that there is still a large scope for improvement in this direction as the Ph. D. programme itself could provide another means of strengthening the link which has not been fully explored so far. The following recommendations are made to enlarge the area of collaborative programmes :

- (1) Establishment of a dynamic group in the Institute for close and day to day contact with those industries with whom the Institute can interact meaningfully. This group may be organized by the Dean of Research and Development and may consist of members having the necessary background and awareness of what is expected from the industry and how to negotiate with them.
- (2) The same group should also coordinate research and development activities to be jointly undertaken with other institutes.
- (3) We envisage the following three broad classification of the projects :
 - (a) Sponsored Research : This may involve consideration of problems for Ph. D. work sponsored by the industry/institutes for work at this Institute.
 - (b) Collaborative Research : This may consist of problems sponsored by the industry/institutes with work partly done in the industry/institutes and partly at this Institute leading to a Ph. D. degree.
 - (c) Cooperative Research : This may involve consideration of problems sponsored by the industry/institute with work done in the industry/institutes itself leading to a Ph.D.

In each of these cases, the course and the seminar credit requirements would have to be completed by the candidate at this Institute.

4) The Institute may consider forming an association with industry on nominal membership fee. The association by organizing occasional meetings of its members could bring men from Industry and Institute together with the possibility of informal discussions on problems of mutual interest. As the association grows, the Institute could also help the industry in matters of sophisticated but routine type of investigations for which facilities with the industry are not available. We believe that such an association would also lead to a larger number of sponsored research projects flowing to this Institute.

(5) The members of faculty at all levels may be encouraged to spend summer/winter vacation in the Industry for laboratory and design work, discussions, seminars etc.

(6) Staff members from the industry may be invited to spend summer/winter months at this Institute to participate in short term courses as and when offered.

(7) Qualified staff members from the Industry may be invited to give part-time lectures at various levels of the programmes at this Institute.

(8) Some fellowships may be established by the Institute especially for industrial collaborative projects and the industry also be requested to institute similar fellowships.

If these measures are implemented together with other efforts made to create an all-round atmosphere for such participation and interaction, with industry and other R and D organizations, our Ph. D. programme will receive a great impetus.

5.5 Research Bulletin :

One of our important endeavours should be to create a free and unfettered communication channel between research workers both within and outside the Institution. The publication of a Research Bulletin at least once in a year about the research and developmental activities of the Institute is considered most desirable as it provides information to staff, students and organisations both inside and outside the Institute regarding the nature of problems being pursued in various departments of the Institute. Also, the workers directly concerned will derive satisfaction and incentive to do more work to get the results of their investigation published.

We also recommend that this bulletin may incorporate information regarding important problems, instruments, devices etc., suggested for solution or fabrication, particularly through Ph. D./M. Tech./DIIT research projects.

A record of the research work done at the Institute should be centralized rather than kept in the sole possession of individuals or departments. Every Ph. D./M. Tech. student should be required to send a brief report on his

project work to the office of the Dean, Research and Development. A committee may screen this work and extracts of important ones be published in the Bulletin.

5.6 Problems Facing Students

We circulated a questionnaire specifically meant for the present Ph. D. students with a view to elicit their opinion about the objectives of the Ph. D. education and the impediment they are facing in the realization of these objectives during their stay at the Institute. As indicated elsewhere, the response from them has been critical of the present system. In personal discussions, many voiced their feeling of frustration arising from reasons such as economic hardships, bleak future prospects, limited facilities of work and several other academic problems. As all of these cannot be dealt with in this report, we suggest creation of suitable agency for looking into these problems.

We recommend the following measures for implementation :

i) Scholarships and financial assistance :

The present scholarship of Rs. 400/- p. m. to M. Tech. and Rs. 250/- p. m. to B. Tech. / B. E. / M. Sc. degree holders for pursuing the Ph. D. programme, is totally inadequate and this should be revised to Rs. 500/- in the former case and Rs. 350/- in the latter. Further, lump-sum grant of Rs. 500/- may be paid to the research students to meet a part of the expenditure for the preparation of the thesis.

For a candidate admitted under the provision of external registration, appropriate scholarship for which he is eligible by virtue of his basic degree may be paid during the period of his residence at the Institute.

According to the existing rules, the scholarship awarded to a student is discontinued on the very day he submits his thesis. The committee recommends that the scholarship be continued upto the date of the viva-voce examination provided that he continues to work in the Institute. This intervening period can profitably be utilized by the candidate in writing the results of his work in the form of papers for publication, carrying further experiments to fill in any gap in the work presented in the thesis or any ad hoc assignments in current projects at the institute.

ii) Participation in Teaching Programmes:

A research student may participate in the teaching programme of undergraduates, which may generally be limited to laboratory demonstrations and tutorials. This arrangement will prove to be educationally useful to him because this will broaden his outlook, provide teaching experience, improve clarity of expression and help acquire good basic knowledge of the subject. He will also get to know the teaching staff more intimately and develop a sense of belonging to the department.

We recommend that this system of research students' participation, be restricted only to well qualified, sincere and talented students. A suitable remuneration may be given commensurate with the amount of work done.

(iii) Whenever a research student communicates any paper which is accepted for presentation in an important seminar or symposium he may be permitted to participate in the same and travelling and daily allowance may be given to him.

(iv) At present the Institute research scholars are given annual leave for 15 days only. This may be increased to 30 days in a year as normally granted to research scholars financed by other governmental agencies.

5.7. Problems Facing the Faculty :

It cannot be overemphasized that every faculty member, particularly those teaching in a postgraduate institution, should in some way or other get involved in research activities of the institute. Through such an experience, not only he can do more inspiring teaching but also derive some sort of respect from the taught.

We have mentioned elsewhere that appropriate attention be given to develop research groups and well-equipped research laboratories in order to create an atmosphere of research and to promote the involvement of every faculty member in such activities.

Further incentives should be provided by implementing the following :

(a) A liberalised sabbatical leave system should be introduced to enable the staff members to get exposed to a different advanced research and teaching environment. During this period they may participate in the research and teaching programme of that institute or spend time in developing new courses, learning new techniques or write scientific or technical books or monographs of research work.

If the request for sabbatic leave is considered relevant and important, this may be granted even after three years of service. The Institute is likely to gain as the staff member will return with fresh ideas and good experience.

(b) Faculty member registered for the Ph. D. degree may be given partial or full relief from normal teaching and other academic assignments, if requested, when his full attention is urgently needed to expedite or conclude the work.

(c) A faculty member is normally permitted to participate in a seminar or symposium if he is invited to present a paper which has been accepted. It is recommended that, if it is a symposium of national or international importance, a faculty member directly interested in it, may be permitted to attend the same with normal deputation allowance even if he is not presenting a paper.

In conclusion we wish to say that it is not possible to fully legislate about good Ph. D. education. For major advances in this programme, the

indispensable pre-requisite is the efficient, conscientious and high quality faculty. This may be maintained through their involvement in research, mobility and scope for interaction with research schools both within and outside the Institute, and introduction of fresh blood in the faculty continuously.

5.8 Problems Facing Research and Technical Assistants :

The research and technical assistants should play an important role in the advancement of the research and development programmes of the Institute. The Committee examined the problem of their involvement in the academic programme, particularly relating to the Ph. D. education. They should provide a link between the faculty and Ph. D. students. This could be done through their participation in experimental programmes in which they have wide experience and skill. A Ph. D. student should get from them valuable assistance in the Design and Development of instruments. Also, the research and technical assistants can train the Ph. D. students in the handling of sophisticated equipment and analysis of experimental data.

Many of the present research and technical assistants may be potential Ph. D. candidates with adequate qualifications. As a matter of fact, a number of them carry out assignments which can functionally be considered as equivalent to the duties of a teaching assistant. They have adequate spare time, including the vacation periods, for participation in advanced research projects which may eventually help them to acquire a Ph. D. degree. We are now recommending the introduction of course work, as a pre-requisite for registration for the Ph. D. degree. This system will automatically pick up, with a high degree of certainty, those who measure upto the prescribed standard. It is therefore recommended that adequately qualified research and technical assistants be permitted to join the Ph. D. programme provided it does not interfere with their normal duties.

5.9 Campus Life :

The residential character of the Institute offers excellent opportunities for the students and the faculty to have intimate mixing on social and academic planes. Our discussions with the students revealed that not much advantage is taken of this opportunity. For instance, many students complained that the hardship to which they have been subjected on account of the general increase in the cost of living during the past few years, has not provoked sympathetic response from the faculty. Similarly, there does not exist at present a central body which could look at the problems of general nature pertaining to Ph. D. education. For example, the students are not happy over the existing system of submission of synopsis, abstract and resumé of the thesis at various stages as prescribed to meet the requirements. Some of them are also not happy about the present language requirement for the Ph. D. degree. Many such issues need to be discussed informally between the students and the faculty before these are considered by the appropriate authorities for

necessary action. One possible suggestion may be to form an association of P. G. students. Discussions in such forums would lead to exchange of views amongst students from various disciplines and enrich them with wider experience.

At present, the accommodation facilities for post-graduate students seem to be adequate. The recent commissioning of the married students' quarters has fulfilled a long-felt need to some extent. However, future growth of the student population should be anticipated and suitable action be taken well in advance to provide more accommodation of this kind.

At present, there does not seem to exist suitable accommodation for visiting professors for periods extending from a few days to say, a year. The guest house presently under construction may cater to the needs of a limited number for this type of floating population. If our recommendations for intensive short-term courses are accepted, we expect at any one time accommodation for ten to twelve persons. Slowly this number may grow. If suitable accommodation is planned and provided, it would facilitate organizing such programmes.

CHAPTER 6

SUMMARY OF PRINCIPAL RECOMMENDATIONS

1. The Ph. D. education should be broad-based to achieve intellectual broadening and maturing of the candidate with ability to evaluate evidence and discover new principles by intelligent application of modern research methods. (4.1 page 19).
2. To achieve the above objectives, necessary background preparation through a scheme of formal course programmes with credits has been recommended (4.2 page 19).
3. i) Each department may indentify reasonably well-defined areas of research activity with a minimum of about four faculty members and about six Ph. D. students forming a research group. A department cannot profitably support more than about four to five such areas of research in the present context (5.2, page 33).
ii) Research groups at the interdepartmental level may also be encouraged to promote interdisciplinary and collaborative programmes (5.2 page 33).
iii) The research group should regularly meet to exchange views and review the progress of work. (5.2 page 33)
4. The selection of research projects should be oriented towards specific needs and relevance to social and national objectives (4.8 page 23).
5. For broadening the research experience and for promotion of collaborative work, joint supervisory system has been recommended (4.9 page 24).
6. For successful utilization of applied research and for flow of challenging and realistic problems into the Institute, a continuous interaction between this Institute and industry and other R and D organisation is desired. Ways and means of strengthening this interaction have been highlighted and it is strongly recommended that a dynamic R and D unit at the Institute level be established to be in charge of all these activities (5.4 page 37).
7. a) Admission to the Ph. D. programme may be allowed twice a year at the beginning of each semester on the basis of a comprehensive viva-voce examination, and if necessary, supplemented by a written test (4.11 page 27).

- b) A successful candidate may be admitted to a broad area of research in a department and a supervisor may be assigned after first semester of his stay at this Institute (4.11 page 27).
8. The external registration is permitted but the entry qualification and the admission procedure would be the same as for a full time candidate. The admission is not restricted to graduates of the Indian Institute of Technology only. A minimum residence requirement of one semester at this Institute has been recommended (4.10, page 24)
 9. The foreign language requirement is recommended to be dropped. A student motivated to learning a foreign language may however be given all facilities and be awarded a certificate on successful completion with a corresponding mention in the transcript. (4.4, page 21).
 10. a) Before the synopsis is submitted by the candidate, a system of internal assessment is proposed where critical comments could be made available with a view to improve the quality of the final thesis (4.12 page 28).
b) It is recommended that the external examiner may make a definite recommendation regarding the attainment of the standard of the thesis for the Ph. D. degree (4.12, page 28).
c) The viva-voce defence examination may be conducted by a panel of examiners with an invited audience only (4.12 page 28.)
 11. The institution of higher degrees such as D. Sc. etc., at this stage is not felt desirable. (4.14 page 31).
 12. To ensure proper implementation of these recommendations, the formation of Institutional and Departmental Postgraduate Committees is recommended. (5.1, page 32).
 13. A healthy growth of research and development activities is dependent on ancilliary facilities such as library, workshop, mechanical, electrical and analytical testing equipment, precision instrumentation and computational aids. These need considerable strengthening and change in their organizational structure. (5.3, page 34).
 14. The publication of a research bulletin dealing with the research and developmental activities at the Institute is recommended (5.5, page 39).
 15. Increase in the amount of fellowships of the Ph. D. students is strongly recommended. Other problems of students have been mentioned. (5.6 Page 40).
 16. Some of the problems facing the faculty and the recommended measures for their active involvement in research and teaching are highlighted (5.7 page 41).

17. The important role of the research and technical assistants in strengthening the Ph.D. research programme has been indicated (5.8, page 42).

Sd/- Y. N. Bapat

Sd/- R. E. Bedford

Sd/- P. H. Prabhu

Sd/- C. K. Ramesh

Sd/- R. P. Singh

Sd/- C. M. Srivastava

Sd/- P. D. Sunavala

Sd/- A. B. Biswas (Convener)

APPENDIX I

ANALYSIS OF RESPONSES TO THE QUESTIONNAIRE

In response to the questionnaire, replies were received from faculty members (25 %),* past (40%) and present (15%) research students of this Institute as well as industrial managers (12%) and academicians (20%) from other organizations. A brief analysis of the response is given here :

I . Dependence of the objective of Ph. D. education on Socio-economic stage of development of the country :

The general feeling amongst faculty members, Ph. D. students, and academicians, is, by and large, divided with a substantial majority in favour of the same, while the rest is not very sure about the advisability of linking the basic objective of a Ph. D. programme to the socio-economic conditions and the prevailing stage of development of the country. The majority of industrial managers felt that for Sciences this should not be tied down but for Engineering and Humanities the present and future of the state of national & social development should be considered.

II Objective of Ph. D. education :

More than 85% of the respondents are of the view that advancement of knowledge, original contribution and training in methodology of advanced, independent research should be the objective of Ph. D. education.

III Whether Ph. D. is an essential qualification for high level research work :

About 50% of faculty members, industrial managers and academicians feel that it is essential. Some academicians, however, feel that it is desirable but not essential. More than 85% of the present Ph. D. scholars feel that it is essential.

IV Reasons for poor quality of Ph. D.s and remedial measures :

The main reasons given for poor quality of Ph. D's from Indian Institutions are i) inadequate theoretical background, ii) lack of appreciation & training in instrumentation, iii) poor laboratory facilities, iv) lack of motivation amongst research scholars, v) insufficient communication between the scholar and the guide, vi) quality sacrificed at the expense of quantity, due to unhealthy competition in the publication of papers, vii) lack of integrity amongst supervisors (plagiarism permitted, knowingly or unknowingly), viii) problems picked out from foreign journals, ix) guiding research scholars has become a status symbol and a big game.

* The number in the parenthesis gives the percentage of replies received.

Some of the remedial measures suggested by the faculty members include i) introduction of advanced level courses and training in instrumentation ii) better monitoring of the work carried out by the Ph. D. students, iii) reduction of committee work iv) more contact with distinguished scientists v) increased number of seminars by research scholars and vi) publication of research bulletin.

Suggestions in this regard by academicians are as follows :

i) only those persons who have done genuine original work should be permitted as guides, ii) the number of students under a guide should not exceed three, iii) greater emphasis should be placed on problem identification and formulation, iv) at least one paper should be accepted for publication in an international journal of repute before the degree is awarded, v) appointment of referees should not be left at the sole discretion of the guide, vi) conscious effort must be made to reject a thesis of low quality, vii) Ph. D. education in engineering should be permitted only at a few selected institutions like I. I. T's & I. I. Sc. viii) an internal assessment by a committee before the thesis is sent to referees. ix) the criterion for admitting Ph. D. students should not be academic brilliance alone, candidates with proper motivation and analytic bent of mind should also be accommodated, x) good central facilities should be provided and xi) faculty exchange programmes should be encouraged.

V Unwillingness of research & industrial establishments to employ Ph. D's and suggested remedial measures.

Most of the academicians and industrial managers are of the view that as India and other developing countries spend only about 0.5% of their Gross National Product (G. N. P.) on research and development in contrast to developed nations which spend 2 to 3 %, useful employment of Ph. D's in industrial and even R & D organization is difficult. Some, however, feel that there is a definite need of properly trained Ph. D's in industry and that this need will increase in the near future.

Industrial managers have stated that they had no special difficulty in recruiting Ph. D's if they wanted to and this was done mostly by interviews, recommendations and personal contacts.

Regarding remedial measures industrial managers and academicians suggest the following : i) ivory tower attitude of Ph. D. scholars should be discouraged through proper background courses and orientation lectures, ii) establishment of better liaison of teachers with industry through sponsored research, running of special courses and formation of advisory panels from industry and iii) inculcating some awareness of cost and time.

VI Duration :

There is overwhelming majority in favour of introducing course programme of one year duration after B. Tech and M. Sc, and half year after M. Tech. followed by about 2-3 years of research work.

VII Institution of other degrees :

Regarding institution of an intermediate degree like M. Phil, more than 70% of the faculty and academicians are against it, as in their view, it would not achieve much but is likely to lead to greater confusion due to proliferation of degrees. There is almost an unanimous opinion against instituting a higher degree such as D. Sc. at the present moment.

VIII Collaboration between academic, research and industrial establishments:

Regarding collaboration with other academic Institutions opinions are generally in favour of programmes like the Q. I. P. involving in-campus residence requirement for at least 3 years. Some have raised doubts if such programme will have lasting value as the one way traffic between the "mighty and the weak" may not exist for a long time-

Opinions are in favour of greater collaboration between this Institute and National and Regional Research Laboratories.

A closer liaison with industry has been generally recommended but the industrial managers feel that this may be feasible only in special cases as guides from industry may not always be available. Some have even warned that except for a few industry, the majority may be apathetic.

Amongst others the various suggestions for improvement of contacts with industry are i) practical training programmes ii) placement efforts through on-campus interviews iii) industrial personnel serving on academic bodies iv) sponsored research and v) participation with the activities of professional institutions. Some feel that Institute publications, data collected and the library should be available for service to the industry.

IX Supervisory system

Most academicians and faculty members feel that a co-guide from the same department is unnecessary whereas a co-guide from other department or from external institutions is desirable, whenever necessary. Some of the arguments presented are i) joint responsibility is neither conducive nor successful for proper guidance of a research scholar ii) often supervisors are afraid of sharing ideas with others iii) to reap maximum credit for guidance complications may arise between the guides and iv) Heads of Departments may try to get in as one of the supervisors and claim credit without doing any work.

X Intensive developmental type of work for Ph. D. Degree:

About 70% of the faculty members and academicians have favoured in the context of the present national interest the recognition of an intensive type of developmental work leading to a Ph. D. degree. They have stressed the importance of applied research stating that we should not become a 'scientific colony' of the West by working on research topics which have no relevance to the industrial development of our country. About 30% of the faculty members and academicians have opposed the idea stating that the

main objective of Ph. D. training is original and creative thinking which is not imparted through such a programme. They are further afraid that this may lead to back-door or short-cut methods for obtaining a degree.

XI Formation of research schools :

Majority have favoured the formation of research schools consisting of 3-6 staff members and 5-15 research scholars.

XII Foreign Language :

Majority have opposed compulsory requirement of foreign language for the degree as now English translations of well known foreign journals are readily available.

XIII Facilities at I. I. T. Bombay :

About half the faculty members feel that laboratories, work-shop, equipment and material facilities are poor while the remaining think that these are satisfactory.

The faculty members and the past and present students are critical of the workshop facilities.

Most student respondents are happy with the library facilities, ancilliary staff, and opportunities for contact with fellow Ph. D. students. However they are very critical regarding our administration, purchase procedures and funding system for research programmes.

APPENDIX II

EXTRACTS OF SOME REPLIES FROM ACADEMICIANS, INDUSTRY, FACULTY AND STUDENTS :

A Academicians :

1. "A great debate on this (intensive developmental type of research work) is going on all over the world. No one is prepared to make a beginning. There is however no doubt that intensive development work requires as much intelligence and hard work as the thesis for a Ph. D."

2. "Because of the scarcity of jobs the industry can afford to look for jig-saw puzzle pieces to fit into a slot in their requirements. This will not pay in the long run. What industry should be made to understand is that they (Ph. D. degree holders) are broadly-trained personnel who are needed in any system which accepts innovation as a necessary tool for further progress."

3. "I would recommend that if we really want our Ph. D. programme to improve, the beginning should be made at the faculty level: The recruitment policy should be such that people who know the subject and have brought some originality to it (which in India is unfortunately synonymous with the number of publications) should be encouraged to do research work in diverse fields."

4. "M. Tech. is a design oriented programme with initiation to research, Ph. D. is a research programme. The diploma programme is not worth the time spent."

5. "Things will of itself improve as time passes and supervisors get matured."

"There is no crying need for Ph. D. education in engineering in the present stage of development of the country."

7. "The most important handicap at present is that the supervisor is at the mercy of the administrative Heads for his day-to-day requirements for research. I feel that it would be a great improvement if the institutions are given funds for purchase of costly equipments only. On the other hand the supervisors should get grants for research and for employment of supporting lab staff directly."

8. "There should be a rational or real purpose behind a research project. "Something will crop up" - type attitude may not be desirable."

9. "The progress made by the supervisor should be evaluated by expert committee every 3-5 years and if he does not show sign of competence, he may be asked to vacate."

10. "Generally Ph. D.'s in engineering in India are truly Ph. D. in applied mechanics, the so-called "Engineering Sciences" Sometimes, their knowledge in engineering technology is very poor and as such the science-based industries or applied research and development laboratories cannot utilise them effectively."

11. "It is desirable that every educational establishment of advanced learning concentrates only on certain fields."

12. "M. Phil should be given for developmental work and Ph. D. retained for creative efforts."

13. "Today we have too many B. Sc.'s & M. Sc's who do not know what they could do with their present education — Not more than top 20% of the graduates should go in for M. Sc. & Ph. D. courses."

14. "There should be a provision for sabbatical leave for the members of the faculty so that once in five or six years a faculty member can devote himself completely to research and newer developments in his field."

15. "It is understood that for many selected areas additional financial help is being offered by Govt. agencies and industry but it is because of the lack of rapport between the academic people and these agencies that proper utilization of these finances is not being done. It is high time that we, the academic people should reorganise ourselves for the fulfilment of the socio-economic objectives of the nation."

16. "The number of science and engineering graduates produced in this country today is comparable to that in some of the technically advanced countries but the resulting impact both in terms of contribution to the frontiers of knowledge or to technology in general is very small. Obviously, something is going wrong somewhere. Perhaps we have not built a tradition for excellence as far as academic work is concerned and have not acquired a practical and innovative approach as far as technology is concerned."

17. "Before a candidate is given to a staff, it should be ensured by an expert committee that there is a worthwhile Ph. D. problem with the staff member; only knowing the title of the problem is not sufficient."

18. "There should be a central organization, with its jurisdiction all over the country, to co-ordinate research in a particular subject... A committee of top people must examine the research schemes and assign all members to one of these schemes."

1. "We would not consider the Ph. D. degree *per se* as the essential criterion for high level development work. The stress would be more on the enquiring mind, skill and knowledge which the individual brings with him, whether he has the Bachelors's, Master's or Ph. D. degree..."

2. (The essential objectives of the Ph. D. programme is) "enrichment of knowledge. I am doubtful whether the objective may be to depend on the socio-economic stage of development of the country to any great extent. However, problems of 'Ecology' which has a social bearing may be stressed upon. In the field of humanities, the socio-economic aspect has been all along of importance, I reckon".

3. "Whereas there is no doubt about the pursuit of candidate in Engineering and Humanities to be geared to socio-economic needs, certain laxity can be allowed in case of candidates of Science. It will be in the larger interests of any society to leave certain freedom to a limited number of people to pursue their researches in Science".

4. "Ph. D. training is, in our view, a formal education for scientific work. It should be kept independent from industries requirement. Efforts to 'Strengthen' the links between research schools and industry must be made".

5. "The purpose of Ph. D. is not to train a man for this job or that. It is a recognition of a man's outstanding contribution to knowledge in a particular field".

6. "A joint programme between the Institute and the Industry may not be feasible as a general case. Joint projects with or without industry support may be possible in some specific instances ... serious consideration should be given to the possibility of faculty members taking up summer vacation assignments in industry".

7. "This (a joint programme between the Institute and Industry) is not altogether impossible but many of the Industrial people will find it difficult to devote sufficient time to act as an official guide".

8. "... I feel this (a student working with a person from industry as a co-guide) would be a fruitless effort as a person in the industry, due to lack of contact with library facilities and time factor, does not keep himself abreast of the latest fundamentals of science and technology. Secondly the person in the industry tends to specialise in the nature of the work he is doing, and hence forgets the sight of the peripheral knowledge of different branches of science and technology associated with the administration of a research programme. I believe education programmes in this country should better be left to the educationists and while occasional consultation with people in the industry would be a great asset. The industrial

people should not be allowed in any way to associate with the academic programme directly”.

9. “We consider a formal course programme essential to broaden the graduates views”.

10. “Compulsory course work for a person having an M. Tech. in engineering should not be necessary. But options for choosing a few subjects may be there for a period of one year. Some felt that compulsory course work with particular emphasis on mathematics should be there”.

C Past Ph. D.s.

1. “Availability of library facilities was excellent. We would get almost everything we wanted. I am grateful to the library staff for every cooperation they rendered. Laboratory equipment is rather poor all over IIT. We have to select the project based on the facilities available with us. To get anything through our Central Stores within reasonable time is impossible. Something has to be done there”.

2. “The Central workshop is good for nothing. Months and months it takes to make small things which I find here just a question of one day. Each department should have a good workshop and glass-blowing section. Getting a potentiometer or a hardness tester here is as difficult as getting a Ph. D. problem”.

3. “Excellent (opportunities for contact with fellow Ph. D. candidates) we used to have regular discussions for understanding each other’s work and difficulties. Many times the fellow candidate already has a solution for the problem that is bothering you for a long time. The best course is to discuss out even the silliest things on the earth. We, fortunately, had a group”.

4. “I will always remember with happiness my stay at IIT, Powai. The campus life was the best one with the natural surroundings, good hostel facilities, library etc.... The institute itself should give a better transport facility. Otherwise, the academic and social life at IIT was the best I had till that time”.

D. Present Ph. D. Students:

1. The way the Ph. D’s are got these days, it is not much of a qualification” “ It is not essential but helpful for high level research work”.

2. “Lack of proper guidance from supervisor is a reason for poor quality research. First of all the problems are chosen from American journals which do not find ground here. Hence, efforts are in vacuum. Then grumbling about unnecessary-work for personal benefits and prestige, getting appointed in committees” etc. pours cold water on the initial enthusiasm of the student.

3: "I have nothing to say about the professional excellence of my supervisor. He definitely knows the subject very well, but the quality and extent of supervision in general is not upto the mark. I feel he should devote more time and his skill for his student'.

4. "The supervisor should not rest on his laurels but be prepared to follow contemporary work and think ahead of the times. He should be clear in his mind as to what is expected to be done by the student, without however spoonfeeding the latter. It would be good for the student and the supervisor to have around a second faculty member conversant with the subject for discussion or suggestions. After understanding the objective of the project, the student should have a say in its planning and executions".

5. "Most of the students in our Institute are from Bombay and spend their weekends in the city. Because of their absence in weekends and holidays, campus looks deserted. This prevents students taking part in some constructive work. This will be minimised if students of Bombay are selected for other IITs and students of other regions are taken in Bombay IIT.

6. 'Hostel life with its T. V., radio, magazine, canteen, messes and servants is, on the whole, lively. Apart from this, there is the library working more than 12 hours a day, the Convocation Hall, film society and club etc. add more to the thrill of the campus life. In the Department side, one can go to the Department at any time of the day and sometimes even in the night. No one interferes with your work. It is almost an utopic for all purposes but for his project. To get a material/equipment..... in time he has to go through the proper channel and get stuck in the bureaucratic machinery like Stores Office with all its progress, purchase etc. sections.

Regarding the settlement of his account, he has to go to the departmental office, climb two floors, go to academic office, administrative office, accounts office, hostel coordination unit, Dean's office, locate the clerk who deals with a particular department,... tolerate all the indifference shown to him".

7. "I feel that at least once in a week the guide must discuss with the student. But the professors are usually busy with committee meetings, tours etc.

8. "Some of us were discussing about a possibility where a student takes a problem from the department and starts working without anyone as guide. He is free to contact anyone in the faculty. Probably in such a situation student-faculty member contacts will attain high frequency."

9. "Professional excellence of the guide is not generally upto the mark. The student working under him is taken as a personal property and so he tries to exhibit maximum authorities on the student. The frustration among research students is partly also because of the helplessness in trying to maintain good relations with the guide."

10. "Campus life is quite satisfactory. But the participation by the staff members towards the institution's improvement and the student is absolutely nil."

11. "It should not be difficult to see that it is impossible to have independent maintenance in Rs. 250/- p. m. Besides it is very shameful on the part of research students to be still a sort of burden to the parents for spending some more years like this for reasons not known to them,...."

12. "The scholarship should be Rs. 350/- and fees should not be collected. As the cost of living increases it should be adjusted accordingly. No difference should be shown between engineering and science Ph. D. workers. If it is said that engineering students spend 2 years more doing their M. Tech., then science graduates should be paid Rs. 400/- during their 3rd year".

E. Faculty

1. "There is very little administrative work for staff (except for the Head). You are perhaps comparing with America! Compare yourself with an equivalent country on developmental plane. You will find we are considerably better off. Our contribution to GNP by way of research is practically nil."

2. "Development work and collaboration with industry should be the keynote. With this in view, registration of non-IIT M. Techs working outside IIT (Bombay) in recognized research/development establishments should be allowed."

3. "We have not been able to produce in a large measure, persons who imbibe strength and confidence to accept challenge in the new areas required by their employers. They are not prepared to come out of their narrow area of activity. This is in many cases an indication of inherent weakness."

4. ("Regarding intensive developmental type of research work fulfilling the requirement of a Ph. D. degree). In short, you want to give Ph. D. to a person who makes a lot of nitrobenzene or pig iron (under Indian conditions) The idea looks to me ridiculous."

5. "It is a bitter truth that our Institute has not yet been able to earn the reputation of a 'Centre of excellence. It is high time that well-defined policy regarding research as a whole is adopted. A high power committee may be constituted to consider all the aspects of the relevance of research and lecturing and to adopt a firm policy."

6. "Considering the socio-economic and technological stage of development of the country, it would be useful to give Ph. D. recognition occasionally to good developmental work."

7. "Guiding students for a Ph. D. is a very personal business. Some people are not capable of guiding one student, while some could readily guide half a dozen. Nevertheless an upper limit is desirable. I would suggest a number like ten."

8. "It is absolutely essential that an atmosphere of free thinking and free expression prevails amongst the Ph. D. students of the Institute. Instead of looking upon them as mere assistants in the research work of the faculty members they should be regarded as independent research workers in their own right."

9. "I would fervently hope that out of the present exercise a viable "relevant-in-the context" Ph. D. programme format would emerge, which would above all be firmly rooted in the volume of down-to-earth local experience that has been built up over the last decade or so at this Institute. What is necessary is a firm, purposeful balance, between the *ideal* and the *practical*."

APPENDIX III

MISCELLANEOUS EXCERPTS

The Committee has also been benefited considerably from the current literature and also personal discussions with many on some aspects of higher education and their impact on society. A few excerpts from the same are presented here to highlight the general trend in this regard.

1. "Public expectations of spectacular achievements are far greater than science and technology can produce. To serve the public most effectively, scientists and engineers need a friendly and sympathetic environment and one in which their limitations are understood".
2. "Basic research scientists are so preoccupied with the exquisiteness of their protocols and the refinement of their research approaches that they missed entirely the objective and intent of taxpayers who are funding their ivory tower isolationism".
3. "The oversupply of Ph. D's will seriously affect higher education and national science policy".
4. "There is the danger that there will be overemphasis on the applied phase of science, for the public is alert to the tangible benefit to be had from it, but hardly realizes the fact that they are all dependent upon long-term advance in fundamental science. There is also a danger that control of funds by layman may occasion injurious dictation to science".
5. "We must take a critical and cool look at the claims of the fundamental research scientists. Overstatement in defence of their right to pursue new ideas may ultimately discredit themselves. It would be healthier to wonder whether our ideals have been developed in the luxury of self-interest, and whether what we profess, may begin to be irrelevant in a world that asks for something different as the mark of education".
6. "We should be actively critical of the habitual attitudes of universities and begin to tilt the balance more away from the academic contemplation of perfection towards the different and less elegant phenomena of real world".
7. "What we impart and learn should be controlled to a greater extent by what goes on in the world outside inhabited and to a great extent governed by the non-scientists. We find employers are losing faith in the ability of scientists to help them in their problems".

8. "Progress in science is much hindered because people concern themselves with that which is not worth knowing and that which cannot be known".

9. "The continuing importance of fundamental research will not only have long term value to industry, but have a necessary part of a balanced and fertile educational background".

10. "The Ph. D. education should be flexible enough to be able to choose a career from a wide variety of posts both within the broad-field of his speciality or right outside it."

11. "The most common complaint is that the pressure on the supervisors to publish, forces him to regard the research student primarily as an aid to promotions. Considerable amount of other work—teaching, committee and administrative work—keep the research student's place at the bottom of the priority list. Too much of power can be exercised by one man who may not be a good supervisor."

12. "A shortage of technicians often causes frustration due to delays and spending considerable time on routine tasks requiring neither skill nor intelligence. A Ph. D. student should do a part of his construction work, but not so much that it becomes a major part of his effort. Research and technical assistants should be associated with such tasks."

13. "Grants (Scholarship/Fellowship) should be adequately raised to enable doing of work without financial worries."

14. "The designation (Research) Guide is bureaucratic and obsolete and should be replaced by 'Consultant' to give a proper meaning to the Ph. D. education system."

15. "Universities are repositories of much of the brain power and knowledge. The pressure of discipline orientation (Physics, Chemistry, etc.) and the tradition of individual scholarship are strong among faculty members, but not strong enough to counter the pressure of social concerns."

16. "We feel that major advances in Ph. D. programme that might be made, would come not so much from changes in procedure or requirement, but from more efficient, conscientious and intelligent faculty."