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IN INDUSTRY**

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*(Resolution of October 25, 1926, revised February 6, 1933)*

# MECHANIZATION IN INDUSTRY

HARRY JEROME

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HARRY JEROME

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## INTRODUCTION

THE machine has been the foremost factor making for economic and social change in the western world during the past hundred and fifty years. It has impinged upon man's modes of living in diverse ways. The means by which his productive energies have been utilized, and the directions in which those energies have been expended, have been substantially altered. The productivity of his labor has been increased; his standard of living has been advanced. The physical features of the world in which he works and lives have been changed, and a transformation has occurred in the character of the commodities entering into daily consumption and use. After generations of slow change, the skills essential to economic survival have been profoundly modified. Under the pressure of mechanization men have had to learn to do new things in new ways.

All this is commonplace enough. That the machine has worked great changes in human life is no discovery of the past few years. For more than a century social observers have commented on the progress of machine industry. All men alert to the currents of social change have known that major shifts in the modes and manners of living were in process. But the prevailing conceptions of what, precisely, was taking place have been vague and inadequate. In spite of the universality of the process of change, it was a move-

ment difficult to see and appraise as a whole. Here a new invention brought a striking change in productive procedure, and threatened the displacement of thousands of men. There a new application of power promised a ten-fold increase in output. A movement marked by wide diversity of attributes and by almost infinite ramifications was known to man, individually, only through isolated instances of technical change. It is not strange, therefore, that wild fears paralleled wild hopes in contemporary appraisals of the growth of machine technology. One man saw it as a Frankenstein monster, threatening the very life of its creator. Another saw a dawning millennium of ease and plenty in a world of push-buttons and buzzers through which man controlled his millions of yoked and mechanized horsepower.

In the face of these vague conceptions we have had sore need of an account in realistic detail, but presenting these details in a broad economic setting, and interpreting them with reference to the mechanization process as a whole, and to related processes of economic life. For in dealing with the characteristics and consequences of mechanization, as in many other economic fields, a part, to be truly appraised, must be seen in its place in the whole working of the economic system.

It is a great virtue of Dr. Jerome's study that he has tried to do this difficult job and has, indeed, done it better than it has ever been done before. We find here a wealth of detail as to the actual changes which mechanization has involved, over a wide area of industrial activity. Conveyors, electric hoists, mechanical stokers, concrete mixers, steam ditchers, steam-jet weed destroyers, rotary ballast sweepers, power tie tampers, portable escalators, trench excavators—these are the stuff of modern industry. Here is realism about the industrial process. But Dr. Jerome sees beyond his details. He has emphasized, as has no one before him, the wide range of

consequences which must be traced if one is accurately to measure the effects of a mechanical change. In doing so he provides an effective corrective alike for the visions of doom and for the prophecies of a mechanical millennium.

The mechanization process in its countless manifestations reacts upon the volume of employment, the skills and the working methods of the human factor in production. Dr Jerome's treatment of one point, the effect of technical change upon the saving of labor time, furnishes an excellent example of careful technique and, by contrast with procedures confined to obvious consequences, illustrates the necessity of trying to see these movements in their broad relations to the working of the entire economic system.

To begin with, we must note the distinction drawn by Dr Jerome between 'productivity-increasing' changes (those which increase the units of output per hour of labor) and 'labor-displacing' changes (those which reduce the number of workers required). The two concepts are closely related, of course, but the distinction refines our tools of analysis in the study of technological improvement. We do not stop here, however. A given change in technique may affect the productivity of *operating labor* (that required directly in a particular process), of *auxiliary labor* (plant labor necessitated by the use of a machine, but not engaged directly in its operation), of *embodied labor* (labor applied to the production of the machine itself, or to the production of power, oil, or some other commodity used in its operation), or of *indirectly required labor* (that is, all additional labor required, as for transportation, advertising or merchandising in putting the given commodity in the hands of the final consumer ready for use). Furthermore, with reference to labor displacement, Dr. Jerome insists that we take account of labor requirements in the specific operations directly

affected, in the occupation in question, in the plant, in the industry, and in the economic system as a whole.

The mere citing of these diverse channels along which the effects of a given change may be felt is sufficient to indicate how fatuous it is to confine ourselves to the direct and immediately observable results of technical improvement. Technical change has brought striking advances in the efficiency of human labor, and has given rise to real problems of adjustment and adaptation, but we secure only a grotesquely distorted picture of the consequences of technical improvements if we take a microscopic view of that small industrial area in which the direct mechanical change happens first to appear. Dr. Jerome's study should improve our perspective.

The results of this investigation are made available at the end of a decade of intense interest in the processes of mechanization, and in their economic consequences. Before the beginning of the present *dépression* 'technological unemployment' was a subject of wide discussion, and the machine has been given a prominent place in many explanations of the current industrial crisis. Dr. Jerome does not undertake a precise definition of the part played by the mechanization process in the economic developments of the post-War era, but there is rich material here for the student of this period. That mechanization always involves some disturbance of an existing situation, in the markets for goods or in the markets for labor, or in both, is clear enough. Was the degree of disturbance intensified during the post-War years? Were the consequences of mechanization during this period materially different, in kind or degree, from the consequences of earlier mechanical changes in industry? These questions arise, inevitably, in any survey of recent industrial movements.

As to the relative speed of the mechanization process during the post-War period, in comparison with earlier periods,

it is difficult to give any precise figures. Dr. Jerome's general results accord with other evidence in indicating that mechanical improvements were being applied more generally throughout the industrial system, and probably more rapidly, during the years following the War than during the years preceding the War. The speed with which, in post-War years, a perfected technical innovation was introduced throughout an industry was not approached during the earlier phases of the Industrial Revolution. Taking account of the area, industries and occupations affected, it is a safe conclusion that the rate of technological change was high in post-War years, in relation to previous experience.

But the economic and social consequences of technical innovations do not depend on the speed of mechanization alone. It is probable that in post-War years certain other conditions contributed to accentuate the problems arising out of the widening scope of machine technology. In appraising these conditions we shall do well to recognize the distinction Dr. Jerome has drawn between changes that increase output and changes that displace labor. This distinction is highly useful in tracing the incidence of mechanization and in distinguishing different stages of industrial development.

One of the major factors determining the economic effects of a given technical change is the degree of elasticity of demand for the products of the process affected. With highly elastic demand lower prices stimulate new buying. Under these conditions mechanical improvements leading to lower per-unit costs and lower selling prices will make possible the marketing of a much larger volume. Output will be increased, and the net effect of the innovation may well be a substantial rise in the amount of labor employed. The growth of the automobile industry is a concrete manifestation of a series of such improvements in the making of a commodity for which the demand is elastic. Improvements in industries pro-

affected, in the occupation in question, in the plant, in the industry, and in the economic system as a whole.

The mere citing of these diverse channels along which the effects of a given change may be felt is sufficient to indicate how fatuous it is to confine ourselves to the direct and immediately observable results of technical improvement. Technical change has brought striking advances in the efficiency of human labor, and has given rise to real problems of adjustment and adaptation, but we secure only a grotesquely distorted picture of the consequences of technical improvements if we take a microscopic view of that small industrial area in which the direct mechanical change happens first to appear. Dr. Jerome's study should improve our perspective.

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But the economic and social consequences of technical innovations do not depend on the speed of mechanization alone. It is probable that in post-War years certain other conditions contributed to accentuate the problems arising out of the widening scope of machine technology. In appraising these conditions we shall do well to recognize the distinction Dr. Jerome has drawn between changes that increase output and changes that displace labor. This distinction is highly useful in tracing the incidence of mechanization and in distinguishing different stages of industrial development.

One of the major factors determining the economic effects of a given technical change is the degree of elasticity of demand for the products of the process affected. With highly elastic demand lower prices stimulate new buying. Under these conditions mechanical improvements leading to lower per-unit costs and lower selling prices will make possible the marketing of a much larger volume. Output will be increased, and the net effect of the innovation may well be a substantial rise in the amount of labor employed. The growth of the automobile industry is a concrete manifestation of a series of such improvements in the making of a commodity for which the demand is elastic. Improvements in industries pro-



ducing commodities of inelastic demand, on the other hand, may be expected to lead to actual displacement of labor or, under certain conditions, to an uneconomic expansion of output. For such commodities may not be disposed of in much larger quantities, in a given market, even though costs and prices are reduced materially by technical changes. Given a labor supply without fixed job tenure, and therefore subject to ready reduction, real labor displacement may be expected to result from technical improvement. If the labor supply be tied to the productive processes in question (as it is in agriculture, to a large extent) an expanding output, produced under conditions of lower cost and without much regard to the ability of the market to absorb the increased supply, may be expected. Marketing troubles, price weakness, social distress and reduced living standards may result from this combination of circumstances.

With the widening, in recent decades, of the area within which mechanical improvements were being applied, it is probable that the proportion of technical changes affecting commodities of inelastic demand was greater than in earlier periods of mechanization. Retail coal handling, street cleaning, train operation, stevedoring provide examples of occupations the products or services of which are not marked by high elasticity of demand. But the outstanding example of such a shift is furnished by agriculture. The mechanization process in this important field lagged for years, and still lags, in comparison with the changes machine technique has brought in manufacturing industries. But recent years have seen a substantial advance in the use of mechanical methods and new sources of power in farming. Tractors, combine harvesters, potato-digging machines, milking machines, the application of gas engines and electric motors to agricultural operations—these are but examples of a process which has been going forward at accelerated speed in the last decade

and a half. Dr. Jerome cites figures compiled by the United States Bureau of Labor Statistics indicating that technical improvements in agricultural production were sufficient to have displaced 2,530,000 workers between 1919 and 1927, had volume of output been unchanged. Actually, only some 800,000 workers were displaced, because these improvements, in the main, were used to increase output rather than to reduce the number of workers employed.

Normally, increased efficiency in the production of goods of inelastic demand would tend to displace labor, rather than to increase output. The great technical advance in agricultural production during the decade in question did not have this result. One reason for this is that agricultural producers are, traditionally, tied to the soil. They do not react to innovation as would a market-conscious manufacturer, with a relatively mobile labor supply at his disposal. The effects of mechanization in this field, therefore, have been quite different from the effects experienced in other industrial areas, at earlier periods. A glutted market, with prices abnormally low even when account is taken of lowered costs of production, has resulted.<sup>1</sup>

In part, however, mechanization in agricultural industries displaced labor during this period, and probably contributed to the volume of unemployment which characterized the post-War years. Mechanization in other economic areas marked by inelastic demand for commodities produced tended also to displace labor, rather than to increase production, and so to widen the margin of unemployment which

<sup>1</sup> Other factors, of course, contributed to the agricultural situation that has prevailed in the United States since 1920. Reduced demand in foreign markets, after the War-time stimulus, and declining demand for animal feeds, resulting from the increased use of motor power on farms, have re-enforced certain of the tendencies due to mechanization. The industrial depression was a major factor in the agricultural distress following 1929.

has always been a feature of an industrial economy. It is true that the purchasing power released when consumers are able to buy certain commodities at lower prices may be expected, ultimately, to find an outlet in increased demand for other commodities, and so to lead to the absorption elsewhere of the displaced labor. But this may be a very slow process, mitigating but slightly the immediate evils of labor displacement. Some portion of the increased unemployment which characterized the post-War years in the United States may be attributed to the mechanization of industries producing commodities of inelastic demand.

But other factors, as well, contributed to this widening margin of unemployed men. Among these we must include the pricing policies followed in those industries in which rapid technical improvement occurred in the post-War years. For whether a given technical advance shall be 'labor-displacing' or 'productivity-increasing', in Dr. Jerome's terms, depends not alone upon the relative elasticity of demand for the commodities affected. With demand elastic the given innovation may still displace labor, rather than increase output, if the reduction of costs is not passed on in the form of correspondingly lowered prices to buyers. If the reduction of costs served exclusively to swell profit margins or, conceivably, to increase wage rates, the final effects of the innovation might be to yield higher profits or earnings to producers, to leave the volume of production substantially where it was before the change in productive methods was made, and to displace a quantity of labor corresponding to the enhanced efficiency of the manufacturing process. Here, again, the increased purchasing power represented by higher dividends or other disbursements might be expected to offset the reduction of purchasing power due to the displacement of labor and to lead, ultimately, to increased demand in other economic areas and to increased employment elsewhere. But

the time lag between displacement and ultimate re-employment might be a very long one indeed.

The actual effects of mechanization, at any time, are undoubtedly a blend of the various possible consequences. To some extent profits may be increased, to some extent wage rates may be advanced, to some extent prices may be lowered and the volume of output increased, and to some extent labor may be displaced. The state of competition, the bargaining position of labor, the character of the demand for the product and the pricing policies of management all combine to determine the relative importance of these possible consequences. During post-War years these different effects of mechanization were all present, in varying degree. Although the physical volume of production was substantially increased, it is probable that in certain manufacturing industries full advantage was not taken of opportunities for increased production at lower prices. This was partly due to relative inelasticity of demand for the products of some of the industries in which advances in mechanization occurred. It was probably also due, in part, to the observance of policies of price maintenance, even where lowered prices might have served materially to stimulate demand. The existence of relatively high prices for manufactured products was a characteristic feature of this post-War period. To some extent, then, mechanization during post-War years was manifest through labor displacement as well as through increased output. The margin of unemployment which has persisted since the industrial system came into being, and which tends to expand during a period of rapid technical change, was widened still further by the special conditions characteristic of the post-War years. The focusing of public interest on 'technological unemployment' was a consequence of this combination of circumstances.

In appraising some of the results of the mechanization process which Dr. Jerome illuminates in the following pages we should take account, also, of the relative ease, or difficulty, of the industrial readjustment which any innovation necessitates. The concept of general economic equilibrium remains a somewhat vague one, in so far as the actual processes of economic life are concerned, and the conditions of such equilibrium in an industrial society have not been defined. Yet, even without such definition, it is a fair assumption that technological changes disturb in greater or less degree the equilibrium, or the tendencies towards equilibrium, which prevailed prior to such innovations. The more rapid the rate of technical change, the more thoroughly mechanized and integrated the economic system, and the more rigid its parts, in relation to one another, the more difficult adaptation to such changes must be. On all these counts we should expect the problems arising out of the mechanization processes of the post-War years in the United States to be of exceptional difficulty. Dr. Jerome's studies indicate that the rate of technical change was relatively high during this period. Furthermore, our national economic system and the world economic system had become more thoroughly mechanized and more highly integrated than in earlier eras. The increasing importance of fixed costs in industrial operations, and other forces operating both within and without the industrial system proper, had probably tended to lessen the flexibility of the industrial structure. Post-War mechanization broke with exceptional force, then, upon this system, and involved greater difficulties of adaptation than had similar mechanical innovations in earlier stages of our industrial development.

The process of mechanization described in the following pages is thus not merely a technical affair, of interest only to production engineers and factory managers. It needs no

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argument to establish its relevance to the major problems of the day, and its bearing on the central processes of contemporary economic life. When exaggeration and fantasy about the machine are duly discounted it remains, it is safe to say, the most compelling factor in the changing culture of modern man. It is the story of the machine, in its recent and mature development, which Dr. Jerome tells in the pages of this book.

FREDERICK C. MILLS

*New York*  
*August, 1934*

**MECHANIZATION  
IN INDUSTRY**

## CHAPTER I

### SUMMARY

#### ORIGIN AND SCOPE OF SURVEY

IN TYPE the problems raised by advancing mechanization are common to the more than a century and a half since the beginning of the Industrial Revolution although in degree they may have been accentuated by the events of recent years. Our survey had its origin in the hectic years of the post-War decade as an inquiry into the extent to which the effects of immigration restriction upon the supply of labor were likely to be offset by an increasing use of labor-saving machinery. Then conditions changed so that the center of interest shifted from the possibility of a labor shortage, caused by immigration restriction, to an apparent threat of a surplus of labor, arising from improvements in efficiency, and the emphasis in our study was shifted to the characteristics, conditions and effects of progressive mechanization. Since it is to the post-War period that we must look for much of the evidence available to illustrate the nature and effects of mechanization, let us first sketch in broad outline certain significant events and tendencies of that in many ways remarkable decade the better to define our problem and its setting.

The decade opened at the peak of the post-War boom, but before the first year had closed the slump to the depression of 1921 had begun. War conditions had provided an effective check on emigration from Europe to the United States, and in the immigration acts of 1921 and 1924 this check was con-



tinued by legislative restriction.<sup>1</sup> As industry began to recover and approach the 1923 peak of activity, questions began to arise concerning a possible or actual shortage of labor. Some urged that the bars on immigration should be lowered. Others voiced the opinion that labor-saving machinery and other improvements in efficiency would fill the gap. But, as the decade wore on, doubts began to be voiced whether the machine was not doing its work too well, for there appeared to be a substantial volume of unemployment even though industry was relatively active. The term 'technological unemployment' became current. Then, with the close of the decade, a prolonged depression set in. If some of the evils

<sup>1</sup> The extent of the slump in immigration may be readily indicated by comparing the net immigration (immigrants less emigrants) in three periods. (1) the pre-War seven-year period ending June 30, 1914; (2) the War and early post-War seven-year period ending June 30, 1921; (3) the first eight years of the quota restriction period, ending June 30, 1929. Net immigration in the first period was 4,646,000, in the second, 1,254,000, and in the third, 2,314,000.

If we compute 'deficits' by finding the excess over the actual net immigration of that net immigration which would have occurred if the annual average net immigration of the pre-War period had continued in the War and post-War years, we reach some interesting estimates. The deficit for the seven years of the War and early post-War period was 3,392,000, and for the quota period, 2,996,000.

The decline in immigration was heaviest from the sources of the so-called 'new' immigration, that is, the countries of eastern and southern Europe. The deficit from this section of Europe was 3,410,000 in the eight-year quota period.

The 'deficit' in the net immigration of the unskilled was 1,565,000 in the War and early post-War period, and 1,451,000 in the quota restriction years. To reach this estimate we have counted as unskilled all those listed as having an occupation and not classified by the Bureau of Immigration as 'professional', 'skilled', 'merchants and dealers', 'agents', 'servants', 'farmers', or as in various other 'miscellaneous' occupations, totalling only 6,067 in the year ending June 30, 1929.

The corresponding deficits for all occupations are over 2,500,000 for the War and early post-War period, and over 2,200,000 for the first eight years of quota restriction.

attendant on changing mechanization had been unduly minimized in earlier years, now the pendulum swung back and there came a sharp emphasis upon, if not an exaggeration of, the actual and potential adverse effects of the machine. It was noted that the decade had brought marked increases in productivity in leading industries. F. C. Mills estimates an increase in output per wage earner in manufacturing from 1919 to 1929 of 43 per cent, or 3.8 per cent per year, compared with 1.7 per cent per year for the decade and a half, 1899-1914.<sup>2</sup> David Weintraub estimates the increase in output per man-hour in manufacturing, 1920-29, to have been 48 per cent (Ref. 23). For the same period, we estimate a 28 per cent gain in productivity per man-hour in the operation of steam railways in the United States and, in terms of annual output per 300-day worker, of 20 per cent in bituminous coal mining, 74 per cent in the mining of copper ore, and 82 per cent in iron ore. Productivity in anthracite coal, on the other hand, declined about 5 per cent.<sup>3</sup>

<sup>2</sup> In 60 individual industries for which the change in productivity per wage earner was computed by Mills the average annual rates of change from 1923 to 1929 increased in 56 industries, the maximum of 8.8 per cent being in the production of other than gas-house coke, and declined in 4 industries, the maximum decline of 3.6 per cent being in the organ industry. *Economic Tendencies in the United States* (National Bureau of Economic Research, 1932), pp. 290-7.

<sup>3</sup> The estimate for railroads follows the procedure used by W. H. Dunlap in an article in the *Monthly Labor Review*, March 1927, pp. 471-8. The 'traffic units' used in estimating the combined output of the freight and passenger departments were computed by adding to the total revenue ton-miles of freight each year the passenger mileage multiplied by 3. The productivity estimates for mining are computed from output data published by the U. S. Geological Survey in the annual issues of *Mineral Resources of the United States*, and from data on employment, in terms of equivalent 300-day workers, in bulletins issued by the U. S. Bureau of Mines on *Metal-Mine Accidents in the United States* and *Coal-Mine Fatalities in the United States*. Both underground and surface workers are included.

Doubtless substantial gains have been made in other industries for which data are not so readily available.

To appraise the causes of observed unemployment is a task rendered difficult by the fact that it is hard to distinguish between the labor-saving consequences of increased productivity and declines in employment that arise from changes in marketing conditions (see Ch. X). A further complicating factor is that, until checked by the depression, there had been tremendous migration from rural to urban areas, involving, among other shifts of population, a northward movement of the negro. Some have attributed these movements in part to marked increases in the mechanization of farm operations.<sup>4</sup>

It is in this setting that the inquiry upon which we are now reporting took shape. In 1923, at the request of the National Research Council, the National Bureau of Economic Research inaugurated a study of the relation between immigration and the supply of labor. It directed its attention first to the interrelation between cyclical and seasonal fluctuations in immigration and business conditions. A report on this subject, *Migration and Business Cycles*, was issued as volume 9 of the National Bureau publications. Later, in cooperation with the Social Science Research Council, the National Bureau continued, under the former's auspices, the study of the relation between immigration and labor supply. Attention was next directed to the possible relation between an increased use of labor-saving machinery and any shortage of labor that might derive from a continued restriction of immigration. We have noted that this question arose during the consideration of the quota acts. Fears were expressed by some that restriction might be disadvantageous to the interests of American industry. It was pointed out that a large

<sup>4</sup> See Ch. IV, section on Agriculture.

proportion of those workers who are engaged in the rough, dirty and unpleasant tasks, the tasks requiring on the whole a relatively small degree of skill but much physical strength and endurance, were of foreign birth. Furthermore, to those raising this issue no general willingness on the part of the native born to engage in such rough manual work was apparent. "How then," was the query, "are we going to get our rough work done? If we bar a substantial portion of the class of laborers from whom our unskilled laborers have been recruited in the past, who will dig the ditches, mine the coal? Can we narrow the sources of our labor supply and expect to achieve the development of our productive enterprises that is considered desirable?"

One suggestion made when this issue arose was that in the absence of large accretions by immigration to the ranks of those able and willing to do the rough and dirty work of industry, we should find not that the progress of industry would be seriously handicapped but that the use of labor-saving equipment, which has always been a marked characteristic of American industry, would be stimulated still further and hence the effects of immigration restriction would be offset, at least in large degree, by increased use of mechanical devices to do the kind of work for the performance of which we have in the past relied upon the brawn and willingness of recently immigrated workers.

Our survey was initiated as an inquiry into the problem just stated. We set out to examine the nature of the occupations and industries in which immigrants engaged and the tendencies towards and possibilities of mechanization in them. But, as indicated above, during the years in which the inquiry has been in progress, the question of the restriction of immigration has passed from the center of the stage. On the other hand, attention has been focused in increasing degree upon the nature and effects of progressive mechaniza-

tion. Consequently, though the form which the early stages of this inquiry took was determined to a large extent by its potential bearing upon the immigration problem, the attempt to relate the analysis to the question of immigration restriction as such has been abandoned; it has seemed advisable rather to study the characteristics, conditions and effects of changing mechanization. To this end we endeavor to set forth as clearly as we can the degree of mechanization in the leading industries, and the nature of the changes taking place as reported to our field investigators or ascertained from other sources of information; and then to formulate at least tentative hypotheses as to the conditions that determine the rapidity of mechanization, and the effects of increasing mechanization, especially upon the number and type of workers required for the production of goods and services.

#### METHODS AND MATERIALS

Our problem is many-sided and our methods of attack upon it have been diverse. We have tried so to conduct our inquiry that it would suffer neither from an exaggeration of spectacular but unrepresentative developments nor from a failure to give due recognition to significant changes. We have utilized whatever pertinent material we could find in the published reports of the federal and several state governments and also in various books, pamphlets, articles in periodicals and unpublished material prepared by many individuals. For a large part of our information we have relied upon data gathered by field representatives in inspections and interviews with executives in several hundred factories and construction operations.<sup>8</sup>

<sup>8</sup> Aside from cotton and furniture mills in the South, lumber mills in the Northwest, paper mills in Wisconsin, and highway construction operations in the Middle West, the majority of the plants inspected were in

Our study and inspections commenced in the autumn of 1924 and were conducted actively in the summer of 1925. Further inspections, especially of machine industries, and inquiries into the proportion which workers engaged in materials handling constitute of the total force in factories as a whole and in the several departments, were made in 1926. Also, supplementary studies of changes in productivity and accompanying changes in equipment were made in the closing years of the decade in lumber, cement, beet sugar, and to a lesser extent in other industries. The collection of information by mail and the examination of published data have been continued through all these years. As a result, our information does not all apply to exactly the same period, and much of it is not fully up-to-date. However, we trust this defect is more than compensated for by the more inclusive nature of our information and the better perspective that the passage of time has made possible.

The tentative conclusions based upon the field surveys have been verified and checked as far as practicable by correspondence and interviews with persons familiar with the technical problems of the several industries and by reference to the published descriptive and statistical material of more recent years.

To some of the industries chosen for special study we sent representatives to observe operations and interview executives. Most of the work of this type was done in foundries, brick yards, steel, cotton and paper mills, highway construction, and the excavating phase of building construction though a limited number of inspections were made in several other industries.

the New England, Middle Atlantic and East North Central states. Further details concerning the geographical location of the plants inspected are given in Ch. III and IV.

## BASES OF SELECTION OF INDUSTRIES

In selecting the industries to which special attention should be given, we aimed at a diversity sufficient to furnish examples of the more important conditions affecting the degree and rapidity of mechanization. We sought examples of both expanding and declining industries; of highly mechanized and of predominantly manual operations; of light and heavy manufacturing; of markedly seasonal industries and of those more continuous in operation; of industries with well-standardized products and of those with diversified products and production in limited quantities; of industries in which mechanization has proceeded leisurely and of those in which it has been rapid and perhaps with revolutionary effects. Furthermore, the peculiarities of certain industries suggest their obvious suitability for special study.

Common brick, for example, was chosen because the relative simplicity of the processes facilitated study, the proportion of unskilled labor is high, the volume of handling work large. Incidentally, it affords an example of an old industry catering chiefly to local markets but scarcely holding its own against severe commodity competition. The foundry is an essential part of the business of producing machines; it involves much heavy and arduous work in the handling of materials and, while using much relatively unskilled labor, also affords examples of the encroachment of machine operations upon skilled handicrafts. The steel industry, likewise, is closely allied to the machine-producing industries and employs a large number of workers, many of them of immigrant origin. And, for our purpose it had the advantage that one of our staff had previously given special study to it and upon certain phases of the industry an unusual abundance of published materials is available. Cotton goods affords an example of an industry that has long been

highly mechanized; its processes are reasonably comparable though the product is varied, and it is geographically concentrated in two major competing areas, the one utilizing in large part female workers of foreign stock of the first or second generation, the other, which has been growing more rapidly, relying almost entirely upon native white workers. Pulp and paper manufacture affords an example of an industry highly mechanized on the processing side, operating customarily on a 24-hour basis and, incidentally, concentrated in this country largely in regions where we were studying other industries. Stevedoring and the handling of retail coal were selected as illustrative of industries that perform almost exclusively handling rather than processing operations. Highway construction affords an illustration of a rapidly growing industry, using a large proportion of unskilled labor and operating under highly seasonal conditions, frequently with considerable urge to the speedy completion of the job.

Further diversity in type is added by the industries for which our own inspections do not constitute the major source of information. For example, bituminous coal mining is of large interest because although overdeveloped and overmanned, it is nevertheless becoming more and more mechanized. As to agriculture, conditions in the post-War period caused large numbers to leave the farm, and thus to swell the ranks of the industrial workers, at the same time that more power machinery was being used in both farm and factory. The mechanization of household tasks illustrates the invasion of the machine into the personal service field. Glass affords an example of a relatively recent transition from handicraft to machine methods, and the pertinent published material available is quite abundant. In the sound movie we have an example, in its effects on the employment of



TABLE 1  
SCOPE OF SURVEY AND SOURCES OF INFORMATION,  
BY INDUSTRIES <sup>1</sup>

INDUSTRY	TOTAL PLANTS IN SURVEYS	PLANTS INCLUDED IN MECHANIZATION SURVEY		PLANTS IN OUTPUT- PER-HOUR SURVEY	CHIEF SOURCES OF INFORMATION <sup>2</sup>
		FIELD	MAIL		
		<i>All industries</i>	1,301		
Allied to machine-producing industry					
Steel works and rolling mills	9	9	...	...	Published statistics; special studies <sup>2</sup>
Foundries	89	83	6	...	} Mechanization field survey
Machine shops	4	4	...	...	
Machine manufacturers	56	52	4 <sup>3</sup>	...	Field survey; machine producers
Other manufacturing					
Brick, tile and pottery	112	65	20	27	Field survey; output-per-hour survey
Textiles	117	80	37	...	Field survey; textile machinery manufacturers
Paper and pulp	45	35	10	...	} Field survey
Furniture	42	28	14	...	
Garments	20	20	...	...	
Cement	104	6	...	9 <sup>8</sup>	
Lumber	42	...	3	39	Output-per-hour survey
Glass	8	4	4	...	Special studies; technical journals
Beet sugar	90	...	...	90	Output-per-hour survey
Miscellaneous <sup>4</sup>	227	100	111	16	Field survey; mail; technical journals and special studies

<b>Construction</b>					
Roads and pavements	122	66	56 <sup>5</sup>	...	Field survey; mail
Building, excavation and structures	120	102	18	...	Field survey; special studies
<b>Handling industries</b>					
Stevedoring	46	22	24	...	Field survey; special studies
Retail coal	38	28	10	...	Field survey
Mining	5	5	...	...	Government statistics; special studies
<b>Other industries</b> <sup>6</sup>	5	1	3	1	See footnotes

<sup>1</sup> For further explanation of the surveys briefly designated in Table 1 as 'Mechanization field survey,' (or, for short, 'Field survey') and 'Output-per-hour' survey see text of Ch. I. Workers in the 1,030 establishments covered by the mechanization survey numbered about 310,000.

<sup>2</sup> 'Technical journals': information obtained from examination of articles in magazines devoted to particular industries or to the manufacturing, construction and engineering industries in general. This type of information has been used sparingly.

'Special studies': monographic reports listed in Appendix D.

<sup>3</sup> Exclusive of machine-producing establishments that furnished annual sales data but not other information.

<sup>4</sup> 'Miscellaneous' manufacturing comprises a few plants each in many industries, including: food products 52; iron and steel products (other than those listed elsewhere in the table) 26; lumber products 3; leather and its products 21; rubber products 7; printing and miscellaneous paper products 8; chemicals and allied products 12; lime 3; brass and other non-ferrous metal products 32; tobacco manufactures 10; passenger automobiles and motor trucks 20.

<sup>5</sup> Includes reports from 31 state highway engineers on mechanization developments in their states.

<sup>6</sup> 'Other industries' includes three hotels, a power laundry and a municipal water works. Also, in Ch. III and IV various industries are discussed that were not included in our field survey and are not listed in this table—agriculture, domestic service and numerous other manufacturing and non-manufacturing industries. The sources of information concerning these industries are indicated at appropriate points in the text.

musicians; of the revolutionary type of mechanization that is sometimes alleged to be typical of the entire process.

In Table 1 we have summarized by industries the scope of our factory inspections and indicated the extent to which information obtained from other sources has been utilized. Some further explanatory details appear in the table footnotes.

#### INFORMATION SOUGHT IN FACTORY INSPECTIONS

In the industries to which we devoted most detailed attention in the field phase of our survey, the general plan of procedure was to determine the successive major processing stages or departments in the industry, and to ascertain for them the proportion of labor force involved, the type of equipment used, the modifications in equipment that had been made since 1920 and their effect on the size of the crew required.<sup>6</sup> We did not attempt to trace the subsequent employment experience of any workers displaced. The scope and form of the questions evolved somewhat as the survey progressed and also varied considerably from industry to industry. Typically they concerned the following points: How many workers are employed in each major process? How many are machine operators or machine helpers and how many hand workers? And, as a clue to the proportion of unskilled workers, how many are receiving the customary rate for common labor? What labor-saving changes have been made since 1920? With what effect?

For a limited number of plants in a few industries we obtained a statement of all major items of equipment, when they were installed and what they replaced, even if they were not specifically identified as labor saving.

<sup>6</sup> In some instances we obtained information for earlier years, but most of the figures are dated 'since 1920'.

In several industries we gave special attention to the equipment, the workers and the volume of work involved in the handling of materials, recognizing that in many industries a transition from manual to mechanical means of handling has played an important role in recent labor-saving developments (see Ch. V).

In the summers of 1927, 1928 and 1929 our field representatives obtained data concerning changes in output per hour, and the accompanying changes in method and equipment, for a substantial proportion of the plants engaged in the manufacture of Portland cement, Douglas fir lumber and beet sugar, and for a few plants in several other industries, notably clay products and wheat flour. These studies have contributed to this report in numerous respects, though the results are not published here in detail.

For the machine-producing industries, we sought information concerning the type of labor used, the conditions that further or retard sales, and the volume of sales from year to year. Some machine plants were included in the inspections made in 1925, and in 1926 the writer visited another group to obtain data concerning the characteristics of the machine-producing industry. Also, in the subsequent years correspondence has been carried on with some hundreds of machine-producers on various phases of our problem. From about a hundred producers we have obtained their annual sales volume.

#### SUPPLEMENTARY SOURCES OF INFORMATION

On selected points we have sought information by mail from a group of machine users in a wide variety of industries, endeavoring in this way to fill some of the gaps left by our necessarily limited selection of industries for field study. For example, reports by mail from between 150 and 200

factory executives stated the nature and effect of the most important labor-saving change made in their respective plants since 1920. Also, inquiries concerning labor-saving changes were directed to the state officials in charge of highway construction.

Finally, we analyzed numerous articles in various technical journals, as a supplementary method of assuring ourselves that we had not overlooked significant movements in mechanization. Such material taken alone is likely, we believe, to be colored by the successful efforts of the more progressive firms; but it has been useful in guiding us in our research and illuminating the information obtained in other ways.

The principal sources of information other than our own survey are cited at the points used.<sup>7</sup> We are heavily indebted to the contributions made by the Bureau of Labor Statistics in its productivity studies of merchant blast furnaces, stevedoring, the dial telephone, printer telegraph, cigar machine and other industries. The treatise by William Haber, *Industrial Relations in the Building Industry*, has been relied upon for information to supplement our limited sample of building operations. The studies made by Dr. Elizabeth Baker in the commercial printing industry are especially noteworthy for the comprehensiveness of treatment. In coal mining the report of the Coal Commission, the *Coal Mine Mechanization Year Book* of the American Mining Congress, the statistics compiled by the Geological Survey, and various private studies such as those of Southward, Hamilton and Goodrich, have been our chief sources of information. Special studies by the Department of Agriculture and its statistics of annual sales of farm equipment have contributed largely to

<sup>7</sup> See also Bibliography, Appendix D.

the data on mechanization in agriculture. Similar sources of information could be cited for the other industries.

#### SUMMARY OF FINDINGS

It is not our purpose to essay the formidable task of appraising the relative merits of machine and handicraft civilizations and the cumulated changes wrought in our economic, social, political, moral and artistic life in the course of the long evolution from completely handicraft industries. We are here concerned only with the more limited task of appraising the nature and significance of current changes in the degree of mechanization.

These short-time aspects are of major importance. A return to a pre-machine civilization may be impossible; but it is not impossible to reach such an understanding of current changes that we may in some degree control the manner and rapidity with which they take place.

Now the most important single question about current changes in mechanization is, how fast do they occur? If the rate is unduly checked, industry does not progress. While a moderate rate of change may be relatively painless, it is obvious that an extremely rapid tempo may result in major social maladjustments. Moreover, if the rapidity of increase is overemphasized, exaggerated fears of the deleterious effects may be aroused. On the other hand, if the probability of substantial change is greatly underestimated, we are likely to neglect due precautions to minimize the individual and social disadvantages incident to mechanical progress.

Hence, we shall marshal our evidence so as to throw light upon the rate of mechanization that has prevailed in the relatively recent past and to make possible inferences as to the rate that may be expected to prevail, given substantially similar conditions in the future. The writer interprets the

evidence presented in the following chapters on the nature, causes and effects of changing mechanization as leading clearly to a 'middle-of-the-road' conclusion concerning the rate at which mechanization may be expected to proceed.

To particularize:

1. A continuing increase in mechanization at at least a moderate pace may be expected. For even in modern industry there is abundant scope and ever-present incentive for further mechanization.

First, there are still many operations not yet thoroughly mechanized, if mechanized at all.<sup>8</sup> The extent of mechanization varies markedly not only between industries but also between the several processes in an industry (see Table 30). Thus, fabrication processes are more highly mechanized than handling operations.<sup>9</sup>

Again, at any given time few of the labor-saving devices in commercial use are universally installed throughout the industries or processes for which they are adapted (*cf.* Ch. VII and Appendix B); and the competition of the more modernized establishments affords a more or less constant incentive to further installations. Even in depression periods, although the purchases of new equipment decline sharply (see Ch. VIII), there is a strong incentive to increase productivity through a more effective organization of the equipment already in place. Likewise, the development of new techniques and equipment is never completely at a standstill.

2. No more likely than a near cessation of mechanical

<sup>8</sup>In the aggregate of factory and construction operations inspected by us, hand workers constituted 44 per cent of the total, the ratio ranging from as low as 12 per cent for cotton goods manufacturing to about 70 per cent for ferrous foundries and about 80 per cent in some non-manufacturing industries (Table 29).

<sup>9</sup>In a group of 45 brick plants inspected, handling was by power methods for less than half of the total distance materials were transported (Table 10).

progress is the danger of an uncontrollably rapid mechanization. The phenomenon of increasing mechanization is too complex, too varied, too pervasive, to justify the assumption of a radical change in rate unless conditions are exceptionally favorable. These the near future does not promise. The executive in whose hands lies the decision for or against increased mechanization must weigh not only the technical difficulties to be overcome but also considerations of increased overhead expense, the availability of an adequate market for an increased output, the cost of scrapping the existing equipment, and the difficulties of financing new equipment, the possible opposition of his workers, and sometimes adverse public opinion and even restrictive legislation.

The many-sided nature of changing mechanization will be apparent to the readers of Chapters III, IV and V. Alike in manufacturing and non-manufacturing industries we find numerous examples of labor saving through increased mechanization in a wide variety of forms. Here the gains are through completely new technique or equipment; elsewhere merely through higher speeds or larger and more powerful machine units (Ch. VI). Mechanization in building construction has advanced through changes in materials and consequently in the essential erection processes. In coal mining, on the other hand, the work to be done has retained its general character and the process has been merely one of applying machinery to the kind of task formerly done with hand tools. Many economic changes have indirectly contributed to the growth of mechanization, notably (a) the elimination of inefficient plants and regional shifts to high-productivity areas; (b) in certain industries, a decline in the number of establishments and an increase in their average size, although this movement has not been marked in the decade of the 'twenties for manufacturing as a whole; (c) in many industries, an evident tendency to increase the capacity of indi-



vidual machine units (Table 23); (d) marked gains in the degree to which the manufacturing industries are electrified. It is estimated that the degree of electrification was 44-49 per cent in 1919 and 69-74 per cent in 1929 (Table 24).

The improbability of a sudden change in the rate of mechanization is enhanced by the fact that numerous changes of a minor sort, in some industries at least, outweigh in importance the more spectacular innovations (Ch. X). Examination of the records of labor saving obtained by us in interviews and inspections of industrial and construction operations reveals a preponderance of changes with small reductions in the number of workers required. In half of the instances the number of men saved per plant was under 10, even when allowance was made for increased output of the crew. Evidence supporting the thesis of the relatively high importance of numerous small changes is afforded by other studies of mechanization and changing productivity.

That the several stabilizing factors above mentioned do in fact retard the rate of introduction is evident from a consideration of the typical life histories of machines (Ch. VIII). Most machines require several years to pass through the period of experimentation and trial, several more to reach widespread adoption, after which they continue to increase in use more slowly for several additional years. A sample of 23 machine series, for periods ranging from 11 to 39 years, yields the following estimates of the typical duration of periods in their life histories: commercial trial, 3 to 11 years; rapid increase in use, 4 to 11 years; slackened increase (with a customary annual gain of less than 10 per cent), 3 to 6 years; decline of undefined length. Processes and types of equipment suffer declines for long periods before they pass completely out of use. They linger on in small plants and for special uses long after they have been replaced

by new processes or equipment in the major part of the industry.<sup>10</sup>

It does not appear probable that in the near future conditions will be exceptionally favorable for rapid mechanization. There is on the industrial horizon no clear evidence of that rapid expansion in industries and an easy capital fund market which are particularly favorable to rapid changes in technique. Furthermore, the experience of the closing years of the 'twenties and the subsequent depression period have focused attention as perhaps never before upon the unfavorable aspects of increasing productivity, and it is possible that measures will be designed to check unduly rapid mechanization. Already some measures restrictive of the use and expansion of machine equipment have been written into the codes under the National Industrial Recovery Act, and there have been various proposals for a dismissal wage and taxes on machinery designed to retard excessively rapid and disruptive changes in equipment or technique.

3. Changes in the rate of mechanization, although limited, are not negligible. The record of experience and a consideration of the factors limiting mechanization have led us to the conclusion that the rate of change in mechanization is relatively stable; but this means, not that there are no significant differences or changes in the rate of mechanization, but rather that they are within limits that are to a reasonable degree predictable.

That the rate of mechanization is variable, and in fact, reached a somewhat unusual speed in the 'twenties, is reason-

<sup>10</sup> See *Economic Reconstruction*, report of the Columbia University Commission on Economic Reconstruction (Columbia University Press, 1934). Replies to questionnaires addressed to prominent engineers and business executives indicate a possible improvement of 75 per cent in physical output if existing equipment and management were brought up to the level of the most efficient.

ably clear, despite the lack of precision in the available measures of mechanization and productivity (Ch. VI). With high wages, restricted immigration, relatively low prices for capital goods and an abundant and easy capital market (Ch. IX), the conditions for rapid mechanization were unusually favorable in that decade. At the peak for manufacturing (which was in the biennium 1923-25) the rate of increase in mechanization, as measured by horsepower per wage earner, reached 6.4 per cent.<sup>11</sup> For the decade 1919-29 as a whole it would appear that agriculture, mining and steam railroads show even greater gains than manufacturing in the ratio of horsepower to wage earners.

4. Even within the limited range of fluctuations in the rate of mechanization, there are, as indicated by the experience of the 'twenties, some ill effects requiring thoughtful consideration, but again, the rate and extent of such maladjustments are not beyond reasonable possibility of prediction and control, or at least the effects can be foreseen and ameliorated.

First, the progress of mechanization brings, especially when rapid, a substantial amount of skill displacement and technological unemployment which, even in the case of changes representing a net gain to society as a whole, may bring serious losses to individual workers, particularly to the older and highly skilled.

Finally, while advancing mechanization probably tends to lessen seasonal fluctuations in industry, there is reason to suspect that it may aggravate cyclical fluctuations through intensifying competition, enlarging the function of capital

<sup>11</sup> The rate of increase in aggregate horsepower in manufacturing was on the whole less in the post-War period than in the War and pre-War years; but horsepower per wage earner experienced a more rapid rate of increase in the post-War period, the maximum being reached in the 1923-25 biennium.

goods in the economic system, and (to the degree that it raises the general level of real income) increasing the share of expenditures in those lines, such as durable consumer goods, the effective demand for which is characterized by sharp reductions when a recession sets in. In brief, to the extent that mechanization contributes to the unpredictability and the variability of economic processes, it may likewise contribute to an aggravation of the severity of cyclical fluctuations.

#### LIMITATIONS OF FINDINGS

We are here concerned primarily with labor-saving changes that take the form of increased mechanization. It is beyond the scope of the present inquiry to attempt a detailed description and appraisal of the non-mechanical efficiency devices, though at various points in the text incidental attention has been given to this important phase of industrial change.<sup>12</sup>

Nor have we attempted to describe in detail the industrial processes in which labor-saving improvements have taken place or their technical character. At first we contemplated the inclusion of separate chapters for each of several selected industries, with descriptions of processes, equipment and changes; but it has seemed advisable to restrict ourselves to brief summaries for the several industries.<sup>13</sup> These are given in Chapters III, IV and V, together with bibliographical references which will aid the reader if he wishes further details. Although we have written for the layman rather than the

<sup>12</sup> Cf. the recently published article by W. G. Roylance, Significance of Nonmechanical Factors in Labor Productivity and Displacement, *Monthly Labor Review*, November 1933, pp. 1028-38.

<sup>13</sup> A typed copy of the more detailed draft of the description of processes, equipment and changes in the selected industries is on file in the office of the National Bureau of Economic Research.

technician, we have sought to give a substantially accurate picture of the technical aspects, and to lessen the chances of error we have submitted the more detailed description of changes, in a number of the industries to which special attention was given, for the criticism of persons familiar with the technique and problems of the industry in question. We have not endeavored to state the relative pecuniary costs of particular hand and machine methods, nor to indicate to the factory executive what mechanical devices will be economical for his use.

Paralleling the seasonal, cyclical and technological unemployment of workers is an analogous set of phenomena pertaining to seasonal and cyclical idleness of plant and equipment, and the technological obsolescence of equipment as new competing techniques arise. The entrance into an industry of competitors equipped with new devices and techniques lowers the earning power and encourages the scrapping of out-moded equipment. The job uncertainty that arises for the worker from technological change finds a counterpart in earning power uncertainty for the capital invested in equipment threatened with obsolescence. How can we obtain significant measures of effective capacity, in order to have a sound basis for measuring idleness of equipment? How can we measure the rate of obsolescence and appraise its effects on the nature and profits of industrial operations? Here is a research problem affording a real challenge to the analyst of mechanized industry, and requiring, for thorough consideration, the application of careful accounting and statistical technique and a fund of data not now available. We have not attempted to deal with the problems of equipment unemployment and obsolescence, other than in an incidental way, but they should be recognized as important aspects of mechanization.

Furthermore, this report does not attempt to forecast the

precise nature and effects of anticipated mechanical changes. Obviously, it is impossible to foretell with any approach to precision what developments will take place in the use of mechanical power even within the next few years. Improvements in the use of mechanical equipment and the expansion of scientific knowledge upon which such appliances in large part depend must be recognized as unpredictable in detail. Applied technique, and the science upon which it rests, is in a constant state of flux. Some developments can be anticipated with relative certainty; others are entirely unpredictable.

Finally, as previously noted, this study of mechanization is not designed as a broad comparison of the nature, merits and demerits of a machine civilization in general with more primitive forms of social and industrial organization. It is rather a study of the more immediate differences that arise from the types of change that may be expected from year to year and decade to decade as industry evolves from the stage of development now reached.

Despite the large unpredictable element in the future development of mechanical appliances, we entertain the hope that the reader who scans these chapters and weighs the evidence presented concerning the conditions that affect mechanization will be in a better position to judge for himself concerning the probable limits to the changes to be anticipated in the reasonably near future. The economies of labor-saving machinery pertain to an important phase of our economic life and a phase that has by no means been fully explored. We hope for this study that it may better somewhat our understanding of the conditions which have aided or hindered in the past and which may be expected in the future to continue to affect the development and use of power as a substitute for human labor, or perhaps more accurately, as a complement to human labor, in the production of goods

and services. Even in the many respects in which this study is based upon scanty materials (and the conclusions are necessarily tentative), we hope it will help to point out what further studies are needed. There is much to be done.

CHAPTER II  
TYPES OF  
LABOR-SAVING CHANGES

SOMETIMES a change is described as 'labor saving' when it merely lessens intensity of effort and does not decrease time spent. For example, a fireman and an engineer are required on a railway locomotive whether it is hand-fired or stoker-fired, and hence the labor that is saved by the installation of mechanical stokers may conceivably consist only in a reduction in firing effort. However, any decrease in the intensity of the labor expended probably makes it possible for a fireman to handle a longer run effectively. Ordinarily saving of effort and of time are closely related. In any event, the use of the term 'labor saving' throughout this discussion will refer primarily to the saving of labor time.

**PRODUCTIVITY-INCREASING VERSUS LABOR-DISPLACING CHANGES**

Even when so limited, the term 'labor saving' has two closely associated but not exactly similar meanings. The one implies changes that increase the productivity of labor by increasing the units of output per hour of labor; the other implies labor displacement or a reduction in the number of workers required in a specific operation, plant, occupation or industry.



## BASES FOR COMPUTATION OF CHANGES IN PRODUCTIVITY

For the first of these concepts, the term 'labor promoting' has been suggested, because it calls attention to the fact that the changes involved promote labor in the sense of making it more efficient in production. We shall use the somewhat more awkward, but also more self-explanatory, adjective 'productivity increasing' when we wish to designate changes that increase productivity—the output per hour of the labor applied.

*Labor basis*

In computing the effects of productivity-increasing improvements, it is essential to note what labor is included. For this purpose we may distinguish operating, auxiliary, embodied and indirectly required labor. Operating labor is that required directly in a particular process, such as the operation of a brick-molding machine. Auxiliary labor is that required in the plant for such operations as oiling, inspecting, adjusting and repairing the machine—in short, all plant labor that is necessitated by the use of the machine but is not considered as engaged in its direct operation. Embodied labor is the labor applied to the production of the machine itself and the materials of which it is made (prorated over the useful life of the machine), to the production of the materials used in machine repairs, and to the production of the power, oil, grease and other materials, if any, consumed in the operation of the machine. Lastly, we may extend the scope of our comparison still further by seeking to include not only the labor required in the factory production of the given commodity and in the production of the equipment used in the factory but also the additional labor required to put the given commodity in the hands of the final consumer ready

for use. It is entirely possible, for example, that by heavy investments in highly-mechanized equipment a few well-equipped brick plants might be able to produce bricks at a greatly reduced unit labor-time cost for plant operations; but the necessity for a wider market, which the augmented production entailed, might result in increased outlays for the longer haul to market and for more intensive advertising and merchandising, so that the labor gains in manufacturing would be offset in part at least by increases in the labor required in transportation and marketing. It is the labor required beyond the manufacturing stage that we have designated as 'indirectly required'. While studies in productivity and labor displacement ordinarily stop short of the point of allowing for all these indirect factors, we should recognize that until they are included we have not ascertained the real change in productivity or the real amount of labor saved or displaced.

If labor saving is used in the sense of productivity increase, it seems at first that almost any pecuniarily profitable additions to equipment would also be labor saving, since the entire sum expended for additional equipment is not paid for the labor embodied in the equipment—some is for rent, interest and profits. Hence if the given change pays for itself in dollars and cents, it will ordinarily reduce the labor-time cost even more than the pecuniary expense. The factory manager does not customarily install new equipment unless he expects it to be profitable; hence we may not unreasonably set up an initial presumption of labor saving (compared with supplanted or rejected alternative methods) for all additions to equipment. But exceptions will appear when attention is directed to the types of labor involved. Some equipment is produced by cheap labor and replaces high-priced labor. In such instances the total labor time may be increased by the addition of new equipment. Because of

such exceptions and because of differences in the degree of labor saving and in the channels through which the change in labor time takes place, it is highly important to make a close scrutiny of the concept of labor saving and the types of labor-saving changes.

### *Time basis*

To appraise the relative productivity of two methods it is essential to observe whether the basis is a short period of uninterrupted running time, or an hour, day, week, month or year under actual running conditions. The speed of the cotton warp-tying machine running uninterruptedly (about 250 threads per minute) gives some clue to its possible output, but a more significant figure is a comparison between its output and that of hand tying-in operators during a normal working period that includes customary stoppages and idleness of operators or machines.

### BASES FOR COMPUTATION OF LABOR DISPLACEMENT

The term labor saving is perhaps more frequently identified with labor displacement than with increased productivity. Labor displacement is a decrease in the number of workers required in (1) a specified operation, such as operating the brick-molding machine in our illustration above; (2) the plant as a whole; (3) an occupation, such as carpentry, wherever practiced; (4) an industry as a whole.

To illustrate: If, in a hypothetical plant, new brick-molding machines are introduced which, because of greater speed and more automatic features, make it possible for the machines with five operators to turn out the product formerly requiring ten operators—with, let us assume for the sake of simplicity, no change in the total output—then there

is an 'operation labor-displacement' of five men, a displacement so far as the particular operation is concerned. If these five men are not assigned other work in the same plant there is 'plant labor-displacement'. If they find work in the same plant or in other plants but in an occupation other than that of operating brick machines, there is 'occupational displacement'. If they find work but in an industry other than brick manufacture, there is 'industrial displacement'. If they find no work at all there is 'complete displacement'. If it arises from a technological change, 'complete displacement', either temporary or permanent, is 'technological unemployment'.

Now labor displacement as above defined does not necessarily arise when productivity increases; nor, on the other hand, is labor displacement always accompanied by increasing productivity. They are boon companions but not inseparable. When increasing productivity is accompanied by an equivalent increase in the total output of the plant, there may be no labor displacement.

**SUMMARY**

To summarize, labor saving sometimes means an increase in productivity, sometimes a displacement of labor; the two concepts are not necessarily identical. Furthermore, the productivity comparison may be based upon only the direct operating labor or may be broadened to include auxiliary, embodied and indirectly required labor. In like manner, discussions of labor displacement may refer only to the effect on the size of the crew in a given operation, on the labor in the plant as a whole, on the number in a given occupation, in a given industry or in employment of any kind. Finally, there may be displacement of one type of labor, balanced

more or less by increase in another type; there may be displacement of skill as well as of number.

As discussed more fully in Chapter X, some increases in mechanization increase the demand for skilled labor, others decrease it. Many recent changes are especially effective in reducing the requirements for semiskilled and unskilled labor. But mechanization has also touched the calculative and artistic activities. Bush's electric integrator accomplishes results difficult if not impossible of solution by the unaided efforts of the mathematician. The rapid spread of the 'talkies' has resulted in a sharp decline in the demand for theater musicians. Examples might be multiplied.

In practice most discussion of labor saving refers to labor displacement or increasing productivity in specific operations or plants, sometimes with and sometimes without allowance for increase in output, but ordinarily not allowing for all of the offsetting increases in embodied and indirectly required labor.

Let us endeavor to clarify the distinctions made in the above paragraphs by resort to a numerical illustration based on hypothetical circumstances. Let us suppose that the owners of a group of brick plants with a daily capacity of two million brick find that their brick-molding machines have depreciated to the point where replacement is necessary. They may install either 40 of the 'old' type similar to those previously used, with a production capacity of 50,000 each per day under actual working conditions (55,000 each if no allowance is made for stoppages), or 25 of a new type with a daily capacity of 80,000 each (90,000 if no stoppages are allowed for). They will presumably base their choice on the estimated relative pecuniary costs of purchase and operation; but we are interested in the labor-time costs, which we will assume to be as set forth in Table 2. The old equipment would require 70 operators and 10 auxiliary workers for

TABLE 2  
HYPOTHETICAL CALCULATION TO ILLUSTRATE MEANINGS  
OF LABOR SAVING

TYPE OF LABOR	NUMBER OF WORKERS REQUIRED		OUTPUT PER MAN PER DAY		PERCENTAGE INCREASE IN PRODUCTIVITY <sup>1</sup>
	OLD	NEW	OLD	NEW	
Molding-machine operators	70	50	28,571	40,000	40.0
Auxiliary workers	10	5			
Total, operators and auxiliary workers	80	55	25,000	36,364	45.5
Total plant force	2,000	1,975	1,000	1,013	1.3
Embodied labor	20	30			
Total, plant force plus embodied labor	2,020	2,005	990	998	0.8
Indirectly required labor	200	215			
Total, plant force plus both embodied and indirectly required labor	2,220	2,220	901	901	0

<sup>1</sup> Assuming a total output of 2,000,000 brick per day, both with the 'old' and the 'new' equipment.

oiling, repairing, adjusting the machines, etc.; the new-type equipment, only 50 operators and 5 auxiliary workers. Assuming that none of the other departments in the plant is affected by the choice between the old- and new-type molding machines, the total plant force would be 2,000 with the old, and 1,975 with the new-type. But, let us assume, more labor is required in the production of the new-type machines (30 instead of 20 men).<sup>1</sup> Furthermore, we assume that the

<sup>1</sup> This means that when the labor involved in the production of the machines is prorated over the useful life of the machine, the share estimated for one year is equivalent to the labor of 20 men for the year.

use of new-type machines necessitates the resort to more distant markets or in some other way increases from 200 to 215 men the indirect requirements for labor to get the product to the final consumer. The latter assumption would be more reasonable, perhaps, if we had also assumed an increase in total output; but even if not obviously plausible under the other circumstances we have assumed, the allowance for indirectly required labor will serve to illustrate allowances that should be made whenever a given change does result in greater labor requirements in the subsequent steps of getting goods to the consumer.

Now, it will be noted that the results are quite different, either in terms of productivity or labor displacement, according to what basis we take for the comparison. If operators of the molding machines alone are considered, the new-type equipment represents a 40 per cent greater productivity; if auxiliary workers are added, the differential is still greater—45.5 per cent; but if the entire plant force is considered, the gain is only 1.3 per cent. If embodied labor is brought into the computation, the differential shrinks to 0.8 per cent; and if the increase in indirectly required labor is also considered, the differential disappears. Still other differentials in productivity are obtained if we exclude from the computations plant labor not used in the specified machine operation or auxiliary thereto but include the 'embodied' labor and the labor required indirectly outside the plant.

Similarly, the new method represents an operation labor displacement of 20 men and a plant labor displacement of 25. When the industry as a whole is considered it appears at first that there is no net displacement, for the losses in the plant are offset by increases in the machine-producing, transporting and merchandising industries. However, we have no assurance that the additional men represented by embodied labor and the indirect increases in labor requirements will be

either the same men replaced in the plant or even men of the same occupation or skill. There may be occupational and industrial labor displacement with possibly some technological unemployment, even though the total demand for labor in the industry is unchanged. There may be numerous shifts that result in increasing employment for some individuals and types, and decreasing employment for others.

If no allowance for stoppages is made, the differential of the new-type machine is even greater than computed in Table 2, for we have assumed a one-ninth loss of capacity through stoppages for the new type and only one-eleventh for the old type.

LABOR-SAVING RATIO

The ratio in which labor requirements are reduced by a change in equipment or methods may be algebraically stated thus:

$$S = 1 - \frac{N}{OP}$$

Where,

S=the labor-saving ratio

N=the number of workers required under the new method

O=the number of workers required under the old method

P=the ratio of the total output under the new method to the total output under the old method.

For example, if a new method reduces the crew required from 20 to 10 and doubles the total output, the labor-saving ratio is

$$S = 1 - \frac{10}{20} \times \frac{1}{2} = \frac{3}{4}$$

If the 'P' factor is omitted we are measuring the labor



displacement regardless of change in total output; if it is included, we are expressing the ratio between the labor required under the new method and the labor which would be required under the old method to produce the same total output. This difference measures a constructive rather than an actual displacement of labor, for ordinarily we cannot assume that the total output would have been the same if the old methods had been retained.<sup>2</sup>

As previously noted, 'N' and 'O' may for some purposes include only direct operating labor; for others they are broadened in scope to include auxiliary, embodied or indirectly required labor. If embodied labor is to be included, the necessary computation may be algebraically stated thus:

$$E = \frac{M \times F}{W}$$

Where,

E=the number of workers required for the production of the materials, equipment, etc., for one year of operation

M=the money cost of such materials, equipment, etc., for one year (total cost prorated over useful life)

F=the fraction of money cost that represents payments for labor, including all stages of the industrial process

W=the average earnings per year of workers in the industries in which the 'embodied' labor is employed.

In *The National Income and Its Purchasing Power* Dr. W. I. King has estimated the distribution of the income of the people of the United States among wages, salaries and the payments going to entrepreneurs and other property owners. Basing our conclusions in part on his estimates we reach a rough approximation of the figure that should be

<sup>2</sup> For illustrations of constructive displacement see Ch. X.

taken for F (the fraction of money cost which represents labor) as about 70 cents on the dollar (50–55 for wage earners and 15–20 for salaried workers).<sup>3</sup> For 'W' we suggest \$1.416, this being the average annual earnings of employees (salaried workers and wage earners) in manufacturing in 1925. If used for other years suitable adjustments may be made for changes in average earnings.

#### NON-MECHANICAL CHANGES

This survey is primarily concerned with the causes, volume and effects of mechanical changes in industrial technique—in increasing mechanization—but this limitation should not blind us or our readers to the great significance and tremendous potentialities of non-mechanical changes leading to increased labor productivity. It is pertinent, therefore, to list some of these non-mechanical changes even though we do not pretend to measure their extent or effects.

Much has been accomplished by a better organization of factory work, often without any major additions to mechanical equipment. Re-routing to obtain a straight-line flow often not only reduces the handling labor but also materially increases the output in the processing operations. Greater subdivision of operations may increase productivity and not involve mechanical changes. A better balancing of equipment, perhaps by the elimination of a superfluous underworked unit, may economize labor. Substantial savings in labor have been accomplished by the multiple-machine or 'stretch-out' system, that is, by such reorganization of the work that one operator can handle more machines without an equivalent increase in auxiliary labor.<sup>4</sup>

<sup>3</sup> For methods of arriving at these estimates, see Table 31 (Ch. VIII).

<sup>4</sup> Cf. discussion in Ch. III, Cotton Yarn and Cloth section.

It has long been recognized that a slave economy was always handicapped by labor inefficiency. But studies in industrial psychology and working procedures are now making clear that even under a free labor system the most has not been realized from our industrial workers. Much depends upon personal efficiency. Better training for his job, better working conditions,<sup>5</sup> better conditions at home and opportunities for healthful and stimulating recreation—in brief, all conditions that strengthen the morale and improve the mental attitude of the worker are significant factors affecting productivity. Without passing judgment on a mooted point, we may call attention in this connection to the belief held by some students of the problem that part of the increased productivity of the post-War period may be ascribed to the effects of legal prohibition.

Changes in the type of product demanded affect the proportion of labor required. The substitution of the machine-made cigarette for the hand-made cigar is a case in point.<sup>6</sup> On the one hand are the demand for quality goods and the tendency to style changes that limit the development of quantity production and the consequent lowering of unit costs; on the other, the movement for standardization and simplification, fostered and encouraged by the Federal government and many trade organizations.

Changes in the quality of raw materials affect the productivity of machine operators. The weaver working with good thread that will not break frequently is able to turn out more cloth because his looms are more continuously in operation.

<sup>5</sup> For example, in laundries where the steam pressing tables, hot irons and hot water create an unnatural heat, the productivity of the worker may be substantially increased by an adequate air-washing and ventilating system.

<sup>6</sup> The introduction of a new line was the chief factor making it possible for one clothing manufacturer to dispense with 150 cutters.

Of high importance are those factors which, without necessarily making any alterations in the equipment or processes of industry, promote a fuller use of the available equipment by reducing, in one way or another, the idleness of men and machines. Here we may place the steps towards the elimination of seasonal fluctuations in industry,<sup>7</sup> also the efforts to stabilize cyclical variations and, for the single plant, a better balancing of its various departments,<sup>8</sup> improvements lessening losses through stoppages due to breakdowns, and other similar economies in the use of equipment and men. If fully successful these measures would release large numbers of workers for useful production in other industries. We may reduce railroad labor by organization designed to lessen the number of idle cars; far more laborers are engaged in mining than would be required if kept steadily employed; and many other examples of useless work or unproductive idleness could be cited.

Not all current tendencies in industry point to increased economies in the use of the available supply of labor. Some operate to lessen the supply. The movement for the five-day week or a shorter working day are steps tending to lessen the aggregate hours of labor normally available for production.

That equipment changes are not by any means the sole type of betterment in industry may be illustrated by a summary from a compilation of 97 instances of improvement in manufacturing operations published by Mr. L. P. Alford in *Manufacturing Industries*, September 1926. A dozen or more

<sup>7</sup> See *Seasonal Variations in Industry and Trade*, by Simon Kuznets (National Bureau of Economic Research, 1933).

<sup>8</sup> Several of the plants inspected by our agents were overmechanized in some departments. Thus one brick plant had steam shovel and industrial railroad capacity for a production three times its usual output; another had so many brick machines that the shovel and hauling locomotive could not keep them supplied with clay.

of the instances described by Mr. Alford might be classified on two or more bases, but utilizing as the criterion for classification only what we judge to be the major change, it appears that of the total 97 instances only 45 deal with equipment changes and 52 with changes in methods of operation and control. Of the 45 equipment changes 32 are concerned with conveyors, industrial trucks and other materials-handling equipment. Of the 52 betterments not primarily mechanical 16 are ascribed to production control, time and motion studies, and scientific management in general; 11 to budget control and study of the order market and forecasting; 9 to changes in cost systems and other accounting changes; 7 to methods of selecting workers and determining wages; and the remaining 9 to miscellaneous changes such as improvements in shipping methods, salvage and waste reclamation, improvements in service departments and tool control, and in inspection and office methods. Doubtless this list is not exactly representative, in that manufacturing concerns probably do not reveal changes in their processes quite so freely as they do other changes, but it is noteworthy that less than one-half of the betterments reported were equipment changes.

#### MECHANICAL CHANGES

In discussing the nature of mechanical improvements we may first note that mechanization is not synonymous with regimentation; it is by no means true that all routine operations are machine processes.

In the first place, even in the most highly regimented industries many of the workers are engaged in hand operations. The automotive industry has come to be taken as synonymous with mass production reduced to a simple routine; but in the automotive plants there are many hand workers. Even

on the well-known Model-T Ford assembly belt, although some nuts were screwed down with the aid of air-driven tools, many of the operations were manual. In fact, most assembling, in automobile plants and elsewhere, is hard work.

Likewise, a large part of inspection and testing work is done without the aid of mechanical contrivances; and no small part of the work of packing and otherwise preparing for shipment consists of manual operations.

Nor does a high degree of mechanization always mean that the worker's function is a dreary unthinking repetition of a few simple motions. In fact, with completely automatic machines the function of the operator often becomes largely that of watching and repairing. In the use of automatic lathes, for example, part of the labor required is in adjusting the machine for a new job. Likewise in the weave room of a modern cotton factory many of the employees are 'loom fixers' whose function is to keep the looms in order and adjust them for new work.

#### MEANING OF 'MECHANIZATION'

In the broadest sense we mean by mechanization the use of tools or equipment of any kind to aid the human brain and muscle, and by 'increasing mechanization' we refer to any change in methods or equipment that tends to lessen reliance on the unaided mental and manual endowment of the worker. In this broad sense the transition from plows pulled by men and women to the horse-drawn plow is a step in mechanization, as well as the later replacement of the horse by the power tractor. Our interest centers chiefly, however, in *power mechanization*—in the increasing reliance on equipment driven by generated power, be it steam, electricity, compressed air or gasoline that furnishes the motive power. We return in Chapters VI and VII, in connection

with the measurement of mechanization, to a further discussion of its nature.

#### TYPES OF LABOR-SAVING MECHANICAL CHANGES<sup>9</sup>

Aside from changes so general that comparison can be made only in terms of the net results—and these may be very important—we may note four fairly obvious ways in which changes in equipment may reduce the labor requirement, relative to the output, on specific operations, namely, by: (1) eliminating one or more hand operations; (2) increasing the speed of the machine; (3) enlarging capacity (through greater physical size) without corresponding increases in the labor requirements for feeding and attention;<sup>10</sup> (4) substituting a different process requiring less labor, such as the substitution of electric welding for riveting.

The use of better materials or a greater durability of machine parts has, by keeping the machine in steadier operation, substantially the same effect as making the machine faster or larger.

#### *Elimination of Operations*

Labor saving by the elimination of one or more manual operations is a common type of development. Oil burners replace the firing and coal-wheeling operations and eliminate ash removal. Wick oiling or other automatic oiling devices replace or reduce the hand oiling operation. Automatic looms differ from the non-automatic chiefly in that full bobbins or

<sup>9</sup> We are dealing here chiefly with those changes which are modifications in an existing plant, and not with the rising level of efficiency which may come from the building of newer modern plants and the scrapping of older plants. See discussion in a subsequent section of this chapter.

<sup>10</sup> Cf. discussion of increasing speed and unit size in Ch. VI.

shuttles are inserted automatically so that it is not necessary for the machine to stop while bobbins or shuttles are changed by hand; automatic feeds on presses and other machines may not change the actual speed of a machine during its running time, but may keep it in more continuous operation and eliminate or reduce hand feeding. One paper manufacturer reports that automatic feeders replace one man on each machine and require only the occasional attention of a foreman, with a one hundred per cent increase in production. Serial arrangement of machines often provides automatic feeding by carrying material directly from one machine to the next. On the newer types of soft-mud brick machines the hand-dump feature of older models is replaced by an automatic dump; in a cotton mill the Morton automatic distributors to the pickers reduce the labor required in the feeding operation. The use of pulverized coal or a change from hand to mechanical stoking, or from produced to purchased power reduces or eliminates the powerhouse crew so far as the manufacturing plant is concerned.

Frequently mechanical changes that eliminate or alter specific operations constituting only part of a process have little effect on total output, but operate rather to reduce the crew required. Thus in blast furnace operation the introduction of automatic filling or the pig-casting machine tends to reduce labor rather than to increase the output of the stack.<sup>11</sup>

Sometimes alterations in methods, or in equipment, at one stage in fabrication make possible the elimination of a set of machines in another stage. In cotton manufacturing there has been some tendency in the decade under discussion to eliminate one of the picker processes, owing in part to better 'opening' equipment in the preceding process. Replacement of electricity by waste-heat boilers in the cement

<sup>11</sup> B. L. S., Ref. 37, pp. 29-30.



industry is one example of the reverse tendency, that is, alterations in equipment or technique that add operations requiring manual attention and thus increase the crew.

Discussion of the reduction of labor requirements by increasing the size and speed of machines—important tendencies in the current march of mechanization—is deferred to Chapter VI.

#### *Imitation of Hand Procedure*

Some mechanical substitutes for manual methods radically alter the operation; others are close imitations of the hand processes. The evolution of the bumping and dumping mechanism in the automatic-dump brick machine was an adaptation of the identical principles that were employed in bumping and dumping the molds by hand. Likewise, in the production of window glass the cylinder-machine process is similar to the hand method of blowing a long cylindrical bubble of glass, which, when cool, is split open and flattened. The cylinder machine is simply a mechanical glass blower. In the sheet process, on the contrary, a flat sheet of glass is drawn directly from a forehearth containing a semicooled mass of glass, thus eliminating the splitting and flattening of the cylinder.

Obviously some developments can be considered only as indirect substitutes for hand methods, in that the machines accomplish tasks scarcely performable by manual effort. A freight locomotive pulls a heavy train at a speed that no group of men, however large, could equal. We have, in fact, ceased to consider a freight train as labor saving; yet it is conceivable that the goods now transported in railway trains might be carried on the backs of human beings, as is still done to a large extent in China. From that point of view, a railway train is a substitute for unskilled labor. However,

we are concerned not with fine-spun distinctions but with the more definite problem of the substitution of machines in operations now manually performed, or in changes in machines that reduce the volume or change the type of labor required. We are particularly interested in those machines which perform operations customarily carried on by the common or unskilled laborer.

*Mechanization by Conversion*

Mechanization is frequently advanced by the addition of attachments to existing equipment. Many non-automatic looms have been converted to automatics. Likewise, to many hand-power section cars motors have been added.

*New Construction*

Our field survey dealt chiefly with those types of labor-saving changes which take the form of alterations in existing plants. A highly important phase, however, is the raising of the general level of mechanization by the construction of new, better equipped plants; the older, less efficient plants are gradually abandoned and the high-cost producers 'go to the wall'. This form of evolution to a higher degree of mechanization is especially favored by readily available capital.

**METHODS OR EQUIPMENT DISPLACED**

Does mechanization progress chiefly through the substitution of power equipment directly for hand methods or does it in most instances take the form of labor-saving improvements in operations already mechanized? The available evidence is inadequate both in form and quantity for a

conclusive answer, but we may gain some idea of the relative importance of direct substitutions of mechanical for manual methods. To this end we classified 608 labor-saving changes upon which information was obtained in our survey, and also 234 instances reported in various technical journals,<sup>12</sup> Of this total of 842 instances 47 involved the displacement of horse-motivated equipment by generated power; 536, the displacement of hand equipment and methods; and only 259, improvements in power equipment.

The displacements of horse-motivated equipment were chiefly substitutions of motor trucks and tractors for horses in highway construction, the mechanization of haulage in mines and in brick yards, and the substitution of power trucks with self-dumping devices for horse-drawn wagons in retail coal yards.

#### *Displacement of Hand Methods*

Over half of the instances reported, both in our survey and in the articles in technical journals examined by us, involved the direct displacement of hand methods by mechanical. This seems strange in an age that is reputed to be highly mechanized, and the proportion may be considerably overestimated owing to the tendency for informants to recognize more readily as labor saving a change that directly substitutes a mechanical for a hand process; that is, much labor is saved indirectly from improvements in processes already mechanized. Moreover, when displacements were reclassified by us according to whether they arose in handling or in processing operations, it was found that nearly half of the substitutions of mechanical for hand methods arose in

<sup>12</sup> Excluding 256 instances in our survey or in the technical journals examined which were not classifiable on the bases here used.

handling operations, which have been, and still are, largely manual.<sup>13</sup>

The 186 instances from our field survey which we classified as the displacement of hand methods by mechanical in the processing operations include the substitution of power molding machines for floor or bench molding—even if the floor or bench molding was done with the aid of pneumatic sand rammers (35); the introduction of machines for preparing the mold sand (6); warp-tying machines for hand tying (7); steam pressing machines for hand irons in garment shops; automatic proportioning and metering systems in the cooking of paper pulp (5); the introduction of machine finishing in highway construction in place of men with strike boards (20); various wrapping, packing, labeling and filling machines, which largely replace female labor (11); power screening plants in retail coal yards (4); various wood-working machines; paper-box stitching and wood-box nailing machines; hydraulic core-removing and sand-reclaiming devices; paint-spray guns (3); various garment-working devices, such as basting, stitching, felting, and rotary cloth-cutting machines (5); and mattress-making machines.

#### *Displacement of Mechanical Equipment*

The labor-saving changes in the compilation just mentioned which involved the substitution of one mechanical device for another in handling operations were largely the replacement of steam hoists or power shovels by the electric type (6); of steam shovels, hoists or industrial locomotives by the gasoline type (6); alterations in conveying systems (9); new motor trucks with the power-dump feature for older

<sup>13</sup> For the importance of the handling operations and the proportion of labor-saving instances that pertain to handling, see Ch. V.

types of trucks in retail coal handling (12); and the substitution of caterpillar tread for wheel tread on power shovels.

Between a fifth and a sixth of the total labor-saving instances classified are changes in mechanical methods of processing, including in that term practically all operations not covered by the phrase 'handling operations', such as fabrication, assembling, packing and packaging, and the production of power and heat. As previously suggested, it is our belief that the proportion indicated considerably underestimates the relative importance of this group of changes in the increasing efficiency of our industries. This underestimation is in part at least due to the indirect ways in which much of the labor saving from improvements in processes already mechanized arises.

#### INDIRECT SAVINGS OF LABOR

Changes in industrial technique not altering materially the amount of labor involved in the operation immediately affected, may, nevertheless, alter substantially the labor required in other processes; for example, through a reduction in the floor space required, in reduced waste of materials or damage to product, or through savings in fuel, power, supplies, or wear and tear on machinery. All these—floor space, materials, equipment—require labor in their construction, and any economies in their use have an indirect effect on the demand for labor.<sup>14</sup> Thus the electrification of the power department of a factory may reduce maintenance labor owing to the absence of belts and shafting.

One excellent example of the saving of labor through reduction of waste in the use of materials is afforded by the improvement in the utilization of fuel in the production of

<sup>14</sup> For further discussion of these indirect savings, see Ch. X.

power. According to estimates of the Geological Survey, from 1919 to 1929 the average quantity of coal required to produce a kilowatt-hour of electricity has decreased from 3.2 to 1.7 pounds.<sup>15</sup> This refers to the production of electricity by public utility power plants in the United States, and inasmuch as the consumption of coal or coal equivalent of other fuels in the production of such power amounted in 1929 to 52,574,000 net tons, it may be estimated that the reduction in the amount of fuel required for a kilowatt-hour, from 3.2 to 1.7 pounds is equivalent to a saving of about 46 million tons of coal, which, of course, lessens the need for coal-handling labor not only in public utility plants but also in the transportation and mining stages.

#### CLASSIFICATION OF MACHINES

##### OPERATION IN WHICH USED

For our purpose a significant distinction is between equipment used in handling and in processing, in converting materials into different forms or combinations. Handling equipment includes, for example, conveyors, overhead cranes and trucks (*cf.* Ch. V). Processing equipment includes a great variety of devices used in converting materials into different forms or putting them into different combinations such as: metal-working machines, wood-working, painting, labeling, wrapping and packaging equipment and devices for lubrication and cleaning. Here also we may, broadly speaking, include the equipment for power generation and transmission, though for some purposes we may wish to differentiate power equipment from both handling and processing equipment.

<sup>15</sup> Ref. 31, p. 198, and *Commerce Yearbook*, 1930, I, 271.

**DEGREE TO WHICH AUTOMATIC**

A higher degree of mechanization does not necessarily mean recourse to completely automatic machines. In fact, relatively few machines are completely automatic in all phases of their operation, especially if feeding of materials and the removal of their products are included. The distinctions between non-automatic, semiautomatic and automatic do not in practice follow rigid rules and their meaning must be examined in each particular instance.

The non-automatic loom, for example, is really a semi-automatic piece of machinery which requires hand operations in refilling with full bobbins when the thread has been exhausted. Again, a piece of equipment may not be automatic at all in the sense that it is driven by generated power, and yet it may save labor. Witness the Barber and Boyce knotters, used by textile weavers, which are merely devices to facilitate the hand tying of knots.

Not all automatic equipment is labor saving. Thus automatic train control is generally regarded as a safety device.

**TYPE OF POWER**

The mechanized unit is most commonly one that is driven by generated power of some kind—steam, electricity, water, gasoline, waste heat, compressed air—but when we speak of the progress of mechanization in the broadest sense, we hesitate to exclude the substitution of wind power (windmills) or of horse power for hand power.

The progress of mechanization may be either extensive or intensive. The former describes a wider use of a given type of equipment, the latter, the transition to more and more automatic types in a given process. Such a transition is seen in the substitution, first, of non-power driven simple tools

for the unaided hand, then the addition of horse power, and finally of generated power devices of an ever-increasing degree of automatic operation.

AGENCY BY WHICH PRODUCED

If we classify by origin, we may distinguish three types of labor-saving equipment, which may conveniently be designated as 'homemade', 'tailor-made' and 'ready-made'.

'Homemade' devices are machines, attachments or adaptations worked out by the machine user himself. Many of the larger machine-using factories maintain a staff whose chief function is the development of new equipment for their own use. Even when a machine is manufactured by a specialized machine-producing plant, its perfection, particularly in the initial stages, is often due partly to the suggestions contributed by the user who is thus a co-inventor. In fact, many machines are first developed in crude form by users, perhaps under the pressure of emergency, and then later improved and commercialized. The cotton sled, for example, was at first a homemade device. An enumeration of a few of the many machines found in our field investigation, that had been built by the users, will illustrate their diversity: a machine for pipe core making; a device for pulling out the cupola drop in a foundry cupola; finishing wheels for spinning-frame rolls in a textile machinery factory; paper folders in a paper factory; twisters in a carpet factory; trimmers in the cloth room of a sheeting factory; strike boards in the placing process on highway construction; a homemade hand pavement finisher; homemade pile drivers; homemade sub-graders; adjustments for applying pressure in tire core-building; a feeding device for the calendering machine in a tire factory. The *Brick and Clay Record* publish a little book entitled *101 Ideas for Improving the Clay Plant*, which is a



compilation of short items describing miscellaneous machines, equipment and apparatus, many of them homemade, that manufacturers have installed in their plants to improve certain processes. We surmise that the relative importance of such homemade improvements is minimized in most studies of the extent of labor-saving changes, for the users are often reluctant to reveal the nature of their specialized machinery. As the manager of one plant wrote us, "we make our own labor-saving machinery. We do not care to give out any information."

Probably the most significant labor-saving changes in equipment in the decade just past have been 'tailor-made' by engineering firms whose special function is the designing and installation of mechanical equipment. True, as noted in the above paragraph, there are thousands of appliances and adjustments worked out by machine users, but these are not likely to be extensively adopted by other concerns until improved and more or less standardized by machine manufacturers. As one prominent agricultural engineer expresses it, progress cannot "wait for the accident of genius; research has taken the place of inspiration." In the installation of conveying systems, particularly, the work of specialized engineering concerns has been an important factor in recent labor economies.

'Tailor-made' equipment has some of the elements of secrecy characteristic of 'homemade' equipment. In reply to our inquiries concerning labor-saving machinery produced by it, one concern engaged in making machines to order writes: "In regard to the numerous special machines that we manufacture under contract, these machines are practically all of the labor-saving type, but in most cases the design is furnished to us by the customer and built in accordance with the customer's blue prints and specifications. We are not at

liberty to disclose what these machines are nor what their production record is."

'Ready-made' equipment is produced in more or less standardized units, in varying sizes perhaps, but sufficiently standardized so that some degree of quantity production is possible on the part of the machine producer. Here we may list such equipment as portable conveyors, trench diggers, steam shovels, automatic looms, paving mixers, paint-spray guns, pneumatic hammers, electric trucks, domestic sewing machines, vacuum cleaners, brick-molding machinery—all equipment whose use has become so general that it is not necessary to build a machine to order for each user. The extensive development of a 'ready-made' machine-producing industry is dependent upon a reasonably certain large market for the product. The 'tailor-made' machine builder relies on a smaller number of more diverse orders. Consequently such stimulus to the machine-producing industries as has arisen from the immigration restriction of the War and post-War periods has probably been most influential in the development of the 'ready-made' branch of the industry.

Perhaps to the three types mentioned should be added the sporadic output of the 'born inventor'. The manager of a plant manufacturing nationally-advertised products of diverse types stated that in their processes the device of the outside 'born inventor' seldom worked; that a machine prepared for a particular task by a company specializing in making such devices seldom works at first but must be gradually modified to fulfill its particular function. The best results come from devices perfected by their own staff.

In general, the typical new machine that becomes of wide use goes through an evolution starting perhaps with the genesis of an idea in the mind of an individual, is experimentally developed as a 'homemade' or 'tailor-made' machine, tested by users with adaptations on the basis of work-

ing experience, and finally becomes sufficiently standardized to pass over into the 'ready-made' class.

#### SUMMARY

We shall have accomplished our major purpose in the present chapter if we have made it obvious that the phrases 'labor-saving', 'labor displacement' and 'increasing mechanization' have many shades of meaning which may advantageously be distinguished though none can be arbitrarily selected as solely appropriate for use; furthermore, that the agencies by which labor saving, labor displacement or increased mechanization may be accomplished are of almost unlimited variety. This multiplicity of agencies and processes in labor saving explains the diversity of approach in the subsequent chapters and the difficulties in reducing the problem to simple statements and solutions.

CHAPTER III  
CHANGES IN MECHANIZATION  
IN SELECTED MANUFACTURING  
INDUSTRIES

**EVEN** if full information were available, limitations of space would prevent us from attempting a complete recital of recent changes in technique and equipment in American industry. In the technical books and journals there is a vast volume of literature dealing with such changes, but even it falls short of giving a complete picture. Nevertheless it does appear worth while to present a brief statement of the nature of changes taking place in selected industries, particularly where the changes can be set forth in quantitative terms. Thus we may get a better basis for understanding the generalizations in subsequent chapters concerning the nature, rapidity and effects of changes in mechanization. Accordingly in this chapter we give brief summaries of the labor-saving developments peculiar to the processing operations of selected manufacturing industries. The two following chapters are devoted to similar summaries for non-manufacturing industries and for the handling of materials which is more or less common to all industries.

**SOURCES OF INFORMATION**

These summaries are based chiefly upon three sources of information: (1) the labor-saving changes reported to us in

our survey of several hundred manufacturing and other industrial operations (see Table 1); (2) records of annual sales or installations of labor-saving devices (detailed in Appendix A); (3) government reports and other special industrial studies listed in the Bibliography, Appendix D.

#### LABOR-SAVING CHANGES IN ESTABLISHMENTS SURVEYED

The establishments included in our special survey reported 757 labor-saving changes since 1920. These are based on 710 inspections in 1925, and 320 replies to inquiries by mail, 1925-28. Of the total number reported, 282 are instances of improvements in materials-handling devices and are discussed in Chapter V. The remainder are distributed as follows: 333 changes in processing equipment; 36 in the production of power and heat; 58 in excavation and grading equipment; 13 other mechanical changes; and 35 miscellaneous improvements not primarily changes in machinery or equipment.<sup>1</sup>

#### ANNUAL SALES OF LABOR-SAVING EQUIPMENT

The statistics of annual sales or installations of machines known or presumed to have labor-saving qualities, which are assembled in the tables in Appendix A, serve (1) to show as objectively as possible how rapidly specified types of machines have been introduced; (2) to furnish material useful in the analysis in Chapter VIII of the characteristics of the machine-producing industries.

<sup>1</sup> The 'miscellaneous' group includes 14 instances of labor saving reported as due to greater subdivision of labor and, in some instances, accompanying increases in the number of machines tended; 14 gains through changes in methods of wage payment or methods of training and handling workers; 5 alterations in buildings; and 2 changes in materials or processing methods other than in equipment.

If convenient, the series in Appendix A are given in terms of the number of machines sold. Several series, however, have been reduced to index numbers, usually with 1925 as the base, either because the absolute numbers would be unimportant or because they might reveal confidential facts concerning the business of individual machine-manufacturing establishments. Some series, chiefly those in Table 47, are expressed in dollar values. Most of the series represent shipments, sales or new orders; but several, such as automobile truck registrations, semiautomatic glass bottle machines and automatic telephone switchboards, give the number in use.

These series vary widely in source and scope. Several, such as motor trucks, electric hoists, electric overhead cranes and electric locomotives, are compiled from published statistics and cover all or substantially all sales of the given type of equipment. Other series in these tables have been made available to us by the courtesy of the machine manufacturers. Some of these, such as the data for yarn-working machines listed in Table 38, are presumably complete records for their types. Other series, though not complete, cover a sufficient number of models to be fairly representative of the probable fluctuations and trends in the total sales of the specified machines. Here we may include the statistics for self-feeding wagon loaders and lumber carriers and pilers (Table 46). A number of series, particularly several in Table 38, are based on the sales of too small a proportion of the total industry to be considered fully representative of the type. Rather they are useful as indicative of trends in single lines for a few manufacturers.

In presenting this material we are limited because we cannot fully explain the nature of some of the series without violating the conditions under which we were given confidential data on the machine sales of individual manufac-

turers. For this reason it has been necessary in a few instances to give titles to series that do not make fully obvious their importance as labor-saving machines.

Comments on the nature of the several series, together with sources of information, are given in the footnotes in Appendix A. Further comment appears in the following paragraphs dealing with selected industries.

### SUMMARY OF IMPORTANT CHANGES IN MECHANIZATION

The manufacturing industries to which we gave most attention in the field phase of our survey were steel and iron, ferrous foundries, brick plants, cotton mills, and pulp and paper mills, but for a number of other manufacturing industries there are sufficient data available from other sources to afford the basis for a summary of important changes in mechanization.

#### IRON AND STEEL (BLAST FURNACES AND STEEL WORKS) <sup>2</sup>

The heavy iron and steel industry is the center of a galaxy of industries. Strictly defined it embraces the smelting of iron ores, the refinement of iron and steel in their intermediate forms and the manufacture of crude or unfabricated iron and steel products. The production of crude iron and semifinished steel is a highly mechanized, integrated series of processes with large capital investment per worker. The

<sup>2</sup> This section has been prepared by Meredith B. Givens, who conducted field inspections in the steel industry for the National Bureau during the summer of 1925. He is joint author with Ewan Clague of *Productivity of Labor in Merchant Blast Furnaces*, Bulletin 474, U. S. Bureau of Labor Statistics, Washington, 1928, which presents in part the results of a comprehensive field study of productivity in the smelting and refining branches of the industry. See Table 36.

modern steel plant is composed of blast furnaces, steel works (converters, open hearth or electric furnaces) and rolling mills, usually with an auxiliary by-product coke plant in addition to foundries, machine shops and numerous satellite processes.

All forms of finished iron and steel have once been pig iron, the crude, unrefined product of the blast furnace, a vertical cylindrical crucible in which iron is separated from the gangue of its ores by smelting in direct contact with flux (limestone) and fuel (metallurgical coke). The product of the blast furnace is the raw material for steel-making and for the forges and iron foundries. Crude steel from converter, open hearth or electric furnace must be rolled, hammered or cast into finished shapes, sometimes after further refinement.

In the '80's blast furnace workers comprised about 25 per cent of the total number of wage earners in the industry. In 1920 only 10 per cent of the workers were found in this department, and during the depression of the '30's this proportion dropped to about 5 per cent. This change is explained in part by the relatively more rapid increase of productivity in smelting, by the increased use of scrap in steel-making, and by the diversification of product in the rolling and finishing departments, with a consequent increase in employment in those branches of the industry. Since the '80's American blast furnaces have been the most efficient in the world and have steadily increased in productivity. Average daily output per mineral fuel blast furnace in the United States in 1884 was 54 tons; in 1930 it was 584 tons, more than ten times as much. A corresponding increase in the average output per wage earner has taken place. In 1849 the output of pig iron per worker in the United States was only 24 tons per year, in 1869 it had reached 70 tons. In succeeding decades production per worker in the mineral



fuel furnaces has increased more than tenfold, from 170 tons in 1884 to over 1,700 tons in 1929. The advance during the post-War years was especially marked. Meanwhile the number of necessary positions in blast furnace crews has fluctuated within narrow limits. Approximately the same direct operating crews are required for large furnaces as for small, although the output per worker may differ manyfold. Approximate computations by the writer indicate that the average mineral fuel stack required 116 men in 1884, 185 men in 1908 and about 120 men in 1929. Direct labor displacement over this period of several decades has kept pace with the steady increase in tonnage to be handled.

The principal explanation of this remarkable advance is found in increasingly hard driving of the furnaces and the steady increase in their size and efficiency. The essential principles of operation have remained the same since the early furnaces of the Middle Ages, but in scale and method of operation, design, auxiliary equipment, and effective utilization of materials the changes of the past four decades are among the most spectacular in the annals of technology. Blast furnace design has steadily evolved in the direction of a straight-lined stack with wider and wider sections; larger stacks have required increased blast at higher temperatures; the unit consumption of fuel and flux has been remarkably reduced, and the percentage of iron loss has dropped each year. Ore unloaders and car dumpers, the ore bridge and electrically-controlled stocking equipment have so reduced minimum labor requirements that the stocking side of up-to-date furnace plants is nearly manless. On the casting side the increased use of direct metal and the employment of the pig-casting machine have eliminated large crews and the heavy manual tasks. Introduced in 1895, casting machines numbered 80 in 1908, and 180 in 1927. Concentration of production in fewer and larger plants has signaled the

virtual elimination of the isolated furnace and its replacement by the completely modernized multiple furnace plant operated in conjunction with the so-called 'continuous process' of steel-making, with the consequent labor economies.

In integrated operations the open hearth furnace or Bessemer converter receives molten pig iron directly from the blast furnaces, and the time and labor formerly required for casting and subsequent remelting are thus eliminated. With large producers this procedure was customary in the '90's; by 1912 nearly half of the annual output of pig iron was delivered in molten condition for further refining. Of the 65 per cent of all pig iron produced for the steel furnaces in 1931 nearly 97 per cent was used within the same plant, and of this steel-making iron 92 per cent was used in molten condition.

The net change in the productivity of steel works and rolling mills is likewise measured by the annual output per worker. In 1900 85 tons of finished steel were produced per wage earner employed; this was about three times the productivity of 1880. By 1910 the yearly output per worker had increased to 110 tons, to 114 tons in 1920, and to 138 tons per worker in 1929. The modal furnace for the industry has a capacity ranging from 75 to 100 tons per heat, but large producers are now building open hearths with tonnage capacities ranging from 150 to 200 tons per heat. As in the case of blast furnace operations, fewer wage earners per unit of output are required to operate these larger units. Hand charging of the open hearth furnace has long been a thing of the past and mechanical equipment for materials handling is now practically uniform in most plants.

In the smelting and refining processes the steady reduction of the number of workers per ton of product is due to continual improvement in control of combustion and temperature, the construction of ever larger furnaces, the universal

adoption of standard labor-saving methods which in the main had been devised before 1911, and constant eliminations and combinations of occupations, especially under the stimulus of the three-shift system generally inaugurated in 1923.

One of the important long-time technical changes in the industry is the increased use of steel and iron scrap in steel-making, as a result of which the annual output of steel now regularly exceeds the output of pig iron. In the United States in 1896 approximately 750,000 tons of scrap were remelted in making steel; in 1900 about 2,000,000 tons were used in this manner, and in 1929 the consumption of scrap reached the enormous total of 25,000,000 tons, about 45 per cent of the total production of steel. If there were a scrap famine today, twice the existing number of blast furnaces would be required to support the steel industry at maximum production. Conversely, the increasing use of scrap has reduced the number of workers necessary in the production of pig iron; in 1929, 15,000 additional persons would have been required to produce the pig iron equivalent of the scrap used in that year. Meanwhile the scrap industry is expanding but no reliable information exists to reveal the extent of its increased employment.

Straight-line production and automatic control have reached their highest development in the rolling mills. Here the most important aspect of recent change has been the electrification of drives and controls. Steam-driven mills were clumsy, mechanically inefficient, subject to frequent breakdown, and required relatively large numbers of operators and attendants. The labor-saving significance of electrification cannot be estimated with accuracy but the effect has been enormous. The introduction of highly-developed automatic specialty mills has been made possible by standardization of shapes and chemical specifications. In the continuous mills the hot ingot is taken from the soaking pits (the metal

never having cooled since leaving the blast furnace) and is transformed into finished shapes by passage through a series of automatic rolls arranged in tandem. In 1905 there were only five electric main roll drives in the industry; in 1920 there were 674, and in 1931, 1,806, with a rated capacity of 3,000,000 horsepower out of a total horsepower of little more than twice this figure for all branches of the industry.

Occupational changes associated with technological improvements in this industry are characterized by a leveling of skills as measured by the changing spread in wage rates. Analysis of reports compiled by the United States Bureau of Labor Statistics reveals a relatively wide range in the wage structure of 25 or 30 years ago. In 1910 the average rate of earnings for selected representative occupations in major departments of the heavy iron and steel industry was 120 per cent greater than the earnings rate of common laborers in the same departments of that industry. By 1931 the average earnings of these same key occupations were only 77 per cent greater than the earnings of common labor. This narrowing of wage differentials reveals a leveling up in line with a trend which was accentuated by the premium on unskilled labor during the World War. Further analysis of the data for these same occupations in nine principal departments indicates that the proportion of common laborers was cut approximately in half from 1910 to 1931. The evidence is unmistakable that recent progress has eliminated unskilled labor to a much greater extent than other grades. In addition, jobs have become more specialized and more highly differentiated during this leveling process, and at the same time the distinctions in earnings among the more specialized grades of work have been generally softened.

The most significant single change in steel manufacturing in recent years was the introduction in 1927 of a remarkable process of continuous strip-sheet rolling. Since the early days

in Wales it had been inconceivable that steel sheets could be rolled directly from the ingot. In the United States the bulk of the product has been produced on simple hand rolls, and in 1929 there were roughly 1,400 mills of the traditional type in the industry, with an aggregate annual capacity of 7,500,000 gross tons of sheets. A single continuous mill of the new type can now produce more than 400,000 gross tons of sheets of uniform gauge, equivalent to the normal output of 40 or 50 of the old-style mills. For the sheet steel industry as a whole, the complete adoption of strip-sheet rolling will mean the displacement of ten thousand men and the concentration of sheet and tin plate production in the hands of a few dominant concerns.

The elimination of the pig iron stage in steel manufacture has often been predicted but appears unlikely on a large scale. Sponge iron can now be made directly from the ore without the introduction of impurities from the coke and flux of the blast furnace, but this process of direct conversion is practicable only on a small scale at present, and the product is too expensive for large tonnage production. The new process is effective in smelting ores not readily usable in the blast furnace and can provide iron for small concerns in outlying districts where a large blast furnace would be uneconomical. In the wrought iron industry the recently-perfected Ashton mechanical puddling process has successfully produced in a fraction of an hour an amount of wrought iron which from the time of Henry Cort had required a day's labor. Wrought iron is not likely, however, to be a serious competitor of tonnage steel despite its advantages in the manufacture of pipe, railroad accessories and certain specialties.

Increased productivity in the basic iron and steel-making processes and in the production of coke has been paralleled

by similar progress in the mining of iron ores.<sup>3</sup> Average daily output per wage earner in ore mining has increased steadily, rising from 3½ tons in 1911 to approximately 8½ tons in 1929. The percentage of production from open pit mines has not changed materially in recent years; hence the increased productivity must be explained largely in terms of improved equipment and operation. In the underground mines mechanical slusher hoists have been extensively introduced, increasing shift production per man from 8 or 9 tons by the hand process to 15 or 18 tons with the new equipment. A leading maker reports a total of 15 such installations in 1921, and 425 in 1928. In the open pits the flexibility of equipment and operation has been consistently improved.

The growing demand for quality steel is an influence partially counteracting the effect of extremely large furnaces upon labor requirements. From 1925 to 1930 the alloy steels composed from 5 to 7 per cent of total American production. Alloy steels are refined in the open hearth furnace or in the smaller electric furnace which has largely replaced the slower and more costly crucible process for making finer steels. Alloy production places a premium on the employment of responsible and highly-skilled workers to supervise the more precise control of temperatures and chemical reactions.

If the 1929 tonnage of iron and steel were produced with the techniques and equipment of 1890, approximately a million and a quarter men would have been required in blast furnaces, steel works and rolling mills instead of the actual employment of four hundred thousand. At the efficiency level of 1900 eight hundred thousand men would have been needed for the 1929 production. Of course it would be absurd to say that workers have been displaced in such numbers by increased productivity since 1890, although this ar-

<sup>3</sup> See also section on Metal Mining in Ch. IV.

gument is frequently advanced to prove the severity of technological unemployment. Except for the depression years actual employment has increased consistently until the highest point in the history of the industry was reached in 1929. Needless to say, production could not have advanced eight-fold during this period if technique had not changed. Expanding employment was made possible by the mounting production of iron and steel products and the continued extension of the market for these products. If the iron and steel industries are to sustain their employment in the future, however, it must be by means of diversification of product and new emphasis upon quality rather than by sheer growth of tonnage production.

From the point of view of this study the progress of the iron and steel industry since 1880 may be divided into two distinct but overlapping phases: (1) the drive to increase tonnage at any cost, to meet the demands of the growing market for iron and steel products; (2) the effort to reduce costs per ton which has followed the attainment of large tonnages and the tapering-off of the rate of growth of the industry. During the first stage changing productivity has created no problem of technological displacement. In recent years the maturing industry has confronted the problem of stabilization rather than expansion, and in this stage it is possible that further progress may mean net displacement of labor for absorption elsewhere.

#### FERROUS FOUNDRIES

A great variety of castings are made in ferrous foundries, but the processes are sufficiently similar to justify treating all such foundries as comprising one industry. Flasks and patterns must be made, sand conditioned for use in the molds, cores baked, and molds carefully built up with the aid of

these flasks, patterns, cores and sand. Then the metal must be melted and poured in the molds, and the castings shaken out and cleaned.

Our foundry inspections covered 87 plants, including 4 automobile foundries. Of these, 34 reported one or more labor-saving changes subsequent to 1920,<sup>4</sup> or a total of 161. The 4 automobile foundries employed only 38 per cent of the total workers but reported nearly half of the labor-saving changes. The processing and handling improvements were about equal in number, the labor-saving changes that affect handling equipment occurring more frequently in the automobile foundries, and the processing changes more frequently in the other foundries.

Among the labor-saving improvements in processing equipment the more noteworthy were sandslingers and other machine molding equipment, machines for sand cutting and mixing; various improvements affecting the shakeout process; and a variety of changes in the cleaning, inspecting and repairing departments, such as tumbling mills and straightening presses. A summary of these reported labor-saving changes for which the effect on number of men required can be computed is given in Table 3.

The molding operation is the most important in the manufacture of castings, and employs about 25 per cent of all foundry employees. The entire process of preparing the mold may be, and often still is, done by hand. However, in recent decades, especially where many molds of the same type are to be made, more molding is being done by ma-

<sup>4</sup> Of the plants not reporting labor-saving changes after 1920, 7 had made labor-saving changes but they were all prior to 1921, 4 went into operation after 1920 and hence extensive changes would scarcely be expected, and 4 others refused information concerning their labor-saving changes. Some of the remaining 38 plants doubtless made improvements but failed to report them. A substantial portion of the total number actually reported were by one large automobile foundry.



TABLE 3

## INSTALLATIONS OF LABOR-SAVING EQUIPMENT IN FOUNDRIES

The following list indicates some of the changes made in recent years which are considered by the users as labor saving. It includes only those changes reported by the foundries covered in our survey for which an estimate of the number of workers saved was made, and omits a considerable number of changes for which no definite estimate was given.

PROCESS IN WHICH USED AND TYPE OF EQUIPMENT	NUMBER OF UNITS INSTALLED	YEAR IN WHICH THE CHANGE WAS MADE	WORKERS SAVED PER INSTALLATION AS STATED BY USERS
<b>MATERIALS HANDLING EQUIPMENT</b>			
Cupola charger	1	1925	6
Sand-handling conveyors	11	Since 1920	11 <sup>1</sup>
Core-handling conveyors	2	Since 1920	9
Flask-handling conveyors	3	Since 1920	5
Scrap-handling conveyors	3	Since 1920	9
Slag elevator	6	Since 1920	8 <sup>1</sup>
Fordson with special body and shovel, for handling raw materials	2	1924	2
Monorail in cleaning room	1	Since 1920	2
Hot-metal carriers	2	1925	2.5
Storage-battery trucks	2	1921, 1923	3
Other conveying units	27	Since 1920	12 <sup>1</sup>
<b>PROCESSING EQUIPMENT</b>			
<i>Melting</i>			
Coal-pulverizing equipment	1	1924	30
Sand-cutting and mixing equipment	5	1923 (2); 1924 (3)	3 to 4
Core-blowing machines	3	1924; 1925	2
<i>Molding machines</i>			
Roll-over	7	1923 (3); 1924 (4)	4
Sandslinger	7	1923 (4); 1925 (3)	5
Jar-squeezer	1	1922	1
<i>Shakeout</i>			
Shaker riddle	1	Since 1920	10
Gravity knockout system	1	Since 1920	124 <sup>1</sup>

TABLE 3 (cont.)

INSTALLATIONS OF LABOR-SAVING EQUIPMENT IN FOUNDRIES

PROCESS IN WHICH USED AND TYPE OF EQUIPMENT	NUMBER OF UNITS INSTALLED	YEAR IN WHICH THE CHANGE WAS MADE	WORKERS SAVED PER INSTALLATION AS STATED BY USERS
<b>PROCESSING EQUIPMENT (cont.)</b>			
<i>Shakeout (cont.)</i>			
Knockout platform system	1	Since 1920	45
Hydraulic core-removing and sand-reclaiming system	1	1925	17
<i>Cleaning</i>			
Sand blast	4	1924	3
Large tumbling barrels	3	Since 1920	9 <sup>1</sup>
Air hammer	2	1925	1
Rim grinder	1	1924	1
Annealing: bump machines	2	1924	16.

<sup>1</sup> These data include the experience of one very large foundry, and hence can scarcely be considered typical.

chines.<sup>5</sup> The operations in making the molds that lend themselves to mechanical methods are packing the sand, rolling over the flask to make it possible to draw the pattern, and the actual drawing of the pattern from the mold. Sand packing requires much time. Even in so-called hand packing a pneumatic rammer is in general use for medium and heavy castings. Sand-packing machines are designated as squeezer, jolt-ramming or sandslinging types, according to the method of packing. The 'sandslinger' or sand-throwing machine was a relatively recent development at the time of our inspec-

<sup>5</sup> Though each of the two molding machine series in Table 38 is limited to the sales of a single manufacturer for selected types of machine, they are characteristic of the earlier development of hand equipment. One series is for a hand-power molding machine with the peak in sales as early as 1916. The other series covers two or three models of power molding machines with the peak of sales in the early post-War year 1919. After the post-War boom neither series reaches its War-time level again.

tions. It is an electrically operated machine, which by centrifugal force hurls the sand into the mold with sufficient force to pack it properly.<sup>6</sup>

The difficulty of generalizing concerning the nature and effect of the important group of changes in molding equipment is evident when we note the variety of types included in the 31 instances reported. Many of these installations included but one machine; others as many as two dozen. The total number is not exactly known but it exceeded one hundred, including a wide variety of the combinations of the squeezer, jolt, roll-over and pattern-draw features, in addition to the sand-throwing type, and ranging in size and installation cost from machines of the small squeezer type for small molds, costing only a few hundred dollars, to giant roll-over machines capable of handling castings of 30 tons or more and costing some \$20,000. A continuous conveyor system for handling molds and sand was even more expensive. However, two generalizations may be made concerning the effect of the changes in molding equipment. They made substantial reductions in the quantity of labor required, as

<sup>6</sup> The 9 reported installations of sandslingers included 19 machines in 7 separate plants and cost from \$8,000 to over \$26,000 each. The majority were of the portable or tractor type. All were installed in 1923 or later years, replacing hand or air ramming of molds. The plants using the sandslingers were all large manufacturing or specialty plants, employing 300 or more men and pouring 50 or more tons of castings per day, some of which were very large castings for turbines and other power plant equipment. Judging from this small group of installations, this innovation in mold packing saves floor space—one plant reported a 50 per cent saving—speeds up production and cuts production costs. The saving in labor ranged from 2 to 11 men, averaging 5 per machine. In some instances, though not in all, semiskilled labor replaced skilled on the mold-packing operation. One user pointed out that the later models of this machine were 60 per cent more efficient than the early installations, and that further gains in efficiency with further experience were probable.

shown in Table 3, and they lowered the grade of skill required in the immediate molding process.

The most numerous changes in handling equipment were additions of conveyors or alterations in existing conveying systems in the automobile foundries; other handling changes included the addition of overhead traveling cranes, monorail systems, industrial trucks and tractors, and furnace-charging equipment.

#### THE MANUFACTURE OF BRICK

Important centers for the manufacture of brick are in the Hudson River section and the Chicago area, but the geographical distribution of the industry is wide, and production is largely for local markets; moreover, despite the simplicity and relative standardization of the manufacturing processes there are wide differences among plants in degree of mechanization and efficiency. The improvements mentioned below are by no means in universal use.<sup>7</sup>

The brick industry is an old industry and, as noted, its processes are relatively simple; hence, as might be expected, no sweeping changes have been made recently in method. However, there have been substantial increases in mechanization, partly from the abandonment of older, less mechanized yards and the opening of new plants on a more highly mechanized basis; and partly by improvements in existing plants.

We may conveniently distinguish seven stages or departments in the manufacture of brick: (1) mining or digging the clay; (2) transporting the clay from the pit to the preparation plant; (3) preparing the clay for the molding operation; (4) molding; (5) drying; (6) burning; (7) interprocess

<sup>7</sup> See Ch. VII for degree of mechanization by processes.

handling, including loading the brick from the kilns to the common carrier.<sup>8</sup>

In the course of the War and the following decade, power shovels have largely replaced hand methods in digging the clay; bigger and more powerful machines have been developed for preparing it for molding; and the capacity of the molding machines has been increased, partly by enlarging the machine and partly by running it at a more rapid rate. But most labor-saving changes have been in the handling operations. In the haul from pit to preparation machine the industrial locomotive has to a large extent replaced the horse car; and in the subsequent handling there are numerous instances of mechanization by the addition of conveyors, industrial trucks, overhead cranes and other handling devices. The acme of mechanization in interprocess handling is reached in plants equipped with a mechanical overhead handling device used to set the bricks in the kiln and then, after burning, to remove them to storage or shipment.<sup>9</sup>

The preceding generalizations rest in large part upon the record of changes in the plants surveyed, some further details of which follow.

<sup>8</sup> The transportation of materials from the pit to the clay preparation plant is identified as a process separate from other handling because it ordinarily involves a much longer haul and different equipment than the other handling operations.

<sup>9</sup> A special kind of stacking of the bricks on the dryer cars makes it possible for this device to pick up a unit of from 800 to 1,000 bricks as they are brought from the dryers and place it in the kiln. The bricks on the bottom row of the unit are stacked to leave a small space between each brick to provide entering space for the fingers of the setting machine. As the load starts to rise, the weight causes a series of grip plates on the fingers of the carriage to close automatically on the bottom bricks of the unit (Bul. 356, Ref. 34).

EQUIPMENT CHANGES IN PLANTS INSPECTED <sup>10</sup>

For a group of 35 plants, of which 28 made common brick and 7 special types of brick, our field agents took a census of the major equipment, ascertaining the machines in use, the date of installation and the method or equipment displaced. An analysis of these data reveals the nature of equipment changes, not only for the early years of the 'twenties but also for the preceding decade.

In all, we obtained comparable data for 222 departments (in 35 plants). Of this number 20 departments still had only hand equipment. In 87 mechanical equipment installed at the time the plant was started was still in use. The mechanical equipment in the remaining 115 departments represented displacements of older mechanical equipment in 64 instances, of manual methods in 39 and of horse-motivated equipment in 12.<sup>11</sup>

<sup>10</sup> The field phase of the mechanization survey of the clay products industry in 1924 and 1925 covered 65 plants, chiefly in New Jersey, New York and Connecticut. This group included 48 that produced only common brick. Of the others, 7 produced building or floor tile, 2 fire brick, 4 face brick, 2 sand-lime brick (not strictly a clay product) and 2 were pottery plants. In addition we obtained somewhat more limited information by mail from 16 plants widely distributed through the United States; and in the output-per-hour survey in 1927-29, we obtained output, employment and equipment change data from 27 plants, chiefly in the Chicago district (Ref. 20-c).

<sup>11</sup> The figure of replacements in 115 departments refers to changes in equipment or methods regardless of whether they saved labor or not, and the information at hand does not allow us to state with assurance that all of them did save labor; for in many instances the equipment in place at the time of our inquiry had been installed many years before 1920, and, although our informants volunteered information concerning some labor savings made in earlier years, we made no effort to get a complete record of labor-saving changes made prior to 1921. Of the total of 45 changes in this group of plants reported as labor saving, 19 occurred in 1915-20, and in order to have a broader basis we have included these earlier changes,

A brief summary for each of the major processes brings out more clearly the specific nature of equipment changes in the plants surveyed. In the stripping and loading operations all the mechanical equipment in use had been installed since 1915, and consisted chiefly of power shovels.<sup>12</sup> In 3 plants electric shovels displaced the steam-driven type. In haulage from the pit a principal change was the substitution of industrial railroads for horse cars or horse carts, chiefly during 1916-20.<sup>13</sup> In the preparation stage most of the 20 changes reported were merely the substitution of new models for old, with the exception of the displacement in 4 plants of soaking pits by pug mills. In about half of the plants there was no reported change in the brick-molding equipment. The principal recent change in the brick machines of the soft-mud type was the substitution since 1920 of automatic for hand-dump machines.<sup>14</sup>

In two of the tile plants, new tile-molding machines had brought reductions in the labor force; and our inspectors were informed that the tile industry was rapidly turning to the power press, at that time rather a recent development, to take the place of the slower hand presses. In the stiff-mud type, capacity has been enlarged without proportionate in-

together with those made since 1920, in appraising the labor-saving effects of equipment changes in brick yards.

<sup>12</sup> Hand shovels were displaced by power shovels, excavators or planers in 5 plants. Wherever the results are known the changes reduced the required labor force for digging and loading by 5 or 6 men. The displacement of a steam by an electric shovel saved one man.

<sup>13</sup> The substitution of a gasoline locomotive for teamsters saved 6 men in one instance; in another, in substitution for a steam locomotive, it saved 2 men.

<sup>14</sup> Labor saving by this change was reported in 6 instances, usually with reductions in crew of 2 to 5 men. In addition, production was ordinarily increased about 25 per cent. In the soft-mud plants, of 27 hand-dump machines, only 2 had been installed after 1920; but of 13 of the automatic dump type at least 5 were installed after that year.

crease in crew by improvement in the materials and design of the machines to allow higher operating speeds. Data concerning drying equipment were obtained for 29 plants. Natural heat (that is, either sun-dry or open-air racks) was in use in 12, and some kind of artificial heat in 17. Most of the natural heating systems had been installed prior to the World War, whereas 9 of the artificial heating systems were installed in the years 1917-20, and all but two after 1916, usually to take the place of former open-air racks. There had been but few changes in burning methods since the yards were opened, except in the substitution of oil for wood as kiln fuel.<sup>15</sup>

As noted, many of the changes in equipment were in the handling operations. Yet in 13 of the plants in this group of 35, no handling equipment other than wheelbarrows was in use, and all of the mechanical handling equipment in the other plants had been introduced since 1915, most of it in the period 1916-20. In 18 instances conveyors of various types had been substituted for wheelbarrows or hand trucks.<sup>16</sup>

The other reported changes in handling included the

<sup>15</sup> In one plant the introduction of a Dressler continuous kiln was stated to have saved at least 9 men who formerly were engaged in wheeling and setting, and at the same time increased production from 48,000 to 70,000 brick per day. The labor saved by the change in fuel was little.

<sup>16</sup> Including an overhead crane handling system in one plant consisting of a special setting machine operated on an overhead electric crane, and including an outrigger to load barges directly from the kiln. But the most numerous labor-saving changes in handling were the replacement of wheelbarrows by cable conveyors for handling brick from the brick machine to and through the dryer. An epidemic of cable conveyor installation occurred in 1918-20 among the plants surveyed. These conveyors ranged from 180 to 340 feet in length. In some instances the effect of these installations could not be isolated from the effects of other changes; but for 7 of them, averaging 308 feet in length, the requisite labor force was reduced by 44 men, at a total installation cost of \$20,500, or less than \$500 for each man saved. This relative inexpensiveness may readily account for the frequency with which cable conveyors were adopted.



substitution of gravity-roller conveyors for hand methods in the several movements in a tile plant from dryer to shipping room; a power-driven turntable for one manually operated; of electric power for mules in hauling transfer cars from dryer to kiln; and of industrial tractors, in 3 plants, for manual labor in pulling hand trucks from kiln or storage to barge or car for shipment.<sup>17</sup>

Changes were most frequent in the War and early post-War years. Of the equipment units in use in 1925, those in 92 departments had been initially installed or substituted for other equipment in the five years 1916-20, as compared with similar changes in only 44 departments in the period 1911-15, and in only 54 in the period 1921-25. All of the 50 recorded substitutions of mechanical for non-mechanical methods for which the date is known were made in the decade beginning in 1916, 34 occurring from 1916 to 1920, and 16 after 1920. Most of these changes were in the digging, hauling and handling processes.

#### DECLINE IN NUMBER OF ESTABLISHMENTS

As a rule, productivity in the typical brick yard varies directly with the size of the yard, and a part of the increase in productivity in the decade 1919-29 arose from the elimination of small and inefficient plants. For example, the number of establishments in clay products other than pottery declined from 2,414 in 1919 to 1,749 in 1929, and the average number of wage earners per establishment increased from 24 to 53. Such increases in average mechanization as are due solely to this process of 'natural selection' are in addition to increases of the type described in the preceding paragraphs—that is, improvements within the plants inspected; for con-

<sup>17</sup> For discussion of volume of handling in brick plants, see Ch. V.

ceivably the average of mechanization may be raised through the elimination of the less mechanized plants rather than through improvements in the plants that continue to operate.

#### POTTERY <sup>18</sup>

The pottery industry includes the manufacture of pottery and porcelain products ranging in quality from the crudest kitchen crockery to the finest table china, but the production of vitreous china sanitary ware, such as bathtubs and other plumbing fixtures, so-called whiteware, hotel china and porcelain electrical supplies constitutes something more than two-thirds of the total value of products in the industry.

The manufacture of pottery is still largely a hand industry, as is evidenced by the high proportion of wage costs to total value added in manufacture (52 per cent) and the relatively small amount of power used.<sup>19</sup> The operations in the mixing department are largely mechanical, and in the subsequent operations the hand processes are frequently carried on with the assistance of mechanical devices, but the worker is rarely merely a machine tender and most of the occupations require some degree of skill.

#### CHANGES IN EQUIPMENT AND PROCESSES

Aside from those incessant minor changes which take place

<sup>18</sup> Our factory inspections included only two establishments in the pottery industry, one engaged in the manufacture of sanitary ware, and the other, electrical porcelain ware. The information obtained in those inspections has been supplemented by correspondence with other plants and by examination of published literature on the pottery industry (B. L. S., Bul. 412, Ref. 35).

<sup>19</sup> Of the 312 workers in the two plants inspected, 70 per cent were engaged in hand operations, 24 per cent in machine operations or work auxiliary to the machines, and the balance as teamsters or supervisory workers.

in almost any establishment or industry, the more significant steps in mechanization in the pottery industry are:

1. The introduction of casting in place of hand pressing, notably in sanitary ware
2. The introduction of the tunnel kiln
3. Improvements in the methods of transportation
4. The substitution of artificial drying for air drying.

The casting method of making pottery is not new, having been employed for years for such articles as pitchers and vases, but its use in the production of sanitary ware was extremely limited until about 1922. At that time a prolonged strike of skilled potters led some manufacturers to change to casting. The casting method requires considerable expense in the way of machinery, molds, piping systems, etc., and some degree of skill on the part of the operator, but is not so dependent upon skilled potters as is the hand pressing method. In the plants from which our information was derived, only pieces ordered in such small quantities as not to justify the expense of making up special casting molds were hand pressed or molded by skilled potters. Our field agent found that in one instance 35 workers using the casting process were able to turn out the amount formerly produced by 51 using the hand pressing method. We were informed that this change was taking place generally throughout the sanitary ware industry and was weakening the position of the potters' union.

The extensive use of the continuous kiln in the pottery industry is a relatively new development. A report of a survey made in 1925 by the Bureau of Labor Statistics of the tableware branch of the pottery industry states that, "there are only two or three tunnel kilns in operation in this country" (Ref. 35). In response to inquiries by mail concerning their most important labor-saving change since 1920, we were advised by two manufacturers of tableware that the

substitution in 1927 of continuous tunnel kilns for upright periodic kilns resulted in a direct and indirect saving of semiskilled and skilled labor, one plant reporting that with no change in the crew the output was increased, and the other that 6 men are now able to turn out the same amount of work as 11 men prior to the change. We understand that the continuous tunnel kiln is especially suited for steady quantity production.

Like many other industries, the pottery industry has experienced various improvements in the methods of handling materials. In one plant inspected the most notable change in recent years affecting the productivity of labor was the installation of a power-driven conveying system some 900 feet long which runs through the room where the sagger boxes are loaded and unloaded with the small pieces of ware and past the door of each kiln. To a cable running continuously around the circuit are attached at intervals small flat cars about two feet wide and three feet long. Sagger boxes filled with the pieces to be fired are placed on the cars as they pass and are removed as they pass the door of the kiln being loaded. On 'drawing' or unloading the kiln the procedure is reversed. We were informed that this installation, made in 1924, enabled 4 men and 10 girls to do the work formerly requiring 18 men with a system of hand carrying. Also, we are advised by two manufacturers of tableware that their principal labor-saving changes since 1920 have been in handling methods, one substituting an overhead conveyor for hand trucks and wheelbarrows, in 1927, and the other a belt system for handling the sagers during the process of filling them with dinnerware for burning in the kilns.<sup>20</sup>

We also understand that the use of artificial drying instead

<sup>20</sup> This change, made in 1922 as a substitute for hand labor, enabled 35 men to do work that would formerly have required some 50 men, the labor displaced being skilled and semiskilled.

of air drying has cut down the cost of operation with a saving of space and time.

#### PORTLAND CEMENT

As early as 1919 Portland cement was a highly mechanized industry, with wage expense constituting only 35 per cent of value added. Productivity has been increasing in recent years, output having risen from 81 million barrels in 1919 to 170 million in 1929 though the average number of wage earners rose only from 25,524 to 33,368.

The man power essential in the industry had been greatly lessened by the introduction and general adoption of the rotary kiln and improved crushing and grinding machinery even before the relative shortage of labor created by war conditions. The major changes in equipment in subsequent years have been largely in the way of increasing the size and capacity of equipment units, such as longer kilns, more powerful rock crushers. (lessening the quarry work required in crushing the limestone rock to small pieces) and larger power shovels in the quarry. Other changes are improvements in conveying systems, increased electrification of quarry and mill equipment, and the introduction of waste-heat boilers, beginning about 1915, which eliminates some powerhouse labor.<sup>21</sup>

#### COTTON YARN AND CLOTH<sup>22</sup>

A relatively high degree of mechanization had been reached in the manufacture of cotton cloth even before the War, and subsequent changes have been relatively few. Of

<sup>21</sup> Based upon data collected from numerous cement plants and on the statistics of increasing length and capacity of kilns given in Table 23.

<sup>22</sup> Our inspections covered 53 cotton mills, 48 of which were both spinning

the 53 mills inspected, over half reported that no labor-saving changes had been made since 1920. Also, many of the savings reported were minor. Doubtless there were some unreported changes; but for many of these mills we have collateral evidence, in the form of the installation dates of the principal items of equipment, that corroborate the conclusion that in many plants there had been only minor changes in recent years.

Twenty-one mills reported labor-saving changes since 1920. In the weaving process, which employs about a third of cotton mill labor, the changes reported included, in six mills, the installation of automatic looms or the addition of improved automatic features to looms already in place, and in three mills, reductions in the weaving force by reorganization of work. Similar labor-saving reorganizations of work in other departments than weaving were reported in several mills. Warp-tying and drawing-in machines were added in five mills. Other changes mentioned were the addition of Morton automatic distributors for feeding cotton to the picking machines and a reduction in the number of picking processes; newer and faster combers; the American system of carding in place of the English; power brushes on trimming boards; better materials; and more attention to overhauling and maintenance.

For a few important developments in labor-saving equipment and practices, we need to examine briefly the earlier history in order to understand the situation and developments in the post-War period. Of special interest are the

and weaving mills, and 5 yarn mills only. This sample covered about 3.9 per cent of the total number of mills in the United States in 1925, 8.9 per cent of the wage earners employed, and 11.0 per cent of all cotton mill spindles. Sixteen mills were in North Carolina, South Carolina and Georgia, and 37 in the New England district, including 15 in the Fall River group, which was, at that time, a relatively declining section of the industry.

automatic loom and the warp tying-in and drawing-in machines. Somewhat more recent tendencies deserving special attention are the reorganization of work and the automatic spooler and high speed warper.

#### THE AUTOMATIC LOOM

For several decades practically all commercial looms in the United States have been power looms, but not all power looms are automatic. An automatic loom has an automatic stop, which operates when a thread breaks, and also has automatic devices, either of the bobbin-changing or shuttle-changing type, to replenish the filler thread as bobbins are exhausted and thus minimize stoppage time on the machines.

A few automatic bobbin-changing looms were introduced in 1894 after about ten years of experimentation, and production on a commercial scale began in the following year. By 1919 slightly over one-half of all cotton looms, aside from webbing and ribbon looms, were automatic. In our 1925 sample practically all of the plain looms in the southern mills and 59 per cent of those in the New England mills were automatic. Recently-constructed mills on plain weaves had been equipped at the start with automatics, and most of the old mills whose owners were convinced of the value of automatics had installed them prior to the War. Nevertheless, even after 1920 the conversion to automatics continued at a moderate pace, as shown by the following summaries:

Mill A in 1923 replaced its old one-shuttle looms by automatics at a cost of \$150,000, thereby reducing its weaving force about two-thirds.

Mill B in 1922 substituted 528 4-color box automatics for non-automatics and added 112 plain automatics.

Mill C in 1922 added automatic box looms requiring 1 weaver to 12 machines as against 1 to 8 with non-automatics.

Mill D junked 2,450 26" non-automatics, requiring approximately 260 weavers, substituting 1,738 40" looms, requiring 88 weavers, for plain weaves.

Mill E in 1924 substituted 180 automatics for non-automatics, reducing the weavers from 15 to 10, adding one loom fixer and increasing output from 360 yards per week to 380.

Mill F added about 308 automatics and converted 224 non-automatic looms to automatics.

The statement commonly heard in the industry that a weaver can tend twice as many automatic looms as non-automatic is roughly borne out by data on the number of looms per weaver obtained in our inspections, but the labor saved is partly offset by increases in the number of other workers in the weave room, and is sometimes partly achieved by reorganization of work in the weave room.

#### REORGANIZATION OF WORK

By the end of the War too large a proportion of looms were already automatic to afford great scope for savings by changes of the type just listed. However, several mills reported that they had saved labor by greater specialization of occupations in the weave room. By the assignment of various incidental duties to less skilled workers, the weavers were freed to devote their entire attention to watching the looms and mending breaks, and thus were able to tend more looms. Changes in the duties of the weaver and the number of looms tended were ordinarily associated with concurrent improvements in the quality of materials used and better maintenance of machines, so that it is difficult to determine the exact amount of labor saved by such 'doubling-up', but the following summaries of savings reported in the mills inspected are of interest as indicative of tendencies.<sup>28</sup>

1. On one-color Draper automatics in Mill G, the number of looms per

<sup>28</sup> For a brief description of the introduction of the 'multiple loom and frame' system in a New England mill and its marked effect on the size of the labor force, see *Monthly Labor Review*, October 1926, pp. 701-12.



weaver was changed from 10-12 to 24-36, but much of the routine manual work, such as battery filling and cleaning, oiling and sweeping, was assigned to other workers, leaving to the weaver only the task of watching the machines and removing the cloth on lower numbers of thread.

2. By the use of a better grade of cotton the number of non-automatic box type looms per weaver in Mill H was increased from 6 to 8; the weaver's duties remained substantially the same. This change was in progress in 1925.

3. Mill J, by greater specialization of the duties of the weaver, combined with the introduction of better materials and better maintenance of machinery, reduced the number of weavers about one-third.

4. A similar reorganization of work was in progress in another mill, K, at the time of inspection.

As compared with the installation of automatics, this tendency towards high specialization in weavers' work is of recent development and of much less extensive adoption. It appears to have been stimulated by the necessity for cost reduction in the textile slump of the post-War period.

Specialization such as we have just mentioned for the weave room has also been applied to other processes in the cotton mill, notably in the spinning division. In two of the mills inspected, such reorganization applied to other processes as well as weaving resulted in savings as high as 24 and 28 per cent, respectively, of the total labor force.

#### TYING-IN AND DRAWING-IN MACHINES

Power equipment had been developed for the major processes of spinning and weaving for decades before inventive ingenuity solved the problem of mechanically tying a new set of warp threads to the old set in the loom. The first Barber-Colman warp-tying machine was installed on an experimental basis in 1904. The tying-in machine can be used to advantage when the pattern does not have to be altered and, provided there is no change in the number of threads, even pattern alterations are possible. The modern models tie about 250 threads a minute in non-stop operation. The

economies of this machine gained rapid recognition, and 1907 sales reached a peak of 72 machines.<sup>24</sup> Then sales fell off, never rising above 50 until War demands induced a second boom in 1916-19. This machine, it is claimed, will do the work of about 15 hand operators. Three users estimated the number of hand workers displaced by each machine to be 11, 14 and 16 respectively. It can be run by one tender; frequently, though, there is a helper for every one or two machines.

Drawing-in machines draw threads into the apparatus by which the warp threads are suspended, instead of merely tying them to threads already in the loom, and hence can be used even when pattern changes are made. The first models, invented by Mr. M. F. Field, were in operation in 1899 but adaptations were necessary and introduction in commercial use was slow until a textile exposition in Philadelphia in 1907 gave it a marked impetus. By 1919 most existing installations had been made. At that time 450 to 460 were in use in the United States. Approximately 100 more were sold by the end of 1925. The advantage of the drawing-in machine is that it can be used even when there is no old warp in the loom; on the other hand, it does not save as much labor as the tying-in machine. It is estimated that each machine, requiring ordinarily the attention of one operator and half the time of an assistant, replaces from 5 to 6 hand drawers-in.

The market for both tying-in and drawing-in machines is about saturated, so that future sales will be chiefly replacements and installations in new plants. In our inspections we found only three mills that had neither type.

<sup>24</sup> The annual sales of tying-in machines, 1904-29, are presented in Table 38.

## AUTOMATIC SPOOLER AND HIGH SPEED WARPERS

In order to get the long threads essential for the warp in the weaving process, the warp yarn is first rewound on spooling frames from the bobbins to spools holding larger quantities; then the warp threads are drawn parallel on a warper and wound on a beam. In the mills inspected about 7 per cent of the total labor force were employed on these two processes of spooling and warping.

It is at the spooling and warping stage that we find one of the relatively recent developments in automatic machinery in the cotton industry—the automatic spooler and high speed warper combination. At the time of our survey these new devices were still in the early stages of commercial adoption; indeed, we found only one mill so equipped, although the managers of another said they planned to install them. The automatic spooler winds the warp thread from the bobbins to ‘cheeses’ (a name indicative of their shape), automatically tying the thread ends in a weaver’s knot as each bobbin is exhausted. From the ‘cheeses’ the thread is wound on the warp beam by the high speed warper at a rate 8 or 10 times that of the ordinary warper. This astonishing increase in speed is made possible by a device that allows the warper thread to be run at light tension, with special automatic stops to prevent tangling if the thread breaks.

Available evidence indicates that the new-type spoolers and warpers can reduce the labor requirements in spooling and warping about 50 per cent, and make equally sharp reductions in the floor space required.<sup>25</sup>

<sup>25</sup> The above figures are based chiefly upon a series of engineering estimates, prepared to show prospective customers in 38 mills the savings in space and labor to be expected from the substitution of the new-style methods for the old. The estimates were made available for our inspection by the courtesy of the manufacturers of these machines. What little evidence we collected from users is consistent with them.

These machines were first installed experimentally in three mills about 1912 and went through a process of extensive experimental evolution, the developmental work involving in all the expenditure of at least several hundred thousand dollars. Commercial marketing began about 1921, and by the middle of 1926 they had been installed in or ordered for some 36 plants, 25 of which were in the South.

We find, then, in this long-mechanized industry, operating under unfavorable market conditions in the post-War period, evidence of only a moderate rate of change; yet it is noteworthy that even here mechanization was continuing, by way of both continued adoptions of devices of long-established effectiveness and more recent innovations.

#### GARMENT INDUSTRIES

Important centers of the garment industries are found in New York, Chicago and Philadelphia. In New York, where our inspections were made, much of the work is done in relatively small shops. In a limited sample of 11 men's and 7 ladies' garment establishments surveyed in New York, employing a total of 904 workers, half were machine operators or helpers, though probably not engaged on machines all their working time. Half of the 18 establishments surveyed had made no labor-saving changes in equipment since 1920. Seven had substituted steam pressing machines for the hand-iron and sponge method. Six of these reported an aggregate reduction in labor requirements for the pressing operations from 74 to 38 workers, or 49 per cent. Three establishments replaced 1600-, 2200- and 2300-stitch per minute sewing machines with 2300-, 3200- and 4000-stitch machines, respectively, and reported labor reductions of 15 to 20 per cent. Two establishments substituted rotary cutting machines for hand cutting, with a reduction in crews from 22

to 8. An increase of multiple-ply cutting with the aid of these cutting machines has been one of the important developments in the industry since 1920.<sup>26</sup>

#### PULP AND PAPER

The pulp and paper industry embraces establishments engaged primarily in the preparation of fiber pulp, chiefly from wood, and the manufacture of paper and paperboard from this pulp and from waste paper and rags. The principal paper products, ranked in order of value, are: paper boards, book paper, wrapping paper, newsprint, writing paper, tissue paper, and building papers.

The paper industry is a continuous industry, ordinarily operating 24 hours a day in some of the key departments. It is highly mechanized in the processing operations, but in many plants there is much manual handling of materials in certain stages, particularly of raw material in baled form and of the finished products.<sup>27</sup>

We may conveniently distinguish four major stages in pulp and paper processing operations: (1) pulp making, or the preliminary preparation of the paper stock: (a) from logs by the mechanical or grinding process; (b) from logs by one of the chemical processes; (c) by the conversion of rags and waste paper to pulp; (2) the beating and refining of pulp, or mixing and proportioning in the case of some cheaper papers such as newsprint; (3) the paper-making process proper, in the paper machine; (4) the finishing processes, which vary considerably with the various types of paper.

Although, as we shall note presently, there were few labor-

<sup>26</sup> For a study of the occupational displacement arising from this and other changes in the Chicago garment industry, see Robert J. Myers, Ref. 18.

<sup>27</sup> See Table 4 for power used, and Table 30 for degree of mechanization by occupations.

saving changes in equipment of a revolutionary nature, yet gains in productivity were substantial in the decade of the 'twenties. The Bureau of Labor Statistics estimates the index of productivity for pulp and paper, with 1914 taken as 100, as follows (Bul. 541, p. 605, Ref. 41):

1904	83	1921	95
1909	95	1923	117
1914	100	1925	127
1919	105	1927	140

Some of the major causes of the observed advance in productivity are indicated by statistics of the increasing use of power, and the increasing capacity of equipment units, and by the nature of the labor-saving changes in the establishments surveyed.

INCREASING SIZE OF EQUIPMENT UNITS

The capacity of major processing equipment units has steadily increased, as shown by data in Table 4. In the pulp department, the sulphite digesters, for example, have increased from an average annual capacity per digester of 2,864 tons in 1904 to 3,465 in 1919, and 5,119 in 1924. Similar increases occurred in the capacity of digesters in the soda and sulphate processes. Grinders in the mechanical pulp mills increased in 24-hour capacity from 5.09 tons in 1919 to 6.52 in 1929. Fourdrinier paper machines increased from a capacity of 11.4 tons in 1904 to 16.9 in 1919, and 23.6 in 1929; cylinder machines from 7.7 tons in 1904, to 15.4 in 1919, and 29.9 in 1929.

Changes in mechanical equipment frequently occur in this way. The general principles of the paper machine were well established prior to the period in which we are especially interested, and much of the improvement in equipment has

TABLE 4  
CHANGES IN CAPACITY OF MECHANICAL EQUIPMENT:  
PULP AND PAPER <sup>1</sup>

Unit: one short ton (2,000 pounds)

CENSUS YEAR	HORSE- POWER PER WAGE EARNER	AVERAGE YEARLY CAPACITY PER DIGESTER			AVERAGE 24-HOUR CAPACITY PER MACHINE		
		SULPHITE	SODA	SULPHATE	PAPER MACHINES		
					GRINDERS	DRINIER	CYLINDER
1904	16.57	2,864	1,176	2	2	11.4	7.7
1909	17.16	3,595	1,778	2	2	13.1	9.3
1914	18.32	3,716	2,535	3,384	4.42	15.8	11.8
1919	16.25	3,465	2,299	4,288	5.09	16.9	15.4
1921	<sup>2</sup>	4,386	2,502	3,755	5.48	18.0	20.4
1923	18.05	4,435	2,596	4,115	5.80	18.3	17.1
1925	19.60	4,658	2,945	4,365	6.52	21.1	23.7
1927	21.42	4,895	2,934	5,709	6.32	22.1	26.1
1929	23.18	5,119	3,189	6,549	6.52	23.6	29.9

<sup>1</sup> Census of Manufactures, for the respective years.

<sup>2</sup> Data not available.

been by means of augmenting the capacity of the machine units, largely, in the case of the paper machines, by accelerating the speed at which they operate.

#### REPORTED LABOR-*SAVING* CHANGES <sup>28</sup>

The pulp and paper mills included in our survey are, perhaps, not sufficiently representative to afford in themselves an adequate picture of the labor-saving trends in recent

<sup>28</sup> The inspections of pulp and paper mills by our representatives in 1925 covered 35 establishments in six states, employing 6,905 persons, or about 4.5 per cent of the total number of establishments and 5.6 per cent of the total number of wage earners in the industry. This sample covered about 79 per cent of the wage earners in the industry in Connecticut, but only from 4 to 12 per cent in the other 5 states. Four of the 35 schedules are for mills or departments making pulp only; 6, both pulp and newsprint; and 1,

years; but such other evidence as we have noted indicates that the changes reported are fairly typical. Fourteen of the paper mills inspected, chiefly long-established plants in Connecticut and Massachusetts, reported no recent labor-saving changes.

A number of the labor-saving changes reported are not peculiar to the pulp and paper industry. Two mills changed from coal to oil furnaces, and one from steam to purchased electric power, thus reducing their power production force.

One recorded substantial gains in efficiency through a bonus wage plan, and 5 by rearrangement of equipment, simplification of operations and improved management, with a total reduction in the labor force required in the 5 mills of from 150 to 200 men. Six mills recorded gains by speeding up or otherwise increasing the output of existing equipment without major alterations, or by merely replacing old units with newer models of the same type.

Manual feeders on printing machines were eliminated in one plant by the installation of automatic feeders. The elimination of other specific manual operations was accomplished in one mill by the substitution of automatic feeders for manual feeders; in another by the substitution of wick oilers on the paper machines and Corliss engines for manual oiling, and, in 4 mills, by the introduction of stitching machines for

a plant making newsprint from purchased pulp. The remaining 24 mills purchased their pulp, the principal products manufactured being paper board (11 mills), tissue papers (6), writing paper (5), building papers (1) and book paper (1). Wrapping paper constituted part of the product of 3 mills. The newsprint mills were using wood pulp for their raw material; the paper board mills, chiefly waste paper and wood pulp; the tissue mills, wood pulp; and the writing paper mills, rags, waste paper and some wood pulp.

The inspections were made by Mr. G. T. Benson, Mr. H. F. Girvin and Miss Edith H. Handler. We also obtained information by mail from 10 mills concerning their principal labor-saving changes since 1920 (Ref. 20-d).



paper boxes, or nailing machines for wood boxes, in place of hand stitching and nailing.

In the processes more peculiar to the industry, air-drying machines replaced loft drying in a writing paper mill, and a new bleaching ball in one plant and an improvement in the drying system in another were credited with labor-saving results; but the most distinctive change in the processing operations was the introduction, since 1920, in 4 of the 7 newsprint mills inspected, of the Trimbey metering and proportioning system for the ingredients of newsprint stock to take the place of the intermittent batch method under manual control by the beater engineers. Adoption of this system began about the beginning of the decade, and by 1929 some 129 installations had been made; about 90 per cent of the newsprint industry, including most of the new mills, were equipped with the system.<sup>29</sup> In the three mills in which this method had been in use sufficiently long to furnish a basis for estimating the results, the force on this particular operation had been reduced from 59 to 18 men, constituting a labor reduction of 69 per cent. The incidence of the change falls principally upon the beater engineers and is reflected, apparently, in the decline since 1919 in their rate of pay relative to other occupations in the industry.

Numerous labor-saving changes were reported in the handling operations. In one plant there was an increase in the use of grab-bucket cranes in unloading cord-wood. Another mill installed an overhead conveyor from the pulper to the beating engine, eliminating one man; belt conveyors were added in two plants, reducing the handling crew by two in one instance, and in another increasing the output of the crew over 50 per cent. New power tiering trucks were reported by 3 mills: 1 for handling pulp from storage to the

<sup>29</sup> See Tables 38 and 55.

beater room, saving 2 men on each of 3 shifts; 1 in a paper-label plant, saving 3 men; and one for handling bundles of paper, saving 2 men. The rather general tendency in the pulp and paper industry to use more electric trucks is indicated by the increase in their number from 35 in 1920 to 346 in 1929 (Table 11). Another development tending to reduce handling labor which is said to be rather general in the industry is an increase in the practice of pumping pulp from the pulp department to the paper mill instead of first making it into lap, thus rendering unnecessary the intermediate handling of the pulp in the dried state.

#### COMMERCIAL PRINTING

The commercial printing industry includes the printing and publishing of books, periodicals, catalogues and telephone books, also job printing, but not the printing of newspapers or music. The principal mechanical departments of the industry are the composing room, the pressroom and the bindery. Technical changes in pressroom equipment are the outstanding developments of recent years.

The progress and effects of mechanization in the pressroom department since 1912 have been surveyed by Dr. Elizabeth F. Baker of Columbia University.<sup>20</sup> Her conclusions rest in part upon records of printing press sales from 1913 to 1928, and in part upon a study of the changes in a group of plants in New York City in the five-year period from the winter of 1923 to the winter of 1928. In all, 53 establishments were surveyed, but the detailed analysis pertains chiefly to 36 medium-size union plants, employing from 5 to 20 men in their pressrooms.

The two outstanding technical changes in commercial

<sup>20</sup> See Bibliography, Ref. 4, 5 and 6.

printing are the rapid increase in the use of high-speed 'job automatics' with built-in self-feeding mechanisms, which, first introduced in 1914, have been rapidly "crowding out platens on the one hand and the larger cylinders on the other"; and, second, the substitution, on other types of presses, of an attachment for automatic feeding for the old hand feed-board.<sup>31</sup> For details of these changes and their effects the reader is referred to the monograph and articles describing the survey, which afford an excellent model for further studies of the relation between technological change and labor displacement.

#### NEWSPAPER PRINTING <sup>32</sup>

The major processes in newspaper printing are (1) composition, or preparation of the page of type, (2) stereotyping, or the casting of plates from molds made from the type pages, (3) presswork, or the actual printing and folding of the paper.

By the beginning of this century machines were available for all three of these processes—the linotype for composition, the 'Autoplate' equipment for automatic casting of stereotyping plates, and rotary presses for printing. Subsequent gains in productivity have arisen partly from a more general introduction of the available types of equipment and through improvements in the machines, such as multiple type-magazines, partly through labor-saving accessories, such

<sup>31</sup> Statistics of yearly sales of machine and hand-fed types, automatic-feeding attachments and 'job automatics' are given in Baker, Ref. 4, pp. 201-5; see also Table 37.

<sup>32</sup> The effects of the introduction of the linotype in newspaper printing are described by Barnett, Ref. 3, Ch. I; and a more general discussion of the evolution of printing equipment, together with productivity comparisons for 1896, 1916 and 1926, are given in Bul. 475, prepared by S. Kjaer for the Bureau of Labor Statistics (Ref. 38).

as automatic metal feeders, and partly through application of efficiency to shop management (Ref. 38, p. 52).

In the composition department the number of line-casting machines in use increased 50 per cent from 1916 to 1926.<sup>33</sup> The intertype, closely akin to the linotype, was introduced in 1913, and the monotype, first commercially used in 1894, came into more general use, though it has been more extensively used in book and magazine publication than in newspaper work.

Speed is the paramount consideration in the printing of a modern daily newspaper, and possible gains in productivity are sometimes sacrificed in the effort to reduce the clock-time required to get an issue off the press. For example, in the stereotyping department, an important improvement was the adoption of dry molding. This reduced the clock-time required to prepare the matrices and plates; but in 1916-26, in a representative plant, productivity in this department decreased 16 per cent owing to an increase in the average number of plates cast from each matrix in order to reduce the time required for preparing the issue of an edition.

In the presswork departments of the larger newspaper establishments the rotary press had displaced other presses as early as 1896, but in some of the smaller plants the hand press was still used and the newspapers were folded by hand after printing. As late as its 1926 survey, the Bureau of Labor Statistics reported that "even at the present time quite a few newspapers, especially country weeklies, are turned out

<sup>33</sup> "By 1896 the evolution from hand composition to machine composition had made some progress, but a number of establishments still existed in which all of the type was set by hand. In 1916 the bulk of the news composition was on machines, and by 1926 a relatively larger portion of it was by that method. Part of the type, however, was still set by hand, so that in a modern composing room both machine and hand methods are in use" (Ref. 38, p. 4).

on cylinder presses" (Ref. 68, p. 135). Subsequent to the first introduction of rotary presses larger and faster models have been developed and rapid automatic folding devices perfected.

As summarized by the Bureau of Labor Statistics (Ref. 38, p. 13),

"Between 1916 and 1926 the machines were further improved through time-saving and labor-saving devices, though no startling innovation was brought out. . . . Attention was directed strongly toward layout of establishments, cooperation between departments, factory management, and building facilities, subjects which were not included in the surveys but which exert immense influence on production. As a result many newspaper publishers have recently established up-to-date and model plants for their products, and applied efficiency methods to the printing processes."

Despite the lack of sweeping innovations, there were substantial gains in productivity in newspaper printing between 1916 and 1926;<sup>84</sup> but as in previous periods, their potential effect on the volume of employment has been offset to a large extent by expansion in the total volume of newspaper printing, due chiefly to the remarkable growth in the circulation and size of the daily newspaper. The total number of newspapers, however, has decreased since 1909, and especially since 1919.

#### THE GLASS INDUSTRY<sup>85</sup>

After the raw materials for glass have been mixed and melted, the molten glass is manipulated either by hand or machine, or both, into window glass, plate glass, bottles and

<sup>84</sup> The increase in output per man-hour for composition, stereotyping and presswork on 10,000 copies of a 4-page section of a representative newspaper, 1916-29, was estimated as 36.5 per cent, the smallest increase, 7.8, being in the presswork, and the largest, 40.7, in composition (Ref. 38, p. 19).

<sup>85</sup> In the glass industry we have not relied primarily upon field inspections, although Mr. Alfred Briggs, who prepared for our use a report on

jars, and pressed or blown glassware. For each of these four major products there is an essentially distinct branch of the industry.

These four branches afford some of the most striking examples of the substitution of mechanical equipment for hand processes in recent decades; they also furnish good examples of the diverse effects of mechanization upon the grade of labor required. For example, in the manufacture of bottles and window glass, the effect of machinery has been to displace skilled labor; but in plate glass, to displace common labor.

#### WINDOW GLASS

At the beginning of the twentieth century the manufacture of window glass was almost entirely a non-mechanical process. The cylinder machine was introduced in 1903, and the sheet process in the early years of the World War. The record of a quarter century of effort on the part of the hand industry to survive in competition with the more highly mechanized processes is a fascinating and instructive chapter in the history of mechanization.

In the hand process the liquid 'metal' is fashioned into a sheet of window glass by five crafts of skilled workers—gatherers, blowers, snappers, flatteners and cutters.<sup>36</sup>

mechanization in the window- and plate-glass branches, did spend several weeks inspecting glass factories and interviewing glass factory executives and others familiar with the industry. Other principal sources of information are the studies by Barnett (Ref. 3) and Stern (Ref. 36), hearings on the tariff, files of trade journals and the trade directories for the glass industry.

<sup>36</sup>The snapper was the least skilled of the five and is hereinafter considered a semiskilled worker.

*Cylinder machine*

The cylinder machine is simply a mechanical window-glass blower. Unlike the sheet machine, which is built upon a radically different principle, the cylinder process follows the hand method of blowing a long cylindrical bubble of glass, which, when cool, is split open and flattened. The cylinder process is the result of more than half a century of experimentation, beginning with a device patented by a Frenchman in 1854. Numerous other attempts were made before an American, J. H. Lubbers, brought out his window-glass machine in 1903. By 1905 many hand plants had gone out of business, wages of blowers and gatherers were reduced 40 per cent, and the new machine may be said to have achieved commercial success.<sup>37</sup> Later, other variations of the cylinder machine were developed by other manufacturers.

*Sheet process*

In the sheet process a flat sheet of glass is drawn directly from a forehearth connected by a cooling tank with the melting tank. This eliminates the splitting and flattening of the cylinders, and leaves only one skilled trade, namely, cutting. Two types of machine for drawing window glass have been perfected and are in common use—the Colburn and the Fourcault. A third type, closely resembling the Fourcault, is used by one company. The Colburn was developed first and is more firmly entrenched.

The sheet machine is, like the cylinder machine, the result of more than half a century of experimentation. Patents were secured as early as 1857 for production by the sheet process, but it was not until after many years of experimentation by

<sup>37</sup> *National Glass Budget*, June 3, 1905.

Mr. Colburn, and the expenditure of large sums, that commercial production of this type of machine was begun, by the Libby-Owens Sheet Glass Company, in 1917.

The Fourcault type of sheet machine was developed in Belgium by Emile Fourcault and patented by him as early as 1901, but it was not until 1924 that operations with this machine were begun in this country.

#### *Decline of the hand branch*

The decline of the hand industry and the rise of the machine in window-glass production are indicated in broad outline by Table 5, giving the number of cylinder machines, sheet machines and hand pots in each year, 1903-27.<sup>38</sup>

The recorded decrease in the number of hand pots is doubtless an understatement of the rapidity of the decline in the hand branch of the industry. Firms are slow to report changes, especially when they involve the abandonment of all or part of existing equipment. Furthermore, during the years 1919-25 a scheme of production curtailment prevailed, and the hand plants were divided into two groups: those which operated only during the first period in the year and those which operated only in the second period. This effort at rational non-competitive industrial control stabilized the industry for a time and prolonged the life of the hand branch. It permitted twice as many pots to operate but for only half as long. For example, Table 5, based on the directory, shows 2,108 hand pots in 1919, but data obtained by us from the records in the office of the National Window Glass Workers, which had a 100 per cent closed shop in the hand

<sup>38</sup> As the term is used here, a 'pot' is a work place in a hand window-glass factory. With exceptions noted in the footnotes to Table 5, these data were all secured from a file of the *American Glass Trade Directory* in the Carnegie Library in Pittsburgh.



## MECHANIZATION IN INDUSTRY

TABLE 5

## EQUIPMENT IN THE WINDOW-GLASS INDUSTRY: 1903-1929

(See accompanying text for explanation of lag in these data)

YEAR	TOTAL			
	CYLINDER AND SHEET MACHINES <sup>1</sup>	CYLINDER MACHINES <sup>1</sup>	SHEET MACHINES <sup>1</sup>	HAND POTS <sup>2</sup>
1903	24	24	...	...
1904	...	...	...	2,280
1905	124	124	...	2,342
1906	...	...	...	2,772
1907	130	130	...	2,881
1908	...	...	...	2,699
1909	160	160	...	2,391
1910	116	116	...	2,315
1911	128	128	...	2,438
1912	128	128	...	2,257
1913	162	162	...	1,564
1914	155	155	...	1,452
1915	284	284	...	1,625
1916	308	308	...	1,913
1917	327	321	6	1,826
1918	318	312	6	1,903
1919	350	344	6	2,108
1920	335	329	6	2,367
1921	341	329	12	2,735
1922	344	324	20	2,660
1923	310	284	26	2,101
1924	335	257	78	1,300
1925	348	264	84	888
1926	344	269	75	567
1927	339	265	74	186
1929 <sup>3</sup>	177	60	117	...

<sup>1</sup> Sources of information:1903, *National Glass Budget*, January 17, 1903;1905, *1905 Census of Manufactures*, p. 846;1907, *National Glass Budget*, June 29, 1907;1909, A. B. Morton, Machinery in the Window Glass Trade, *The Johns Hopkins University Circular*, April 1910, No. 4, p. 43. This figure seems high even though it was reported by Morton to be "estimated by a competent authority";

- 1910, *National Glass Budget*, October 22, 1910;  
 1911-27, *American Glass Trade Directory*, 1911-1927;  
 (The 1927 edition is styled *Glass Factory Year Book and Directory*).  
<sup>2</sup> 1904-27, *American Glass Trade Directory*, 1904-1927.  
<sup>3</sup> 1929, *1929 Census of Manufactures*, II, 871.

branch during that period, show only 1,157 pots in operation in the first period in 1919 (February-May), and 924 in the second period (August-December), or a total of 2,081, indicating that only about half of the hand pots listed in the directory were actually in use at any one time in the years 1919-25.

Another version of the decline of the hand branch is afforded by the following estimates of the percentage of window glass produced by the hand process:<sup>39</sup>

1899-1900	100
1913-1914	44
1915-1916	39
1919	34
1922-1923	24
1925	6
1926	2

As shown in Table 5, the cylinder machine was well established within a few years of its introduction and steadily displaced the hand process until shortly after the commercial appearance of the sheet machine in 1917. The early cylinder machine was dubbed the 'Iron Man', but the sheet machine was to prove an iron genius with more nimble fingers, capable of making the glass not in cylinders but directly in great sheets, eliminating the arduous and expensive hand flattening

<sup>39</sup> These estimates are perhaps not strictly comparable, since they are from a variety of sources the principal of which are: *Census of Manufactures*; *Annual Report of American Window Glass Company*, 1910; *National Glass Budget*; *The National Glass Worker*; and *Tariff Information Surveys B-9* (Washington, 1921), p. 74.

process, as the cylinder machine had eliminated the highly skilled blower and gatherer and the semiskilled snapper.

To summarize, in the quarter century following the introduction of machine blowing, the window-glass industry, one of the last strongholds of specialized handicraft skill, has undergone a technological revolution resulting in the almost complete disappearance of the hand branch of the industry and the elimination of two skilled trades and one semiskilled, and also the partial elimination of the skilled flatteners. The contest for supremacy now lies between the cylinder and the sheet machine processes.

The *1925 Census of Manufactures* reported 216 cylinder machines with a capacity of 1,928,417 square feet per 24 hours, and only 79 sheet machines, with a capacity of 265,000 square feet; but the corresponding figures for 1929 were only 60 cylinder machines (capacity, 732,000 square feet) and 119 sheet machines (Fourcault, Libby-Owens and Pittsburgh Plate Glass with a total capacity of 1,939,220 square feet), indicating the increasing dominance of the sheet method.

#### PLATE GLASS

Window glass, as we have seen, is blown in cylinders or drawn in sheets. Plate glass is cast molten, rolled to the desired thickness, then ground and polished on large plates or tables. At first the chief use of plate glass was for large store and office windows; but the more recent expansion of the industry has been caused by the huge demand for plate glass from the automobile industry.

The principal technological difference that affects the quantity of labor required is between the discontinuous and continuous processes of casting and finishing. In the older, discontinuous process, the raw materials are melted in large pots in furnaces, the pot is removed and the molten

contents poured upon a casting table, smoothed to a large sheet by a heavy roller and immediately placed in an annealing lehr. When cooled, the defects are cut out and the glass ground smooth and polished. In contrast to the intermittent casting of one pot at a time, in the continuous process, which first came into use in 1921, there is an uninterrupted flow of the glass from a tank to the rollers and then through the lehr. In addition, after it is annealed there is a continuous passing of the ribbon of glass under a series of grinding and polishing machines, in contrast to the old process where circular tables are moved about from one machine to another.

Of 18 plate-glass plants listed in the *1927 Glass Factory Directory* 4 were using the continuous process, 3 of these being owned by automobile manufacturers. According to the *1929 Census of Manufactures* the capacity of the continuous flow machines was about half the total capacity of plate-glass machines.

The continuous process eliminates most of the casting crew. Stern, comparing the productivity of a discontinuous and continuous plant under the same management, finds a 60 per cent increase in productivity in the latter.

#### GLASS CONTAINERS <sup>40</sup>

The manufacture of bottles and jars is the largest branch of the glass industry. In 1899 it employed 28,370 wage earners, but in 1925, only 21,704, despite an increase in output from less than 8 to over 26 million gross. The history of the successive technological changes contributory to this situation affords instructive examples of a variety of defen-

<sup>40</sup> This section is based chiefly upon the studies by Barnett (Ref. 3) and Stern (Ref. 36).

sive measures against machine encroachments upon an old and highly-paid skilled trade.

The major operations are blowing, annealing, and assorting and classifying. The significant changes in mechanization have been in the blowing process. Prior to 1898 bottle manufacture was carried on by the hand method of mold-blowing. Since then successive developments in machinery have revolutionized the blowing process and superseded hand blowing in all manufacture of bottles and jars except for small quantity production. Barnett (Ref. 3, p. 67) summarizes the developments as follows:

"1. From 1898 to 1905, semi-automatic machines, requiring for their effective working skilled workmen, largely displaced hand blowers in the manufacture of wide-mouth ware.

2. From 1905 to 1917, the Owens automatic machine, which required only supervision and the amount of whose product was independent of the speed of the watcher, was the chief factor in the displacement of hand blowers and of the skilled operatives of semi-automatic machines. Contemporaneous with the introduction of the Owens was the appearance of semi-automatic machines for making narrow-mouth ware.

3. From 1917 to 1924, the trade has again been revolutionized by the introduction of 'feed and flow' devices which, while requiring more attention than the Owens machine, produce more ware than the semi-automatics. The attendants, moreover, need not be skilled workers, although the question of the relative superiority of skilled and unskilled workmen as attendants is still in dispute."

The semiautomatics substituted a combination of machine pressing and blowing for hand mold-blowing. Following a period of slow development in the experimental stage the number of these machines in use for wide-mouth jars rose rapidly from about 20 in 1897 to some 250 in 1905. Barnett estimates that these 250 represented a potential displacement of about 1,500 hand blowers; but that, in fact, almost no displacement occurred, because concurrently with their introduction the demand for bottles had so increased that the potential displacement of hand blowers could be met success-

fully in two ways: “(1) by the conversion of jar blowers into blowers of other forms of ware unaffected by the machine; (2) by placing hand blowers in positions as machine workers” (Ref. 3, p. 71). The first method proved the more effective.

The Owens machine, introduced in 1904, is, with its later modifications, almost completely automatic and highly productive. Even from the first the machine took the place of five of the crew of seven in a typical hand ‘shop’. Later the addition of automatic conveyors eliminated all but one semi-skilled operator required to run the machine.

Despite the high capacity of the Owens machine and the relatively small crew required for its operation, it did not quickly supersede hand blowing and other machine methods; and concurrently with its introduction several types of semi-automatic machine were introduced for use with narrow-mouth ware, which ultimately developed into an automatic process essentially different from the Owens. The machines went through several stages of development until the principal difference between them and the Owens was in the use of a gatherer to feed the glass to the machine instead of the suction process used in the Owens.

After 1917 the use of the semiautomatic process declined rapidly, owing to the introduction of ‘feed and flow’ devices which did away with the gatherer and provided a process like the Owens in being almost completely automatic, but different in technical features. These feeder devices, which can be used with almost any of the old-style semiautomatics, about doubled the output of the semiautomatics and required a relatively unskilled attendant.<sup>41</sup>

<sup>41</sup> For estimates of comparative productivity of hand, semiautomatic and automatic machines, see Stern, Ref. 36.

*Extent of introduction of automatic machinery*

Since the introduction of the Owens machine, "the proportion of the total production of bottles and jars made on automatic machines has constantly increased." Barnett states that "in 1917 it was 50 per cent; in 1922-23, 80 per cent; and in 1924-25, 90 per cent."<sup>42</sup> The number of Owens machines increased from 8 in 1905-06 to 200 by 1916-17, and their total capacity, owing to successive improvements, increased by an even greater percentage. However, the number of semiautomatics, particularly the narrow-mouth machines, increased in the same period, from 19 in 1909 to 292 in 1916, as indicated by union records.<sup>43</sup> In 1917 the wide- and narrow-mouth types totaled 428, but after the introduction of feed and flow devices, the number declined rapidly to 72 in 1924.

At present the greater part of the field is shared by the two types of automatics, although there is still a hand branch of the industry, limited to small orders and oddly-shaped bottles.<sup>44</sup>

PRESSED WARE<sup>45</sup>

Owing chiefly to the multiplicity of products, machinery has been introduced very slowly into the branch of the glass

<sup>42</sup> Ref. 3, p. 85.

<sup>43</sup> *Ibid.*, p. 93.

<sup>44</sup> The 1929 *Census of Manufactures* (II, 871) records the number of machines in use for all types of pressed and blown ware as: 960 with automatic feed, of which 916 were full automatic forming machines; and 149 hand-feed machines, of which 61 were full automatic forming. The total capacity of the automatic-feed machines was 10,677 tons per 24 hours as compared with only 193 tons for the hand-feed machines. The corresponding capacity figures for 1925 were 7,169 tons automatic-feed and 579 hand-feed.

<sup>45</sup> The paragraphs on pressed and blown ware are based largely upon Stern, Ref. 36.

industry devoted to products pressed in molds. For some staple articles the hand-power side-lever press has been gradually displaced, first by the semiautomatic press, introduced in the first part of this century, then by the more revolutionary change in the way of automatic-feeding devices introduced about 1917 and similar in general to those previously mentioned for bottle blowing. These machines have been restricted largely to staple products produced in large quantities, such as tumblers; and many hand plants survive in the manufacture of the many novelties made in very small quantities to appeal to individual tastes. At present there seems to be no indication that the machine will invade the novelty business.

Stern's studies of the relative output by hand and machine methods for a number of pressed ware commodities show reductions by the machine in labor time of from about 80 to 92 per cent, and in labor cost of about 87 to 93 per cent.

#### BLOWN WARE

This branch of the industry is more nearly akin technologically to the bottle branch than is the pressed ware, and also more similar in the rapidity with which machinery has been introduced. A semiautomatic machine for lamp-chimneys dates from 1894, but hand production is still an important factor in the lamp-chimney branch of the industry, partly because it is declining and hence offers less inducement to machine development. On the other hand, marked progress has been made in the development of machinery for making electric light bulbs.

"Since 1917 hand production has been almost entirely displaced—first by the semiautomatic Empire E machine and more recently by the completely automatic Westlake machine and the Empire F machine operated with an automatic feeder. At present more than 95 per cent of all the electric bulbs are made by the two automatic processes. The semiautomatic



machine has been almost completely abandoned, while a few hand shops have been retained for experimental purposes or for the purpose of making oddly shaped and colored electric bulbs" (Stern, Ref. '36, p. 6).

In 1917 the Danner machine for making glass tubing was introduced. The new method was so superior in both quality and quantity of output that "in the comparatively short period of less than 8 years it displaced the old hand process, and not a single shop can now be found making glass tubing by hand."

Stern estimates that in blown ware, machine methods as compared with hand methods reduce labor time from about 30 per cent for lamp-chimneys to 97 per cent for electric bulbs, and labor cost from 37 to 97 per cent (Ref. 36, p. 7).

#### ELECTRIC-LAMP INDUSTRY <sup>46</sup>

The filament wire, glass tubing, base and other crude parts essential to the complete electric light bulb are subjected to additional processing and assembled in what are known as 'lamp-assembly plants'. The productivity of labor in these assembly plants, which employ most of the labor required in the manufacturing division of the electric-lamp industry, "is estimated to have increased continuously from a base of 100 in 1920 to 438.9 in 1931, and the decline in employment in the same plants is estimated at 68.3 per cent." To this gain in productivity hundreds of technological changes in the making and assembly of the various parts have contributed, but two developments are cited as of outstanding importance:

##### A. The group or unit system of manufacture.

"The underlying principle is the coordination and synchronized operation of the various related parts of a production unit, and it is extensively

<sup>46</sup> *Monthly Labor Review*, Ref. 65, especially pp. 1213-4.

applied throughout the industry. A typical instance is the high-speed unit lamp-assembly machine in five sections, for (1) stem making, (2) stem inserting, (3) filament mounting, (4) sealing the mount in the bulb and exhausting the air, and (5) attaching the base."

B. The development of automatic cam-operated turret machines, in many forms, which can perform a wide variety of operations in succession, some of the most delicate nature. With machines of this type many operations that formerly required manual labor can be automatically performed; for example, the "48-head Ohio bulb-making machine. . . indexes at 48 positions and turns out finished bulbs (except for frosting)".

#### LUMBER MANUFACTURE AND WOOD-WORKING INDUSTRIES

The older method of handling lumber in the yard was by horse-drawn trucks. More than a decade ago the gasoline lumber-type tractor, commonly known as the 'jitney', was introduced and quite generally adopted by various mills and lumber yards as a substitute for the horse in hauling loads of lumber around the yards. Shortly afterwards the 'Hammer-head' overhead crane and lumber carriers of the mobile type, such as the Ross, began to supplant both horse and 'jitney', and the annual installations of the jitneys have dwindled in recent years. The Ross carrier is a device which might appropriately be described as a mechanical elephant. It is a mobile electric or gasoline-driven frame which straddles the pile, raises it with lifting fingers or tongs and carries it away.<sup>47</sup>

Significant tendencies in lumber manufacturing are illustrated by the record of five plants in the Northwest engaged

<sup>47</sup> See Table 46, for annual sales of four models of carriers and high lumber pilers, and Table 52 for estimates of extent of use.

in the primary manufacture of lumber for which productivity and equipment records are available, 1916-17.<sup>48</sup>

In one of the five plants mentioned, 'jitneys' displaced horses in 1922 but were in turn displaced by Ross carriers in 1926 and 1928. In the other plants the displacement of horses by carriers began in 1915, 1918, 1921 and 1923, respectively. Travelling cranes were added in one yard in 1922 and in another in 1926, and a third added two caterpillar traction cranes in 1927 for use in loading lumber to ships. Aside from various expansions in plant and equipment, four of our five plants made replacements which were believed to have increased productivity. In two plants old units were replaced in 1922 and 1924 by larger and faster edgers. In 1925 in one plant an old planer was replaced by a larger type, and in another a more efficient head rig was installed.

#### WOOD FURNITURE

Labor-saving changes in wood-working machinery were also reported from the furniture and building construction industries: carving machines, power saws, planers, lathes, boring and molding machines, and sanding machines for furniture and floor finishing. The labor reductions noted were not large, the greatest being from ten workers to one in carving with machines instead of by hand. Sanding machines were reported more frequently than any other type. On the

<sup>48</sup> These five plants are part of a group of 39 lumber mills of which inspections were made by our research assistants in the Douglas fir region of the Pacific Northwest in 1927 and 1928. The five are selected because comparable records are available for the entire period 1916-27. Logging operations prior to the sawmill are excluded; also such specialized remanufacturing operations as the making of shingles, doors, sashes, broom handles and boxes, so that the data refer only to the operations of the sawmill and such finishing units as the planing mill and dry kilns, and to handling in yard and loading to ships or railroad cars.

average the users estimate that one man with the machines does as much work as four by hand.

We are informed by the producers of heavy wood-working machinery that the outstanding development in recent decades is increased capacity owing to faster speed and automatic feeding tables. For example, up to 1904, the capacity of flooring machines and heavy types of double surfacers

"was around 40 lineal feet per minute. In some instances, under exceptional conditions, a few machines might have been running as fast as 60 to 65 feet per minute. From about 1906 until 1914, by change of design and construction, the capacities of these machines were raised—at first up to 100 lineal feet per minute and then on, by gradual steps, to around 150 lineal feet per minute. In 1914 there were some mills that might get a capacity of perhaps 200 lineal feet. From 1914 on to 1924 the continual development in the manufacture has raised the average rates of feed to around 200 to 250 lineal feet per minute, and in some cases maximum feeds of up to 400 lineal feet. By the development of accessories, such as automatic feeding tables, it has been possible for one man still to feed most of these machines at the very greatly increased rates."

A similar situation holds with respect to mouldings:

"Up until 1904, depending entirely upon the class of mouldings to be run as well as the kind of wood itself, the mouldings were run at anywhere from 8 lineal feet per minute up to as high as 25 lineal feet per minute in some cases. From then on until 1914 there were some improvements in design and manufacture, but nothing commensurate with the advance made on the planer and matcher types. However, in some instances it was possible to run certain classes of mouldings as high as 75 lineal feet per minute; but the average range of feeds was probably only slightly higher than that of the period of 1904. From 1914 on to 1924, or principally in the last few years, by changes in design and construction, the moulding machines today are capable of producing, on various types of mouldings, at anywhere from 35 lineal feet per minute up to 200 lineal feet per minute, all depending upon the particular type of machine, class of moulding, etc. The labor cost of feeding the mouldings is practically the same, measured by the number of men."

*(Letter to the writer from a leading manufacturer of wood-working machinery, written in 1925.)*

## MOTOR-VEHICLE INDUSTRY

The automobile industry and mass production have become almost synonymous terms. The essential basis of this mass production, in its highest development, has been the standardization and interchangeability of parts, a high division of labor, and the progressive assembly of parts on intermittently- or continuously-moving conveyors.<sup>49</sup> The expanding market of the post-War era was in part a result of the prices made possible by economies in production and in part the phenomenon that made such economies possible. There have been remarkable gains in productivity in the industry, and with the various technological changes numerous occupational shifts which cannot be detailed here.<sup>50</sup>

## RUBBER TIRES AND TUBES

Particularly in the tire and tube branches of the rubber industry an expanding demand and active competition have brought rapid developments in technique and equipment. One firm reporting to us in 1926 stated that they practically made over their entire tubing department in three years and also scrapped a large part of their tire machines as obsolete every two or three years. Conveying systems to minimize handling and facilitate continuous processing and assembling have been extensively introduced.

<sup>49</sup> For a sketch of the development of mass production in automobile manufacturing, see R. C. Epstein, *The Automobile Industry*, Ch. II.

<sup>50</sup> In reporting the results of a survey of 25 automobile plants in 1925, M. W. La Fever details the reduction in labor hours per automobile in individual plants and describes various developments in the industry which help to account for these reductions (*Monthly Labor Review*, October 1924, pp. 735-60); in a more recent analysis, the Bureau of Labor Statistics outlines the Effect of Technological Changes upon Occupations in the Motor Vehicle Industry (*ibid.*, February 1932, pp. 248-52).

In tire production there have been remarkable increases in man-hour productivity, especially since 1926.<sup>51</sup> However, revolutionary changes in the general method of tire construction have been few; in fact, the one revolutionary change was the substitution of the flat-drum method (and later the shoulder-drum), for the old method of construction around an iron core. More influence is ascribed to the evolutionary effect of the aggregate of many small changes, of which the most important are probably those arising from motion-time studies (Ref. 62, p. 1267).

Only minor attention was given the rubber industry in the field phases of our survey, nevertheless the labor-saving changes reported are suggestive of tendencies in the industry.<sup>52</sup> In the milling department, where the rubber stock is prepared, a chief development in the first half of the 'twenties was the introduction of larger rolls—so that one operator handled probably 300 pounds where formerly he had tended only a 100-pound batch. In tire building the replacement of "a lot of husky labor" was attributed to the substitution of pneumatic bags for the iron cores formerly used in building the 'carcass', and the use of folding machines for inserting these air bags, as well as by adoption of the flat building method.<sup>53</sup> Among the other reported changes were the replacement of individual calenders by a train calender, reducing the crew from 28 to 14; new equipment for quantity

<sup>51</sup>The comments in this section not based upon information directly collected by the National Bureau of Economic Research from manufacturers rest upon a report of a survey by the Bureau of Labor Statistics covering the 1922-31 records of six plants, producing from 45 to 60 per cent of the total output of tires (Ref. 62).

<sup>52</sup>See also list for two plants in *Monthly Labor Review* (Ref. 62, p. 1266).

<sup>53</sup>One producer reported a crew reduction from 42 to 26 upon adoption of the flat building method; two others, by the adoption of flat building and other changes common to the industry, achieved 50 to 60 per cent reductions in labor requirements.

production of tire bead which wrapped the fabric around the bead—cementing, pressing, trimming and cutting it to desired lengths; a machine by which the bead is built in as an integral part of the tire-building process; another machine for cementing two plies of fabric together before they reach the skilled builder; an assembling machine for side-wall strips; new tire-tread machinery; and, in tube manufacture, watchcase heaters in place of open vulcanizers and the tank system for testing tubes, with mechanical deflation after testing.

#### LEATHER

In contrast to such rapidly growing industries as the automobile and tire industries, most branches of the leather industry declined from 1919 to 1929, not only in number of establishments and of wage earners but also in the value of product added by manufacture. Nevertheless, a study made by the Bureau of Labor Statistics reveals an increase in production per man-hour, 1923–31, ranging from 4.4 per cent for sheepskins to 27.2 per cent for side leather.<sup>54</sup>

The major part of these gains is ascribed, not to the improvements in processing or handling machinery (though there were some gains from these causes), nor to improvements in layout or operation at a higher percentage of capacity, but chiefly to improved management of labor, made possible in large part by the fact that at the beginning of the period the industry was operating at a relatively low level of efficiency compared with other American industries. The comments on this point merit extended quotation:

<sup>54</sup> *Monthly Labor Review*, Ref. 58. This study covered five branches of the industry—sole leather, side leather, calfskin, kid leather, and sheepskins—and included most of the large and medium-size tanneries. Only 'productive' labor has been included in these estimates.

"In a majority of the tanneries visited for the purposes of the survey, it was hard to find evidence that any cause other than the stricter and more intelligent management of labor had played any part at all in increasing the output per hour.

"As regards the methods whereby this improvement in labor efficiency in the tanning industry has been effected, there have been a few important cases of the bringing in of consulting industrial engineers and of the adoption of elaborate premium scale systems. Even where the latter cannot be said to be in use, bonuses have often played a part of consequence in stimulating effort. But on the whole the characteristic procedure has been merely for company officers, superintendents, and industrial engineers already on the ground to apply their attention to minimizing the waste and loss of time" (Ref. 58, p. 488).

#### SHOES<sup>55</sup>

Shoe machinery went through its initial stages of development in the 'eighties and 'nineties, and changes since then have been for the most part refinements on the basic devices.<sup>56</sup> A minute subdivision of labor, with wages on the piece-rate basis, is prevalent in the industry.<sup>57</sup> The major machines in use are controlled by the United Shoe Machinery Corporation and the Singer Sewing Machine Company. The United Shoe Corporation, instead of selling their machines outright, install them on a royalty basis, a practice which probably helps to accelerate the general adoption of a new model and to equalize the degree of mechanization in

<sup>55</sup> See B. L. S., Bul. 360, *Time and Labor Costs in Manufacturing 100 Pairs of Shoes, 1923*, for comparisons of productivity in 1863, 1895, 1916 and 1923, in the individual operations in shoe manufacturing.

<sup>56</sup> Nevertheless, one study shows a reduction of hours under the machine method from 142.7 per 100 pair in 1916 to 106.9 in 1923 (Bul. 360).

<sup>57</sup> A rubber shoe plant inspected by the writer afforded an instructive example of a plant in process of increasing subdivision of labor. Part of the factory was still on the old basis where each worker completed a substantial part of the shoe, another part operated with a much greater subdivision of processes and specialization by the workers. In both, although some machines had been introduced for certain operations such as cementing and trimming, the work was still predominantly by hand.



competing plants. The tendency towards frequent style changes militates against the full use of machines. Fancy styles both increase the number of operations and reduce the quantity of any one type to be produced.<sup>58</sup>

Man-hour productivity in the boot and shoe industry increased 24 per cent between 1914 and 1927 (Ref. 43). Among the reasons cited by individual manufacturers for this relatively moderate gain were improvements in the management of labor, including an increasing resort to piece rates, and, for the particular plants reporting, a reduction in the number of styles and grades.

#### BEET SUGAR

From 1919 to 1929 the output of the beet sugar factories increased about 50 per cent, but the average number of wage earners declined about one-third. Part of this increase in productivity may be due to the abandonment of the least efficient plants and the construction of new, more efficient plants, but the data we have collected indicate that marked improvements in productivity have been made by individual plants. For example, in a group of five identical plants the number of tons of beets sliced per man-hour increased from 0.40 in 1917 to 0.54 in 1929.

Substantial investments in additional equipment and replacement of old equipment were made in this period, but we have found it difficult to single out conspicuous labor-saving improvements in equipment. In fact, some of the

<sup>58</sup> One firm reported to us, for example, that they had reverted to hand methods for some operations because of the diversity of styles. Another company reported that where formerly they had made but four styles of shoes, they were then putting out over a hundred. The growth of the style factor throughout the industry is doubtless most pronounced in the high grade shoe.

most marked gains in productivity occurred in that part of the period when investments in improvements were least. Executives of the industry with whom we conferred were inclined to assign as a major explanation of the observed increases in productivity in their plants not changes in the mechanical equipment but rather strenuous efforts by the management to obtain a better organization and functioning of the available staff and equipment. The latter half of the period has been characterized by a reduction in the average number of slicing days, and, at least in the five plants mentioned, an increase in the effective daily capacity, that is, in the average volume of beets sliced per day. Probably much of the gain in productivity is associated with these tendencies.

#### SLAUGHTERING AND MEAT PACKING

This industry has long been characterized by a minute subdivision of labor, which was well developed as early as the 'eighties; the gains in productivity, 1909-25, as shown by Clague's indexes, were relatively small.<sup>59</sup> However, a study of a small sample of plants by the Bureau of Labor Statistics shows substantial gains in productivity in some departments from 1919 to 1931 (Ref. 60). Machinery is extensively used in conveying the carcasses between processes; in fact, a characteristic feature of a packing plant is a conveyor moving just fast enough to allow time for each successive processing operation. However, the actual processing operations are in large part manual rather than machine. The variety in size and contour of the carcasses makes the application of machine

<sup>59</sup> See Ethelbert Stewart, Labor Productivity in Slaughtering, *Monthly Labor Review*, 18: 488-95, and Productivity of Labor in Slaughtering and Meat Packing. . . , *ibid.*, 23: 954-8.

methods difficult except in the conveying and packaging phases.<sup>60</sup>

### TOBACCO MANUFACTURE

The two major divisions of the tobacco industry are cigars and cigarettes. The cigarette branch has long been predominantly a machine industry, but the manufacture of cigars, aside from 'little cigars', remained chiefly a hand process until 1917. One of the two major trends towards mechanization in the tobacco industry since the World War has been the sharp increase in the use of the machine-made cigarette as compared with a decline in the consumption of cigars. From 1918 to 1930 the production of cigars decreased from nearly 8 billion to less than 6½ billion; but the output of cigarettes weighing three pounds or less per thousand increased from about 47 billion in 1918 to 124 billion in 1930.

The second major movement towards increased mechanization in the tobacco industry is the rapid introduction of the cigar-making machine.<sup>61</sup> In the making of cigars the major processes are the stripping of the leaves from the tobacco stem; the arrangement of the filler into bunches; the addition of a binder to hold the bunch together; the addition of the outer wrapper; and the packing and labeling of the finished cigar. Various aids to the handicraft process of cigar-

<sup>60</sup> For example, in a small group of five local packing plants inspected by our representatives, of a labor force totalling 974 only 197 workers were machine operators or helpers. Most of the equipment in use had been installed prior to 1920; subsequent changes were in the way of improvements to the conveying system, the substitution of oil for coal furnaces in the power plant, and a few new machines of minor importance.

<sup>61</sup> This section is based upon information obtained from the manufacturers of the cigar-making machine, from a few cigar plants included in our field survey, and on the report of a survey by the Bureau of Labor Statistics, *Technological Changes in the Cigar Industry and Their Effects on Labor* (Ref. 47).

making have long been in use, such as the wooden mold, the suction table, the stripping machine and the bunch-making machine. "The first successful machine for the making of a completely headed, long-filler cigar in one continuous series of operations" was patented and placed in operation in 1917. With four operators this machine carries out all the necessary operations "from the feeding of the filler leaf into the machine by the first operator to the inspection of the cigar by the last operator". From 1918 to 1929 inclusive, over 4,400 cigar-making machines were installed or ordered by principal cigar manufacturers; and they are now in use by most or all of the large cigar-manufacturing establishments. From estimates of the output of machine-made long-filler cigars prepared by the Bureau of Labor Statistics we compute that the ratio of such machine-made cigars to the total output weighing over three pounds per thousand ranged from less than 1 per cent in 1917 and 1918 to about 35 per cent in 1929, and 47 per cent in 1930.

After the cigar has been formed, it is usually wrapped in cellophane and banded. Wrapping machines for this purpose are now quite generally used by all cigar manufacturers and most of the larger machine factories are now operating cellophane-wrapping machines and banding machines as a unit.

"Some cigars are banded only, while others are first banded and then wrapped in cellophane. However, the usual method now employed is to first cellophane the cigar and then band it" (Ref. 47, p. 1, 278).

## CHAPTER IV

### CHANGES IN MECHANIZATION:

#### NON-MANUFACTURING INDUSTRIES

MECHANIZATION tendencies in the non-manufacturing industries vary widely in type, cause, rapidity of change and effect. Mechanization on the farm has depended in large part upon the gasoline engine; in the home, upon the electric motor. Evolution has been in the direction of larger units in the railroad locomotive, the freight car, the paving mixer, and the farm tractor in the dry farming areas, but towards smaller tractors, for example, in row-crop farming areas. In building construction, the trend to steel and cement involves the use of materials made under more highly mechanized conditions and requiring more machinery in erection. In coal mining, on the other hand, there has been little change in the work to be done but rather an adaptation of mechanical equipment for established procedures. The labor-saving qualities of the harvester-thresher combine are felt directly in the harvesting process; those of the pulverized coal system in power production indirectly in the decreased amount of coal that must be mined. Declining traffic has stimulated the adoption of the one-man street car; the expansion of cement highway construction has encouraged the contractors to make investments in central proportioning plants, larger pavers, finishing machines, and motor truck haulage. Legislation has favored the introduction of the mechanical stoker on railroad engines but discouraged the use of the spray gun in painting. In mining, the undercutting

machine is near the saturation point; the mechanical loader is just getting a good start. The total number of telephone operators has increased despite the spread of the dial telephone; also the employment opportunities for licensed motion-picture operators have increased with the introduction of the sound movie; but, on the other hand, this innovation has sharply reduced employment opportunities for theater musicians. The sound movie brought a swift and revolutionary change in the methods of providing theater music; but the mechanization of railway maintenance has proceeded slowly and without major alterations in maintenance procedure. The printer telegraph has tended to displace the skilled Morse operator; but improved handling devices in bituminous coal mining, building construction and retail coal distribution, and likewise improved equipment in highway construction, are in large part competitive with the unskilled workman. Mechanization in the mine has limited somewhat the traditional independence of the coal miner's working habits and lessened his isolation; in the home and on the farm the increased use of machinery has lessened the necessity of employing hired workers and hence increased the isolation, and, in a sense, the independence with which the housewife and farmer carry on their work.

These examples are but illustrations of the variety of mechanization movements briefly described in the following summaries.

#### AGRICULTURE <sup>1</sup>

We may conveniently distinguish hand-power, horse-power and mechanical-power stages in the development of agriculture. The hand-power stage lasted until about 1850.

<sup>1</sup> The volume of annual sales of selected types of farm machinery is given in Table 39; and summaries of available information on extent of

Then the introduction of such horsedrawn implements as the steel plow, the reaper, mower, and corn planter, together with the post-Civil War expansion of agriculture, carried us swiftly into the horse-power stage.<sup>2</sup> About 1910 the use of generated power on farms became sufficiently important to justify the designation of the succeeding decades as the mechanical-power stage.<sup>3</sup>

It has been estimated that the total power of all kinds in use in agriculture increased from 1.32 horsepower per agricultural worker in 1849 to 2.52 in 1909, and 4.74 in 1923, at which time animals were contributing about 42 per cent of the total power, windmills 1, gas tractors 17, trucks 15, stationary gas engines 14, steam engines 6 and electric motors 5.<sup>4</sup>

#### IMPORTANT DEVELOPMENTS IN THE MECHANIZATION OF FARM OPERATIONS

The key to the modern movement towards farm mechanization is the internal combustion engine. By it are pro-

use in Table 48. The sources of information are stated in the footnotes to these tables.

<sup>2</sup> For a description of the developments of mechanization in early agriculture in the United States, as well as some recent changes, see the *Monthly Labor Review*, Ref. 45.

<sup>3</sup> Though still the source of a large part of the power used, the number of horses and mules on farms fell from 26,436,000 to 19,476,000 in the years 1919-29. If we include the decline of horses in cities, the total decrease is still greater, with the result that many million acres of land formerly required to produce feed for work animals have been released for other purposes. W. I. King estimates that a shrinkage of six and one-quarter million work animals from 1920 to 1928 decreased the acreage required for production of feed by 21,000,000 (*Journal of Agricultural Economics*, January 1929, p. 71).

<sup>4</sup> The estimates in this paragraph are from C. R. Daugherty (Ref. 31, pp. 47, 54 and 71); his figures, in turn, are based chiefly upon estimates by C. D. Kinsman (Ref. 25).

pelled the farmer's auto, truck, tractor and many other machines. Motor trucks on farms increased from 139,000 in 1920 to 900,000 in 1930 and have altered the entire system of marketing livestock and other farm produce. Also the passenger automobile has been integrated into the farm system and a substantial part of its use may be charged to farm business. Automobiles on farms numbered 2,146,000 in 1920 and 4,135,000 in 1930. Other applications of the gas engine of large importance are the tractor and the tractor-drawn equipment of various types.

### *Tractors*

The tractor is essentially an automobile specialized for draw-bar or belt power rather than for speed. The number on farms in 1920 was 246,000, in 1925 it had increased to 506,000, and by 1930 to 920,000.<sup>5</sup> In the 'twenties the annual sales of tractors in the United States usually exceeded one hundred thousand machines.

The dollar value of power machinery sold compared with that of other types is presented in Table 6. The very important role played by gasoline tractors in the mechanization of farm operations is indicated by the proportion of the total value of farm implement sales that they constituted: over one-fifth annually from 1922 to 1928, and over one-third in the last three years of the decade. The influence of the tractor is also evidenced in the increasing percentage that tractor-drawn equipment is of the total for implements of the specified type. The percentages for tractor-drawn mold-board plows, disk plows, listers, grain drills, cultivators and

<sup>5</sup> The statistics on automobiles, motor trucks and tractors are from the 1930 *Census of Agriculture*, Vol. II, Pt. I, p. 2, and are expressed to the nearest thousand.



TABLE 6

CHANGES IN PROPORTION OF POWER FARM EQUIPMENT SOLD<sup>1</sup>

*Dollar value of engine-power equipment expressed as a percentage of combined sales of hand-power, horse-power and engine-power equipment of same type*

TYPE	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929
Gas tractors (percentage of all farm equipment)	34.3	<sup>2</sup> 23.5	20.5	26.6	27.2	28.8	33.6	30.5	33.9	
Tractor-drawn										
Moldboard plows	50.8	36.7	47.0	31.9	34.1	40.6	39.6	50.1	56.2	65.6
Disk plows	76.0	75.3	64.4	58.4	66.2	71.0	69.5	84.2	85.3	83.2 <sup>3</sup>
Listers	14.2	13.6	16.3	6.4	15.3	15.5	26.7	45.8	34.9	<sup>4</sup>
Grain drills	2.3	4.0	5.3	1.8	0.6	2.6	5.6	13.9	17.7	30.7
Cultivators	<sup>2</sup>	2.2	2.5	2.5	<sup>2</sup>	1.9	3.1	8.3	9.9	16.6
Disk harrows	47.3	52.7	46.1	39.9	48.1	47.8	48.8	53.1	54.9	60.5
Corn shellers	<sup>2</sup>	83.5	81.4	82.8	82.3	83.7	77.0	80.7	84.4	82.8
Hay presses	75.8	70.9	80.4	74.6	78.0	79.9	81.2	79.8	82.3	84.4
Feed grinders and crushers	93.5	97.2	95.9	92.7	89.2	98.2	96.9	97.0	98.4	98.6
Cream separators	<sup>2</sup>	<sup>2</sup>	6.8	5.2	2.1	7.4	6.1	6.5	7.4	<sup>4</sup>
Spraying outfits	<sup>2</sup>	42.9	76.6	62.0	60.2	54.7	63.8	67.3	67.6	69.0
Combines (percentage of all harvesting machinery)	11.7	26.8	16.3	11.3	17.0	14.2	33.2	41.9	49.8	51.9

<sup>1</sup> Computed from data given in the publications listed in footnotes to Table 39.

<sup>2</sup> No data available for these years.

<sup>3</sup> Not including 'one-way disk tillers' which were reported in 1929 for the first time.

<sup>4</sup> Comparable data not available.

disk harrows all reach their maxima in the closing years of the decade.

Tractors were first used extensively in the great wheat-growing areas, but later the development of lighter and more easily manipulated tractors has encouraged their introduction into the more humid area of the Corn Belt. Not

only are they used for plowing with multiple-bottom plows, but also various processes of seed-bed preparation are now combined with the plowing proper. A large tractor may draw a disk harrow, pulverizer and grain drill all in one operation. Also there is a marked tendency towards an increasing use of tractors suitable for both soil preparation and cultivation. And in order to make the cultivator equipment for tractors approach the capacity of a machine capable of doing the heavier draw-bar work, three- and four-row cultivators are now regularly on the market.

#### *Harvester and thresher combines*

The combine for cutting and threshing grain in one operation was first developed as a harvester of wheat in the Pacific slope region of the United States. Skepticism as to its usefulness in the more humid hard winter wheat area was not demonstrably overcome until 1917. One-half of the wheat in this area was so harvested in 1927,<sup>6</sup> and more combines were sold in the next two years than ever before. The use of the combine has spread from the Pacific Coast to the Atlantic, and its applications have increased with its territorial range. While it has long been utilized to some extent for the harvesting of wheat and other small grains, it has more recently been adapted to clover seed and soybean threshing. However, in the Corn Belt and other livestock-producing areas only a small percentage of the small grains is harvested with combines.

The sales of combines ranged from less than 3,000 in 1920 to nearly 20,000 in 1929; and the ratio of the dollar value of combines to the value of all harvesting machinery

<sup>6</sup> W. E. Grimes, *Journal of Farm Economics*, January 1928, p. 226.

sold ranged from less than 12 per cent in 1920 to over 50 in 1929.

### *Cotton-crop machinery*

In the cotton regions, particularly the uplands of Texas and Oklahoma, the increase in the acreage a man can cultivate with a tractor is effecting a revolution in crop growing. Whereas 10 to 20 acres of cotton is the family-sized crop in the older cotton area, one man with modern machinery can prepare the soil, seed and cultivate as much as 200 to 250 acres of cotton in this upland area. Hand picking has also been a limiting factor in cotton growing. Since cotton can be left on the stalk until the entire crop matures only in the dry upland area, it is there alone that mechanical picking has met with any substantial degree of success. The cotton sled or stripper, a device which is drawn through the field and combs the cotton boll from the plant, has been used most extensively when prices were low. It "harvests cotton six or seven times faster than can be done by hand picking, and gathers a large per cent of the cotton." † When the broken bolls and other trash are removed by special ginning processes the value of the cotton is only slightly less than when it is picked by hand. There has also been some experimental use of mechanical cotton harvesters of the picker type.

### *Corn-crop machinery*

Corn is usually planted in rows and cultivated with horse-drawn one- or two-row cultivators, although three- and four-row cultivators are on the market for use with light 'all-

† D. L. Jones, *et al.*, *Mechanical Harvesting of Cotton in Northwest Texas*, Circular No. 52, Texas Agricultural Experiment Station, p. 31.

purpose' tractors adapted to row cultivation. Possibilities of further labor saving are seen in the rotary hoe,<sup>8</sup> which may be used under favorable soil conditions, that is, in soils free from stones, to cultivate corn to a height of 6 to 9 inches. This eliminates the tedious early plowing which is difficult with multiple-row cultivators. The combination of 2 or 3 units drawn by a tractor cultivates as much as 75 acres per day with one operator.

The greater part of the hand labor required in the production of corn is in the snapping or husking of the ripened ears. Machines for this purpose have been available for many years but the early types obtained their power from the forward movement of the machine as it was drawn through the field, the power being transmitted to the husking apparatus by the revolution of a lug-wheel in contact with the ground; consequently their use was difficult when the fields were slippery. Since the perfection of devices to transmit power from the tractor to accessory machines the performance of the picker has been more satisfactory. One type is dragged behind the tractor, the other is so constructed as to be fitted onto and be carried by the tractor. The picker is still little used but was gaining prior to the depression of 1929.<sup>9</sup> It has not been adopted more extensively in part at least because a certain percentage of shelling is unavoidable when the machine is used, not all the ears are picked if the corn stalks are 'down', and the stalks are left broken over in

<sup>8</sup> This tool consists of one or more rows of pronged wheels on a common axis, the prongs perforating the ground and stirring it to a depth of 1 to 3 inches, depending upon the condition of the soil. The teeth are small and so set that almost no damage is done to small growing crops but the weeds are destroyed. It can also be used to cultivate soybeans drilled broadcast. Rotary hoes were used for most of the cultivation on 4.3 per cent of Illinois farms included in a survey made in 1928 (see Appendix B).

<sup>9</sup> In 1928 mechanical corn pickers were used on 11,000 Illinois farms, or 4.9 per cent of those over 50 acres in size.

such fashion that deterioration is more rapid in bad weather and hence the fields are less valuable for stalk pasture in the livestock areas.

#### *Other labor-saving equipment*

Farm machines are now manufactured in almost endless variety. While those previously described seem to be the major recent innovations, others are very definitely labor saving in the sense of being substitutes for hand labor. Potato-digging machines are now being combined with a grader and bagger. Farm water systems, farm lighting plants, and feed and litter carriers are all important elements not only in the saving of labor but also in increasing the amenities of farm life.<sup>10</sup>

#### *Rural electrification*

The gas engine is the principal source of power in farming operations, but with the growing availability of electricity the electric motor is gaining in importance, especially for use with labor-saving devices in farm homes and barns. It has been estimated that the percentage of farms electrified rose from 1.9 in 1924 to 10 in 1930.<sup>11</sup>

#### FARM CONDITIONS, 1920-29

After the decline from the War-time level, the prices of agricultural products were at substantially lower levels than those for non-agricultural, taking pre-War conditions as a

<sup>10</sup> Data on the annual sales of some of these devices are presented in Table 39; and memoranda on the extent of their use, in Appendix B.

<sup>11</sup> Based on estimate that 125,000 farms were wired for electricity by 1924, and 650,000 to 700,000 by January 1930; *Farm Implement News*, December 19, 1929, p. 22.

standard. Agricultural depression was accompanied by a large migration of the rural population to the cities until this urban movement was checked by the 1929 recession in industry. The farm population is estimated to have fallen from 31,000,000 on January 1, 1920 to 27,222,000 on January 1, 1930. The natural increase due to excess of births over deaths is greater in the rural regions; but the annual net loss due to migration from farms to cities, 1922-30 inclusive (exclusive of 1923 for which comparable figures are not available), was about 700,000.<sup>12</sup> Exactly how much of the urge cityward may be ascribed to conditions for which mechanization on the farms is responsible may be a moot question; but at least it is clear that the rapid exodus from the rural regions favored mechanical substitutes for manual labor.

#### TENDENCIES

Since the use of the tractor became extensive the development of power machines has tended towards, on the one hand, larger and larger units, and, on the other, lighter and smaller units. The rapid adoption of the all-purpose tractor in the areas of row-crop cultivation is an important illustration of the latter tendency. The further development of rotary power by power take-offs from the tractor, such as are now used for binders, combines, corn pickers and mowers, seems probable.

The conditions created by the industrial depression of 1929 will doubtless sharply check the progress of farm mechanization, although, once initiated, there is a certain momentum to the mechanization process. The farmer who owns a tractor finds potent arguments for supplementing it with tractor-drawn tools in order to utilize better his entire equip-

<sup>12</sup> *Yearbook of Agriculture, 1931, p. 1031.*

ment. The greater use of the multiple-row tractor-powered cultivators, the combine, the farm-size grain separator and the corn picker may be considered as phases of this process of integration. Moreover, since hired men customarily live with the farmer's family, the farmer may prefer to use more machinery rather than take outsiders into his home.

## MINING

### BITUMINOUS COAL MINING

The percentage of bituminous coal obtained by strip mining rose from 1.2 in 1919 to 3.8 in 1929.<sup>13</sup> The coal is made available by the removal, by means of power shovels or similar appliances, of the entire surface overlying the vein. In underground mining, mechanization developments of interest are in the process of undercutting the coal prior to blasting it down, in loading the coal from the mine floor to the pit cars, and in gathering and transporting these cars to the surface.

Statistics of 'machine mined' coal usually refer to the percentage undercut by machine, even though the coal is subsequently loaded by hand. The undercutting machine is not a recent innovation. Its manufacture for sale began in the United States about 1880, and as early as 1891 there were 545 in use, cutting 5.3 per cent of the bituminous coal mined. By 1900 this percentage had risen to 24.9, by 1920 to 59.8, and by 1929 to 75.4. There has been, likewise, an increase in the annual tonnage per machine, from 11,328 in 1891 to 24,224 in 1928.

This increase in the mechanization of the undercutting process doubtless accounts in part for the increase in tonnage

<sup>13</sup> Unless otherwise stated, the statistics cited in this section are compiled from reports of the *Geological Survey*.

per man-day in the bituminous mines from 2.57 in 1891 to 4.85 in 1929, despite shorter hours. Since nearly three-quarters of the total tonnage of bituminous coal is now undercut by machine and its use is not economically advisable in all mines, prospects of further substantial reduction in the labor requirements lie in the loading rather than in the undercutting process.

In the typical bituminous mine, the coal, after it has been broken down, is shoveled by hand into small mining cars and drawn into the heading, where it is picked up by mule or electric motor. This heavy manual work of loading coal has been described as "the most widespread form of drudgery existing in industry today", and the major current developments in coal mine mechanization are in the way of substituting mechanical for manual loading.

Some types of mechanical loader are self-feeding; others require mechanical shoveling to the lifting and car-loading conveyor.<sup>14</sup> The development of the various types of mechanical loader is the result of experimentation which began over forty years ago. Attainment of a recognized commercial status has been slow, although much more rapid in recent years. Two or three types of loading device introduced as early as the period 1908-11 have continued in use. The next period, 1912-17, is characterized by the introduction of conveyors and scrapers in thin and pitching seams. From 1918 to 1923 developments were along various lines and a "great number of mechanical loading devices were improved to the extent that they could be commercialized". In the four following years interest in mechanical loading increased markedly and a noteworthy stage was reached in September 1928 with the signing of the wage agreement in Illinois, as

<sup>14</sup> For description of the various types of loader and statistics on extent of use, see the *1929 Coal Mine Mechanization Year Book*, Ref. 2.



this was "the first state contract that dealt with mechanical loading devices and made it possible for the operators to negotiate local agreements covering working conditions". A state agreement was likewise made in Indiana in November 1928.

The tonnage of bituminous coal loaded by self-feeding loading devices increased from 1,880,000 in 1923 to 19,291,000 in 1929. With similar rapid increases in the tonnage handled by non-self-feeding loaders, the volume of mechanized loading, including both types, increased from approximately 2,000,000 tons in 1923 to 37,862,000 tons in 1929.<sup>15</sup> Obviously, the statistics of the growth of mechanized loading are impressive, not so much in the total volume attained as in the rate of growth in recent years.

Mine cars are hauled by locomotives, chiefly of the electric trolley or storage battery types, by power cable hoists, mules and horses, and, to a minor extent, by hand power. Hand and animal haulage is chiefly in the initial stages of gathering. The principal device in the typical mine, especially for the longer hauls, is the electric industrial locomotive, capable of handling rapidly a considerable train of mine cars.<sup>16</sup> Messrs. F. G. Tryon and L. Mann, of the Coal Division, United States Bureau of Mines, state that "in the field of haulage, mines equipped with one or more electric locomotives now supply 85 per cent of the output, and 33 per cent is produced by mines in which even the gathering is done electrically and no animals whatever are employed".<sup>17</sup> Some additional mech-

<sup>15</sup> *Mineral Resources* (Ref. 32), 1929, II, 758-9. In 1929 the number of mechanical loading devices in bituminous coal is given as: mobile loading machines 488; scrapers 126; duckbills and other self-loading conveyors 99; pit-car loaders 2,521; other conveyors, in 130 mines (*ibid.*, p. 764).

<sup>16</sup> For annual sales of electric mining locomotives, see Table 47; for extent of use, see Table 53.

<sup>17</sup> Ref. 2, p. 21.

anization in haulage is to be expected, especially with the further development of mechanized loading.

#### ANTHRACITE COAL MINING

Undercutting machines were introduced into the anthracite area as early as 1910, but, because of the thin and variable veins, their use has not become nearly as extensive as in bituminous coal. In 1929, the 137 machines in use cut only 1.6 per cent of the coal. On the other hand, interest in loading coal mechanically from the face appears to be growing. The depletion of the thicker seams has, in fact, stimulated the use of mechanical loading devices, of which the scraper and conveyor types have proved most valuable. Mr. H. D. Kynor reports that in the Pennsylvania anthracite field in 1928 there were 293 scraper units, 184 conveyor units and 13 loading machines, loading mechanically over 2,000,000 tons, or about 3 per cent of the total output (Ref. 2). In addition, 3.4 per cent was mined by stripping with power shovels.

#### METAL MINING

The decade 1920-29 has seen substantial increases in output per man-day in the metal mines. An examination of the technical literature of metal mining indicates that these gains in productivity are the result, not of a few sweeping changes, but of a steady stream of minor improvements. Probably, however, the chief labor-saving changes in the period have been those which reduced the amount of hand mucking or ore loading either by changing the methods of mining so as to take more advantage of gravity in removing the ore from the working face or by the substitution of mechanical loading devices for hand mucking. Also, in open-

pit mining electric shovels have been extensively substituted for steam-driven shovels, and more caterpillar mounting used.

Van Barneveld records the introduction of some mechanical loading devices into metal mines as early as 1912, but until the War and post-War years brought a coincidence of a large demand for ore and a relative shortage of labor, especially unskilled, mechanical loading did not receive extensive attention. In the decade of the 'twenties it made substantial progress.<sup>18</sup> The introduction of mechanical loading has been most rapid in the eastern half of the country, notably in three districts: the southwest Missouri lead district; the Birmingham district of Alabama; and in the Lake Superior iron districts. In the Minnesota iron mines open-pit mining is almost entirely mechanized, and even in the underground mines, according to Mr. Tansig, "hand shoveling or mucking the ore into cars is a thing of the past in most mines, loading into cars and chutes being done by slushers or scraper loaders."<sup>19</sup> In the Michigan copper mines also "the employment of mechanical loaders and scrapers has replaced shoveling in large measure".<sup>20</sup>

#### BUILDING CONSTRUCTION

The construction industry is one of the last strongholds of the traditional handicrafts. The transition from hand to machine methods was later in getting under way than in manufacturing and has reached a less advanced stage. There was, in fact, no substantial movement towards mechanization

<sup>18</sup> See Ref. 22, p. 396; and Lucien Eaton, *Mechanical Loading in Metal Mines in 1929*, in *Mining Congress Journal*, July 1929, pp. 536-7.

<sup>19</sup> *Iron Age*, 122:1430-1, December 6, 1928, *Mechanizing Minnesota Iron Mines*, digest of a paper by A. Tansig.

<sup>20</sup> U. S. Bureau of Mines, Ref. 30, based upon data collected in 1927.

in the building industry until the present century.<sup>21</sup> The subsequent evolution and expansion of the industry has been accompanied by mechanization along three major lines: (1) the use of materials produced under more highly mechanized conditions than were the older materials; (2) an increasing amount of mill and shop preparation before the material reaches the job; (3) an increasing use of power equipment in the actual erection.<sup>22</sup>

One outstanding development underlying the three tendencies mentioned has been the increase in the height of buildings, necessitating the extensive use of hoisting machinery for construction operations and requiring materials whose preparation and erection is in other respects a more highly mechanized process than is involved in the traditional lumber, brick and stone structure.<sup>23</sup> Cement and steel are essentially machine industries; also their competition for the building trade has probably stimulated mechanization tendencies in the industries producing the older types of material.

#### INCREASE IN PRELIMINARY SHOP WORK

With the shift to steel and other substitutes for lumber, much of the material that goes into a building comes to the job more nearly ready for installation than does wood. The

<sup>21</sup> Aside from information obtained in our direct inspections of construction operations and from manufacturers of construction equipment and others familiar with the industry, the major source of information for this section is the scholarly treatise on *Industrial Relations in the Building Industry*, by William Haber, Ref. 13.

<sup>22</sup> For further discussion of these points, see Haber, Ref. 13, pp. 24-35, 45.

<sup>23</sup> This increase in the height of buildings has been dependent largely upon the use of structural steel skeletons, the development of the power elevator, particularly the electric elevator after 1890, the invention of the pneumatic caisson method to facilitate the sinking of foundations adequate

work on structural steel beams, metal window frames, etc., is largely done in the shop; and even when wood is used there is an increasing tendency towards standardized forms prepared in the mill or shop with more mechanical aid than is ordinarily available on the erection job. Likewise, the invasion of the stone-planer not only displaced skilled stonecutters using chisel and hammer but also shifted the work of preparing stone more largely to the quarry. "From 1895 to 1900 they [stone-planers] were rapidly introduced in the Bedford limestone region, and by 1915 they had become a necessary part of stone-working equipment in all parts of the United States."<sup>24</sup>

#### MECHANIZATION ON THE JOB

On the erection job itself, though much of the work is still done by hand, there have been, since the beginning of the century, many increases in the use of mechanical equipment. In the excavation of basements, the power shovel has largely displaced the hand pick and shovel on the larger jobs and in the quantity production of houses such as is sometimes seen in suburbs, and has become a familiar sight on smaller excavation jobs. The development of the small, full-revolving type with caterpillar tread has made it possible for the shovel to do work for which it was formerly not well adapted. The caterpillar tread and the increasing substitution of gasoline and electric shovels for steam are relatively recent developments.<sup>25</sup>

for higher buildings, and the development of reinforced concrete as a cheaper substitute for much of the steel required in the steel skeleton building as first developed.

<sup>24</sup> Barnett, Ref. 3, p. 31.

<sup>25</sup> Of 49 contractors who reported their labor-saving changes to us in the period 1920-25, 5 had replaced wheel-tread shovels with the caterpillar tread type, 2 of these replacements being the gasoline type for steam. The gaso-

The growing popularity of the contractors' sizes of power shovels is indicated by increases in the annual sales of a group of manufacturers who were producing as early as the first decade in the century. They sold 485 in the first decade; 2,715 in the second; and over 4,000 in the next five years (Table 41).

In the erection of steel girders, derricks and power hoists are essential; also hand riveting has given way to the pneumatic riveting machine, invented in 1898. A pneumatic device has been tried for passing the hot rivets from the heater to the riveter (they are customarily tossed up) but does not seem to have been adopted generally. Also, electric welding has begun to supplant riveting on steel work.

The power hoist—steam, gasoline or electric—has come into extensive use for elevating other materials as well as steel to the upper parts of the building; and has largely, though by no means completely, taken the place of the hod carrier in brick construction. Hand lift-trucks have also been used to lighten the labor of the hod carrier.<sup>26</sup>

In cement construction, the power-driven concrete mixer has practically displaced hand mixing. Furthermore, on

line motor, it was suggested, obviated the necessity of laying a water pipe and 'getting up steam' an hour beforehand every morning. One contractor estimated that caterpillar tread and a gasoline motor increased efficiency 30 per cent over the old shovel; another that a higher lift and caterpillar treads increased the efficiency of his shovel 25 per cent; and another that, in general, the efficiency of the excavating shovel had been increased about 15 per cent since 1920 by the substitution of caterpillar treads for wheels and gasoline motors for steam.

<sup>26</sup> In the small group of 49 building contractors reporting labor-saving changes to us, 7 reported changes or additions in their hoisting service, usually reducing the crew a man or two by substituting gasoline or electric hoists for steam-driven hoists. Only one reported a direct substitution of a gasoline hoist for hod carriers; he estimated that the hoist would take the place of from 3 to 10 men, depending upon the height material was to be lifted.

many concrete construction jobs the mixture is mechanically dumped from the mixer to distributing tower hoists which elevate it to the upper part of the structure in process; it is then gravity-fed through chutes to the cement forms.

Also a machine for mixing lime-and-cement mortar has been introduced. In floor finishing, "for surfacing hardwood, terazzo, marble, tile, cork, composition and many other types of flooring, power surfacing machines have so completely demonstrated their superiority that they are today almost universally used." The compressed-air paint-spray gun and the plaster gun are invading the painting and plastering fields respectively. "The spray is used extensively in rough work and, where the union does not control, for general painting." The rapidity of its introduction has been retarded somewhat by doubts concerning the quality of the work done and by some state legislation restricting its use on health grounds.

#### LABOR-SAVING CHANGES REPORTED BY CONTRACTORS

To obtain data concerning changes over a specific period of time is unusually difficult in the case of contracting operations. The scene and type of operations shift, the staff personnel changes, records are negligible, the memories of foremen and other executives are none too certain, and their attitude towards 'investigations' often indifferent if not suspicious. However, our inspectors did obtain statements from 49 contractors on the 100 construction operations surveyed, giving the labor-saving changes, if any, made in their methods of operation between 1920 and the time of inquiry in 1925.<sup>27</sup>

<sup>27</sup> Of these 100 inspections 47 were in New York City and other parts of New York State, and the balance were distributed in Connecticut, New Jersey, Pennsylvania, West Virginia, Baltimore, Richmond, and the Middle West, in the spring and summer of 1925. More effort was made to get samples of operations involving excavation than for the later stages of erec-

These reports, we believe, understate the changes actually made, but they serve to indicate what came to the minds of a group of builders when questioned concerning labor-saving changes in the years immediately following 1920, and, taken in connection with the more general discussion above, help to indicate the nature of developments in the early part of the decade. We have previously noted reported changes in the use of power shovels and hoists. One contractor had added belt and bucket conveyors in excavation work which had cut the labor requirements 10 to 25 per cent. The substitution of a gasoline-motor crane for a steam crane saved one man on the crew. Three contractors mentioned the acquisition of air compressors and pneumatic tools for drilling, trenching and pavement-breaking jobs, to take the place of hand tools, one estimating that 3 men operating the engine and drills did the work of from 12 to 15 men. An increase in the use of small concrete mixers was reported, and substitutions of gasoline for steam power with mixers. One contractor had purchased mortar-mixing machines for all brick-laying crews. Others reported labor savings through the use of motor trucks in place of teams or trucks with larger wheels to enable more efficient operation in wet weather. Three contractors mentioned the purchase of gasoline-power saws for cutting rafters, planing, matching, and miscellaneous cutting. Two had purchased sanding machines for floor finishing, one estimating that with the machine the labor time required for finishing hardwood floors was reduced more than half. In some instances these machines were owned by the dealers in materials rather than the erecting contractors. One con-

tion and finishing; and 21 of the inspections cover excavation, trenching and earth handling only; 30 cover foundations or foundations and excavation; 45 cover various stages of erection and finishing residences and other types of buildings; and the remaining inspections include subway, curb and sidewalk construction, and street repair.



tractor ascribed labor-saving qualities to patent mortars; another, to metal closet partitions. In steel erection, one contractor reported having tried a pneumatic rivet passer from forge to hammer-men but found it impractical. Others made general statements of increased use of machinery in the five years; but 27, or over half of the group reporting, disclaimed having made any labor-saving changes in this period, one remarking "I have not bought a new machine for 10 years."

#### RURAL HIGHWAY CONSTRUCTION

The history of the development of mechanization in the highway industry is largely a recital of the displacement of animal power by mechanical power. In the grading operation, more or less common to all types of road, the horse-drawn scraper has given way on many jobs to the power shovel and the elevating grader, and the truck has partly displaced the horse in hauling away the excavated dirt; in the haulage of materials to the paving crew, the horse-drawn wagon has been almost entirely displaced on the larger jobs by the industrial railway and, to an even greater extent, by the power truck; and the old method of dumping paving materials on the subgrade and delivering them to the mixer by wheelbarrow has given way to centrally-located proportioning bins from which the delivery trucks are loaded and which in turn dump their load directly to the mixer. In the paving process proper, the subgrader, the power mixer, and the mechanical finishing machine have come to dominate.

#### GRADING EQUIPMENT

The power shovel was first utilized in road work about 1910, its success resting chiefly on the development of the full revolving type and of small portable units of from  $\frac{5}{8}$

to 1 cubic yard capacity. It was still hampered by a lack of full portability on the job, however, and its use increased but slowly until the adoption of the caterpillar type of tread about 1920. A canvass of grading contractors in fifteen states in 1926 indicated that the caterpillar tread had made the power shovel much more adaptable to road work. Since 1926 its relative use has advanced still further. It is most effective where heavy cuts are necessary.

The elevating grader is simply a loading device, combining in one operation the loosening and loading of the earth.<sup>28</sup> It may be drawn by either horses or tractors, and is especially adapted for use in long and relatively shallow cuts through rockfree soils. It first made its appearance on highway work in those states just west of the Mississippi to whose soil it is particularly adapted. Confined to this location for several years, it began to spread about 1921 and has since appeared in numerous states east of the Mississippi.

Of 48 grading jobs inspected by us in 1925, power shovels were in use on a dozen, elevating graders on 20, and scrapers on the remaining one-third. At that time horse-drawn wagons were still extensively used in hauling away the excavated earth.<sup>29</sup> In more recent years a greater part of haulage is by motor truck and tractor.

<sup>28</sup> A disc plow, mounted on a heavy four-wheeled frame, turns its furrow onto a belt conveyor, which is operated by the turning of one of the wheels. The conveyor elevates the earth to the proper height and dumps it into the horse-drawn wagon or motor truck which follows alongside the grader.

<sup>29</sup> Only one of the 16 scraper outfits was mechanically powered. Of the 20 elevating grader outfits, 5 were drawn by horses and served by horse-drawn hauling equipment; 13 were power-operated but likewise served by horse-drawn hauling equipment. Of the power shovel outfits all but one were served by horse-drawn hauling equipment.

## PAVING EQUIPMENT

In the paving process for cement-concrete surfacing, the principal items of equipment are the subgrader for finishing the grade to the appropriate degree of smoothness before spreading the concrete; the paving mixer; the finishing machine, and tractors for hauling the subgrader and other machines. The subgrader came into use in 1922, and was rapidly adopted throughout the paving industry so that by the middle of the decade it was employed on most paving jobs.<sup>30</sup>

The specialized type of power concrete mixer adapted to paving purposes was first evolved about 1910; it came gradually into use, and at present is found on all large paving operations. The tendency in the development of pavers has been in the direction of a large increase in capacity, made possible by the use of caterpillar treads which, first introduced in 1918, had, in a few years, almost replaced the wheeled mixer. On most of the jobs inspected in 1925, the pavers in use were the 21E or 5-sack capacity. By 1926 both the sales demand of the manufacturers and the expression of opinion on the part of the contractors from whom we made inquiry indicated a growing preference for the 27E 6-sack paver, and it has subsequently become the standard size in use.<sup>31</sup>

<sup>30</sup> This machine is rather heavy and consists of a truck on four small wheels which use the side forms as tracks. Mounted on the under part of the truck are adjustable blades, which, as the machine is dragged along the steel forms, cut the subgrade to the exact elevation desired, leaving the excess earth in windrows to be shoveled out by hand. As the machine itself carries no engine, it must be hauled either by truck or tractor.

<sup>31</sup> It has been found practicable not only to increase the size of the batch used with the 27E, but also to shorten the mixing time. See report by T. C. Thee, Assistant Highway Engineer, U. S. Bureau of Public Roads, in *Public Roads*, January 1932, pp. 269-89.

The finishing machine, for shaping the surface of the concrete, was put on the market about 1916. Its first extensive use was in Illinois in 1917; from then on the increase in its use was rapid, and in 1925, at the time of our field inspections, only two or three states still required hand finishing.<sup>32</sup>

In 1926 we inquired of state highway departments concerning the causes of increased productivity in paving operations. Of 28 replies received, all but one cited the use of larger pavers, and all but 6 better methods of hauling materials as either first or second in importance. Opinion voiced at that time by representatives of several of the states that were active in building roads, and supported by subsequent studies by the Bureau of Public Roads, indicated the improvement in efficiency of the paving-crew organization afforded a real opportunity for further increases in output.<sup>33</sup>

#### CENTRAL PROPORTIONING

About 1920, specifications of many states were revised so as to prohibit the practice of dumping materials on the subgrade and wheeling in barrows to the paver.<sup>34</sup> In addition,

<sup>32</sup> Reports from 27 state highway departments in 1926 indicated that machine finishing predominated in 11; in 9 both machine and hand finishing were used; and in 7 hand finishing predominated. Of 23 contractors reporting on their use of the machine, 7 had used it for the first time in 1924 and 1925. It was in use on 32 of 39 paving operations inspected by us in 1925.

<sup>33</sup> See J. L. Harrison, *Efficiency in Concrete Road Construction*, *Public Roads*, March 1926.

<sup>34</sup> In the older method the material for a concrete highway was loaded on dump wagons or trucks, hauled to the job, and dumped on the subgrade in approximately correct quantities for the distance between piles. From these piles, a crew with wheelbarrows proportioned and loaded the material to the mixer skip. In the central proportioning-plant method, the materials are concentrated at a single place called the proportioning plant,

a more accurately proportioned batch was demanded. The resulting transition from wheelbarrow proportioning to the central proportioning bin has both reduced the crew required and greatly increased the pavement yardage the contractor can lay in a day. Highway officials and contractors estimated that about 25 per cent had been saved in labor by the new process while yardage increases averaged about 50 per cent.

#### LABOR-SAVING CHANGES REPORTED BY CONTRACTORS

The contractors engaged on the highway construction jobs inspected by us in 1925 were asked to state what labor-saving changes they had made since 1920.<sup>85</sup> Of the forty-seven changes reported, 10 were for the grading phase. These included the substitution of a power shovel for a steam roller and scarifier in tearing up the old surface; of tractor and trailers for horse-drawn wagons in earth haulage; of tractor and scraper for team and scraper; of tractor and blader for horse-drawn wheelers; of power blader for horse-drawn blader in rough grading (3 instances); and of power shovel and team haulage of earth for wheelers and bladers. In the haulage of paving materials, trucks displaced wagons in 4 instances, industrial railways displaced trucks in 2, and 7 contractors substituted central proportioning plants and direct

in stock piles and storage sheds. A portable power crane is used for unloading sand and gravel, building stock piles, and keeping the proportioning bin filled. The bin delivers by gravity automatically-proportioned batches of sand and gravel to the transporting units.

<sup>85</sup> These sample inspections included 61 operations of various types in 5 middle western states then active in highway construction (Illinois, Iowa, Minnesota, Missouri, and Wisconsin) and 5 in eastern states. To supplement the field inspections, inquiries were made by mail of equipment manufacturers, state highway departments, and highway contractors.

dump to the mixer for wheelbarrow handling from roadside dumps.<sup>26</sup>

About half of the total labor-saving changes reported were in the paving operation. They consisted in the substitution of horse-drawn or power-drawn subgraders for hand methods (8 instances), of finishing machines for hand strike boards (7); the use of larger pavers in 3 instances; and 4 changes in the curing system, chiefly in the way of chloride spreaders for hand spreading. Two contractors mentioned saving labor through the substitution of form-line trenchers for hand trenching.

#### STEAM RAILWAYS

Mechanization in the steam railways has proceeded along divers lines. Among the noteworthy developments in the operation of trains we may mention the greater size of locomotives and freight cars, the further installation of automatic locomotive stokers, the partial transition to electric and oil engines and the increasing use of automatic devices and methods in train control.

#### IMPROVEMENTS IN CARS AND LOCOMOTIVES

In 1929, as compared with 1920, the average locomotive was more powerful by some 23 per cent; the average capacity of freight cars had increased from 42.4 to 46.3 tons; on the average more cars were hauled in one train and the average speed had increased from 10.3 to 13.2 miles per hour; and, largely as a result of these several factors, the gross ton-miles per freight-train-hour increased from 14,877 to 24,539. With

<sup>26</sup> All but one of the changes from the old wheelbarrow method of handling paving materials were reported as made prior to 1923, indicating that this method had been rather generally adopted early in the decade.

longer and faster trains, fewer engine and train men are required to handle the traffic.<sup>37</sup>

The mechanical stoker for locomotives reduces the coal to the requisite fineness, conveys it from the tender, and distributes it in the fire-box, usually by steam jets. Its use makes the handling of more powerful locomotives feasible, lightens the manual work of the fireman, and reduces his exposure to extremes of cold and heat incident to the opening of the fire-door in hand firing. Commercial application of mechanical stokers began in 1910, and they were rapidly installed during the War period. In 1917, 1,611 of the leading makes were reported in service, and on January 1, 1919, 3,717. By June 1, 1924, 8,989 stokers had been applied to locomotives.<sup>38</sup>

The increase in the proportion of electric and oil-burning engines is altering the task of the locomotive engineman. By December 1930, the number of electric locomotive units in freight and passenger service on Class I roads had reached 618. The number of oil-burning locomotives increased slowly from 7,326 in 1924 to 7,472 in 1930 while the total number of steam locomotives was declining from 65,006 to 55,875.

#### AUTOMATIC CONTROL OF TRAIN OPERATION <sup>39</sup>

Labor-saving changes in the train control phase of railway operations have been especially rapid since 1921 and have materially affected the employment of Morse telegraphers.

<sup>37</sup> Annual data for these changes in equipment capacity and operating results are given in *Statistics of Railways, 1930*, by the Interstate Commerce Commission; and *A Review of Railway Operations in 1931*, by the Bureau of Railway Economics.

<sup>38</sup> Estimates in this paragraph are from various reports cited in *Railway Age*, 66:1705, and 79:533.

<sup>39</sup> This section is based largely upon an article in the *Monthly Labor Review*, Ref. 54.

The principal changes include (1) a continued encroachment of the telephone on the telegraph in the control of train movements; (2) "the elimination of operators by the substitution of automatic for manual block-signal systems;" (3) "the displacement of Morse operators and messengers in the handling of message traffic by typists as operators of printer telegraphs;" (4) "the economizing of labor in the control of train movements, by the development of remote control, especially in the form known as centralized traffic control." In 1908 only a small mileage (10,819) was controlled by the automatic block-signal system. By 1921, the mileage had risen to 38,544, and by 1932 to 63,531. In 1908 only 8 per cent of the mileage under manual block signals was under telephonic control. By 1921 the percentage had risen to 52, and by 1932 to 61.

In subsequent paragraphs we note the transition from the Morse system of telegraphy to the printer telegraph in commercial offices, news agencies and market quotation agencies. A similar transition has occurred on the railroads. As a result of this and the other technological changes affecting telegraphers, the total of railroad employees designated as "telegraphers, telephoners and towermen" declined from 27,226 in 1921 to 13,187 in 1929.

The number of crossing and bridge flagmen and gatemen decreased from 23,007 in 1924 to 19,835 in 1930, the decline being ascribable in large part to the installation at grade crossings of automatic signals of various types.<sup>40</sup>

#### TRACK AND ROADBED MAINTENANCE

The maintenance of way and structures department probably employs more unskilled labor than all the other depart-

<sup>40</sup> For description of these changes and their effect on employment of watchmen, see *Monthly Labor Review*, Ref. 53.



ments of a railroad together. For example, in 1922 track and roadway section laborers on Class I steam railways numbered 200,675, and extra-gang and work-train laborers 39,680.<sup>41</sup>

Data are lacking for a precise chronological statement of the progress in mechanization of maintenance of way operations. All we can do is to sketch briefly some of the mechanical devices that have been introduced and give such fragmentary information as is available concerning the extent of their use. Some of the devices mentioned were, in an experimental way at least, inaugurated before the War and post-War period. Maintenance of way operations may conveniently be classified as (1) transportation of the work crews; (2) ditching and drainage preparation; (3) tie renewal; (4) rail maintenance and renewal; (5) cleaning and weed control.

For decades, section crews transported themselves to and from the piece of track on which they were working on hand-propelled cars. After the invention of the gasoline engine the newer models of section cars were equipped therewith at the time of construction, and to many of the old hand cars an engine was added. Data from three manufacturers show annual sales of from 2,500 to 3,000 motor section cars 1914-27 (Table 41). By 1927 some 55,000 were in use, representing, it is estimated, about an 83 per cent motorization of the railway section car (see Table 54). This phase of mechanization has about reached the saturation point; that is, section crews are equipped with the motorized car in most instances where its use is advantageous.

<sup>41</sup>Maintenance jobs of such magnitude as to be beyond the scope of the section crew are done by these extra gangs, consisting largely of foreign labor recruited from employment agencies. On many railroads Mexicans are being employed for this work more than formerly; see Paul S. Taylor, *Mexican Labor in the United States: Chicago and the Calumet Region*, p. 32.

When rough labor was plentiful, hours long, and wages low, the ditching and ditch cleaning requisite for track drainage were done by hand; later by teams and scrapers; within recent decades, hand and team work have been largely displaced on the more extensive jobs by the steam ditcher and the ditcher-spreader. The latter machine "will trim the ballast, shape the subgrade, and at the same time dig a uniform ditch of standard cross-sectional area, the flow line of the finished ditch being on the same grade as the track."

A great deal of labor is required in tie renewal. On some roads tie renewal labor has been reduced some 5 or 10 per cent by various methods of treating ties to make them last longer. A power tie lifter has been devised to aid in unloading ties. For packing the ballast beneath newly-inserted ties the power tie tamper (pneumatic or electric) is coming to take the place of hand tamping with pick, shovel or tamping bar. The improved quality of the tamping is a chief factor encouraging its use.<sup>42</sup> "From statistics supplied by 12 roads (in 1927) it appeared that three of these roads were fully equipped with tamping outfits and that the other nine roads were increasing the number in use each year."<sup>43</sup> On the whole, however, the use of machines has not become general in tie renewal.

In weed control along the right of way, the hand scythe and brush hook is being displaced on much-traveled tracks by the power mower and disc weeder, operated from a moving railway car, and by various types of chemical, steam-jet, or oil-burner weed destroyers, mounted on motorized railway cars.

In ballast cleaning (necessary to maintain good drainage),

<sup>42</sup> Also, "eleven railroads, replying to a questionnaire in 1926, reported an average saving of 37 per cent over the cost of hand tamping."

<sup>43</sup> *Railway Engineering and Maintenance Encyclopedia* (3d ed., 1929), p. 182.

the old ballast is dug up, cleaned, and the cleaned ballast returned to the roadbed. Removing the ballast from between the ties is still a manual operation in large part, and formerly the cleaning was done manually with ballast forks. Now machines have been developed for power screening and for handling the ballast from between two lines of track and on the shoulders. There is also a rotary ballast sweeper, consisting of a steel brush equipped with a conveyor system, for removal of cinders and other surface dirt. Snow removal is largely motorized.

Other tendencies and equipment which have some bearing on the amount of maintenance of way labor are the increasing use of metal posts for fencing, and of spray guns in painting bridges and buildings, and the possibility of economizing the available supply of track labor by a reduction in the seasonal variation of track and structure maintenance. Such stabilization has long been under discussion but the monthly statistics of expenditure and employment on maintenance operations do not indicate that much has been accomplished.

#### *Obstacles to mechanization*

Despite the various labor-saving devices available after fifteen years or more of intensive development of mechanical devices for maintenance of way operations, the number of workers in the maintenance of way and structures department increased nearly 13 per cent from 1922 to 1929; the total of all other railroad workers in Class I railways declined slightly. The explanation is to be found partly at least in the fact that the increasing volume of traffic, together with heavier locomotives and cars, has thrown a greater burden upon the maintenance of way department. Furthermore, the use of the various devices mentioned is by no means uni-

versal. Mechanization has been retarded by the conservatism of railroad executives, arising from the very nature of railroad operations which tends to develop strong traditions in methods of organization and operation. Methods and equipment that have proved safe and workable for decades are changed reluctantly and slowly. One technical difficulty is that the free movement of trains is a first consideration in railroad operation, and on heavy traffic lines the necessity for frequent removal of a machine from the track handicaps it as against the more mobile gang of workers with hand tools.

#### MAINTENANCE OF ROLLING STOCK

The repair work involved in the maintenance of railway rolling stock does not lend itself readily to the mass production methods which account for rapid productivity gains in some lines of manufacture. Cars and locomotives are of many different models and the repair work required varies from car to car. However, many improvements have been made in the metal-working tools required; some shops have installed extensive motorized systems of handling materials; lacquer painting has gained some foothold; and it is reported that the adoption of the progressive system of car repairs is the most important development in working methods in the shops and "has brought about a revolution in car repair in practically all parts of the country". In this system, the cars are worked through the shop in a certain number of spottings, with each crew more or less specialized in one phase of repairing.<sup>44</sup>

<sup>44</sup> It is stated that in shops where it was previously an effort to maintain a schedule of 100 to 125 cars a month, it is now possible to turn out 350 to 400 cars. *Railway Mechanical Engineer*, 103:595-7, October 1929.

## STREET RAILROADS

The street railroad is engaged in a struggle for existence against the competition of the private automobile and the motorbus. From 1922 to 1927, the number of employees declined from 300,523 to 267,115, and the number of passenger cars from 77,301 to 70,309. Among the changes made in the effort to reduce costs may be mentioned various improvements in shop practices and in track construction, such as the use of electric track welding; and the increasing use of the one-man car and the two-car train. The number of one-man passenger cars increased from 11,628 in 1922 to 19,771 in 1927, despite a decrease in the total number of cars.<sup>45</sup> Street-car lines in numerous cities, including, for example, Buffalo, Bridgeport, Kansas City, Missouri, Newark and Jersey City, are now operating one-man cars exclusively.

## HIGHWAY TRANSPORTATION

In 1929 the passenger cars registered in the United States numbered 23,121,589, the trucks 3,379,854. Some 92,500 motorbuses were in operation that year, 48,350 being revenue carriers and most of the others school buses. The total of livestock hauled by truck in 1929 was estimated at 14,500,000 head; and 73 per cent of fruits and vegetables for metropolitan use were hauled by motor truck in 1928.<sup>46</sup>

The motorization of highway transportation evidenced by these statistics has had a profound effect on other industries. The bus and passenger automobiles have taken part of the

<sup>45</sup> From reports on *Electric Railways* (1922); and *Electric Railways and Affiliated Motor Bus Lines* (1927), U. S. Bureau of the Census.

<sup>46</sup> Estimates in this paragraph all quoted from the National Automobile Chamber of Commerce, *Facts and Figures of the Automobile Industry*, 1930 ed.

passenger traffic of the railroads and street car lines, and the truck has become an important competitor in freight handling. In urban transportation, the cab driver and teamster have been largely eliminated; in rural communities, the automobile has reduced the time required to market commodities. Employment in truck and passenger car operation, service and maintenance has greatly increased, but this gain in employment is offset in part at least by declines in the industries curtailed by the skyrocket growth in motorized highway transportation. In the handling of coal, gravel and similar bulk commodities, the labor-saving tendencies of motor truck transportation, as compared with horses and wagons, have been accentuated by the development of the automatic-hoist dump-body feature on trucks.<sup>47</sup>

#### STEVEDORING

A stevedore is one who contracts to load and unload ship cargoes. The men whom he employs to do the work are known as longshoremen. The principal port facilities involved are wharves and docks, transit sheds for the temporary storing of cargoes, and more or less hand and mechanical equipment for the hoisting and lateral movement of goods.<sup>48</sup>

Much heavy manual handling is involved in the work of

<sup>47</sup> See the sections in this chapter on Rural Highway Construction and Retail Coal Handling.

<sup>48</sup> The principal sources of information for these paragraphs are inspections of stevedoring operations and interviews with stevedoring agencies in 1925 by Mr. G. T. Benson of our staff, at the ports of New York, Boston, Baltimore and Philadelphia; the recently published report of the Bureau of Labor Statistics of a three-year study of productivity in port operations made by Boris Stern (B. L. S., Ref. 42); a series of reports issued by the Engineer Corps of the War Department with detailed description of the facilities in the United States ports (Ref. 66); R. S. MacElwee, *Ports and Terminal Facilities*; and various articles in the technical journals.

the longshoreman, hence the essential requirements for the job are "a mighty arm, a hard muscle, and a large strong back". Nevertheless, a considerable experience and a certain type of skill are required for that part of the work involving the handling of ship's gear and the stowing of cargo in the hold. The work of the longshoremen and the equipment used by them vary widely with the type of ship, the port, and the cargo handled, not to mention differences between docks in the same port. Ocean-going freighters are ordinarily loaded through hatches in the deck, but the cargoes of lake and coast vessels are frequently loaded and discharged from the side. Bulk cargo is shipped in mass without containers, and 'general' or 'package' cargo in units or packages.

In most ports, little stevedoring is required in the handling of bulk cargoes. Petroleum in bulk is pumped to and from the oil-carrying ships. Grain is largely loaded by gravity and unloaded by chain-bucket conveyors or pneumatic elevators using suction. Ore handling on the Great Lakes was highly mechanized even before the War-time impetus to labor saving. The car dumper—a mechanism that lifts an open-top car loaded with coal and turns it over, so that the coal can flow into the ship by gravity—is the basis of large-scale cargo coal loading.<sup>49</sup> In the handling of such bulk cargoes as grain and cargo coal, the work of the stevedore is ordinarily limited to rigging or adjusting the equipment, and to trimming, that is, moving the cargo to and from those parts of the hold that cannot be reached readily by the mechanical loaders or unloaders. Even here the machine encroaches, for "most of the coal piers are now equipped with automatic trimmers which are capable of shooting the coal

<sup>49</sup> At the Sewall's Point, Virginia, coal-handling plant of the Virginian Railway Company, there is a double car dumper which can handle two 60-ton cars or one 110-ton car; MacElwee, *op. cit.*, p. 349.

into the farthest and most inaccessible compartments of the ship, thus at times completely dispensing with the services of longshoremen as coal trimmers".<sup>50</sup>

Standardized package cargo includes such commodities as bananas, cotton, flour, coffee, sugar, lumber, cement, case oil, and newsprint paper rolls. The methods for handling standardized package goods often do not differ from those for handling miscellaneous package cargo in the same ports. Standardization, however, facilitates mechanization, and for many of these commodities specialized handling devices have been developed at some ports. The Bureau of Labor Statistics concludes that "labor productivity in handling these uniform cargoes has recently greatly increased, due to the use of the newer types of pier equipment."<sup>51</sup> Differences in the equipment, methods, and productivity at the various ports and piers are still substantial.

Miscellaneous package cargo is shipped in bags, barrels, bales, boxes and crates, of all shapes and dimensions, and sometimes in no containers at all. It is in the handling of this heterogeneous type of cargo that hand methods make their most effective resistance to the advance of mechanization. The two principal difficulties in the way of mechanization of miscellaneous package cargo handling are the requirement for individual attention in the stowing of the goods in the hold of the ship, and in the sorting of packages in the discharging process.

The transference of goods from the apron of the pier to ocean-going ships is largely by mechanical means even in miscellaneous package handling. In United States ports the

<sup>50</sup> B. L. S., Ref. 42, p. 9.

<sup>51</sup> B. L. S., Ref. 42, p. 15. For description of methods in handling bananas, case oil, raw sugar, newsprint and coffee, and illustrations of gains in productivity, see pp. 44-61. For differences in productivity, see pp. 52, 65 and the General Tables, pp. 113-559.



ship's gear, that is, the booms and winches with which each freighter is equipped, is largely used. Side-port loading and discharging is generally accomplished by longshoremen with hand trucks passing back and forth between the vessel and shore along a gang-plank, except when there is a low tide creating too steep an incline between the side port and the pier platform.

Also, the machine has come into use in handling miscellaneous package freight on the pier. The once universal 2-wheel truck, and its later development in the 4-wheel platform truck, have given way in part to the electric truck, the tractor and trailer, and various types of portable conveyors and elevators. The machines have made most headway in the piling of goods and in relatively long hauls from shipside to warehouse. The low-lift type of electric truck for use with skids (interchangeable trays or platform bodies) and the high-lift type and crane-equipped trucks, for tiering, have demonstrated their special usefulness in cargo handling on the piers.

On the 22 stevedoring operations inspected by us in 1925, inquiry was made of the stevedore or foreman as to "changes in gear or method made in the last five years". In 12 instances, no change had been made. Two had added Henshaw portable escalators, which engage the axle of hand trucks and help them up inclines, and estimated the increases in tons per man-hour to be from 0.88 to 0.95 and from 0.80 to 0.86, respectively. Four stevedores had inaugurated partial use of electric trucks. One stevedore was using two trucks on trial; another had added a couple of lift trucks, and estimated that the output of the gang of 21 had increased from about 20-25 to 28-30 tons per hour. In the handling of dates hand trucks were replaced by electric trucks with demountable and interchangeable bodies to enable some selection of the cargo according to consignee's marks at the

ship's side, thus lessening the amount of sorting necessary when the loads were brought to the storage space, and increasing productivity for a gang of 22 from approximately 32 to 40 tons. Similarly in the handling of sugar, hand trucks had first been displaced by a gasoline tractor and then the tractor by electric trucks with demountable bodies; output had been thereby increased from 29 or 30 to 48 tons per hour for a gang of 18. In hauling lumber, a Fordson tractor had been added for long hauls, increasing the output of the gang of 17 from 8,000 to 10,000 board feet per hour. At an ore-handling pier, a mechanical trimmer had been added to aid in moving the last part of the cargo so that it could be more readily reached by the unloading buckets; this sharply increased the man-hour productivity in the trimming operation. At a coal-handling pier, the two Boston towers had been rebuilt and the size of the buckets increased from one ton to one and one-half tons, with man-hour output increased from 10 to 16.5 tons. At a general cargo pier, 4-wheel trucks had been substituted for 2-wheel, and flat wooden platforms or 'aeroplanes' for cargo nets, in hoisting drafts of general cargo from the ship, with an estimated change in productivity from 0.95 to 1.4 tons per man-hour.

On the whole, stevedoring has been backward in the introduction of machinery. But the above examples will serve to illustrate the tendency for mechanization to nibble away at the hand operations despite the diverse nature of the cargo and the greater adaptability of hand methods to the large amount of sorting required, rough and narrow pier surfaces and other physical limitations of some docks. The diversity in productivity shown by Stern's study suggests the possibilities of further gains by modifications in methods and equipment.

## COMMUNICATION

Recent mechanization developments of special interest in the field of communication are the automatic telephone, the printer telegraph, and the high-speed stock ticker.

THE AUTOMATIC TELEPHONE <sup>52</sup>

The first commercial installation of an automatic switchboard was in 1892. It has been estimated that in 1922, 5.1 per cent of the total number of telephones were automatic. The decade of the 'twenties witnessed a steady increase in the introduction of dial telephones. The percentage which they constituted of the total in the Bell system increased from 1.7 in 1919 to 2.7 in 1921, 15.5 in 1926, and 31.9 in 1930.<sup>53</sup> By 1929 over four million stations were served by automatic switchboards in the Bell system. The dial telephone is not restricted to urban districts but is coming into use in the rural districts and also in railroad telegraphy.

The automatic switchboard does not eliminate operators entirely, for during the period in which the automatic system is being introduced and some offices are still manual additional apparatus and labor is required for the satisfactory

<sup>52</sup> This section is based in part on information made available by the courtesy of the Bell Telephone system (see Table 41), and in part on the results of a survey by the United States Bureau of Labor Statistics, reported in the *Monthly Labor Review*, Ref. 50.

<sup>53</sup> Full records of installations are available only for the Bell system, but inasmuch as in 1930 this system owned 86 per cent of the manual telephones and 92 per cent of the dial telephones, and had on its payrolls 88 per cent of the workers in the employ of commercial telephone companies, the record for the Bell system may be taken as approximately representative of the trend and status in the industry as a whole. The lead in the introduction of dial phones was taken by the independents but by 1930 the percentage of automatic phones in the Bell system exceeded the percentage for the independent systems.

handling of calls between different types of switchboard. Furthermore, toll or long distance calls are, on the whole, handled by manual operators, though the recent trend has been rapidly towards the automatic handling of the simpler types of toll call.<sup>54</sup>

#### THE PRINTER TELEGRAPH<sup>55</sup>

The principal branches of the telegraph industry are the commercial telegraph systems, handling messages for the general public; railroad telegraphy; the news-gathering organizations, such as the Associated Press; and the market quotation systems. All of these have been affected by the printer telegraph and allied developments.<sup>56</sup>

In the manual or Morse system of telegraphy the message, coded in dots and dashes, is sent by the intermittent depression of an electric contact key by an operator skilled in the Morse system; a Morse operator is also required at the receiving end. The principal inroads upon the Morse system have been made by the printer telegraph and associated devices, such as the new high-speed stock quotation ticker.

The printer telegraph (also known as the teletypewriter or teletype) in appearance and mode of operation resembles an ordinary typewriter. The depression of a key causes the

<sup>54</sup> For further discussion of labor-saving qualities of the automatic telephone, see Ch. X, and the *Monthly Labor Review*, Ref. 50; for the extent and effects of its increasing use in private exchanges, see *Monthly Labor Review*, Ref. 56.

<sup>55</sup> Based upon studies reported in the *Monthly Labor Review*, Ref. 51, 52, 54, 55 and 56.

<sup>56</sup> The displacement of Morse telegraphers by the printer telegraph in railroad telegraphy is closely associated with other technological changes, such as the automatic block-signal system, and hence is discussed in a preceding section dealing with changes in railroad operation. The printer telegraph is also extensively used in private wire systems (Ref. 56).

electric transmission of a character impulse and the character is automatically printed, in ordinary characters, on a 'blind' printer at the receiving end of the wire or on several machines connected by telegraphic drop circuits.

The introduction of the printer telegraph in commercial telegraphy was slow at first. In 1902 only 0.8 per cent and in 1907 only 1.6 per cent of the mileage of commercial telegraph systems had automatic circuits. During and after the World War, the use of the automatic telegraph increased rapidly.<sup>57</sup> By 1931 about 90 per cent of the commercial message handling of one of the leading companies and 80 per cent of the traffic of another was by printer telegraph.

There are several large news-gathering organizations and many more which render specialized services, such as financial news and syndicated news features. Their telegraphic handling of news is by means of leased-wire trunk-line circuits tapped by drop circuits connecting the individual newspapers with the main circuits.

The news agencies began to use printer telegraphs in 1915. By 1922, 416 out of 1,597 drop circuits in the principal news organizations had printer service; and by 1930, 2,317 out of 2,715. The number of Morse operators increased from 1,114 in 1915 to 1,549 in 1922, despite the printer telegraph, but from 1922 to 1931 declined to 586, while the number of printer operators increased from 67 in 1922 to 335 in 1930.<sup>58</sup>

<sup>57</sup> "Conversion of the principal circuits to multiplex printer operation continued till 1928, when the program was merged with, and in a measure superseded by, the installing of simplex printers", the introduction of which had begun in 1926. With the 'simplex system' the use of the printer is feasible under lighter traffic conditions than formerly necessary for economical use.

<sup>58</sup> It is estimated that in 1931 the work of the printer operators was equivalent to 243 full-time positions, and that to operate these and the 2,317 receiving positions which they serve, with a complete Morse manual

The ticker is a variation of the printer telegraph. Ticker service for reporting market quotations originated shortly after the Civil War.<sup>59</sup> At first, direct circuit service was restricted to the financial district of New York and a few great financial centers,<sup>60</sup> and the transmission of market quotations to other points was handled by Morse telegraphers. In some instances quotations so relayed were redistributed by local ticker circuits.

For the principal market-quotations services the number of tickers in use increased from 3,706 in 1921 to 13,736 in 1929, but decreased to 11,178 in 1931. The extension was especially rapid in the late 'twenties. In 1926 only 121 cities in 24 states were receiving service for New York Stock Exchange quotations by 5,267 stock or bond tickers. By 1929, the service had been extended to 336 cities in 41 states, using 10,505 tickers. In 1930 there were more than 30 security or commodity exchange ticker systems, some of them local or regional.

Under the impetus of the expansion of stock-exchange operations a new high-speed ticker service capable of handling the enlarged volume of quotations with a minimum of delay and error was introduced in 1929 and installed in 1930 throughout the country. "On September 2, 1930, for example, it automatically printed the New York Stock Ex-

system, would require 3,737 Morse operators, or in the ratio of about fifteen Morse operators to one printer operator.

<sup>59</sup> Data on the extent of ticker service and productivity of the operators in the New York Stock Exchange ticker service are available from 1890 to date. *Monthly Labor Review*, Ref. 55, p. 1271.

<sup>60</sup> In direct circuit ticker service, the operator types the symbols in which the market quotations are expressed on the master transmitter, and the identical symbols are simultaneously printed on tapes by the tickers in the receiving offices.

change quotations on 8,623 stock tickers in 43 States and Territories and in Canada, with circuits in 377 cities.”<sup>61</sup>

The important displacement effect of the ticker is on the number of Morse telegraphers employed in intermediate and receiving service by brokers, newspapers, and local ticker services though the number displaced cannot be determined. Thus it is seen that alike in commercial, railroad, news-service and market quotation telegraphy, the opportunities of the Morse operator have been lessened by the printer telegraph and associated technological changes.

#### UNITED STATES POSTAL SERVICE (Ref. 59)

An estimate by the Bureau of Labor Statistics, using conservative methods, places the gain in output per employee in the United States postal service, compared with 1908, as 20.7 per cent by 1912, 67.3 by 1926, and 71.8 by 1930, with a decline of 5 per cent from 1930 to 1931 arising from the decreased volume of business. About 197,000 additional employees would have been required to do the 1930 volume of work at the 1908 level of efficiency.

A Congressional committee reported in 1908 that there was “a lamentable lack of labor-saving devices practically throughout the whole Postal Service”. Subsequent improvements are ascribable in part to mechanical labor-saving devices and possibly in still larger part to administrative changes for the promotion of efficiency. Among the mechani-

<sup>61</sup> In the high-speed system, the quotations are first typed by several printer telegraphs in code on perforated tapes, then automatically re-perforated on a single tape and fed into the master transmitting ticker, which is geared at a speed of 500 characters per minute. The action of the master transmitter is synchronized with that of each of the several thousand receiving tickers throughout the country, and reception and printing by them is entirely automatic.

cal changes may be mentioned the motorization of the collection of mail, mechanical facing tables in the larger offices for arranging letters for the canceling machine, improved postmarking and canceling devices, postage-metering machines, automatic conveyors of many varieties, and in the accounting division, the extensive use of "many kinds of the most efficient types of bookkeeping and calculating machines".

Among the administrative steps contributing to increased productivity are "a definite budgeting of funds for encouraging invention and for buying or renting and maintaining labor-saving devices", the establishment of a division of cost ascertainment "for carrying on a continuing study of the various phases of income and expenditure . . . remarkable economies in the money-order accounting system," . . . and "surveys for the purpose of discovering the most efficient methods, formulating plans for standardized procedure and making available to the entire system the best methods found anywhere in the system." (Ref. 59, p. 746). Recently a system of efficiency ratings has been developed, and intensive study has been made of labor management and administrative organization and methods, illustrated by surveys carried on between October 1929 and April 1931 in 55 of the largest offices in the country. The continuing adaptation of the physical plant to changing conditions and needs has played a large role in raising the level of efficiency.

#### RETAIL COAL HANDLING

The usual operations in retail coal handling are (1) receipt into storage; (2) screening if necessary; (3) loading to delivery trucks or wagons from overhead bins or ground storage; (4) haulage; (5) unloading to customer's storage.

Our study of retail coal handling at first hand was re-



stricted to a survey covering 16 anthracite coal-handling establishments in New York City and five establishments in Connecticut towns; together with somewhat less complete data concerning a group of 7 dealers in Binghamton, New York; and information by mail from 10 New York dealers. Obviously this is not a large or representative sample of retail coal handling for the country as a whole. Nevertheless, if its limited scope is kept in mind, it may be useful as suggesting some tendencies in coal handling.<sup>62</sup>

At the time of inspection, the 21 plants in New York City and Connecticut were quite well mechanized. For the bin-loading operation, largely from barges, all had power equipment of some kind; all but five had some sort of mechanical cleaning system; and all loaded for delivery by gravity chutes or used portable electric loaders where loading from ground storage. For haulage, all establishments had gasoline one-to ten-ton trucks (168 in all) with power-hoist dump-bodies, and hired additional motor trucks when needed.<sup>63</sup>

The information concerning the equipment used in the 7 Binghamton retail coal plants illustrates a less mechanized type of establishment. Only four of the yards were equipped with portable power loaders. Only two had any motor trucks of the power-hoist dump-body type. Six were using horse-drawn wagons with non-dump wagon bodies.

Except for some of the overhead wooden bins, all the equipment in use in 1925 had been rebuilt or added since

<sup>62</sup> The 21 establishments surveyed in New York City and Connecticut had daily capacities of from 70 to 850 tons and employed about 666 men when in full operation.

<sup>63</sup> In addition, three of the establishments had horse-drawn trucks or wagons totaling 26 in number, most of these being equipped with hand-operated dump-bodies. The only reason given by the coal dealers for continuing to use horses was that some of their old drivers could not learn to drive a motor truck; the horses were being retained until these drivers were retired.

1907, either as initial equipment or to replace older types. The Boston towers took the place of mast-and-gaff loaders or bucket elevators, from 1910 to 1916, or were initial equipment. The mast-and-gaff loaders and the locomotive cranes had all been installed by 1917 as initial equipment or to replace bucket elevators or cruder types of hoist. The mechanical screening apparatus was initial equipment in 4 plants and had been substituted for hand screening in 12 plants, all in the years 1915-19, with the exception of 2 changes as late as 1924.

In 8 of the coal-handling establishments surveyed, the power-dump trucks in use in 1925 had displaced horses and wagons in the years 1914-18 inclusive. In 12 additional establishments they displaced horses and obsolete and worn-out motor trucks in the period 1912-24. The portable electric loaders had been added since 1920.

It will be noted that most of the changes we found in retail coal-handling establishments had been made during or before the World War. Of one group of 21 establishments 15 reported that they had made no change since 1920 considered significant from a labor-saving point of view.

#### PRODUCTION OF POWER

Noteworthy tendencies in the production and consumption of power in the 'twenties were the increasing use of electric power, a shift from produced to purchased power on the part of manufacturing plants, more use of oil and powdered coal for fuel, the further displacement of hand-fired coal-burning furnaces by mechanical stokers, and centralization of electric power production in favorably located plants operated by electric light and power companies.<sup>64</sup> From 1917 to 1927,

<sup>64</sup> See Ch. VI for the increasing proportion of electric power in manufacturing. The change to oil burners was reported by a score of our in

though the number of central stations decreased from 6,542 to 4,335, the number of employees increased from 105,541 to 251,020 and the power generated by them increased even more—from 25 to 75 billion kilowatts. Power production is so far mechanized and the number of workers employed relatively so small that large savings in labor are no longer possible.<sup>65</sup>

The size of equipment units in central stations has been increasing rapidly. For example, from 1922 to 1927 the average horsepower of prime movers increased from 1,499 to 2,868, and the average rated capacity of generators from 1,127 to 2,157 kilowatts.<sup>66</sup>

In the smaller power plants the crude labor-consuming method of stoking furnaces with hand shovels is still prevalent but in the larger industrial and electric power plants it has been generally displaced by various types of automatic stoker, such as the endless-grate system.<sup>67</sup> Stoking labor has been reduced also by the increasing use of oil burners and the introduction of pulverized coal equipment.

formants, who emphasized the resulting improvement of working conditions in the powerhouse. The number of men involved in power production is not large and the reduction in the number was ordinarily small, ranging from 1 to 6 in most instances, although one large manufacturing plant reported a reduction of its powerhouse crew from 57 to 11. Electrification tends to eliminate the powerhouse crew and, according to some of our informants, also reduces the maintenance crew because of the absence of shafting, belting, etc., incident to steam-engine drive.

<sup>65</sup> Information received in 1925 from 120 power plants, 52 of which were equipped with mechanical stokers and the remainder hand-fired, showed a total of 506 firemen, coal passers, etc., or an average of only 4.2 men per plant (*Industrial Management*, April 1925, Vol. 69:242).

<sup>66</sup> Data on central stations taken from 1922 and 1927 issues of *Census of Electrical Industries: Central Electric Light and Power Stations*.

<sup>67</sup> See Table 41, for annual sales of mechanical stokers. "During 1928, of the coal burned for the production of electric power, 97.7 per cent was fired mechanically, while 2.3 per cent was burned under the hand-fired boilers still used by a few small plants" (Ref. 57, p. 255).

**PULVERIZED COAL**

The pulverized coal system was first used on a considerable scale in a commercial power plant at the Lakeside plant in Milwaukee, built in 1921, after a period of experimentation in another Milwaukee plant. This plant is equipped with a mechanical car dumper to the crusher, and from the crusher the coal is mechanically carried through all subsequent processes with no manual handling. One man watches a battery of furnaces. According to statistics published by the Bureau of the Census for 1930 and 1931, new orders received by the principal manufacturers of coal-pulverizing equipment totalled 433 pulverizers of the unit-system type and 4 of the central-system type.

**AUTOMATIC DISTRIBUTING STATIONS**

About the limit in the elimination of human labor has been reached in the remote control system for electric power distributing plants, first put in successful operation in 1921. On September 17, 1928, the New York Edison Company opened one of these manless distributing stations in New York City which will ultimately be able to supply power sufficient to light the homes of approximately 300,000 families. The plant is controlled from another station more than three miles away, and it is necessary for human beings to visit the station only about once a week to inspect the apparatus.<sup>68</sup>

<sup>68</sup> Mimeographed press release from New York Edison Company. The number of unattended substations in 5 representative electric light and power systems surveyed by the Bureau of Labor Statistics increased from 46 in 1920 to 193 in 1930; and "in one large system, in 1931, of a total of 325 substations in operation, 233 (72 per cent) were entirely automatic while the other 92 (28 per cent) required some attendance" (Ref. 57, p. 258).

## FUEL ECONOMY

Of greater interest than the immediate effect of various changes on the amount of labor directly employed in power production is the remarkable advance in the efficiency of fuel utilization and the consequent reduction of labor required in the production of the fuel. In 1919 the average consumption of coal or its equivalent in the generation of electric power by the public utilities was 3.2 pounds to the kilowatt-hour. Each year since consumption has decreased, being in 1929 only 1.68 pounds per kilowatt-hour, a saving of 47.5 per cent in the decade. Similar improvements in fuel efficiency have been made in the consumption of coal by railroad locomotives and in the production of pig iron. As a result of the improvements in fuel efficiency, together with the competition of fuel oil, demand for coal has failed to keep pace with the general growth of industry.

## STREET CLEANING AND MAINTENANCE

In the interminable repair necessary on city streets, extensive use is made of pneumatic tools to break up old pavements. Motorized sprinklers and rotary street sweepers have been adopted (*cf.* Table 41). In the larger cities of the North, mechanical devices have been developed to aid in the removal of snow. On rural highways, an increasing mileage of which is kept open for motor traffic in the winter, the snow can be plowed to one side, but on a city street, complete removal is more satisfactory. A common practice has been to plow the snow over to the curb and then to load it to trucks, either by hand shovels or machine, to be hauled away and dumped elsewhere. When loading is by hand there is much idle truck-time while the process of loading is going on. In 1925 a member of the staff of the New York City bureau of

snow removal estimated that about 25,000 persons were employed in the city to remove snow after a large fall, of whom about 18,000 were casual workers. The equipment was estimated as about 1,000 snow-plows, 2,200 motor trucks, 900 horse-drawn wagons, and a few cranes and portable-conveyor type of snow loaders. The conveyor type of loader is a self-propelled, more or less self-feeding device, which drives into a windrow of snow and with a bucket conveyor feeds the snow rapidly into the body of the waiting truck.<sup>69</sup> The motor trucks used for haulage are equipped with automatic hoist bodies.

The facility of removal arising from the development of the machine snow loader has probably resulted partly in a decline in the amount of labor required, partly, however, in an increase in the volume of snow removed. The introduction of the machine has been retarded by the tradition that snow removal is a means of providing temporary employment for large numbers of unemployed, and especially in a depression period, public sentiment and political interests are adverse to it.

#### TECHNOLOGICAL CHANGES IN THE AMUSEMENT INDUSTRY <sup>70</sup>

In the introduction of the sound movie, the motion-picture branch of the amusement industry underwent an exceptionally rapid technological revolution. The first sound picture was produced in August 1926. The introduction of

<sup>69</sup> An observer from our staff clocked one of these loading snow on the New York streets, under almost ideal snow conditions, and found that it loaded six 9-cubic-yard trucks in less than nine minutes. In another check, 22 trucks were loaded in 96 minutes, including 26 minutes stoppage while waiting to be shifted.

<sup>70</sup> Unless otherwise indicated, the quoted phrases and facts in this section are based upon articles in the *Monthly Labor Review* (Ref. 44 and 46).

sound-producing machines was relatively slow at first but rapid in 1929 and 1930, so that by January 1, 1931, 13,128 of a total of 21,993 theaters in the country were sound equipped.

The chief displacement effect of the 'talkie' arises from the 'canned music' feature—the synchronization of the musical score with the picture, making unnecessary the employment of living musicians in the projecting theater. Formerly even the straight motion-picture houses ordinarily employed from one to seven musicians. As a result of mechanical music, these musicians have been largely dispensed with, and consequently, the number of employed musicians declined in the two years ending June 30, 1931 by some 9,885, or about 50 per cent. In Washington, D.C., a reduction, in all theaters, of slightly over 60 per cent was made in October 1930, by agreement between the motion-picture theater owners and the local union of musicians.

As a partially offsetting factor, there is a growing demand for local musicians by the local radio stations, and it has been estimated "that from 500 to 600 musicians throughout the country earn a living through radio broadcasting". Nevertheless a study of the status of 101 displaced musicians in Washington indicated that the earnings of a majority have been reduced subsequent to their discharge from the motion-picture theaters; and even when able to get some sort of a job, only a few have improved their status. The adjustments that the majority have had to make have been extremely painful.

On the other hand, the change from the silent to the sound movie has been accompanied by an improvement in the status of the motion-picture machine operator, both by replacing the customary boy helper with a licensed operator, and by increasing the average earnings of the projectionists. "Representatives of the five large moving picture circuits

claim that the 13,000 theaters which installed sound equipment in the last few years have added more operators than the approximately 10,000 musicians who lost their jobs through the introduction of the sound picture."

In the small 'translux' theaters, the picture is projected from behind the screen, obviating the necessity of a darkened theater; and here the ticket taker has been replaced by a turnstile operated from the cashier's booth, and the ushers and pages dispensed with.

The employment of musicians in the vaudeville houses and the theaters giving combination vaudeville and motion-picture shows has not been directly affected by the sound movie; but the popularity of the straight motion-picture house is indirectly responsible, at least in part, for changes in the legitimate stage and the passing of the vaudeville house. In 1922 there were nearly one thousand 'big time' and 'small time' vaudeville theaters. Most of these have become straight motion-picture houses or part-time vaudeville in combination with motion pictures, the elimination of the vaudeville feature being hastened by the depression. With the elimination of the vaudeville artist "also go the musicians and the entire back-stage crew".

#### OFFICE EQUIPMENT

The extent to which the machine has a recognized and growing place in the modern office is evidenced by the dollar volume of sales of selected types of office equipment (Table 7).<sup>71</sup> In 1929 adding machines with a factory value of about

<sup>71</sup> In the 94 insurance companies, public utility companies, publishing firms, chain stores, mail order houses, banks and investment firms covered by surveys of industrial change in clerical work made in Philadelphia and St. Louis by the Women's Bureau, "438 women worked on bookkeeping or billing machines, only 177 women being found who still carried on this



TABLE 7  
 VALUE OF SELECTED TYPES OF OFFICE EQUIPMENT PRODUCED,  
 1925, 1927, 1929<sup>1</sup>  
 (unit: \$1,000)

TYPE OF MACHINE	1923	1925	1927	1929 <sup>2</sup>
Adding	2	33,830	33,386	25,910
Addressing and mailing	5,769	9,035	9,788	10,537
Calculating	2	2	10,614	11,617
Card-punching, sorting, and tabulating	2	2	4,850	2
Check-writing	2,489	2,093	1,780	2,346
Manifolding (mimeographs, multigraphs, etc.)	2	3,884	3,779	3,489

<sup>1</sup> Compiled from *Census of Manufactures, 1929*, II, 1098-1100.

<sup>2</sup> No comparable data available for these years.

<sup>3</sup> Number of machines in 1929: adding, 157,740; calculating, 57,201; check-writing, 63,576 (incomplete); typewriters, 959,627.

\$26,000,000 were produced in the United States; and the value of the calculating machines and addressing and mailing machines amounted to over \$10,000,000 each. About one million typewriters were manufactured.

A partial census of adding and calculating machines of the principal American makes, manufactured to March 1928, records 1,707,400 full keyboard type, 326,500 10-key keyboard type, and 314,000 miscellaneous non-listers.<sup>72</sup> An officer of one of the companies manufacturing dictating machines estimated for us early in 1928 that approximately 200,000 dictating machines were in daily use in the United States and that the number was increasing at about 10 per cent a year.

It would be difficult to estimate the man-power equivalent of the great number of typewriters, adding and calculating

work by hand." Mary Anderson, *The Clerical Worker and Industrial Change*, *American Federationist*, vol. 39, p. 1025.

<sup>72</sup> Letter, March 22, 1928, from Equipment Research Corporation, Chicago publishers of *The Business Machines and Equipment Digest*.

machines and other mechanical office equipment, and the results when obtained would be somewhat misleading if taken to indicate the labor displacement arising from machines; for it is probably true that in large part the work now done by the machines would not be done at all were it not for the facility of output with machine equipment. If letters were all written by hand, and computations all made by laborious and expensive human effort, there would be a marked shrinkage in the volume of correspondence and computation considered necessary and economical.

#### MECHANIZATION OF HOUSEHOLD TASKS

Many modern tendencies lead indirectly to an increased mechanization of household tasks by transferring them from the home to the factory. The increasing proportion of families who live in apartments and perform few household tasks; the rise of the power laundry; the increasing resort to canned goods, prepared breakfast foods and bakery goods—are illustrations of tendencies which either reduce the labor required to maintain a household or transfer much of it from the individual household to the more or less specialized factory with its relatively greater use of mechanical equipment. Some of these tendencies are by no means entirely new, but most have been accelerated in the post-War period. From 1919 to 1929 the number of wage earners employed, on the average, in establishments with value of product \$5,000 or more, had increased from 130,489 to 233,187 in power laundries; from 18,408 to 59,148 in dyeing and cleaning establishments using mechanical power; from 76,326 to 98,866 in the canning and preserving of fruits and vegetables; and from 140,477 to 200,841 in the manufacture of bread and other bakery products. In 1919, 35 persons in each thousand of the total population were employed in the four

industries just mentioned; a decade later, 49 persons. In the same period, employment in manufacturing as a whole was declining.

#### ELECTRIC APPLIANCES

The decade of the 'twenties witnessed a rapid increase in the use of power appliances in the home, chiefly in the way of electric-motor-driven equipment. Estimates of the rapidity of introduction and changes in the extent of use, derived largely from statistics furnished by the manufacturers and published in the trade journals, appear in Tables 43-45. Estimates of the number sold each year, 1923-30, are given in Table 43; estimates of the number of users of selected electric household appliances at the close of each year, in Table 44; estimates of the percentage of wired homes at the close of each year equipped with the specified electric appliance, in Table 45.

Most power-driven household labor-saving appliances are electric, and the extent of use is frequently expressed in terms of the percentage of wired homes equipped with the given device (Table 45). It is estimated that the number of persons living in electric-lighted dwellings in the United States increased from about 35 million at the beginning of 1920 to about 85 million at the close of 1929, or from 33 to 70 per cent of the total population.<sup>73</sup>

The number of users of electric washing machines has increased from about three and one-half million in 1924 to over seven million in 1930, but these labor-saving devices are still lacking in nearly two-thirds of wired homes. Electric irons are even more extensively used, the number of homes equipped with them having about doubled from 1924 to

<sup>73</sup> *Electrical World*, January 7, 1928, p. 32; January 4, 1930, p. 10.

1930, when the number is estimated at 20,000,000. The more elaborate ironing machine (for flat work) has been installed at an annual rate of some 50,000 to 100,000 or more, the number of users increasing from slightly over 200,000 in 1924 to about 680,000 at the close of 1930, but even so only a small proportion of wired homes were equipped with ironing machines.

About one million electric vacuum cleaners were sold each year, and the number of users increased from about 5,000,000 in 1924 to about 9,000,000 in 1930, with some 44 per cent of wired homes equipped. Electric floor polishers were much less common, annual sales numbering about 50,000.

In the six years, 1925-30, some 1,818,000 electric sewing machines were sold, but the electric type is still far outnumbered by the foot-power type.

A small but increasing proportion of wired homes are equipped with electric cookers and ranges (Table 45); and by the close of 1930 there were some 2,625,000 users of electric refrigerators, in about 13 per cent of wired homes. Numerous minor aids to the preparation of food are in use but in a relatively small number of homes. Electric dish washers, for example, were in 1925 used in less than one per cent of urban homes, according to the Women's Club Survey,<sup>74</sup> and total sales, 1925-30, are estimated as only about 57,000.

#### HEATING

Several recent developments tend to reduce the household labor incidental to heating, notably the introduction of the automatic oil burner, and, to a lesser extent, central steam heating plants, automatic coal stokers, gas furnaces and

<sup>74</sup> Based on mimeographed reports of surveys made under the direction of the Industrial Survey and Research Service for the General Federation of Women's Clubs (Table 51).

electric heating. By 1929 several hundred thousand homes were equipped with oil burners, requiring ordinarily little or no attention from the housekeeper.

#### COMMERCIAL PREPARATION OF FOOD AND DRINK

Since for some services in hotels and restaurants personal attention is ordinarily requisite, the extent of mechanization is limited, yet the machine has made substantial inroads upon manual labor. Both light and heavy vacuum cleaners are extensively used in hotels. Dish-washing machines have long been common and more recently dish-drying machines have come upon the market. In the preparation of food various types of mechanical peelers, slicers, dough mixers and fruit-juice extractors are extensively used, particularly in the larger hotels and restaurants. The series for bottle-washing, dough-mixing, dish-washing and vegetable-paring machines in Table 42 suggest some of the lines along which mechanization is proceeding in dairies, hotels and restaurants. Doubtless, considerations of sanitation and of greater certainty of accomplishing the work within time limits, as well as labor saving, are factors in encouraging the use of bottle- and dish-washing machines; and at least some types of vegetable-paring machines are said to be less wasteful of food than hand paring.

#### OTHER MECHANICAL EQUIPMENT

We might list innumerable other labor-saving machines in various stages of development. Practically no field of human endeavor is free from the competition of the machine. For example, the electrical integraph, developed in the Massachusetts Institute of Technology, has been described as a 'mechanical mind', which readily makes mathematical

TABLE 8  
 VALUE OF SELECTED TYPES OF MACHINERY PRODUCED<sup>1</sup>  
 (unit: \$1,000)

TYPE OF EQUIPMENT	1919	1921	1923	1925	1927	1929 <sup>2</sup>
Air compressors	18,650	15,729	27,762	29,473	29,319	39,683
Canning machinery	2	5,139	9,691	9,766	7,339	8,535
Clothing-pressing machines	2	2	6,282	8,409	9,078	7,216
Dish-washing machinery	2	2	1,066	1,474	2,018	3,424
Laundry machinery (for commercial laundries only)	10,801	12,983	19,077	24,198	27,204	28,893
Lawn mowers, power	2	2	2	930	1,979	2,521
Lawn mowers, hand	2	2	2	7,117	7,290	8,432
Machine tools	2	2	2	91,459	105,555	186,061
Milking machine units	2	2	941	1,118	1,339	1,778
Packaging machines	2	2	3,484	4,387	5,038	5,757
Sewing machines, household						
Electric	2	2	2	2	12,700	16,482
Foot and hand	2	2	2	2	9,094	8,613
Sewing machines, industrial						
Electric	2	2	2	2	9,607	11,145
Other	2	2	2	2	801	857
Slicing machines	2	2	3,539	4,860	4,680	4,507
Stokers, mechanical	4,280	7,161	14,095	9,420	10,213	14,054
Typesetting machines	2	19,650	27,088	23,581	20,077	18,750
Welding machines, electric and other	2	2	2	2	7,091	13,583
Vending machines	1,646	2,466	3,777	4,202	7,059	8,821

<sup>1</sup> Compiled from the *Fourteenth Census of the United States*, X, 368-74 for 1919 data; *Census of Manufactures, 1927*, pp. 1081-6, for 1921 and 1923; and *1929*, II, 1098-1102, for 1925, 1927 and 1929 data.

<sup>2</sup> No comparable data available for these years.

<sup>3</sup> Number, in 1929: clothing-pressing machines, 16,602; dish-washing machines, 7,033 (incomplete); power lawn mowers, 16,527; electric sewing machines, 323,474 household type, 113,890 industrial type; mechanical stokers, 8,838 (incomplete).

calculations too complex for the human brain. To enumerate and appraise, even in a sketchy way, the innumerable labor-saving devices in use would require an encyclopedia.

In Table 8 we give the dollar value of the output in recent census years of divers types of machinery which illustrate the many points at which mechanization is proceeding, each of which runs into millions of dollars.

The air compressor, of which nearly \$40,000,000 worth was produced in 1929, is the mobile power plant for the ever-increasing variety of pneumatic tools. Canning and dish-washing machinery represent in part direct or indirect substitutions for household labor. Clothing-pressing machines represent, in part, the inroads of the machine in the field of valet service. The power lawn mower is becoming an important factor in the care of large lawns. The annual production of milking machines nearly doubled in value from 1923 to 1929. Mechanical stokers, of both industrial and domestic types, are replacing the hand stoking of boilers and furnaces. In household equipment, the dollar value of electric sewing machines has come to exceed that of foot- and hand-power machines. The electric sewing machine dominates the industrial field. Machine tools, the master tools of manufacturing industry, exceeded \$186,000,000 in 1929.<sup>75</sup> Packaging machines, of many ingenious types, are steadily increasing in dollar volume. Some \$20,000,000 of typesetting machines are turned out each year. The production of welding machines almost doubled from 1927 to 1929, and they are being employed for an increasing variety of purposes.

<sup>75</sup> The 'machine tools' industry does not, of course, cover all productive machinery but only that part of metal-working machinery which conforms to the definition: "any machine operating other than by hand power which employs a tool for work on metal".

## CHAPTER V

### CHANGES IN MECHANIZATION: HANDLING OF MATERIALS

THE 210,959 establishments listed by the Census as engaged in manufacturing in 1929 are classified into 326 separate industries. Even among the establishments in these separately listed industries there is frequently a wide variation in the kinds of materials utilized and the processing to which the materials are subjected. The result is a bewildering diversity of processing method and equipment, a diversity that makes a reasonably brief description of changes in mechanization and generalizations concerning their nature extremely difficult. There seems little in common between a giant press that can shape a steel ingot, a silk loom that can weave a complex pattern, a machine tool that can cut steel to minutely precise dimensions, and a mill that can grind cement so fine it will pass through a mesh with 40,000 holes to the square inch. The processing operations and the equipment used in processing are in large degree peculiar to each industry. In the immediately preceding chapters we have mentioned some of the major labor-saving developments in processing equipment in important industries, but a detailed recital is impracticable. However, even the most diverse industries have one operation in common—handling. In all it is necessary to move materials from one processing operation to the next.



## HANDLING EQUIPMENT

The equipment involved in handling may be continuous or intermittent in action; operated by gravity or power; used for loading, conveying or unloading; adapted to bulk materials or package goods. One classification distinguishes mobile, semimobile and stationary types.<sup>1</sup> The mobile type includes equipment that has no fixed route of travel and requires no track; for example, the storage-battery industrial truck and the gasoline or electric tractor with trailers. The semimobile type, such as the traveling crane, the ordinary freight elevator and the installed or non-portable conveyor, has a fixed path of travel. The built-in straight or spiral chute for lowering packages or loose materials is the best example of the completely stationary type.

In the section dealing with the labor-saving handling devices found in our field survey, we have relied largely upon a classification by mechanical construction. On that basis we may distinguish locomotive and overhead cranes, derricks, hoists, power dumps on trucks, monorails, industrial locomotives, electric trucks, tractors with trailers, rotary car dumpers, tiering machines, coal-handling towers, conveyors, portable wagon loaders, and so on for a long list.

As we shall note in more detail presently, many of the labor-saving developments in recent years have been in the substitution of mechanical means for hand labor in handling operations. Furthermore, the workers displaced by mechanical handling devices are largely of the unskilled type. Hence it is particularly pertinent that we should (1) indicate the relative importance of handling operations in modern industry, (2) inquire into the proportion of hand and machine labor in these handling operations, and (3)

<sup>1</sup> Statistics of annual sales of mobile types are given in Table 46; of fixed and semimobile types in Table 47.

note the development and extent of use of a few important types of handling equipment. First, however, let us define more fully what is included in the handling processes.

#### DEFINITION

Materials handling, or just 'handling' for a shorter term, is moving in contrast to processing. We may conveniently distinguish four phases in handling, although all may not be involved in any given operation: (1) loading or picking up; (2) moving horizontally; (3) elevating or lowering; (4) unloading. These may be performed in handling materials in yard or storeroom prior to the first processing operation, in interprocess movement, or in delivering the finished product to storeroom or common carrier.

Processing, on the other hand, includes grinding, crushing, sawing, cutting, boring, melting, molding, spinning, weaving, dyeing, painting—in short, any operation that changes the nature or form of materials.

Obviously, many operations, in whole or part, lie in a twilight zone between clearly defined instances of processing and handling. This introduces a margin of error into all calculations concerning the relative magnitude of the handling and processing operations in industry. Most processing workers do some incidental handling, and a large element of handling enters into many operations ordinarily considered processing. For example, laying brick is largely a matter of putting brick and mortar in the right position; but although the work of the hod carrier who brings the brick to the point of construction is clearly handling, the reader will probably agree that a common sense classification of operations will designate the work of the bricklayer as processing.

In this chapter we have not attempted to measure or allow

for the incidental handling performed by laborers whose primary work is processing, such as the operation of feeding a processing machine from a nearby pile of material, but have rather listed as employed in handling only those workers who are primarily engaged in moving goods.

#### IMPORTANCE OF MATERIALS HANDLING

The movement of materials constitutes almost the sole function of the industries devoted to the transportation of freight by railway or motor truck and its handling at marine and land terminals. Likewise, the retail coal yard, in its physical operations, is engaged chiefly in loading, moving and unloading coal.<sup>2</sup> Also, the operations and equipment involved in the excavation phase of construction are essentially similar to those in the handling processes in other industries. The narrow trench excavator is a form of the bucket elevator; the power shovel that excavates a basement is merely moving materials; and the construction of a highway consists in large part of the two processes of moving dirt to establish the desired grade, and of delivering the essential paving materials to the point of construction. Finally, intrafactory transportation and other phases of the movement of goods constitutes a large part of the processes of the manufacturing industries, particularly those engaged in heavy manufacturing.<sup>3</sup>

<sup>2</sup> See the brief discussion of these industries in Ch. IV.

<sup>3</sup> One indication of the growing recognition of the importance of the materials-handling phase of manufacturing is the increasing space devoted to articles dealing with the various aspects of the conveying process in magazines that give particular attention to the production aspect of manufacturing. For example, *Industrial Management* (formerly the *Engineering Magazine*) in 1900 devoted less than 2 per cent of its space to materials handling; in 1915, 6 per cent; in 1924, 16 per cent; and in 1926, 19 per cent.

## MAGNITUDE OF HANDLING IN MANUFACTURING OPERATIONS

The magnitude of handling as compared with processing in the manufacturing industries is indicated by the proportion of the labor force engaged in moving materials and of the manufacturing cost constituted by handling. Further evidence is afforded by computations of the actual volume of handling required in selected manufacturing operations. Table 9 gives the percentage distribution, in each of five

TABLE 9  
PERCENTAGE DISTRIBUTION OF MACHINE AND HAND WORKERS,  
IN PROCESSING AND MATERIALS HANDLING, IN PLANTS  
SELECTED TO REPRESENT DIVERSE TYPES OF  
MANUFACTURING

*Percentage of total workers exclusive of supervisory workers<sup>1</sup>*

PLANT	TOTAL PROCESSING AND HANDLING	PROCESSING					HANDLING				
		TOTAL PROCESSING	MACHINE OPERATORS	MACHINE HELPERS	HAND	TOTAL HANDLING	MACHINE OPERATORS	MACHINE HELPERS	HAND		
Auto body	100.0	95.3	22.6	0.5	72.2	4.7	0.4	<sup>2</sup>	4.3		
Tire and tube	100.0	83.5	47.5	7.4	28.6	16.5	1.9	5.4	9.2		
Steel foundry	100.0	78.4	13.6	0.6	64.2	21.6	5.4	6.6	9.6		
Machine shop	100.0	88.6	76.5	0.7	11.4	11.4	7.2	4.2	<sup>2</sup>		
Hosiery	100.0	96.5	58.5	5.3	32.7	3.5	<sup>2</sup>	<sup>2</sup>	3.5		
Five plants combined	100.0	91.3	36.5	2.9	52.0	8.7	1.4	1.9	5.4		

<sup>1</sup> The total number of workers in these plants, with the exception of a few departments that could not be classified on the basis used in this computation, was 7,215, of whom 373 were reported as foremen, assistant foremen and similar supervisory workers. These supervisory workmen were excluded in computing the percentage distributions, inasmuch as they are associated with both the processing and handling phases in indeterminate proportions; hence the distribution applies to 6,842 workers. These data were obtained in 1926.

<sup>2</sup> Less than one-tenth of one per cent.

plants selected to represent industries of diverse types, of the workers engaged in processing and in handling; it also indicates whether they are manual workers or machine operators or helpers.

The percentage of total factory workers, exclusive of supervisory and office workers, engaged in handling varies from as low as 3.5 in the hosiery mill, which is very light manufacturing, to about 22 in the steel foundry, which is engaged in the production of heavy castings. For all five plants combined it is 8.7 per cent. The small proportion in the automobile-body plant, a relatively heavy type of manufacturing, arises in part at least from the use of power conveyors in some stages of assembly and painting. The writer believes these percentages are to some extent underestimates of handling in that they do not allow for the fact that in almost all manufacturing many process workers do some handling. For example, in one shoe plant inspected by the writer, a large part of the handling was done by the processing operators. When their particular operation on a group of shoes was completed they put them on special wheeled racks and pushed them to the location for the next operation.

Less than half of the workers assignable to handling in these five plants were machine operators or helpers. In the hosiery plant, as is quite common in light manufacturing, all the handling workers were manual rather than machine workers.

For a few of the pulp and paper mills included in our field survey we were able to ascertain the proportion of workers engaged in handling in yard and storeroom, shipping and conveying between processes. In 4 pulp-making plants 25 per cent of the workers were engaged in handling; in 4 paper-making plants, 22 per cent.

Somewhat more detailed evidence of the importance of

handling in heavy manufacturing industries is illustrated by special studies which we made of the volume of handling operations in foundries and brick plants.

*Volume of handling in foundries*

In a heavy industry like the manufacture of metal castings the lifting and moving of materials constitutes a substantial part of all the work. In 81 foundries inspected in 1925, we found 16 to 17 per cent of the workers engaged in occupations that were primarily handling. In a sample of 20 of these foundries, employing from 50 to 150 men each, 143 tons of pig iron and scrap, 24 tons of coke and 33 tons of new sand were used for each 100 tons of good castings produced. The average handling for each ton of good castings was equivalent to moving one ton of material 763 feet. These computations do not include the yard handling of materials prior to delivery to storage, the hauling of ashes and cupola droppings to distant points outside the factory grounds, or some minor movements such as the handling of limestone. However, they do include most of the handling within the foundry.

Machinery was used to some extent in each of the several handlings, the most highly mechanized movement being the transference of molten metal from the cupola to the molds. For all operations combined, 32 per cent, or nearly a third of the total handling, was by manual methods.

The several movements which make up the total of 763 ton-feet (68) are as follows, the figures in parentheses indicating the percentage handled by machine methods: coke, coal, pig iron and scrap from storage to cupolas and furnaces, 145 ton-feet (51); the disposal of ashes, burnt sand and cupola droppings, 107 ton-feet (43); sand to molds, core room and cleaning room, 45 ton-feet (44); molten metal from cupola to molds, 124 ton-feet (93); castings from molds

to cleaning, 144 ton-feet (68); castings from cleaning through storage to shipping, 198 ton-feet (98).

Although these computations apply only to a group of foundries of medium size and rest upon original data that were necessarily approximations, they afford a striking illustration of the large amount of heavy handling required in foundry operations.

#### *Volume of handling in brick plants*

The manufacture of common brick is another industry with a large volume of handling. For 45 common brick plants our field inspectors obtained data on the capacity of the plant, the distance material was transported while undergoing the manufacturing process, and the methods of transportation. The results are tabulated in Table 10, in both absolute and percentage terms. The first columns of the table give the aggregate distance traversed regardless of the volume of brick handled. Then follow summations of the products obtained by multiplying the distance transported by the daily capacity of the respective plants, to allow for appreciable differences in the methods used in the small and large plants.

The aggregate distance covered in interprocess handling in these 45 plants was 20,061 feet. Haulage from clay pit to preparation plant is not included. When each plant operated at normal capacity, each brick, or the clay from which it was made, was moved, after the clay had reached the preparation plant, about 475 feet on the average.

Much of this handling was manual. True, in 7 of the 45 plants no bricks were transported by wheelbarrow, but in the majority manual methods of transportation were extensively used and the bricks were loaded or unloaded some six or more times by hand. The handling was by wheelbarrows

for 31 per cent of the aggregate distance, by cars on tracks (either propelled by hand or moved by gravity) for 20 per cent, and by power methods for slightly less than half. Even when allowance is made for the volume of brick handled as well as for distance, over a quarter of this transportation was by wheelbarrows and only slightly over half by power methods of any kind.

An allowance for differences in the weight of brick in the several stages of manufacture would reduce somewhat the percentage of the total handling attributed to manual methods, as the processes are more highly mechanized in the earlier stages, and in these stages the brick contain more water and are some 20 per cent heavier than when dried and burned.

The least mechanized plants operated on the whole fewer months in the year than the more highly mechanized. Hence the proportion of the annual output handled by mechanized methods is greater than as estimated above on the basis of daily capacity. A computation based upon the reported total production in 1924 in these 45 plants indicates that 24.7 per cent of the annual aggregate interprocess transportation was by wheelbarrow, 19.6 per cent by cars on tracks, and 55.7 per cent by power methods. Even with this adjustment, it is evident that a very substantial part of the handling in this group of brick plants was by manual methods.

#### *Ratio of handling expense to payroll*

Handling expense constitutes a substantial part of total manufacturing cost. Some clue to this ratio is afforded by a survey made for *Factory* by the A. C. Nielsen Company.<sup>4</sup>

<sup>4</sup> Reported in *Factory*, August 1925, pp. 183-92, 224-72, 276-80.



TABLE 10  
DEGREE OF MECHANIZATION IN INTERPROCESS  
TRANSPORTATION OF BRICK

*Proportion of work done by specified methods in 45  
common brick plants when operated at capacity*

I. HANDLING IN SPECIFIED MOVEMENTS

MOVEMENT	DISTANCE TRANSPORTED (FEET)				DISTANCE MULTIPLIED BY DAILY CAPACITY (MILLION BRICK-FeET)			
	ALL METH-				ALL METH-			
	ODS	BARROW	CAR	POWER	ODS	BARROW	CAR	POWER
All movements	20,061	6,240	4,049	9,772	1,413	368	266	779
Preparation plant to molding machine <sup>1</sup>	1,836	75	...	1,761	114	3	...	111
Molding machine to dryer	10,146	1,655	1,795	6,696	710	73	110	527
Dryer to kilns	5,324	2,715	1,629	980	386	155	127	104
Kilns to storage and carrier	2,755	1,795	625	335	203	137	29	37

One or more departments in 39 plants in various industries and cities were surveyed for cost figures, and the ratio between handling expense and payroll computed. Handling costs were shown to range from 5 to as much as 80 per cent of payroll, the average being 21.8 per cent, and for the majority of the departments surveyed the range was from 10 to 40 per cent. The plants selected had good conveying systems and it seems probable that the expense ratio would be even higher for the general run of establishments.

PROPORTION OF LABOR-SAVING CHANGES CLASSIFIABLE  
AS HANDLING

Of 695 labor-saving changes upon which information was obtained in our survey, 40 per cent were in handling; and

## HANDLING

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TABLE 10 (cont.)

### DEGREE OF MECHANIZATION IN INTERPROCESS TRANSPORTATION OF BRICK

*Proportion of work done by specified methods in 45  
common brick plants when operated at capacity*

#### II. PERCENTAGE DISTRIBUTION OF HANDLING

DISTANCE TRANSPORTED (PER CENT)				DISTANCE MULTIPLIED BY DAILY CAPACITY (PER CENT)				MOVEMENT
ALL METH-				ALL METH-				
ODS	BARROW	CAR	POWER	ODS	BARROW	CAR	POWER	
100.0	31.1	20.2	48.7	100.0	26.0	18.8	55.1	All movements
100.0	4.1	...	95.9	100.0	2.5	...	97.5	Preparation plant to molding machine <sup>1</sup>
100.0	16.3	17.7	66.0	100.0	10.3	15.5	74.2	Molding machine to dryer
100.0	51.0	30.6	18.4	100.0	40.2	32.9	26.9	Dryer to kilns
100.0	65.2	22.7	12.1	100.0	67.6	14.4	18.0	Kilns to storage and carrier

<sup>1</sup> Including movements from dump to preparation plant, if materials when hauled from pit are unloaded to dump rather than to the first preparation machine.

of 332 instances which we abstracted from various technical journals in the years following 1920, 63 per cent. Judging from these data, about half of the labor-saving changes in this period were in handling rather than processing operations. Quite possibly the improvements in handling were more fully reported than those in processing, but even allowing for possible exaggeration, it would seem clear that improvements in handling have been a very important factor in recent gains in industrial efficiency.

## REPORTED LABOR-SAVING CHANGES IN HANDLING

Labor-saving changes in handling equipment since 1920 to the number of 282 were reported to our inspectors in 1925 or given in reply to inquiries by mail in 1928. Additions to or modifications in semimobile equipment, such as installed conveyors, cranes, hoists, monorails, cable hauls and industrial railways numbered 158. Changes affecting mobile handling equipment, such as electric trucks and tractors, portable loaders and motor trucks, numbered 92. In a dozen instances the reported labor saving in handling consisted merely of rerouting and rearrangement of machines. The nature of the reported changes in each of these groups is briefly analyzed in the following paragraphs, except that the analysis of labor-saving changes arising from the introduction of electric trucks and tractors is deferred to the more general discussion of these devices in a later section of this chapter.

## REDUCTION IN THE VOLUME OF HANDLING

One marked tendency in the modern movement for greater industrial efficiency is the effort to reduce handling through the rearrangement of equipment and processes to provide straight-line flow. The serialization of machines and processes reduces interprocess handling to a minimum and in its more highly developed form provides for continuous assembling or processing on conveyor belts. Such reduction of handling by rerouting may conceivably be accomplished with no change in the handling equipment, but it is more likely to be accompanied by the addition of conveyors or some other handling device.

In a dozen instances the savings reported were ascribed to rerouting or rearrangement of machines. The centralization of finishing departments in one paper mill eliminated much

handling and speeded up production by 30 per cent; another paper mill reduced its labor force by 30 men by a change in executives and some rearrangement of machinery; another cut the force by 75 men, chiefly by rearrangement and re-routing, increasing output at the same time about 10 per cent; the newer processes in tire manufacturing were reported to have eliminated much handling between operations; one furniture plant reported gains from a new plant with "no back-tracking", and another from "realignment of machines to save back-tracking"; a small copper rolling mill estimated a 50 per cent reduction in labor requirements from a reorganization of its processes; productivity gains of 15 per cent were reported by two foundries as resulting from new layouts; and minor gains of similar nature were reported by roofing, cotton manufacture, and brick plants.

A closer vertical integration of industries tends to reduce the handling required. For example, it is becoming an increasingly common practice for steel works to use pig iron in the molten state direct from the blast furnaces.<sup>5</sup>

#### PROGRESSIVE-ASSEMBLY CONVEYORS

An important labor-saving handling device is the continuous conveyor used in the progressive-assembly method made famous by the Ford Model-T assembly belt and extensively used in automobile, tire and other industries. It is not exactly a new type. A forerunner of the modern continuous conveyor is the intermittently moving platform for conveying foundry molds from process to process. One of these has been in use for thirty years or more in a Pennsylvania foundry

<sup>5</sup> See Ch. III, section on the steel and iron industry. The reduction in handling labor that arises when goods are shipped in bulk rather than in packages, thus eliminating the filling and emptying of containers, may also be mentioned.

inspected by us. The progressive-assembly conveyor makes possible the performance of mechanical operations on materials while in transit from one point to another. Each occupation occupies an allotted space along the conveyor, in logical sequence, the direction of travel being towards the point of shipment or assembly into larger units.

The progressive conveyor is an important factor in much of modern mass production. It is used for assembly, and less frequently, for other processing sequences. For example, bricks are sometimes moved through the dryer, or castings through annealing ovens, on continuous slow-motion conveyors.

It will be readily understood that ordinarily the most effective organization of the handling work in a factory or other establishment will involve, not the exclusive use of a single type of equipment, but rather a carefully planned combination of several types, the particular combination depending upon the amount and type of material to be handled, the vertical and horizontal distance to be moved, the available space, width of doors, etc. Intermittent handling of small quantities through narrow aisles may be best done by special hand trucks; a steady stream of material over a fixed route, by a continuous conveyor or elevator; heavy loads over variable routes, by industrial truck and tractor and trailer; heavy loads over routes with a fixed range of variation, by the overhead traveling crane.

The instances of labor saving through the installation or remodeling of conveyor systems since 1920 number 105 and cover a wide variety of types. Seven were adoptions of progressive assembly or fabrication, all from a small group of informants in the automobile and tire industries. They cover the assembly of engines and bodies, the movement of bodies during the painting operation, the conveying of semifinished inner tubes through the finishing fabrication steps, and a

gravity conveyor system for the mixing boxes used in assembling the ingredients for tire rubber stock. They replace systems of individual stands with intermovement by hand trucks or of building bodies by small groups where all material had to be moved to the body. One such change increased crew output about 300 per cent; another reduced the required crew 20 per cent; another, the number in the crew from 112 to 90; another, from 29 to 18.

#### OTHER CONVEYORS AND CONVEYING SYSTEMS

In addition to the above-noted changes clearly identifiable as transitions from discontinuous to continuous fabrication or assembly, the reported savings included 98 other instances accomplished by the introduction or alteration of conveyors or conveying systems, many of these doubtless facilitating continuous assembly or fabrication. Both the types of conveyor and the industries represented are highly diverse and illustrate the versatility of this type of handling equipment. The products handled include such heavy manufactures as foundry castings, brick, coal, automobile bodies, paper rolls and smelting materials; such relatively light manufactures as shoes, butter and small electrical goods, bulk goods like coal, large units like automobiles, meat carcasses in process of disassembly, porcelain products passing through kilns, and packaged goods like soap and butter from the packaging machines.

About half of the instances reported were from the foundry industry, indicating the adaptability of the conveying device to this industry; however, this large proportion is not to be taken as representative of the use of conveyors in foundries as compared with other industries, for it is partly due to the relatively large portion of our total survey represented by foundries, and particularly by one or two large

and well-equipped automobile foundries, which made numerous labor-saving changes in their conveying systems in the period covered by the survey.

#### CRANES AND HOISTS, AND MONORAILS

Relatively speaking, the devices in this group (consisting chiefly of electric and gasoline hoists, monorails and hot-metal carriers, overhead traveling cranes, and other types of installed or semimobile cranes and hoists) are not recent innovations in equipment. Nevertheless, some 45 instances of labor saving by their adoption were reported since 1920, chiefly in the foundry, building, coal-handling and machinery industries; that is, in industries requiring the handling of heavy materials. In most instances the reduction in crew reported is not large. Exceptions are a reduction from 30 to 5 men in a paper mill by installation of 3 boom grab-bucket cranes, over a period of years beginning before 1920, and a brass goods manufacturer who reported power hoists as enabling 30 men to do work formerly requiring 120. On the whole, the larger savings occur where the equipment is directly substituted for hand methods. In the hoist installations in building construction the substitution of electric hoists for steam were usually reported as saving one man, but a contractor who reported direct substitution of gasoline hoists for hod carriers states that this type of hoist displaced from 3 to 10 men, depending upon the height to which material was hoisted. Cupola-charging devices are a relatively new development. The 2 included in this compilation were stated to save 4 men each.

**INDUSTRIAL LOCOMOTIVES**

Labor saving through the introduction of industrial locomotives or cable hauls were not of major importance in the establishments included in our survey. These are not new devices, half of the changes reported being prior to 1921, many of them in 1918. Of the 8 since 1920, 6 are substitutions for horses or mules. The crew reductions were not large. For example, a reduction of 2 men in a brick yard, with the introduction of a new type of locomotive; the reduction of a haulage crew from 5 to 4 in one bituminous mine, and in another from 25 to 18 men and the elimination of 25 mules.

**TRUCK HAULAGE AND CENTRAL PROPORTIONING**

The change in the handling of materials in highway construction, from wagon haulage and wheelbarrow proportioning on the subgrade to central proportioning and truck haulage, began before 1921, and most of the instances reported to us occurred in 1919 and 1920, or in the years immediately following 1920 (*cf.* Ch. IV). The labor saved was substantial, usually about 60 per cent of the handling crew. Twelve instances reported involved reductions in crew of 161 men, or about 13 men per crew. If additional allowance is made for stated increases in yardage per crew, the reduction becomes equivalent to 17 men per crew.

Aside from a few instances of hauling around factories and uses in construction other than those included in the above paragraph, the reported labor-saving changes arising from the use of motor trucks were in retail coal yards, chiefly anthracite yards in New York City.



## PORTABLE LOADER AND MISCELLANEOUS CHANGES

Among the important savers of unskilled shoveling labor should be mentioned the various types of portable wagon loader, used chiefly for loading bulk materials, such as snow, coal, sand or gravel, from a ground pile to wagon or truck.<sup>6</sup> The coal-car loader for use in mines is a variation of great potential significance.<sup>7</sup> Portable loaders are usually of the continuous inclined bucket elevator type. The elevating conveyor often dumps to a transverse conveyor or a chute from which the material is discharged to the wagon. If the frame, which carries the elevating element, is mounted on wheels, the unit must be trundled from place to place by hand; if it is mounted on a caterpillar tread, the unit propels itself. The most highly developed types are self-propelled, self-feeding units. If the unit is not self-feeding, the material is shoveled by hand to a hopper whence it flows to the buckets or belt. The self-feeding types have some sort of apparatus at the lower end—rotating blades, revolving disks, etc.—which gathers the material from the pile.

Of the labor savings reported directly to us only a few were ascribed to the adoption of portable loaders. One retail coal yard reported the saving of 2 men through their adoption; another reduced its yard crew from 4 men to 1 by “portable scoop electric loaders replacing hand shoveling from ground storage, with additional saving in the time of trucks.”

The remaining miscellaneous group of handling changes reported to us (some 20 in number) included pulp pumps for a paper mill; hand-power lift trucks substituted for

<sup>6</sup> For use in retail coal handling, see Ch. IV.

<sup>7</sup> See Ch. IV; also Table 40, for statistics of bituminous coal loaded with self-feeding loading devices; Table 46, for annual sales of self-feeding wagon loaders; and Table 52 for rough estimates of extent of use.

wheelbarrows; a mechanical litharge handling system in a paint factory, to avoid the hazard of lead poisoning involved in hand shoveling; a revolving car dumper in place of bottom-dump cars, reducing the crew required from 36 to 6 men; storage silos with gravity delivery of cement, in place of storage bins, reducing the evacuating crew from 61 to 6; and various other changes in handling methods or equipment.

#### ELECTRIC TRUCKS AND TRACTORS <sup>a</sup>

Labor savings through the purchase of industrial electric trucks or tractors since 1920 were reported by 38 establishments, in widely diverse industries, including the foundry, automobile, cotton, stevedoring, smelting and refining, machinery, building tile, paper, brass, lumber and canned fruit. In about four-fifths of the reported changes the truck or tractor displaced carrying by hand or transportation with hand trucks.

Information on the number of trucks installed and the size of the crew before and after the change is not complete for all instances reported. A compilation based on 10 installations of tractors gives a crew reduction of 5 men per

<sup>a</sup> This class of equipment, aptly described as 'trackless transportation', is primarily for use inside buildings, in factory yards, or at marine and railway terminals. Industrial trucks, aside from various hand types, are self-propelled machines that carry their load. Gasoline engines or electric storage batteries furnish the power. The major types are (1) the non-lift platform truck; (2) the low-lift type; (3) the high-lift or tiering type; and (4) trucks equipped with cranes and other special apparatus. The low-lift type has a low platform or other carrying device which is run under loaded skids, then raised by the motor, and the skid and load transported to the delivery point. This method saves handling and also the time of the truck as skids can be loaded while the truck is busy elsewhere. In the high-lift or tiering type the movable platform may be elevated six feet or more for unloading to auto trucks or freight cars and for piling. The industrial tractor hauls its load in a train of trailers.

tractor; and 80 electric trucks, in 13 plants, reduced the crews involved from 336 to 112 men, or a saving of about 2.8 men per truck. This includes a few instances where part of the installations were made prior to 1921, and the effect of these earlier installations cannot be isolated from those made since 1920.

To what extent are the tendencies indicated by the analysis of reported labor-saving changes in the preceding pages representative of prevailing trends in industry as a whole? The data requisite for an answer to this question are most complete for electric trucks and tractors.

Railroad and marine terminals were at first the largest users of electric industrial trucks, but the metal products manufacturers and the automotive industry have now stepped into that position. Also, as is shown in Table 11, there is a

TABLE 11  
ELECTRIC TRUCKS AND TRACTORS IN USE,  
1920 AND 1928: BY INDUSTRIES<sup>1</sup>

INDUSTRY IN WHICH USED	PRIOR TO 1920	JUNE 1928	INCREASE
Total number classified	4,547	14,289	9,742
Metal product manufacturers	1,128	2,994	1,866
Freight, marine and railroad	771	2,580	1,809
Automobile manufacturers	391	1,749	1,358
Iron and steel mills	151	969	818
Foundries	143	917	774
Food manufacturers	188	678	490
Chemical manufacturers	251	639	388
Ceramic manufacturers	80	504	424
Warehouses (public)	273	426	153
Textile manufacturers	140	349	209
Pulp and paper manufacturers	35	346	311
Printing and publishing	6	103	97
Jobbers and wholesalers	2	39	37
Miscellaneous	988	1,996	1,008

<sup>1</sup> Based upon typed report made available for our use by C. B. Crockett, Secretary, Industrial Truck Association, January 29, 1930.

tendency towards extensive use of this equipment in such industries as foods, chemicals, ceramics, and pulp and paper.

The variety of uses to which electric trucks are put is indicated by the following estimate made available by the courtesy of Mr. C. B. Crockett, Secretary of the Industrial Truck Association. The percentages refer to the proportion of users which employs the trucks in the specified operation.

OPERATION	PER CENT
Raw material from common carriers	13
Raw material from storage	10
Material moving through process	11
Material moving through assembly	8
Finished material from assembly	10
Finished material from packing	8
Finished material from storage to common carrier	17
Supplies from storage to process	17
Machines or parts to and from use	18
Millwright and repairs	21
Miscellaneous services	17

Battery-driven trucks first appeared in 1904 at the Altoona shops of the Pennsylvania Railroad and were introduced in railway station use about 1906. These were the load-carrying, fixed-platform type. About 1913 the tractor and the low-lift type appeared. In 1915 the crane-equipped type came on the market and shortly afterwards the high-lift or tiering models.

The number of electric industrial trucks and tractors sold in the United States each year is given in Table 46. After 1916 the annual sales were between 1,000 and 2,000 in all but 3 years. For the first few years the distribution by years is only a rough approximation; for the second period, 1914-24 inclusive, the estimates are based upon sales data furnished by leading producers who manufactured about 60 per cent of the total number sold in the United States in 1925. The estimates for 1914-24, however, are not merely

## MECHANIZATION IN INDUSTRY

TABLE 12  
ELECTRIC TRUCKS AND TRACTORS IN USE, 1920 AND 1928:  
BY TYPES<sup>1</sup>

TYPE	PRIOR TO 1920	JUNE 1928	INCREASE
Total number	4,790	14,103	9,313
Load-carrying	2,508	4,188	1,680
Low-lift standard	1,206	4,560	3,354
Low-lift special	3	519	516
High-lift standard	62	1,203	1,141
High-lift special	6	414	408
Crane trucks	77	909	832
Tractors	926	2,133	1,207
Others	2	177	175

<sup>1</sup> Based upon typed report made available for our use by C. B. Crockett, Secretary, Industrial Truck Association, January 29, 1930.

for the sales of the companies furnishing data but for all producers and are based upon the assumption that the ratio between the sales of these companies and the sales of all producers did not change materially throughout this period.

The total sales from 1914 to 1929, as estimated in Table 46, are 17,995, and a few hundred machines were sold prior to 1914. As these machines are relatively durable, the majority of those sold are probably still in use. In Table 12 we submit estimates that 4,790 units were sold prior to 1920 and 14,103 were in use in June 1928.

The later models are on the whole larger, heavier, and often more specialized; hence the data on numbers alone, as in Table 46, somewhat underestimate the recent rate of introduction.

Since the sharp decline of 1921, the annual additions were relatively steady, although some truck manufacturers estimated in the latter part of the decade that scarcely half of those who could profitably use the types now developed were doing so; furthermore, the tendency is to widen their sphere

of use by the development of types specialized for particular uses.

## OTHER HANDLING DEVICES

For handling devices other than electric trucks and tractors the available data are less detailed and comprehensive. The annual output of conveyors, cranes, power shovels and trench excavators, respectively, runs into millions of dollars, as will

TABLE 13  
VALUE OF SELECTED TYPES OF HANDLING EQUIPMENT  
PRODUCED <sup>1</sup>  
(unit: \$1,000)

TYPE OF EQUIPMENT	1925	1927	1929
Conveying and elevating machinery <sup>2</sup>			
All types	30,688	33,528	48,537
Belt	<sup>3</sup>	10,520	14,206
Bucket	<sup>3</sup>	10,726	9,387
Gravity	<sup>3</sup>	<sup>3</sup>	2,711
Pneumatic	<sup>3</sup>	<sup>3</sup>	1,780
Other	<sup>3</sup>	12,282	20,454
Cranes (including hoists and derricks), total <sup>2</sup>	43,936	44,454	57,840
Locomotive and crawler types	13,162	13,506	12,579
Crawler type	<sup>3</sup>	<sup>3</sup>	6,626
Stationary	11,601	12,340	22,202
Overhead traveling	19,173	18,607	23,059
Excavating machinery, total	41,389	48,098	57,103
Power shovels <sup>2</sup>	26,609	32,106	43,348
Trench excavators	3,130	3,512	2,427
Drag lines and power scrapers	9,006	8,830	7,242
Other	2,644	3,651	4,086

<sup>1</sup> Compiled from *Census of Manufactures, 1925*, p. 1031, and *1929*, II, 1098-1100.

<sup>2</sup> Similar data for earlier years (in thousands of dollars) are:

(1) all types of conveying machinery, 1923, 26,303;

(2) cranes, 1921, 20,446; 1923, 42,197;

(3) power shovels, 1921, 12,858; 1923, 23,684.

<sup>3</sup> No comparable data available for these years.

be seen from the statistics of value of output in the census years 1925, 1927 and 1929, presented in Table 13.

For part, but not all, of the machine types included in Table 13, the number as well as the value is reported, and by assuming that the average value per machine is the same whether the number is reported or not, we arrive at the following estimates of the number of machines produced in 1929: 2,400 crawler cranes, 390 locomotive cranes, 15,700 overhead traveling cranes, 80,700 stationary cranes, 35,500 power shovels, 2,900 drag lines and power scrapers, and 360 trench excavators. The last-mentioned types are excavating machines and not strictly speaking handling equipment; but there is a rather close kinship between, for example, a trench excavator of the bucket type and a bucket elevator for handling grain.<sup>9</sup>

#### EXTENT OF USE

In Table 52, we have assembled the available, but admittedly heterogeneous, information concerning the extent to which various mobile types of handling equipment had been sold or were in use at the time stated. For most types the information available is not as complete as that for electric trucks and tractors, hence in using these data the reader is cautioned to note the date or period to which the estimate applies and the type of information upon which it is based as indicated by the code at the beginning of Appendix B. We have not hesitated to use approximations with quite a wide margin of possible error when no better information was at hand, believing that even such approximations are useful in an effort to give as full a picture as possible of the growth and extent of mechanization. Similar

<sup>9</sup> See also Table 41 for sales of power shovels and narrow trenchers.

estimates for fixed and semimobile types of handling equipment appear in Table 52.

#### EFFECTS OF MECHANIZING HANDLING DEVICES

The increased regimentation of factory procedure that ordinarily accompanies a thoroughgoing and well-conceived mechanization of the handling operations facilitates the subdivision of processing, frequently saves working space, and expedites and cheapens production. It tends to decrease the demand for unskilled labor, both absolutely and relatively, because mechanization not only reduces the number of workers required in handling but also tends to substitute some semiskilled and skilled workers for unskilled. Manual methods of handling, as we have seen, are almost entirely by unskilled workers; but the operation of mechanical handling equipment demands, on the whole, a somewhat higher degree of skill and more repair men; also some skilled men in the construction of machines.<sup>10</sup> Concerning the total constructive displacement of workers by the handling equipment introduced in the decade of the 'twenties we have made one or two estimates for particular types of machine, but any estimate for the total of all types would be almost a pure guess (see Ch. X). Doubtless the man-power equivalent of the total installations runs into hundreds of thousands. To what extent this equipment actually displaced men and to what extent it merely accompanied an expansion in the volume of business is highly problematical.

#### SUMMARY

Handling operations, though more or less common to all industries, require, so far as the available evidence indicates,

<sup>10</sup> See discussion of the effect of mechanization on skill in Ch. X.



from only a few per cent of the total number of workers in some of the light manufacturing industries to 20 per cent or more in some of the heavy manufacturing industries, and to a much larger percentage in the industries primarily devoted to the transportation of goods.

Much of this handling work is manual. We found nearly a third of the heavy volume of handling in a group of 20 foundries to be manual, and in a group of brick plants nearly half of the interprocess transportation of brick was by manual methods.

Here is obviously a large field for possible further mechanization. We find evidence not only of a growing recognition of this fact but also of an advance in mechanization through the development of new types of equipment and more extensive use of older types.

Interprocess handling has long been thoroughly mechanized in such industries as flour and meat packing. Mechanization of handling has more recently made marked progress in the rapidly growing industries such as automobiles and tires. A substantial beginning has been made in the better equipped plants in some of the older industries like foundries, and a start has been made in the mechanization of the loading process in mines. However, from the literature of the subject, from interviews with sellers and users of equipment, and from pondering over the available statistics, the writer has gained the impression that there is still a large field for the gradual replacement of manual with mechanical methods in the handling operations of factories and mines, and even in the handling industries proper, such as stevedoring.

CHAPTER VI  
MEASURES OF CHANGE  
IN MECHANIZATION

IN PRECEDING chapters we have sketched the observed tendencies towards increasing mechanization, first in selected manufacturing industries, then in the non-manufacturing industries and finally in the handling of materials, which is more or less common to all. The reader has doubtless gained the impression that mechanization in the post-War decade proceeded along many lines and with somewhat exceptional rapidity. Can we state this tendency towards mechanization in a more generalized form than by describing the developments peculiar to each industry, and in a form reasonably comparable from industry to industry and from period to period? Just how fast and in what ways has mechanization progressed? Can we measure it or at least delineate its main lines of advance?

For purposes of measurement the concept of mechanization requires a more precise denotation. Here we are limiting it to power mechanization, that is, to processes and methods utilizing generated power. So limited we find several possible ways of measuring its extent. First we may take the amount of power used, or the more readily available figure of rated horsepower capacity of power equipment. But this measure does not give us a ratio of machine work to non-machine work. To obtain such a ratio we may turn to the proportion of product that arises from mechanical as compared with manual methods, and this machine output ratio

is obviously significant in the few instances where it is available. But even this figure does not correctly indicate the proportion of workers engaged in the mechanized process, for 75 per cent of an industry's output might be produced by 25 per cent of the workers if they were equipped with highly productive machinery and the other 75 per cent were using antiquated hand methods. It will be noted that the *machine labor ratio* based upon the proportion of machine workers to the total labor force is a measure of mechanization that facilitates a comparison of the degree of mechanization between two processes in the same industry (see Ch. VII).

A second possible measure of this type is the ratio of expense for labor to the total cost of production. The ratio of wages to value added by manufacture (as a rough measure of the *labor expense ratio*) can be determined from census data by industries, but not for the several processes in an industry. However, if sufficiently detailed cost accounting records were available, it is conceivable that ratios of labor expense to total expense could be computed for each process and used as rough measures of relative mechanization. The labor expense ratio, it will be noted, is affected not only by the number of wage earners, but also by relative wage rates and hence by the grade of labor in so far as wage rates are determined by differences in the type of labor. Another possible measure is the equipment ratio—the dollar value per worker of the power equipment in use.<sup>1</sup>

The horsepower ratio, the machine output ratio, the machine labor ratio, and the labor expense ratio are all more or less *general measures* of mechanization in that they are

<sup>1</sup> Colonel M. C. Rorty remarks that a very interesting, but still not wholly significant, figure might be K. W. hours per unit of output from year to year for a given establishment or industry; and that *intensified illumination* is probably a not unimportant element in increasing power consumption.

applicable (assuming appropriate data are available) to all industries. In contrast are various specific measures which indicate the extent of use of specified labor-saving devices and are consequently limited in their application to the particular industries in which such devices are used.

The several general measures of mechanization do not give precisely the same result when the degree of mechanization between industries or at different periods in the same industry is compared, partly because they refer to somewhat different aspects of the phenomenon of mechanization, and partly because of the inadequacy of the data and complicating factors whose influence cannot be eliminated. There is no adequate single quantitative measure of the extent of the increasing substitution of machines for human effort. We must resort to the composite picture afforded by several phenomena. Though no one of these alone tells the whole story, jointly they throw much light on the trend in mechanization.

Of the several measures mentioned, the most readily available is the rated capacity of prime movers and motors operated by purchased power, expressed in terms of horsepower.<sup>2</sup> Rated horsepower statistics are published in considerable detail, particularly for manufacturing. But the statistics of horsepower, though useful and important, are, as will be explained more fully in subsequent paragraphs, inadequate in two respects: first, they do not give a perfect record of the changes in power used or even of installed power equipment; second, the changes in power per worker, even if precisely measured, are not a complete story of the changes in mechanization. In fact, some important mechanical improvements actually result in a decrease rather than an

<sup>2</sup> Prime movers are steam engines and turbines, internal combustion engines, and water wheels and water turbines.

increase in power requirements. Consequently it is appropriate to supplement our analysis of the capacity of installed power equipment with such other evidence as is available to indicate the changing degree of mechanization.

We are concerned in this chapter with measures that facilitate comparisons of change in mechanization—of the degree of mechanization at different periods—rather than comparisons as in Chapter VII of differences in degree of mechanization at a given time between industries, processes or producing areas. The general measures available for chronological comparisons are not so numerous or adequate as those usable for comparisons of currently existing differences. The ratio of wages to value added by manufacture is available but is of somewhat limited usefulness. The growth of the machine-producing industry is itself a clue to the changing importance of the machine. Also, in addition to the general measures, there are available for particular industries or processes various indicators of change in the use of specified labor-saving devices. For a few processes, such as coal-undercutting in mining, the year-to-year changes in the proportion of output produced by mechanical equipment are on record; for others the proportion of operators equipped with specified labor-saving devices. The annual records of the number of specified labor-saving devices sold, or of the total number in use, afford some additional evidence of changing mechanization. Data of this type for numerous series are given in the several tables in Appendix A.

#### GROWTH IN THE USE OF POWER

The most generally available and most frequently used measure of increasing mechanization is horsepower per

worker.<sup>8</sup> While some useful information is available for several other industries, such as agriculture, mining and transportation, horsepower statistics are most complete for manufacturing.

#### LIMITATIONS OF POWER DATA

Power equipment and the number of wage earners in manufacturing have been compiled in the census of manufactures for 1869, 1879, 1889, 1899, 1904, 1909, 1914, 1919, 1923, 1925, 1927 and 1929. Before examining the statistics of horsepower per wage earner computed from these data, we should note their limitations:

1. The scope of the *Census of Manufactures* has changed in such a way that for neither wage earners nor rated horsepower are available data strictly comparable from period to period.
2. The increasing use of electric power is probably accompanied by a decreasing ratio between the machines operated by power and the rated capacity of power equipment.
3. Rated capacity is at best an imperfect index of power actually used.
4. Even power actually used would not be an entirely adequate measure of mechanization.

#### *Changes in the scope of the Census*

Prior to 1904 the *Census of Manufactures* covered not only the factory system proper but also various hand and neighborhood industries. In 1904 and subsequent censuses

<sup>8</sup> Horsepower as used in the *Census of Manufactures* refers to the rated capacity of prime movers and motors driven by purchased current and not to the amount of power consumed.

the hand and neighborhood industries have been excluded. The census for 1919, and the earlier censuses, included all establishments with annual products valued at \$500 or more; after 1919 the lower limit was \$5,000. As data for 1899 are available both with and without the inclusion of the hand and neighborhood industries, and for 1919 both with and without establishments with products valued under \$5,000, we may divide the entire period into three segments for close comparisons, namely:

1. 1869-1899, with data covering both factory and hand and neighborhood industries, for establishments with annual product valued at not less than \$500.
2. 1899-1919, with data covering factory industries only, for establishments with annual product valued at not less than \$500.
3. 1919-1929, with data covering factory industries only, for establishments with annual product valued at not less than \$5,000.

These three periods have been observed in compiling Table 15. Various minor adjustments (indicated in the footnotes to Table 15), some of which are necessarily estimates,<sup>4</sup>

<sup>4</sup> Some additional causes of discrepancy have not been eliminated. While these do not, we believe, seriously impair the usefulness of the data, it may be well to note them. In the censuses of 1869 and 1879, the inquiry called for 'hands employed', and it may be that some workers other than wage earners were included, though the Census Bureau has stated that it does not believe salaried employees were as a rule included. In 1889 employees were separately designated as (1) officers, firm members and clerks; (2) operatives, skilled and unskilled, and piece workers. The data used for 'wage earners' exclude the first group. In all subsequent censuses 'wage earners' have been separately reported as such. Furthermore, in the census of 1899 and subsequently "the average number of wage earners for the year was computed by adding the numbers reported for the several months and dividing the sum by twelve. . . . If a factory employed, say, a hundred wage earners, but was in operation only six months during the year, the method of calculation would show an average of 50 wage earners employed for the year. At the census of 1889 and possibly for prior censuses, such a

have been made in order to render the data for the several censuses in each of the three periods comparable for the period. The scope of the power census has also varied somewhat with respect to equipment covered, being restricted to steam and water power only in 1869 and 1879. Some later discrepancies have been ironed out in the preparation of Table 14. The proportion of the hand and neighborhood industries increased in the census of 1889, largely owing to greater care in canvassing this group. The ratio of power to wage earners was probably lowered thereby but no attempt has been made to correct for this bias.

*The changing significance of rated horsepower*

During the last two decades a rapid increase has occurred in the use of purchased electric power (Table 24). In 1909 electric motors driven by purchased electric power represented only 9 per cent of the rated capacity of manufacturing plants; in 1919, 32 per cent; in 1929, 53 per cent. Dr. Willard Thorp points out that this marked increase in the use of electric power has changed the significance of rated power.<sup>5</sup> When power is produced by steam or water-power engines or turbines in the reporting establishment, even if delivered to dynamos and transformed to electric power, the rated capacity given in the *Census of Manufactures* is the rated capacity of the steam or water-power prime movers rather than that of the electric motors driven by the current generated in the plant; but when current is purchased from the outside, rated capacity refers to the rated capacity of the electric motors. Now, there are essential differences between the rated capacity of steam or water-power prime movers

factory would have been counted as employing 100 wage earners." *Thirteenth Census of the United States*, VIII, 20.

<sup>5</sup> Ref. 21, pp. 379-85.



and the rated capacity of electric motors driven by current generated by these prime movers.

In the first place, the rated capacity of steam and water-power engines and turbines "is generally the maximum load which they can carry". On the other hand, it is possible to run electric motors for short periods at considerably more than rated capacity.

Second, improvements in the transmission of power, chiefly by the substitution of electric power transmission within the plant for the old belt-and-shaft method, tend to reduce the primary power required to accomplish a given amount of work.

Third, when electric motors are driven by current generated in the establishment the rated capacity of the motors is likely to exceed considerably the rated capacity of the prime movers, because all motors in the establishment do not run at the same time or at full capacity. Likewise, when purchased electric current is substituted for water-power or steam prime movers the rated horsepower of the plant, in this case based on the electric motors, is likely to show an increase even though no change is made in the work done. In a subsequent section on the growth of electrification, we have used, as a rough approximation, an estimate that 100 horsepower of electric motors in factories require prime movers with rated capacity of 72 horsepower (Table 24).

Thus, with the increasing use of electric power, two factors—the possibility of running motors with an overload and the improvements in transmission of the individual-motor drive over the mechanical belt-and-shaft system—tend to lower the required capacity without changing the amount of work that can be accomplished. Another factor, probably more important than the first two, tends to increase rated capacity without a corresponding change in work done. No accurate balance can be struck between these factors, but it

should be recognized that they limit the comparability of the statistics of horsepower.

Rated capacity, even if consistently measured, may be a variable index of the actual use of power. In some ways a better index of mechanization would be power used in terms of kilowatt-hours or their equivalent.

*Power an inadequate measure of mechanization*

While the increase in the use of power in industry is doubtless a fair, rough indicator of increasing mechanization, it is clearly not a precise measure. What we need to measure is not rated capacity or even the quantity of energy the machine employs, but rather its producing capacity and its effect on the quantity and quality of attending labor required. For example, in the glass industry the sheet machine and the cylinder machine vary much more in skill displacement than in horsepower employed. It requires little or no more power to draw up a sheet of glass with the sheet machine, and yet the sheet is ready for cutting, while the cylinder must be flattened by skilled flatteners. Likewise the high speed warper in cotton spinning mills, operating as it does under a lighter tension than the old-style warper, probably requires less power, but through its greater speed makes a substantial reduction in the labor required (see Ch. III). A conveying system, utilizing chutes and gravity roller-bearing sections, may require little or no power and yet represent substantial replacement of manual labor by equipment. Doubtless in numerous instances the increase in power used or in rated horsepower is not commensurate with the actual increase in the use and effectiveness of mechanical equipment. That horsepower per worker is not always an adequate index of the degree of mechanization is suggested by consideration of the typical cotton goods factory. A cotton mill

is filled with whirring machinery, and our sample indicates that a large proportion (over four-fifths) of cotton mill workers are engaged in tending machines or in work auxiliary to their operation. Yet in 1929 the horsepower per worker in cotton goods was only 5.28 as compared with 8.41 in butter and cheese, 13.14 in the sugar industry, and 33.47 in the manufacture of ice. Such apparent inconsistencies arise in part from the large amount of power required by industries that work heavy materials and also from the use of power for refrigerating and other processing as well as for driving machinery.

#### PROPORTION OF ESTABLISHMENTS USING POWER <sup>6</sup>

The changes in the proportion of manufacturing establishments reporting the use of power affords some indication of the extension of power manufacturing. Only about one-third of the total number of establishments reported power in the censuses of 1879, 1889 and 1899 (Table 14). However, the early censuses included various hand and neighborhood industries, and when these are excluded from the census of 1899 the percentage of power-reporting establishments rises to 64. By 1919 the percentage had risen to 82 (86 when the small plants with value of product under \$5,000 are excluded), and by 1929, 92 per cent of all manufacturing establishments reported the use of power.

<sup>6</sup> As used in the *Census of Manufactures*, the term 'establishment' usually signifies a single plant or factory. "In some cases, however, it refers to two or more plants operated under a common ownership and located in the same city, or in the same county but in different municipalities or unincorporated places having fewer than 10,000 inhabitants. On the other hand, separate reports are occasionally obtained for different industries carried on in the same plant, in which event a single plant is counted as two or more establishments" (1929, I, 3).

TABLE 14

PROPORTION OF MANUFACTURING ESTABLISHMENTS REPORTING POWER, AND AVERAGE HORSEPOWER PER ESTABLISHMENT <sup>1</sup>

CENSUS YEAR	TOTAL NUMBER	NUMBER REPORTING POWER	HORSEPOWER PER ESTABLISHMENT	
			PERCENTAGE REPORTING POWER	REPORTING POWER <sup>2</sup>
<b>Hand and neighborhood industries included</b>				
1879	253,852	85,923	33.8	41.4
1889	321,584	98,943	30.8	59.2
1899	470,005	157,862	33.6	67.6
<b>Factory industries only, with product \$500 or more</b>				
1899	207,514	133,418	64.3	74.5
1904	216,180	134,481	62.2	100.3
1909	268,491	185,042	68.9	100.9
1914	275,791	205,590	74.5	109.1
1919	290,105	237,854	82.0	124.0
<b>Factory industries, with product \$5,000 or more</b>				
1919	214,188	184,225	86.0	158.5
1923	196,182	173,415	88.4	190.8
1925	187,981	168,282	89.5	212.8
1927	191,866	174,118	90.7	223.0
1929	210,474	193,603	92.0	221.7

<sup>1</sup> Compiled from the *Census of Manufactures* in the United States. A few industries have been eliminated in order to increase the comparability among the census periods. The 1899 data are given first with hand and neighborhood industries included, for comparison with 1879 and 1889, and then with these industries excluded, for comparison with 1904 and subsequent periods. Likewise the 1919 data are given first for establishments with product valued at \$500 or more, for comparison with previous censuses, and then for establishments with value of product of \$5000 or more, for comparison with subsequent censuses. In arriving at the revised 1919 figures, it was estimated that of 65,485 establishments with products valued at less than \$5000, the number reporting power was 43,000.

<sup>2</sup> The total horsepower data are in Table 15.

It is probable that some irregularities in the changes shown

in Table 14 are due to greater efforts at some censuses to cover the smaller establishments, to incomplete reporting of power, and to the impossibility of a perfect adjustment for changes in the scope of the census in 1904 and 1919.

The change in scope in 1904 and 1919 brought sharp declines in the number of manufacturing establishments. But even in the period 1919-29—with no major changes in scope—the number declined from 214,188 to 210,474.

Meanwhile, the horsepower per establishment reporting power increased rapidly—from 41 in 1879 to 67 in 1899 (75 after excluding the neighborhood industries), to 124 in 1919 (159 if establishments with value of product less than \$5,000 are excluded), and by 1929 to 222 horsepower per establishment. Doubtless the elimination of many small plants, the expansion of existing plants and the transition from hand to machine work without an equivalent plant expansion, have all contributed to the marked increase in horsepower per establishment in the half century covered by Table 14.

#### INCREASE IN TOTAL HORSEPOWER

Since the Civil War there has been a continuous increase in the installed capacity of primary horsepower in manufacturing, both in the aggregate and in terms of horsepower per worker. The data for each census period are summarized in Table 15. To lessen the degree of non-comparability arising from changes in scope previously described the statistics are presented in three period groups. For Group A (1869-99) the data cover the hand and neighborhood industries as well as factories whose annual value of product is \$500 or more; for Group B (1899-1919) they pertain to factories only, with value of product \$500 or more; for Group C (1919-29) only factories with an annual product valued at \$5,000 or more are included. The index numbers are chained

TABLE 15  
INCREASE IN RATED HORSEPOWER CAPACITY IN  
MANUFACTURING<sup>1</sup>

CENSUS YEAR	INDEX NUMBERS 1919=100						GEOMETRIC MEAN RATE OF GROWTH PER YEAR SINCE PRECEDING CENSUS	
	WAGE EARNERS (THOUSANDS)	TOTAL HORSEPOWER (THOUSANDS)	HORSEPOWER PER WAGE EARNER	WAGE EARNERS	TOTAL HORSEPOWER	HORSEPOWER PER WAGE EARNER	TOTAL HORSEPOWER (PER CENT)	HORSEPOWER PER WAGE EARNER (PER CENT)
<b>Group A</b> Hand, neighbor- hood and factory industries								
1869	2,028	2,314	1.14	20.2	7.3	36.2	...	...
1879	2,772	3,560	1.28	27.6	11.2	40.6	4.4	1.2
1889	4,171	5,857	1.40	41.5	18.5	44.4	5.1	0.9
1899	5,209	10,670	2.05	51.8	33.7	65.1	6.2	3.9
<b>Group B</b> Factories with \$500 or more product								
1899	4,713	9,942	2.11	51.8	33.7	65.1	...	...
1904	5,468	13,488	2.47	60.1	45.7	76.2	6.3	3.2
1909	6,615	18,675	2.82	72.7	63.3	87.0	6.7	2.7
1914	7,036	22,437	3.19	77.4	76.0	98.5	3.7	2.5
1919	9,096	29,505	3.24	100.0	100.0	100.0	5.6	0.3
<b>Group C</b> Factories with \$5,000 or more product								
1919	8,998	29,209	3.25	100.0	100.0	100.0	...	...
1923	8,777	33,092	3.77	97.5	113.3	116.0	3.2	3.8
1925	8,390	35,807	4.27	93.2	122.6	131.4	4.0	6.4
1927	8,350	38,826	4.65	92.8	132.9	143.1	4.1	4.4
1929	8,831	42,918	4.86	98.1	146.9	149.5	5.1	2.2

<sup>1</sup> Compiled from the *Census of Manufactures*, with adjustments to make the data within each group as comparable as possible, namely: lead pig, quartz milled, and raw cane and sorghum sugar and molasses were subtracted from the original census figures for 1869; in 1879 additions were made for wage earners and horsepower in petroleum refining, for estimates by the writer of wage earners in bottling, gas, and car repairing, and esti-

mates (by W. L. Thorp, Ref. 21) for horsepower in bottling, gas, car repairing, coke, dyeing and finishing textiles, distilled liquors, malt liquors, shipbuilding and glass. Electric light and power was subtracted from data for 1879 and 1889. Druggists' preparations, dressmaking, cotton ginning, and millinery custom work were subtracted from both 1889 and 1899, and trimming and finishing coffins and burial cases, hay and straw bailing, teasels, and mechanical dentistry from 1889. The 1899 horsepower figure was corrected by subtracting 311,016 horsepower of electric motors, and, when used in Group B, a further correction of 157,125 for industries included in the original census in 1899 but not in 1904. For Group C, poultry killing and dressing was excluded from 1919, 1923, 1925 and 1927; and an estimate for coffee and spice grinding and roasting added to 1925. Data for 1919 were also corrected by excluding automobile repairing, purchased power other than electricity (94,432 horsepower), an arbitrary sum of 15,000 for water motors, and 41,251 wage earners and 100,000 horsepower (estimate) for plants with less than \$5,000 value of product.

together at the transition points so as to make them as comparable as possible from 1869 to 1929.

#### RATE OF INCREASE

In which period has the rate of mechanization been fastest? The apparent answer is afforded by the geometric rates of increase in the last two columns of Table 15, computed for the interval between each census date. The annual increase in total horsepower was greatest in the five-year period 1904-09, and least in the post-War period. However, for horsepower per wage earner the showing is quite different. In no period since 1900 has the rate of increase been as great as in any one of the post-War periods other than 1927-29, the most rapid gain being from 1923 to 1925, or 6.4 per cent per year.

To some extent this rate of increase must be discounted to allow for the increasing use of purchased electric power discussed above. Allowing, however, for the respects in which rated horsepower does not furnish a complete account of the

tendency in the use of machinery, it still seems reasonable to interpret the data for horsepower in manufacturing as indicating a relatively rapid mechanization since the World War.<sup>7</sup>

INCREASES IN POWER EQUIPMENT PER WAGE EARNER,  
BY INDUSTRIES

Appendix C gives the horsepower per worker ratios for each of 141 individual industries or industrial groups at each census from 1899 to 1929. For 100 of the individual industries and for the industrial groups we also computed the percentage increase in the horsepower ratio from 1899 to 1925. These ratios of increase for the major industrial groups, and also for the 10 industries having the smallest increases and the 10 having the largest percentage increases, are presented in Table 16.

TABLE 16

PERCENTAGE INCREASES IN HORSEPOWER PER WAGE EARNER,  
MANUFACTURING INDUSTRIES: 1899-1929<sup>1</sup>

GROUP	PERCENTAGE INCREASE
<i>A. Major industrial groups</i>	
Food and kindred products	22.6
Lumber and its remanufactures	39.4
Textiles and their products	78.7
Paper and printing	110.8
Leather and its finished products	114.1
All industries combined	130.3
Iron and steel and their products	157.8
Rubber products	183.1
Miscellaneous industries	220.5
Tobacco manufactures	229.4
Non-ferrous metals and their products	257.9

<sup>1</sup> It is suggested by Colonel M. C. Rorty that each successive increase in horsepower per worker may (and perhaps should) show a decreasing rate of increase in productive efficiency.



TABLE 16 (cont.)

PERCENTAGE INCREASES IN HORSEPOWER PER WAGE EARNER,  
MANUFACTURING INDUSTRIES: 1899-1929

GROUP	PERCENTAGE INCREASE
Chemicals and allied products	276.1
Stone, clay and glass products	299.5
Vehicles for land transportation, including railroad repair shops	317.7
<i>B. Ten individual manufacturing industries with smallest percentage gains</i>	
Wire	7.6
Flour-mill and grain-mill products	13.9
Paper and wood pulp	15.1
Butter and cheese	22.2
Sugar, beet and cane	26.7
Knit goods	27.9
Fancy articles	28.3
Boots and shoes, rubber	40.2
Lumber and timber products, n.e.c.	42.3
Shirts	47.4
<i>C. Ten individual manufacturing industries with largest percentage gains</i>	
Bread and other bakery products	378.3
Steam fittings and steam and hot water heating apparatus	395.7
Glass	406.0
Steam railroad repair shops	430.9
Confectionery, chewing gum, and ice cream	456.9
Carriages and wagons	483.1
Structural and ornamental iron work	512.7
Gas, manufactured, illuminating and heating	795.7
Coke	833.2
Cigars and cigarettes	1,075.0

<sup>1</sup> Computed from ratios of horsepower to wage earners given in Appendix C. N.e.c.=not elsewhere classified.

In the three decades 1899-1929, none of the industries listed in Table 16 declined in horsepower per worker, though the gain was relatively slight for the food and lumber groups and for several constituents of these groups. The individual

industries range from a 7.6 per cent increase for wire to a 1075 per cent increase for cigars and cigarettes. The median increase for the 100 individual industries listed in Appendix C is 158 per cent, and about half show an increase of between 100 and 250 per cent. Doubtless some of the observed peculiarities in the ranking may be due to inadequacies of the data, especially for 1899, and to changes in classification not fully allowed for.

Another picture of the upward drift in horsepower per wage earner is afforded by Table 17, which portrays the

TABLE 17  
FREQUENCY DISTRIBUTIONS OF NINETY-NINE INDUSTRIES, BY  
HORSEPOWER PER WAGE EARNER, CENSUS PERIODS: 1899-1929<sup>1</sup>

HORSEPOWER PER WAGE EARNER	1899	1904	1909	1914	1919		1923	1925	1927	1929
					UNAD- JUSTED	AD- JUSTED <sup>2</sup>				
0-.99	52	45	35	31	26	26	19	18	18	17
1.00-1.99	22	25	30	27	32	32	28	22	20	20
2.00-2.99	10	11	11	15	13	13	16	16	17	15
3.00-3.99	5	7	11	6	6	7	12	12	12	14
4.00-4.99	2	1	2	7	8	6	5	10	9	8
5.00-5.99	1	2	1	3	3	5	6	4	4	5
6.00-6.99	2	1	3	1	4	3	2	4	3	3
7.00-7.99	..	3	..	2	2	2	1	2	4	2
8.00-8.99	1	..	1	1	1	1	2	1	1	2
9.00-9.99	..	..	..	2	..	..	2	2	1	2
10.00 or more	4	4	5	4	4	4	6	8	10	11

<sup>1</sup> Computed from data in Appendix C.

<sup>2</sup> The 1919 'unadjusted' figures cover plants with value of product \$500 or more, and include rented power other than electric; the 1919 'adjusted' figures cover plants with value of product \$5,000 or more, and exclude rented power other than electric. The 'unadjusted' figures are comparable with those for the earlier censuses; the 'adjusted', with the subsequent censuses.

frequency distributions of horsepower per worker for those industries for which data are available at each census from

1899 to 1929. That the shift towards increasing horsepower per wage earner from census to census has been more or less common to the individual industries will be evident from an examination of the several distributions in Table 17. Though the modal class remains at 0 to 0.99 horsepower per wage earner from 1899 to 1914, inclusive, it is evident from the successive distributions in Table 17 that even in this period the zone of concentration is gradually shifting towards the higher ratios of horsepower per wage earner. In 1919, despite the fact that, with a large increase in the number of wage earners, horsepower per wage earner declined in many industries, the center of concentration has shifted sufficiently to bring the modal class into the 1.00-1.99 group, and thereafter the concentration becomes increasingly less, as numerous industries move into the upper ratio ranges. In fact, an examination of the detail in Appendix C will reveal that of the 934 year-to-year changes in horsepower per worker there recorded for individual industries, only 184 are declines. The rate of progress in the several industries has varied, but most have grown in mechanization in each census period.

#### POWER IN THE NON-MANUFACTURING INDUSTRIES

The detail in which data are available has enabled us to discuss at length the growth of power in manufacturing. However, it must not be inferred that growth has been restricted to manufacturing. It has been at least as great in other industries. Estimates for all but a few of the industries making extensive use of power have been compiled by Mr. Carroll R. Daugherty for the decennial census years beginning in 1849, also for 1923.<sup>8</sup> These estimates of the total

<sup>8</sup> See references cited in footnotes to Table 18.

horsepower available in other industries, for 1899, 1909, 1919 and 1929, together with horsepower data compiled from the *Census of Manufactures*, are recapitulated in Table 18.

TABLE 18  
ESTIMATED RATED CAPACITY OF POWER EQUIPMENT IN  
SELECTED INDUSTRIES: 1899-1929<sup>1</sup>

(unit: 1,000 horsepower)

INDUSTRY	1899	1909	1919	1929
Total, prime movers <sup>2</sup>	64,081	112,856	176,143	401,000
Prime movers and motors run by purchased power <sup>3</sup>				
'Productive' automobiles	<sup>4</sup>	256	10,964	162,483
Steam railroads	20,900	45,400	72,300	109,331
Agriculture	23,519	31,107	43,722	69,639
Electric central stations	1,200	5,225	15,250	43,000
Manufacturing	9,942	18,675	29,209	42,918
Mines and quarries	2,868	4,609	6,723	10,500
Ships	1,819	3,155	6,402	9,017
Electric railroads	1,079	3,718	6,327	8,550
Work animals not on farms	3,055	3,405	1,979	1,400
Irrigation and drainage	120	361	816	1,383

<sup>1</sup> Data for manufacturing from Table 15; for other industries, from Carroll R. Daugherty, *Horsepower Equipment in the United States, 1869-1929*, *American Economic Review*, September 1933, pp. 428-40, especially p. 434; see also Ref. 31.

<sup>2</sup> Prime movers include steam engines and turbines, internal combustion engines, water wheels, wind power and work animals, but not electric motors run by purchased current. Pleasure automobiles are excluded. The total for prime movers includes those installed in all the industries listed in Table 18 and also 3,091,000 horsepower in commercial aircraft in 1929.

<sup>3</sup> There is some duplication in these figures in that a portion of the current generated by central electric stations is used to operate motors installed in manufactures, mines and quarries, agriculture, irrigation and drainage and electric railroads. Also, auto trucks are included under both agriculture and 'productive' automobiles.

<sup>4</sup> No data available.

Both agriculture and steam railroads were more extensive users of power than manufacturing at each of the four dates for which estimates are recorded in Table 18. Also, by 1929 the rated horsepower of 'productive' or non-pleasure automobiles, as estimated by Daugherty, exceeded the rated capacity of power equipment in any one of the three fields: agriculture, railroads or manufacture.

To some extent the interpretation of the increase in the use of power by the non-manufacturing industries is clouded by the fact, previously noted in connection with power in manufacturing, that there has been an increasing use of electric motors driven by purchased power, and this increase is not necessarily accompanied by an equivalent increase in the total equipment driven by power.<sup>9</sup>

In some industries the observed increases in the total horsepower available arise in part from the expansion of the industry as well as from increasing mechanization; but that increases in mechanization have been very substantial is indicated by the estimates in Table 19 of horsepower per worker for four major industries in 1909, 1919 and 1929.

In manufacturing the horsepower per worker increased 15 per cent from 1909 to 1919, and nearly 50 per cent in the following decade. In steam railroads, the increase per employee was about 25 per cent from 1909 to 1919 and nearly three times as great in the period 1919-29. In agriculture

<sup>9</sup> The percentages of available horsepower equipment actuated by purchased electric power are estimated by Daugherty as follows (Ref. 31, pp. 49-51):

	1909	1919	1929
Manufactures	.94	31.7	40.4
Mines and quarries	4.5	23.9	33.3
Electric railroads	16.9	31.1	39.6
Agriculture	0.8	3.4	4.6

TABLE 19

## HORSEPOWER PER WORKER IN SELECTED INDUSTRIES: 1909-1929

INDUSTRY	HORSEPOWER PER WORKER			PERCENTAGE INCREASE	
	1909	1919	1929	1909-19	1919-29
Manufactures <sup>1</sup>	2.82	3.25	4.86	14.9 <sup>5</sup>	49.5
Agriculture <sup>2</sup>	2.51	4.10	6.65	63.3	62.2
Mines and quarries <sup>3</sup>	3.64	5.52	8.85	51.6	60.3
Steam railroads <sup>4</sup>	30.21	37.79	65.82	25.1	74.2

<sup>1</sup> From Table 15.

<sup>2</sup> Horsepower per person in agricultural pursuits as given in *Census of Occupations, 1930*; power data from Table 18.

<sup>3</sup> Horsepower per wage earner in mining, exclusive of petroleum and natural gas and sand and gravel (*Census of Mines and Quarries, 1929*).

<sup>4</sup> Horsepower per employee; power data from Table 18; number of employees from Interstate Commerce Commission, *Statistics of Railways*. The data for 1909 cover employees of all operating railroads, except switching and terminal companies, for year ending June 30, 1909; for 1919 and 1929 they cover employees on Class I railroads (except switching and terminal companies), in calendar years.

<sup>5</sup> In computing percentage change, 1909-19, horsepower per worker in 1919 is taken as 3.24 (see Table 15).

and mining the increase exceeded 50 per cent in both decades. These estimates are not strictly comparable in all respects, but we do not believe that strictly comparable records would make an essentially different showing.<sup>10</sup>

It is unnecessary to recount here in detail the many changes which in the aggregate account for the marked increases in the use of power in the non-manufacturing industries, but a few major developments may appropriately be mentioned.<sup>11</sup> Of the total rated horsepower of mine equipment in 1929, over a third was of the mobile type. In some part this is a reflection of the continued expansion of mechanical undercutting and mechanical transportation, and in

<sup>10</sup> For elements of non-comparability, in addition to the increasing use of electric motors run by purchased power, see footnotes to Table 19.

<sup>11</sup> See Ch. IV and V for further detail.

part of the start made in the development of mechanical loading in the decade of the 'twenties. The major portion of the increased use of power on farms consists in mechanical power furnished by tractors and motor trucks. The number of tractors on farms increased from 246,083 in 1920 to 920,021 in 1930, or nearly fourfold. The number of motor trucks on farms increased from 139,169 to 900,385, and in the same period there were large sales of stationary gas engines and a substantial increase in the use of electricity on the farm.<sup>12</sup> The marked increase in horsepower per worker in steam railroads is caused mainly by an increase in the average tractive power of locomotives from 35,789 pounds in 1919 to 44,801 in 1929, in conjunction with a decline in the number of railroad employees.

#### OTHER MEASURES OF CHANGING MECHANIZATION

Because the statistics on horsepower, though available in considerable detail, do not give an entirely adequate picture of the developments in mechanization, it is pertinent for us to examine other measures of the extent to which industry is becoming more completely mechanized.

#### RATIO OF WAGES TO VALUE ADDED BY MANUFACTURE

The more highly mechanized a plant is, the greater the proportionate expenditure for maintenance and repair, materials, power and such items of overhead as interest; hence it would seem a reasonable presumption that with increasing mechanization a smaller proportion of total expenditures will

<sup>12</sup> Indicated by the fact that in 1920 only 452,620 farm dwellings were lighted by electricity while by 1930 the number had risen to 841,310. The *1930 Census of Agriculture* shows 386,191 electric motors and over a million stationary gas engines in use on farms.

go for wages. If this be true, the ratio of wages to value added by manufacture should afford a supplementary measure of changing mechanization.<sup>18</sup> In fact, however, the changes in the ratio of wages to value added, presented in Table 20 for the period 1869-1929, do not appear to be a sensitive meas-

TABLE 20  
RATIO OF WAGES PAID TO VALUE ADDED BY MANUFACTURE:  
1869-1929<sup>1</sup>

CENSUS YEAR AND SCOPE OF CENSUS	RATIO (PER CENT)
Hand and neighborhood industries and factories, with \$500 or more product	
1869	44.5
1879	48.1
1889	44.9
1899	41.0
Factories only, with \$500 or more product	
1899	41.6
1904	41.5
1909	40.2
1914	41.3
1919	42.1
Factories only, with \$5,000 or more product	
1919	42.2
1921	44.7
1923	42.6
1925	40.1
1927	39.3
1929	36.4

<sup>1</sup> Computed from statistics of total wages paid and value added by manufacture in 1919 *Census of Manufactures*, p. 14; 1927, p. 16, and 1929, I, 15.

<sup>18</sup> As used in the *Census of Manufactures* 'value added' is the increment created by the manufacturing process and "is calculated by deducting the cost of materials, containers, fuel, and purchased electric energy used from the value of the products" (1929, I, 8).



ure for the changes in mechanization, at least not of their long-time trend. The wage ratio was 44.5 in 1869, 41.6 in 1899, and 42.6 as late as 1923. Evidently other factors, such as differences in the movement of wage rates and unit prices of manufactured products have acted to conceal the effect of mechanization upon the wage ratio.<sup>14</sup> However, the ratios for 1927 and 1929 show appreciable declines; and that the wage ratio is correlated with changing mechanization is supported by a closer examination of the data by industries in the period 1923-25. If we may trust our horsepower data and other evidence, these two years were characterized by rapid mechanization, and we find not only that the wage ratio for all industries declines from 42.6 to 40.1, but also that this decline is common to all the sixteen major industrial divisions of manufacturing except lumber. Moreover, when we examine the 347 individual industries for which the wage ratio can be computed for both 1923 and 1925, we find that 221 decline from 1923 to 1925.

It is evident that the wage ratio is influenced by mechanization but cannot be relied upon for precise evidence concerning the rate at which mechanization has advanced in various periods.

<sup>14</sup> Colonel M. C. Rorty comments: There is some evidence, notably that afforded by the increasing rates of obsolescence and replacement for machine tools (charges on this account being to expense, rather than for use of capital), to support the hypothesis that, the more highly mechanized an industry becomes, the lower may be the proportion of its value added that accrues to capital. A particular effort of the highly organized and mechanized industries is to increase their rates of capital turnover, i.e., the ratio of gross output to capital employed. Furthermore, in many cases, the highly elaborated machine costs less than the crude machine per dollar of annual output. It should be noted, also, that the ratio of wages to value added was so seriously affected, during the 1920-29 period, by the readjustment of real corporation interest and dividends to normal levels at the end of 1928 (after previous  $33\frac{1}{3}$  per cent decline) that any effects of mechanization must have been obscured.

## PROPORTION PRODUCED BY MACHINE METHODS

One measure of mechanization that is quite significant, though ordinarily not obtainable, is the proportion of output that is prepared by machine methods rather than hand methods in specific phases of producing operations. Such data are available for the undercutting and loading processes in coal mining and for a few manufacturing processes such as the casting process in pig iron production (Appendix A). They furnish realistic measures of changing mechanization—measures the meaning of which can be readily interpreted—and it is unfortunate that similar data are not available for a large number of important manufacturing processes.

The United States Geological Survey compiles figures of the proportion of soft coal which is 'machine mined', that is, undercut by machine. Similar data are presented for anthracite coal. The detailed statistics for recent years appear in Table 40. The proportion of bituminous coal undercut by machine has increased steadily from only 5.3 per cent in 1891 to 24.9 per cent in 1900, 41.7 per cent in 1910, 59.8 per cent in 1920, and 75.4 per cent in 1929. The percentage of anthracite coal undercut by machine is relatively small, between 1 and 2 per cent.

Machine undercutting has probably about reached the saturation point, but machine loading is apparently still in its infancy. The proportion of bituminous coal loaded with self-feeding loading devices, while yet small, has shown a substantial increase from only 0.3 per cent in 1923 to 3.6 per cent in 1929 (Table 40).

In pig iron production the percentage of total merchant furnace output that is machine cast increased from 45 in 1911 to 85 in 1926, but was as low as 31 in 1915 (Table 36).

Machine-made cigars constituted less than 10 per cent of

the total prior to 1924, but by 1930 about 47 per cent of long-filler cigars were machine-made (Table 38).

Likewise, the rapid advance of the automatic glass bottle machine is indicated by the estimate that in 1917 only 50 per cent of glass jars and bottles were blown on automatics; in 1924, 90 per cent<sup>15</sup> (Table 38).

#### PROPORTION OF USERS EQUIPPED WITH SPECIFIED DEVICE

Closely akin to statistics of the proportion of output produced by machine methods are statistics of the proportion of users equipped with a given device. The best illustration of this method of charting the progress of mechanization is afforded by estimates of the percentage of wired homes equipped with various labor-saving devices (Appendix A). It is estimated that from 1924 to 1930 the percentage equipped with ironing machines rose from 1.6 to 3.3, with electric irons, from 77.0 to 97.8, with electric vacuum cleaners, from 37.7 to 44.4, and with electric washing machines, from 26.4 to 35.1.

Somewhat similar data are available for the telephone industry. In 1919 only 1.7 per cent of the total number of Bell-owned stations were served by automatic switchboards. By 1929 this percentage had risen to 26.0.

#### PROPORTION OF NEW EQUIPMENT THAT IS POWER-DRIVEN

Another closely allied measure of changing mechanization is afforded by statistics of the proportion of new equipment that is operated by mechanical power. Thus one of the significant movements in the mechanization of agriculture is indicated by the rapid rise in the ratio of the value of

<sup>15</sup> See Ch. III, Glass, which also gives an estimate for the percentage of window glass made by the hand process.

harvesting combines (all power-driven) to the total value of harvesting machinery sold—from only 11.7 per cent in 1920 to 33.2 per cent in 1926, and 51.9 per cent in 1929.<sup>16</sup>

#### NUMBER OF MACHINES IN USE

Another indicator of mechanization is afforded by statistics of the number of machines of a given type in use, although this measure does not give directly a mechanization ratio. It merely measures progress in absolute numbers; it does not indicate whether the given procedure is gaining ground relatively to hand methods or less mechanized equipment.

In this class of evidence concerning the advance of mechanization we may include such items as the following. The registration of motor trucks has increased from only 85,600 in 1914 to 1,006,082 in 1920, and 3,379,854 in 1929. In 1924 the number of tractors on farms was reported as 505,933; in 1929 as 920,000. The number of semiautomatic glass blowing machines in use declined from 459 in 1916 to only 26 in 1927, yielding to the advance of the full automatic type. The number of Bell-owned stations served by automatic switchboard increased from only 130,000 in 1919 to 4,014,000 in 1929. The estimated number of electric washing machines in use rose from 3,500,000 in 1924 to 7,185,000 in 1930. The number of undercutting machines in bituminous coal mining was reported as 16,507 in 1914; it increased to 21,299 in 1923, but has not held its own since. The decline (to 14,731 in 1929) has been offset by an increasing production per machine. These and other illustrations of measuring the growth of mechanization by changes in the number of equipment units of a given type in use

<sup>16</sup> For further statistics of this type, see Table 6.

appear in Chapters III, IV and V and in the tables in Appendix A.

### GROWTH OF THE MACHINE-PRODUCING INDUSTRIES

With the growth in mechanization indicated by the other indexes examined, have the machinery industries outstripped the other manufacturing industries? By referring to the data in Table 21 we note that from 1899 to 1929 the

TABLE 21

#### GROWTH OF THE MACHINE-PRODUCING INDUSTRIES<sup>1</sup> (EXCLUSIVE OF TRANSPORTATION EQUIPMENT)

INDUSTRY	<i>Thousands of Wage Earners</i>									
	1899	1904	1909	1914	1919	1921	1923	1925	1927	1929
Total, machinery industries <sup>2</sup>	414	478	568	615	998	662	908	859	886	1,091
Percentage ratio to wage earners in all manufacturing industries	8.8	8.7	8.6	8.7	11.0	9.5	10.3	10.2	10.6	12.4
Foundry and machine-shop products, n.e.c. <sup>3</sup>	297	332	379	358	483	321	449	398	398	454
Electrical machinery, apparatus and supplies	42	60	87	118	212	161	235	240	242	329
Engines, turbines, and water wheels	4	4	4	30	78	36	48	51	54	61
Machine tools	4	4	4	4	53	21	33	31	35	47
Agricultural implements	47	47	51	48	54	30	31	29	33	42
Textile machinery and parts	4	4	4	4	32	31	36	28	26	27
Pumps (hand and power) and pumping equipment	1	1	2	8	16	12	15	18	19	23
Typewriters and supplies	4	6	10	11	16	13	15	15	17	17

MEASURES OF CHANGE

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TABLE 21 (cont.)

GROWTH OF THE MACHINE-PRODUCING INDUSTRIES<sup>1</sup>  
(EXCLUSIVE OF TRANSPORTATION EQUIPMENT)

*Thousands of Wage Earners*

INDUSTRY	1899	1904	1909	1914	1919	1921	1923	1925	1927	1929
Cash registers, adding machines, and calculating machines	2	4	7	9	17	10	15	13	14	17
Sewing machines, cases, and attachments	13	17	19	18	19	13	13	12	12	10
Refrigerators, mechanical	5	5	5	5	5	5	5	5	11	17
Washing machines, wringers, driers, and ironing machines for household use	2	2	2	2	6	4	6	7	8	8
Metal-working machinery, other than machine tools	4	4	4	4	4	4	4	6	6	4
Gas machines and gas and water meters	2	3	5	5	6	4	6	6	6	6
Scales and balances	3	3	4	4	5	4	4	4	4	4
Windmills and windmill towers	2	2	2	2	2	1	1	1	1	2

<sup>1</sup> Compiled from the *Census of Manufactures* for the several censuses, 1899-1929.

<sup>2</sup> The totals were computed from the original figures before they were reduced to thousands.

<sup>3</sup> The following industries included in the earlier censuses in 'Foundry and machine-shop products' have been excluded by us, partly by estimate: Locomotives and stoves and furnaces in 1899; cast iron pipe, 1899 and 1904; automobile repairing, 1904 and 1909; steel barrels, drums, and tanks, and tempering and welding of iron and steel, 1899 to 1914.

<sup>4</sup> Included in 'Foundry and machine-shop products' at the census periods for which these industries are not separately listed in this table.

<sup>5</sup> Prior to 1927 included in 'Electrical machinery' or 'Foundry and machine-shop products'.

number of wage earners in the machine-producing industries, exclusive of transportation equipment, increased from 414,000 to 1,091,000, or from 8.8 to 12.4 per cent of the total number of wage earners in manufacturing. The nearly one million wage earners in the machinery industries in 1919 represents the high point previous to 1929 both in absolute numbers and in percentage of the total number of wage earners in manufacturing.

The majority of the machine-producing industries are included under the designation 'Foundry and machine-shop products not elsewhere classified'. From this parent group one special machinery industry after another has been separated at the successive censuses. To maintain comparability both the parent group of 'Foundry and machine-shop products' and the several separately classified machinery industries are included in the totals for the machinery industries in Table 21. The nature of the 'Foundry and machine-shop' group is indicated by the following quotation from the 1927 *Census of Manufactures*:

"This industry. . . embraces the manufacture of those products of boiler shops, foundries, and machine shops which are not assigned to special classifications. The foundry, as the term is ordinarily defined, is an establishment in which metal is cast into various shapes, and the machine shop is an establishment in which work is done by means of machine tools; that is, power-driven tools used in cutting and shaping metals. . . . many foundries and machine shops manufacture a great variety of products." This classification "embraces, so far as practicable, those lines of manufacture which employ foundry and machine-shop processes but which cannot be clearly segregated from one another. Nevertheless, despite its comprehensiveness, a great deal of overlapping occurs between this classification and a number of others" (p. 1,074).

Something of the diversity of the products of the 'Foundry and machine-shop' group is indicated by the fact that in 1914 a "partial list" of the principal products reported on the manufacturer's schedule by establishments assigned to

this industry included 642 items, 402 of which were machines designated for use in the several branches into which the census divides manufacturing, 19 articles each, chiefly machines, for use in mining and agriculture, 70 products intended for use in divers manufactures and 132 intended for general use. Even these last two groups include many types of machine.

For a broad index of the growth of mechanization there is much to be said for the inclusion of the industries grouped by the *Census of Manufactures* under the title 'Transportation Equipment, Air, Land, and Water', or at least that portion of these industries assignable to the production of locomotives and commercial vehicles. For this industry as a whole the number of wage earners in 1921 was 405,773. In 1923 it was 606,328. It declined in 1925 to 559,578, and in 1927 to 494,905, but recovered to 583,355 in 1929. By far the larger proportion of these wage earners is in the two subgroups designated as 'Motor vehicles not including motor cycles' and 'Motor-vehicle bodies and motor-vehicle parts'. The number of wage earners engaged in the production of locomotives and commercial vehicles is not given separately, though a rough estimate might be made from the reported value of these special products. In any event, it is a striking fact that the industries engaged in the production of transportation equipment have employed approximately a half million men in the post-War period, or more than half as many as in the other machine-producing industries combined.<sup>17</sup>

<sup>17</sup> For further discussion of the volume of the machine-producing industries see Ch. VIII.



MEASURABLE TENDENCIES  
CONTRIBUTING TO THE PROGRESS OF MECHANIZATION

Several of the less obvious ways in which mechanization is facilitated are common to so many industries that it is appropriate to call attention to them at this point. We refer to indirect mechanization through the substitution of one process or product for another, the elimination of inefficient plants, regional shifts in industry which involve changes in the average of mechanization and productivity, the increasing capacity of machine units through greater physical size or higher running speeds, the increasing electrification of power equipment, and a group of non-mechanical changes which may conveniently be designated as economies in the use of men and equipment. The latter are not strictly speaking changes in mechanization, but they are significant in studies of changing labor requirements.

CHANGES INDIRECTLY AFFECTING THE DEGREE OF MECHANIZATION

The degree of mechanization in an industry is frequently influenced by changes which do not directly affect the ordinary indexes of mechanization. New industries are constantly arising which, because of their newness and lack of standardization, may have a relatively low degree of mechanization, though the industries which they tend to displace may be applying mechanical devices steadily to more and more operations. Likewise, within any given industry a less mechanized process may partly replace a more mechanized process, or *vice versa*, and thus change the general average of mechanization in the industry as a whole although possibly the degree of mechanization in neither the old nor the new process has undergone any essential change.

For example, an increasing proportion of all bituminous coal mined is by the highly mechanized process of stripping with power shovels.<sup>18</sup> Likewise, the degree of mechanization in pig iron production is raised by the tendency to physical integration of the blast furnace and the steel-making plant, thus virtually eliminating the casting process. The percentage of steel-making pig iron used by makers that is cast in molten condition increased from less than 80 in 1913 to almost 92 by 1931 (Table 36).

In themselves the above illustrations of indirect changes are of relatively minor importance, but the general phenomenon which they illustrate—the growth or decline of mechanization through the substitution of one process or product for another—is an important phase of changing mechanization.

#### ELIMINATION OF INEFFICIENT PLANTS AND REGIONAL SHIFTS TO HIGH-PRODUCTIVITY AREAS

The rising man-hour productivity of the post-War years is ascribable in part to the elimination of inefficient plants or at least to the shifting of a larger proportion of production to the high-productivity units in the industry. Such changes may raise the level of productivity without necessarily modifying the productivity of individual plants.<sup>19</sup>

The merchant blast furnace industry furnishes a striking example of this tendency, though other developments have

<sup>18</sup> See Appendix A for statistics on the percentages of both bituminous and anthracite coal mined by stripping.

<sup>19</sup> Part of the total gains in productivity are, of course, the result of improvements in individual plants. Examples may be cited from the experience of groups of identical establishments included in our output-per-hour surveys (Ref. 20-c). From 1919 to 1927 productivity per hour increased 34.1 per cent in 5 identical Douglas fir lumber mills, and 46.5 per cent in 5 identical beet sugar plants.

also acted to raise its productivity. Most lakeside plants of the Great Lakes District, for example, "are of the most modern type equipped with complete labor-saving machinery". The plants in New York, Pennsylvania and the South, on the other hand, have a relatively low productivity per man-hour, for various reasons: for example, the "plants in the South are operated mostly by negro labor", and "the plentiful supply of this labor tends to prevent the introduction of improved machinery, thus keeping productivity at a low level". In the period 1917-18 to 1926 there was a "rapid decline of these low productivity areas" and an "increasing production in the high-productivity areas, such as the Great Lakes", which tended to "increase the average productivity of the industry".<sup>20</sup>

Between 1912-14 and 1926 the number of active merchant furnaces had been more than halved, despite the building of new stacks. "The period 1923 to 1926 was featured by the abandonment of old plants in Pennsylvania and the construction of new ones in New York and New England."

In general,

"one of the most important causes of the great improvement in output per man-hour [in the merchant blast furnace industry] has been the abandonment of many of the inefficient low-productivity plants. In 1921 the average output per man-hour in merchant blast furnaces was very much higher than in the previous year because the depression forced out many of the weaker plants, leaving mostly high-productivity plants in operation. During the prosperity of 1923 many low-productivity plants came back into the industry, but the keener competition of the steel works blast furnaces since then has driven a great number of them out of business. Less than three-fourths of the merchant plants operating in 1923 remained active until 1926, and the high-productivity average of the later year is due in no small degree to the closing down of inefficient plants" (Bul. 474, Ref. 37, p. 1).

Unfortunately, data on causes of changes in productivity

<sup>20</sup> B. L. S., Bul. 474, Ref. 37, notably pp. 9-15.

as adequate as those for the merchant blast furnace industry are not readily available for other industries, but there is considerable reason to believe that in many industries changing mechanization and changing productivity are in substantial part due to the abandonment of inefficient plants and the construction of new more efficient plants, or arise, even when plants are not entirely abandoned, from a greater relative use of the more efficient plants and shifts in the relative volume of production from areas of low productivity to areas of high productivity. We have noted, for example, that even in the localized industry of brick manufacture, the number of establishments has diminished markedly, especially in the smaller, less modernized plants (Ch. III).

An examination of the movement in various industries towards a reduction in the number of establishments tends to confirm the hypothesis that the elimination of relatively inefficient plants is a large factor in increasing mechanization and increasing productivity.

#### DECLINE IN NUMBER OF MANUFACTURING ESTABLISHMENTS <sup>21</sup>

If allowance is made for changes in the scope of the enumeration, the number of establishments engaged in manufacturing showed an increase at each census up to 1919 inclusive (see Table 14). But the census of 1921 showed an 8.5 per cent drop in number, the next census very little change, and 1925 a further drop of 4.5 per cent. The censuses of 1927 and 1929 showed percentage gains of 2.4 and

<sup>21</sup> The *1919 Census of Manufactures* included establishments with annual product valued at \$500 or more, whereas all subsequent censuses have been limited to those with products valued at \$5,000 or more. In this section, establishments with value of product less than \$5,000 have been eliminated from the statistics for 1919.

10.0 respectively. The net result of these changes is that between the census of 1919 and 1929 the total number of establishments in all industries combined decreased 3,714. But this is far from an adequate indication of the number that passed out of the industrial picture in this decade. The losses in number in the declining industries are neutralized in large part by increases in the expanding industries. And even within a single industry, old plants may be abandoned and new ones put into operation without changing the total number reported in the census. Full information upon the number of abandoned plants is not available, but helpful clues can be obtained by a closer examination of the changes in the individual manufacturing industries.

Table 22 presents the change from 1919 to 1929 in the number of establishments in each of the 12 industries in which the decline in number exceeded 200. If the industries listed were classified in more detail the decreases would doubtless be shown as even greater than is suggested by the total, 18,408, for one part of an industry may be expanding while another part is declining. For example, in the dairy products group of the food industries, from 1919 to 1929 the number of establishments shows a loss of 624, but in this group the cheese industry alone had a loss of 638, and butter of 121, while condensed and evaporated milk showed a gain of 135.

Even if we utilize a quite minute classification of the industries, the recorded decline often understates the number of establishments in an industry which have gone out of business since the previous census, for in the same period new establishments enter the industry. Thus, there were 103 fewer establishments in 'Boots and shoes other than rubber' in 1927 than in 1925, but 283 concerns went out of business between the census of 1925 and that of 1927. Likewise in

TABLE 22  
INDUSTRIES IN WHICH THE NUMBER OF ESTABLISHMENTS  
DECREASED 200 OR MORE: 1919-1929<sup>1</sup>

(ranked in order of losses)

INDUSTRY	NUMBER OF ESTABLISHMENTS <sup>2</sup>		DECREASE 1919-29	
	1919	1929	NUMBER	PER CENT
Total, 12 industries	77,195	58,787	18,408	23.8
Flour and other grist-mill products	9,209	4,022	5,187	56.3
Lumber and timber products	16,016	12,915	3,101	19.4
Cigars and cigarettes	4,336	1,636	2,700	62.3
Marble, granite, slate and other stone products	3,296	1,881	1,415	42.9
Copper, tin and sheet-iron work	3,522	2,161	1,361	38.6
Bread and other bakery products	21,988	20,785	1,203	5.5
Motor-vehicle bodies and parts	2,123	1,154	969	45.6
Saddlery and harness	1,045	260	785	75.1
Cheese	3,396	2,758	638	18.8
Foundry and machine-shop products	9,323	8,880	443	4.8
Clay products and non-clay refractories	2,113	1,749	364	17.2
Cooperage	828	586	242	29.2

<sup>1</sup> Computed from data in *Census of Manufactures*.

<sup>2</sup> Excluding establishments with value of product less than \$5,000.

'Motor vehicles' there was a decline of 33 establishments, but 36 went out of business.

The declines, 1919-29, in the number of establishments were proportionally heavier in some of the smaller industries than in those shown in Table 22. For example, among industries which show declines of between 100 and 200 establishments, the losses exceeded 50 per cent in 'vinous

liquors', 'carriage, wagon, sleigh and sled materials', 'feathers and plumes', and 'pianos'.

Declines in the number of establishments from one census period to another may be due to permanent abandonment of plants, temporary idleness through the census year without permanent abandonment, transfer of individual establishments from one industrial classification to another,<sup>22</sup> decline in total value of product below \$5,000, or possibly to variations in the thoroughness with which the census is taken. As 1919 and 1929 were both decennial censuses, and 1929 an active year, it seems plausible that temporary idleness or change in scope does not account for many of the declines evidenced from 1919 to 1929. Some of them may be due in part to changes in classification of individual plants but the shrinkages are so great in many industries that it is difficult to escape the conclusion that in many lines of manufacturing there is a persistent tendency in recent years towards a decrease in the number of establishments.

The question arises, are the observed decreases in the number of establishments only in the decadent industries, or do they indicate tendencies even in the expanding industries. The four small industries with losses of over 50 per cent in the number of establishments, mentioned above, were all industries in which the average number of wage earners declined sharply from 1919 to 1929. Also, of the 12 industries with declines of 200 or more in the number of establishments set forth in Table 22, 7 show declines also in the average number of wage earners. But the remaining

<sup>22</sup> Each establishment as a whole is assigned, on the basis of its product or group of products of *chief value*, to some one industrial classification; hence if a plant produces more than one product a shift from one census to another in the proportions among the several products may change the classification to which the industry is assigned.

5 industries <sup>23</sup> gained in number of wage earners despite the decrease in number of establishments. The net result, of course, is an increase in the average number of wage earners per establishment.

#### SIZE OF ESTABLISHMENTS

A tendency towards larger plants does not necessarily mean increased mechanization, for a large plant may conceivably have a greater proportion of hand work than a small plant. However, large-scale production ordinarily facilitates the economical use of expensive machinery, and hence an increase in the average size of establishments may be interpreted to indicate at least an opportunity for greater mechanization.

In 1899 the average number of wage earners per establishment was 22.7; in 1909, 24.6, and in 1919, 31.4. These figures cover all establishments with annual product valued at \$500 or more. In later censuses the minimum has been set at \$5,000. If the establishments with annual product valued at less than \$5,000 are excluded from the 1919 census data to make them comparable with 1929, the average number of wage earners per establishment in all manufacturing industries combined is 42.0 in both 1919 and 1929. Evidently the tendency for the size of establishments to increase which was exhibited in the first two decades of the century is not clearly evident in the 1919-29 period, at least not for all industries combined.<sup>24</sup>

<sup>23</sup> Marble, granite, slate and other stone products; copper, tin and sheet-iron work; bread and other bakery products; motor-vehicle bodies and parts; and clay products.

<sup>24</sup> In *Recent Economic Changes* (National Bureau of Economic Research, 1929), the change in size of establishments in individual industries from 1914 to 1925 is analyzed. Eighteen industries at least doubled their average number of wage earners in this period. A few of these, such as aircraft and



There are still many small manufacturing establishments, though the number of establishments employing between 6 and 20 wage earners declined slightly from 54,317 in 1919 to 53,524 in 1929.<sup>25</sup> Slight gains were shown in the number of establishments with over 250 wage earners, which increased from 6,366 in 1919 to 6,558 in 1929. But it is evident that for any marked indications of a tendency towards increasing concentration of production in large units we must turn to an analysis of individual industries rather than the aggregate of manufacturing establishments.

#### INCREASING CAPACITY OF MACHINE UNITS

One generally observable trend in the character of mechanized equipment is the enlargement of the capacity of the machine unit, either by increasing the physical size of the machine or the speed at which its parts function. As such changes are frequently accompanied by less than proportionate increases in the operating crew and thus change the

motor-vehicle bodies and parts, are industries which expanded greatly. Others increased their average number of wage earners chiefly by reducing the number of establishments. On the other hand, some industries declined in average size. The 15 industries reporting the greatest decline in the number of wage earners per establishment, 1914-25, were mostly industries which had suffered from loss of markets with the result that they reported decreases also in the total number of wage earners.

Likewise, in *Economic Tendencies in the United States*, pp. 305-6, Dr. F. C. Mills computes the average annual rate of change, 1923-29, in average number of wage earners per establishment in each of 60 industries. Increases ranging from 0.1 to 9.8 per cent occurred in 35 industries. In 25, there was no change, or there were declines of from 0.1 to 12.7 per cent. The average for the 60 industries was an annual increase of 0.4 per cent.

<sup>25</sup> Establishments with 5 or fewer wage earners declined from 166,315 in 1919 to 103,913 in 1929, but a large part of this decline arises from the fact that in 1919, although not in 1929, establishments with product of \$500 but less than \$5,000 were included and most of these would be in the group with 5 or fewer employees.

ratio of equipment to workers, they may appropriately be described as increases in the mechanization of industry.

In Table 23 we have assembled several series of statistics which indicate the changing size of specified types of equipment from 1909 to 1929. The accompanying text in some

TABLE 23  
ILLUSTRATIONS OF TENDENCIES IN CAPACITY OF INDIVIDUAL EQUIPMENT UNITS

TYPE OF EQUIPMENT	1909	1914	1919	1923	1925	1927	1929
Freight cars, average capacity in tons <sup>1</sup>	35.3	39.1	41.9	43.8	44.8	45.5	46.3
Steam locomotives, average tractive power in thousands of pounds <sup>1</sup>	26.6	31.0	35.8	39.2	40.7	42.8	44.8
Average annual capacity of cement kilns <sup>2</sup> (1000 bbls.)	93	137	186	204	223	252	283
Average daily output, in tons, of active blast furnaces <sup>3</sup>	263	332	343	397	459	507	570
Average horsepower of power units in factories <sup>4</sup>							
Steam engines and turbines	92.7	113.7	139.1	185.4	205.9	230.6	224.8
Internal-combustion engines	21.9	26.3	40.8	77.9	82.6	92.4	109.3
Water wheels and turbines	8.6	10.1	12.6	19.4	21.5	21.1	23.9
Electric motors driven by purchased power	8.8	8.6	9.5	9.4	9.2	8.9	8.4
Electric motors driven by power generated in the same establishment	16.2	15.4	14.3	14.3	13.3	14.2	14.5

<sup>1</sup> Compiled from Interstate Commerce Commission reports on *Statistics of Railways in the United States*.

<sup>2</sup> Computed from statistics of annual capacity as given in United States Geological Survey, *Mineral Resources of the United States*.

<sup>3</sup> Computed from data published in *Iron Trade Review*.

<sup>4</sup> Computed from statistics of horsepower and number of units in *Census of Manufactures for 1919*, p. 122, and *1927*, p. 1270.

instances cites earlier data from the same source. Rarely does the unit size decrease in the later periods; rather as a rule it increases as the years go by.

In railway transportation the trend towards larger equipment units is striking. The average capacity of freight cars has increased from 29.4 tons in 1903 to 35.3 in 1909, and 46.3 in 1929. Likewise, the average tractive power of locomotives has increased from about 22,000 pounds in 1903 to nearly 45,000 pounds in 1929.

In the blast furnace industry the tendency towards larger stacks is indicated by the rapid increase in daily capacity per stack from 230 in 1907 to 570 in 1929. The increase in man-hour productivity in merchant blast furnace operation has been ascribed in large part to the increase in average daily stack output, and this in turn chiefly to the increasing size of the stacks (B.L.S., Bul. 474, Ref. 37, pp. 32-41).

#### *Rotary cement kilns*

One feature of the rapid development of the cement industry in the present century has been an increase in the size of the rotary kilns.<sup>28</sup> In 1910, of the 845 kilns for which lengths are specified in the directory of the cement industry the mean length was 92 feet, the modal length 60 feet. In 1922, only 12 years later, the average length of 644 kilns for which dimensions are given was 118 feet, with the modal length 125 feet (127 kilns). In 1906 only 7 per cent of the kilns in active plants were 125 feet or more in length; by 1910 the percentage had risen to 21; and by 1917 to 43, where it remained for several years.

The same tendency is evidenced by a study of the length

<sup>28</sup> The statistics in this paragraph have been compiled, unless otherwise indicated, from the directories of the cement industry, published annually in recent years by *Cement, Mill and Quarry*.

of kilns in new plants. Of the 7 kilns in plants reported as producing for the first time in 1913 the longest was 170 feet; of 14 new kilns in 1916, 3 were 200 feet or longer, while of 28 new kilns added in the active year 1927 half were over 200 feet long, one of these being 300 and another 343.

Length is closely associated with capacity. In 1922 the average stated capacity was 196 barrels for 60-foot kilns, 623 for 125-foot, 1,125 for 175-foot, 938 for 200-foot, and 1,400 for 240-foot kilns. Hence it seems reasonable to assign the increasing length of kilns as one cause of the increase in the average annual capacity of cement kilns (given in Table 23) from 93,000 barrels in 1909 to 283,000 in 1929.

#### *Power units in factories*

As shown in Table 23 the average size of steam engines and turbines, internal-combustion engines, and water wheels and turbines has increased steadily from 1909 to 1929. On the other hand, there has been relatively little change in the horsepower of electric motors, whether driven by purchased power or by power generated in the plant using the motors. Apparently the increasing use of individual electric motors for small machine units has more than offset the tendency of the increasing size of many types of power-driven equipment to require larger electric motors.

Numerous other instances of the increasing physical size of machine units have come to our attention in studying the nature of the labor-saving changes in the plants included in our survey or as described in the technical literature. In highway construction the introduction of caterpillar tread has furthered an increase in the size of cement mixers (Ch. IV). In the glass bottle industry the capacity of the Owens automatic bottle machine has increased with the later

models. In the cement industry not only has the length of the kiln tended to increase, as noted above, but also larger and more powerful crushers have been developed (Ch. III). In the milling process in the rubber industries the introduction of larger rolls without an equivalent increase in the force of machine tenders has been a major factor because much of the work of the tender is merely waiting for the machine to do its part (Ch. III). In paper making the paper machine has steadily increased in both width and running speed, and likewise in the pulp-making department the digesters and grinders have substantially greater capacity than formerly (Ch. III, Table 4). In the brick industry the brick machines that had been recently installed had larger capacities than the displaced machines.

The increase in the physical size of factory machinery has been furthered by the development of mechanical handling devices capable of lifting and moving materials or product in larger units than could be readily handled by manual methods.

In farming the sales of large harvester and thresher combines, for example, rose suddenly in 1923, as compared with the small machines. In 1921 a total of 4,610 combines with a width of cut 10 feet or less were sold, and only 417 with cut over 10 feet. In 1923 the situation was reversed, 219 being 10 feet or less, and 3,793 over 10 feet. Similar data are not given in the later statistics of farm machinery sales.

#### INCREASING CAPACITY THROUGH GREATER SPEEDS

The capacity of a machine may be enlarged by making the machine run faster rather than increasing its physical size. For example, the capacity of the auger type of brick-molding machine has been enlarged without resorting to "design of larger dimensions of barrel". These machines

have almost exclusively rotary movements, and more capacity has been obtained by greater speed or number of revolutions. "An auger shaft speed of 25 to 30 revolutions per minute in 1914 is now often from 40 to 50 revolutions per minute, without undue breakage of parts."<sup>27</sup>

Such an acceleration of running speed has been made possible by the more durable machine parts and better lubricating systems. Interchangeability of parts in machines produced in large quantities has also contributed to the acceleration in actual running speed by reducing stoppages for repairs. A quotation from a letter from a veteran manufacturer of brick machines illustrates this development:

"The signer of this has been since May 1871 (57 years) connected in various capacities with foundry and machinery concerns that served brick manufacturers. During the first 20 years the service rendered was wholly making parts for and keeping in repair machinery of various makes which, without exception, produced a minimum of both quality and quantity at a maximum cost of both cash and lost time for upkeep. The brick manufacturer who tried to carry a stock of parts from the manufacturer of his machines frequently found their foresight of no avail because the parts were not interchangeable, so the roads between brickyard and our shop were kept hot while the gang loafed."

We noted in Chapter III that an outstanding development in wood-working machinery in recent decades has been accelerated lineal speeds of such machines as flooring machines and molders. In the garment-making industry various establishments reported labor reductions through the purchase of more rapid sewing machines. In paper pulp making, the manufacturer has reduced labor costs by running machines faster without increasing the number of tenders. One paper-machine manufacturer writes: "a machine running at three or four hundred feet per minute will require approximately the same amount of help in the machine

<sup>27</sup> Letter to writer from president of a leading brick machine company, April 16, 1928.

rooms as a machine running eight hundred or a thousand feet per minute or over." One manufacturer of corrugated fibre-board products reported to us that by increasing the speed of his machines he had been able to "triple production since 1920 with approximately the same number of employees".

The superintendent of a beet sugar factory states: "We have done more in increasing the speed of the existing machinery by little odds and ends, each one more or less insignificant in itself, by all working together to increase the speed and by training the crews to quicker and snappier work."

A knitting mill reported that it was introducing new knitting machines which would run 20 per cent faster, make 24 stockings at once instead of 18, and, as were the slower machines, be tended by one man.

English cotton mills are said to make up in part for fewer looms per weaver by running looms at a higher speed. In the warping process in American mills the new-type high speed warper is said to run something like eight times as fast as the old-style warper, though the saving in labor is not so great as this ratio might imply (Ch. III).

#### ELECTRIFICATION OF FACTORY POWER EQUIPMENT

Because of its cleanliness and flexibility, electrification facilitates the more general application of power in industry; hence the pronounced trend towards the electrification of manufacturing plants, clearly brought out by Table 24, is a significant aspect of increasing mechanization. From 4 per cent in 1899 the percentage of power equipment which is electrified has increased to about 30 in 1914, and to about 70 to 75 in 1929.

A precise determination of the degree of electrification

MEASURES OF CHANGE

TABLE 24  
INCREASING USE OF ELECTRIC POWER IN MANUFACTURING<sup>1</sup>

CENSUS YEAR	RATED HORSEPOWER (THOUSANDS)				RATIO OF		
	A Total primary power (B+C)	B Other than electric <sup>2</sup>	C by pur- chased power	D generated in report- ing plant	E ELECTRIC MOTORS DRIVEN BY PUR- CHASED POWER TO TOTAL PRIMARY POWER (C ÷ A)	F Method I <sup>3</sup> $\left(\frac{C+.72D}{A}\right)$	G Method II <sup>4</sup> $\left(\frac{C+D}{C+1.39B}\right)$
1899	10,098	9,915	183	310	.02	.04	.04
1904	13,488	13,046	442	1,151	.03	.10	.09
1909	18,675	16,926	1,749	3,068	.09	.21	.19
1914	22,437	18,540	3,897	4,939	.17	.33	.30
1919	29,324	20,041	9,283	6,969	.32	.49	.44
1923	33,092	19,728	13,364	8,821	.40	.60	.54
1925	35,767	19,902	15,865	10,255	.44	.65	.60
1927	38,826	19,693	19,132	11,220	.49	.70	.65
1929	42,931	20,155	22,776	12,376	.53	.74	.69

<sup>1</sup> Compiled from *Census of Manufactures: 1919*, VIII, 122; *1927*, p. 1270, and *1929*, p. 112. Unlike the data in Table 15 these data are not adjusted for changes in the scope of the census of manufactures.

<sup>2</sup> Includes steam engines, steam turbines, internal-combustion engines, water wheels and water turbines, in the reporting plant; also, for 1899-1914, rented power other than electric. Some of this non-electric power is used to generate current to drive electric motors; hence, to avoid duplication, the horsepower of electric motors driven by current generated in the reporting plant (shown in column D) is not included directly in the total for primary power in column A.

<sup>3</sup> In Method I, which is used by the Bureau of the Census to estimate the "Proportion of 'Electrification' of Factory Power Equipment", the horsepower of electrified equipment is taken as the sum of electric motors driven by purchased current plus the estimated capacity of prime movers used to actuate motors operated by prime movers owned by the reporting factory. It is assumed "that the ratio of the capacity of these prime movers to that of the motors operated by them is 72 per cent". The denominator of the ratio is total primary power; *Commerce Yearbook* (1929), I, 292.

<sup>4</sup> In Method II, the numerator of the ratio is the total of electric motors in the factory, both those operated by purchased power and those operated



by power generated in the factory; and the denominator is the estimated total of electric motors if the plants were all completely electrified. In making this estimate we have followed the Bureau of Census in assuming that 72 horsepower of prime movers will be used to drive 100 horsepower of electric motors.

is made difficult by the fact, noted above, that the horsepower of electric motors driven by purchased power is not logically comparable with the horsepower of prime movers used to drive machinery directly or to generate power for electric motors in the same establishment. In computing the degree of electrification we have assumed that 72 horsepower of prime movers will be used to drive 100 horsepower of electric motors, and have computed the degree of electrification by two slightly different methods, as explained in the footnotes to Table 24. The estimate in column F follows the method used in the *Commerce Yearbook* and yields an electrification ratio for 1927 of 70 per cent. The slightly more conservative method in column G yields an estimate of 65 per cent. Using a still different method of estimate, Mr. L. P. Alford reaches a figure of 78 per cent for 1927.<sup>28</sup> By all three methods the degree of electrification is shown to have at least doubled from 1914 to 1927.

Since 1914 there has been a large increase in the number of electric motors operated by power generated in the same establishment, but the increase in the use of purchased power has been even more marked—from less than 4 million horsepower in 1914 to over 20 million in 1929.

The increase in the use of electric power has been common in many industries. A few specific illustrations may be cited. In the rolling mill branch of the steel industry the greatest change in the last ten or fifteen years has been associated with the electrification of main roll drives and all incidental controls, which is the method of automatic pro-

<sup>28</sup> *Recent Economic Changes*, p. 126.

duction.<sup>29</sup> Electrification has been especially rapid since 1923 in several of the rolling mill processes. Electrification furthers the use of individual drives. In machine tools, to illustrate, there is a marked tendency towards the substitution of group or individual motor drives for pulley drives. For example, the *American Machinist*, in its summary for new machine-tool equipment for the second half of 1927, pointed out that "self-contained motor drives are now the rule rather than the exception, and pulley drives are usually optional".<sup>30</sup> The same issue of the *American Machinist* also calls attention to the "large number of portable electric drills" put upon the market.

Some of the reasons for the growing popularity of electric power in factories are suggested by the following quotation from the *1910 Census of Manufactures* (VIII, 331).

"Electric power is largely applied by means of relatively small motors distributed throughout the manufacturing establishment, some of which are in general use while others are required only at infrequent intervals. As the electric power can be used or cut off at will, it proves both convenient and economical, especially for the operation of machinery which is in use only a part of the time; and the cleanliness and quietness of the electric motor as compared with other sources of power also give it manifest advantages in certain industries, such as the clothing industries. . . . The electric motor run by purchased current furnishes power for manufacturing with a minimum of trouble or attention on the part of the operator. . . ."

#### ECONOMY OF MEN AND EQUIPMENT

Our major concern in this survey is with the changes in the type and quantity of machinery used. Lest this preoccupation with the trends in mechanization make it appear that we are overlooking non-mechanical changes, let us reiterate that there are also in progress in American industry various

<sup>29</sup> See Ch. III and Appendix A.

<sup>30</sup> January 19, 1928, p. 77.

non-mechanical changes in organization and methods of operation, not readily susceptible of measurement with respect to their extent and rapidity of introduction but nevertheless of significance in the past history and for the future development of industry. We have in mind all those techniques included under the none too clearly defined term scientific management, with its time and motion studies, also improved methods of wage payment, and increasing subdivision of labor, such as sometimes accompanies the 'stretch-out' system in textile mills—in short, all efficiency measures which represent a more effective use of the available machinery and man power rather than changes in the equipment itself.<sup>81</sup>

<sup>81</sup> See Ch. II, section on Non-mechanical Changes; also Ch. III, particularly sections dealing with Cotton Yarn and Cloth, Newspaper Printing, Leather, and Beet Sugar.

## CHAPTER VII

### DIFFERENCES IN DEGREE OF MECHANIZATION

IN THE preceding chapter we traced the growth of mechanization in recent years. Here, using in part the same methods of measurement, we endeavor to give a cross-section of the degree of mechanization that has been reached in the various industries and processes, and to compare, in so far as the data make it possible, differences in degree of mechanization among industries, geographical areas, and large and small establishments. Such a summary of the degree of mechanization attained, sketchy and inadequate as it must necessarily be in many respects, furnishes some additional basis for judgment concerning the rapidity with which we may expect further extension of the use of mechanical labor-saving devices now developed or in early prospect.

We noted in Chapter VI that mechanization is a phenomenon with many different aspects and consequently measurable in several ways. It is not essential that we repeat here the analysis of the nature and limitations of the methods, except to point out that some modes of measurement may be more serviceable for the comparison of differences in mechanization at a given date while others are more available or more useful for the comparative study of the process of mechanization over a period of time. Such differences do exist. For example, on the score of applicability the significance of the labor expense ratio may be seriously distorted over a period of years by changes in wage rates that differ

in degree from those in the prices of the other elements in production. But comparisons of the ratio of wages paid to other production expense at a definite time are less open to this objection, though they may still lack adequate accuracy because of geographical or industrial differences in wage rates for the same grade of skill.

Furthermore, some measures or indexes of mechanization which are not available at regular intervals are available at one or two periods. This is largely true, for example, of the statistics we have compiled of the ratio of machine workers to the total labor force, for these were obtained by direct observation and interview, and are not periodically compiled.

We have distinguished five more or less general measures of mechanization: the rated-capacity-of-power-equipment ratio (horsepower per wage earner); the labor expense ratio (notably the ratio of wages to value added in manufacture); the machine worker ratio; the machine output ratio; and the investment-in-equipment ratio (dollar investment in equipment per wage earner). We shall first note the contribution that each of these measures makes to an understanding of the differences in mechanization between industries and then turn to the evidence afforded by the less general measures, that is, data showing the extent to which tractors, harvester combines, automatic telephones, self-feeding wagon loaders, or other particular labor-saving devices are in use.

#### HORSEPOWER PER WAGE EARNER

##### BY INDUSTRIES

Despite the limitations on its usefulness as a measure of mechanization,<sup>1</sup> the ratio of horsepower to wage earners

<sup>1</sup> See Ch. VI.

affords the best measure available at regular intervals for all industries.

The horsepower per wage earner for all manufacturing industries combined, for each of 13 industrial groups, and for 127 individual industries, at each census period from 1899 to 1929, inclusive, are given in Appendix C, arrayed in order of the horsepower ratio in 1925. The average in that year for all industries combined is 4.27, but the range is wide, from only a tenth of a horsepower per wage earner in 'turpentine and rosin' to 47.28 in 'blast furnaces'. The horsepower ratios for the 13 major industrial groups for 1919, 1925 and 1929 are given in Table 25.

TABLE 25  
HORSEPOWER PER WAGE EARNER IN THIRTEEN MANUFACTURING INDUSTRIAL GROUPS: 1919, 1925 AND 1929<sup>1</sup>

INDUSTRIAL GROUP	HORSEPOWER PER WAGE EARNER		
	1919 <sup>2</sup>	1925	1929
All industries	3.25	4.27	4.86
Tobacco manufactures	0.28	0.32	0.56
Leather and its finished products	1.10	1.31	1.37
Textiles and their products	2.03	2.46	2.43
Vehicles for land transportation, including			
railroad repair shops	1.50	2.53	3.30
Lumber and its remanufactures	4.11	3.88	4.39
Non-ferrous metals and their products	2.90	3.96	4.76
Miscellaneous industries	2.25	3.98	3.91
Food and kindred products	4.05	4.64	4.94
Rubber products	2.71	4.65	5.52
Paper and printing	4.79	5.70	6.45
Stone, clay and glass products	5.29	6.70	8.79
Iron and steel and their products	5.10	6.76	7.58
Chemicals and allied products	4.79	7.40	8.80

<sup>1</sup> Compiled from Appendix C. The grouping of industries here is adapted to comparison over the entire period 1899-1929 and is somewhat different from that used in the *Census of Manufactures* for recent census periods and shown in Table 28.

<sup>2</sup> Adjusted to make comparable as far as possible with data for 1925 and 1929.

Why does the chemical and allied products industry average 8.80 horsepower per wage earner in 1929, the iron and steel industry 7.58, and the stone, clay and glass industry 8.79, whereas the industry producing vehicles for land transportation and the textile industry, both of which are in some branches at least considered to be highly mechanized, have only 3.30 and 2.43 respectively? And why do leather and its finished products, and tobacco manufactures stand at the bottom of the list with 1.37 and 0.56 horsepower respectively?

How many of the differences among the ratios of horsepower to wage earners arise from inherent differences in the industries—weight of the units to be handled, complexity or uniformity of the raw materials, degree of standardization in the product? How many, if any, of the observed differences arise from unequal inducements to the use of machinery arising from unequal wage levels? How many, to differences in the attitude towards increased mechanization upon the part of employers or workers in the several industries? What is the effect of the age of the industry? Of its size? The factors involved are so many and so intricately inter-related that it is difficult to obtain conclusive quantitative data on these questions, but the data available do furnish some evidence, and it conforms on the whole to the relations between the horsepower ratio and the nature of the industry that would ordinarily be anticipated.

The data used in Appendix C reveal that the industries having large horsepower per wage earner are chiefly those using heavy materials or materials in a relatively crude state which can be handled easily in large quantities. Among the former are blast furnaces, steel works and rolling mills, locomotive and steel ship plants, marble and stone works, cement, paper and wood pulp mills, coke, paving materials, and smelting and refining plants. Among the products which

consist of units not necessarily heavy but which can be handled readily in bulk may be mentioned oils, sugar, chemicals and acids, milk, butter and cheese, and petroleum. All these fall in the relatively small group having five or more horsepower per wage earner.

As we proceed down the array, we find industries with products in a more advanced stage of fabrication and less standardized, though sometimes still in relatively large units. For instance, in the group ranked between 50 and 75 we find, among other industries, agricultural implements, machine tools, slaughtering, woolen and worsted goods, and foundry and machine-shop products.

At the lower end of the array, with horsepower per wage earner less than 1.0, we find specialties such as watches, fur goods and millinery, where the individual unit of output is small and often not highly standardized.

That the group averages conceal wide differences in the individual industries comprising the group is obvious upon examination, for example, of the constituent industries of the last group in Table 25, chemicals and allied products. The ranking of the individual industries in this group ranges from 6 (coke) to 141 (turpentine and rosin). Likewise, even the individual industry ratios doubtless conceal substantial differences among their several branches and in individual establishments.

#### GEOGRAPHICAL DIFFERENCES

Geographical differences in horsepower per wage earner are indicated in Table 26, which arrays the 48 states in order of horsepower per wage earner in manufacturing in 1929.

The Pacific and Mountain states, as shown in Table 26, are on the whole well equipped with horsepower relative



TABLE 26  
HORSEPOWER PER WAGE EARNER IN MANUFACTURING,  
BY STATES: 1929<sup>1</sup>  
(all 48 states: 4.86)

Arizona	17.12	Virginia	5.37
Montana	13.30	New Mexico	5.17
Nevada	12.36	Arkansas	5.05
Maine	9.68	Maryland	5.03
Utah	7.93	North Dakota	4.91
West Virginia	7.62	Delaware	4.88
Wyoming	7.46	South Carolina	4.85
Colorado	7.11	Mississippi	4.85
Washington	7.10	South Dakota	4.79
Oklahoma	7.04	Tennessee	4.73
Idaho	6.76	Wisconsin	4.68
Alabama	6.57	Kentucky	4.56
Oregon	6.39	Iowa	4.49
Kansas	6.30	Michigan	4.45
New Hampshire	6.14	Illinois	4.06
Texas	6.12	Georgia	4.04
Nebraska	6.00	North Carolina	4.00
Vermont	5.98	New Jersey	3.72
Pennsylvania	5.91	Massachusetts	3.71
Indiana	5.91	Rhode Island	3.68
Minnesota	5.87	Connecticut	3.61
Ohio	5.86	New York	3.60
Louisiana	5.50	Missouri	3.54
California	5.39	Florida	2.97

<sup>1</sup> Computed from horsepower and wage earner data in *Census of Manufactures, 1929*.

to the number of wage earners in their manufacturing industries. The states of the 'Old South', on the other hand, are all in the lower half of the array with the exception of Louisiana and also Alabama, with its extensive steel industry. Many of the differences in mechanization revealed by this array arise from differences in types of industry in the several states. The low ranking of Connecticut and Rhode Island, for example, is largely due to the many highly

specialized industries in these states or to industries, like textiles, with light materials not requiring much power to handle. Is any substantial part of the observed differences ascribable to other causes, such as differences in relative wage rates or in the average size of establishments?

In order to reduce the influence of differences in the types of industry dominant in the several states, and thus to facilitate the study of other causes of differences in mechanization, we have analyzed the association between relative wage rates and relative mechanization (based on horsepower per wage earner) in two groups of states. The 'northern' group comprises the 14 states in the New England, Middle Atlantic and East North Central divisions. These states are characterized on the whole by a high degree of industrialization and relatively high wage levels. The 'southern' group comprises the 12 states in the South Atlantic and East South Central divisions, not so highly industrialized on the whole and having relatively low wage levels. For each of 12 industries we computed the relative annual wages and the relative horsepower per wage earner, in 1927, for the 3 leading 'northern' and 'southern' states, respectively.<sup>2</sup> By this procedure we aimed to minimize the

<sup>2</sup> The 12 industries selected are: slaughtering and meat packing, cotton manufactures, furniture, bread and other bakery products, fruit and vegetable canning, newspaper and periodical printing and publishing, book and job printing and publishing, clay products and non-clay refractories, men's work clothing, planing-mill products, lumber and timber products, and foundry and machine-shop products.

For each of these 12 industries we utilized the data for 6 states—the 3 states with the highest number of wage earners in the 'northern' group, and the 3 states with the highest number in the 'southern' group. In only 2 instances was the number of wage earners in the selected state below 1,000 (826 for slaughtering in Kentucky and 728 for meat packing in Tennessee).

Then for the United States as a whole and for each of the 6 states, we computed, for each of the 12 industries, the horsepower per wage earner and the average wages paid per wage earner in 1927. Finally, to allow for the fact that even in the same state there are substantial differences in

effect of differences due to the type of industry in the several states, and thus to afford a better basis for study of significant geographical differences in mechanization and of the association, if any, between wage levels and the degree of mechanization. The resulting percentage ratios for relative earnings and relative mechanization are plotted in Chart I.

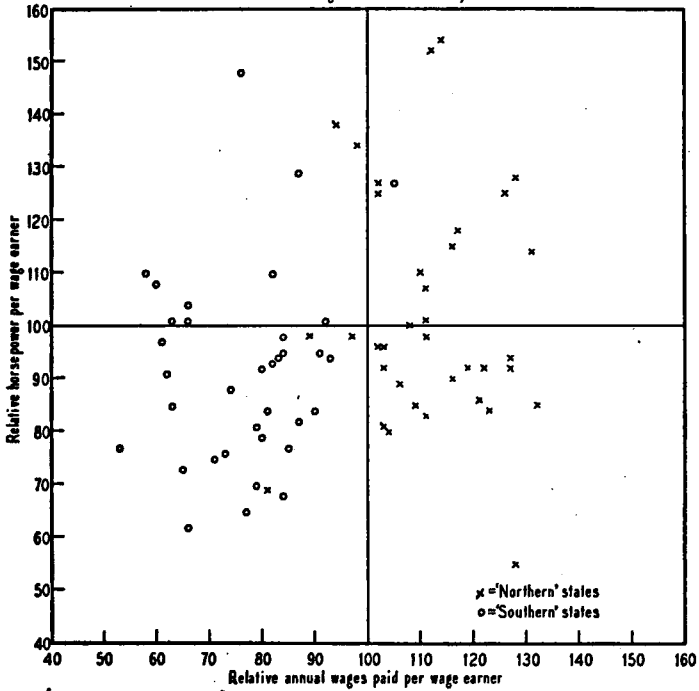
#### WAGE LEVELS AND MECHANIZATION

Chart I raises a presumption in favor of assuming an association between high wage levels and high mechanization, although the relationship exhibited cannot be said to be extremely close. In three-fourths of the instances where the wage ratio is below the average (100) for the industry as a whole, the horsepower ratio is also below average. Also, where the wage ratio is above 100, the horsepower ratio is 80 or more. Hence it seems plausible that the low mechanization in the southern states, indicated by the concentration of circles in the lower left quadrant of Chart I, is ascribable in part to an association of low wage levels with low mechanization. True, the correlation between the wage and horsepower ratios is less obvious if the 'southern' and 'northern' groups are separately considered, and it is, of course, conceivable that the low mechanization of these industries in the southern states is ascribable not to low wages but to some other condition differentiating the southern from the northern group.

average wages and power requirements among the several industries, we reduced these horsepower and annual wage ratios to relatives with the United States average for the given industry as a base.

Chart 1  
 COMPARISON OF RELATIVE ANNUAL WAGES AND  
 RELATIVE HORSEPOWER PER WAGE EARNER IN  
 SELECTED MANUFACTURING INDUSTRIES, 1927<sup>1</sup>

(United States average in selected industry = 100)



<sup>1</sup>Computed from data in the "1927 Census of Manufactures", by methods described in the accompanying text

SIZE AND MECHANIZATION

Are the larger manufacturing plants more highly mechanized than the smaller ones?

The statistics of rated capacity of power equipment per wage earner do not afford conclusive evidence on this point.

Table 27 shows the average horsepower per wage earner for all manufacturing industries, classified by number of wage earners employed. This mechanization ratio is lowest for

TABLE 27

HORSEPOWER PER WAGE EARNER IN MANUFACTURING INDUSTRIES, CLASSIFIED BY SIZE OF ESTABLISHMENT: 1929<sup>1</sup>

NUMBER OF WAGE EARNERS PER ESTABLISHMENT	HORSEPOWER PER WAGE EARNER
All establishments	4.86
1-5	5.94
6-20	4.49
21-50	3.96
51-100	4.16
101-250	4.65
251-500	4.79
501-1,000	5.34
1,001-2,500	5.78
2,501 or more	4.89

<sup>1</sup> Computed from data in *Census of Manufactures, 1929, I, 62, 147.*

the establishments employing from 21 to 50 men. The highest ratios are in the smallest establishments (1-5 wage earners) on the one hand, and in the next to largest size (1,001-2,500 wage earners), on the other. This apparent lack of consistent relation between size and horsepower per wage earner may arise in part from the indiscriminate grouping in these averages of industries differing widely in power requirements. This source of confusion may be minimized by a resort to comparisons of the horsepower ratio in establishments of large and small size in identical industries. For this purpose we have selected the group with 21-50 wage earners to represent the small plants, and the group with 251-500 to represent the large plants. For 1929 data are available for the computation of horsepower per wage earner in these two groups for 111 individual indus-

tries.<sup>8</sup> For 10 of these 111 industries the 1929 mechanization ratio (horsepower per wage earner) was the same for the small and large establishments. For 53 industries the ratio was higher for the larger establishments, the median difference being 0.7 horsepower; and for 48, the ratio was lower in the larger plants, the median difference being 1.2 horsepower.

In the judgment of the writer, the evident failure of the mechanization ratio based upon horsepower per wage earner to show a close association between the plant size and the degree of mechanization arises in part from the fact that in small plants a greater proportion of the work is done by proprietors and firm members than in the larger plants, and hence the ratio of horsepower to wage earners makes the number of workers appear smaller in comparison with horsepower than if the proprietors and firm members were included in the computation. Furthermore, it is quite probable that the smaller establishments have power plants which are large relative to the power work to be done. This does not necessarily mean that the degree of mechanization in a significant sense is relatively high. The power plants may be larger than necessary and the machinery driven by them antiquated. All of which suggests some of the limitations upon attaching a precise significance to comparisons of horsepower between establishments.

Other information at hand evidences more clearly a tendency for the degree of mechanization to vary directly with the size of the manufacturing plant. For example, the ratio of machine workers to total labor force lends some support to the thesis that large plants and high mechanization go together. Among the establishments inspected by us, common brick plants with a daily capacity of 40,000

<sup>8</sup> *Census of Manufactures, 1929, I, 64-71 and 148-55.*

brick or less were only 27 per cent mechanized; those with a capacity of more than 40,000 brick, 40 per cent.<sup>4</sup> No brick plant with a mechanization ratio of less than 30 per cent had a daily capacity of more than 36,000 brick. In the cotton goods mills the mechanization ratio was slightly higher for the larger plants. In the mills with a labor force of 300 workers or less, the typical mechanization ratio was 80 per cent; in the plants employing more than 300, it was 87. In ferrous foundries, the degree of mechanization was 17 per cent for plants with 100 or less men, 29.5 for those with 101-200, 34.1 for those with 201-400, but only 25.1 for those with over 400 workers.

The use of certain labor-saving devices is known to be more prevalent in larger plants. In a survey of merchant blast furnaces made by the Bureau of Labor Statistics it was found that the mechanically-filled furnace was larger than the hand-filled type, the typical output per stack-day being 286 tons for those mechanically charged and 169 for the hand-filled furnaces.<sup>5</sup> Likewise, the typical daily output was 292 tons for furnaces using machine casting but only 189 for those with sand casting. The introduction of the cigar machine "has resulted in the elimination of many small hand plants and has concentrated production in a comparatively smaller number of large plants using machinery" (*Monthly Labor Review*, Ref. 47, p. 1280).

That an increasing resort to mechanical means of production will often accelerate the tendency towards larger plants is obvious from consideration of the fact that many

<sup>4</sup> The mechanization ratio used here is the median ratio of machine workers to the total labor force. See explanation in the section entitled, Relative Number of Hand and Machine Workers.

<sup>5</sup> Ref. 37, pp. 71-103. These comparisons are based upon output per stack-day in 1914 or the first subsequent year for which data are given; we have used the median figure as the 'typical' output.

machines having marked labor-saving qualities are expensive and can be used economically only when the volume of production is relatively high. Furthermore, the economical balancing of equipment and labor force requires a certain minimum size of plant. A power shovel can be used to full advantage in excavating clay for a brickyard only when the daily output of the yard is sufficient to keep the shovel busy. A machine capable of displacing 20 workers cannot be substituted with maximum gain in a plant that employs a crew of less than 20 in the operation affected. Often several machines must be operated in a single establishment in order to make possible the most economical use of various specialized workmen. For example, only one skilled repair mechanic is required for about 8 to 10 cigar machines; hence a plant with fewer machines may find it difficult to take full advantage of the specialized skill of the repairman. Similar examples of the necessity of a certain minimum size of establishment for the economical use of machines might be multiplied many times. On the other hand, the increasing use of individual electric motors, driven by purchased power, facilitates the application of mechanical methods of production in relatively small establishments.

#### RATIO OF WAGES PAID TO VALUE ADDED BY MANUFACTURE

In tracing the chronological development of mechanization we found the ratio of wages paid to value added by manufacture of quite limited usefulness (Ch. VI); but for purposes of comparisons at a given time, this measure may be more reliable because not distorted by changes in wage rates. The ratio of expense for labor to machine expense (depreciation, repairs, maintenance, interest, etc.) would, if available, be a useful measure of mechanization.<sup>6</sup> Value

<sup>6</sup> For distribution of sales value to the several items of expense, in hand



added by manufacture, however, includes more than machine expense. It is the difference between the selling value of the product at the factory and the cost of materials, supplies, containers for products, fuel and power. This difference is made up (in addition to machine expense, wages, salaries, interest and insurance other than that chargeable to machines), of advertising, other sundry expenses, and taxes and profits, if any, included in selling value. Furthermore, the wage ratio is determined in part by differences in wage level. Such differences may be due in part to differences in the type of labor required—variances in age, sex and skill—and this fact gives the ratio the merit of tending to measure quality as well as quantity of labor required. On the other hand, differences in wage level may be due to such variations, extraneous for our purposes, as differences in bargaining power and geographical differences in cost of living. The wage ratio is unique, then, in giving weight to quality of labor. It is of limited value in that the numerator (wages paid) is not a precise measure of either quantity or quality of labor used; and the denominator (value added) includes other items in addition to machine expense.

What picture does the wage ratio give of the relative mechanization of the major industrial groups? The answer is seen in Table 28. In the first column, we have arrayed the sixteen industrial groups in order of the ratio of wages paid to value added in manufacture in 1925. The industry with the smallest ratio, tobacco manufactures, is ranked first, because the smaller the ratio, the smaller, so far as this evidence goes, is the use of labor and the greater, relatively, the use of machinery.

and machine window-glass plants, 1916, see U. S. Bureau of Foreign and Domestic Commerce, *Miscellaneous Series No. 60*, pp. 184-6. In the hand plants 57 per cent represented payments to labor; in the machine plants, 47.

DEGREE OF MECHANIZATION

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TABLE 28

RANKING OF THE SIXTEEN INDUSTRIAL GROUPS IN MANUFACTURING, BY TWO MEASURES OF MECHANIZATION: 1925 <sup>1</sup>

INDUSTRY	PERCENTAGE RATIO OF WAGES PAID TO VALUE ADDED BY MANUFACTURE		HORSEPOWER PER WAGE EARNER		DIFFER- ENCE IN RANK
	RATIO	RANK	RATIO	RANK	
All industries	40.1		4.27		
Tobacco manufactures	16.8	1	0.32	16	15
Chemicals and their products	22.5	2	7.83	2	0
Food and kindred products	29.7	3	5.84	4	1
Paper, printing and related industries	31.8	4	5.70	5	1
Miscellaneous industries	34.3	5	2.31	12	7
Rubber products	35.5	6	4.65	6	0
Machinery, not including transportation equipment	40.4	7	3.16	10	3
Metals and metal products, other than iron and steel	42.9	8	4.21	7	1
Textiles and their products	43.8	9	2.45	11	2
Transportation equipment, air, land and water	44.0	10	3.38	9	1
Stone, clay and glass products	45.0	11	6.65	3	8
Musical instruments and phonographs	47.0	12	2.07	13	1
Iron and steel and their products not including machinery	47.1	13	8.83	1	12
Leather and its manufactures	47.3	14	1.31	15	1
Lumber and allied products	49.8	15	3.77	8	7
Railroad repair shops	86.9	16	2.06	14	2

<sup>1</sup> Computed from 1925 *Census of Manufactures*, pp. 26-7.

The ranking based upon the horsepower ratio is given in the fourth column, and in the last column the difference in the ranks assigned to the respective industries by the two methods of measuring mechanization. Remembering the various limitations upon the accuracy of each method, the differences are no more than would be expected. Only

six industries vary more than two ranks. Tobacco manufactures rank at the top of the list by the wage ratio method; at the bottom, by the horsepower ratio method. If we may venture suggestions as to the causes of the wide discrepancies observed for a few industries, for tobacco manufactures at least part of the observed discrepancy is due to the fact that heavy internal revenue taxes enter into value added, and this, together with a low wage level in the industry, tends to minimize the ratio of wages to value added. For iron and steel, with a difference of twelve in the ranking, and in the stone, clay and glass products industry, the weight of the materials utilized necessitates heavy power machinery and puts these industries high in terms of horsepower, and yet they use a large amount of labor. Furthermore, in iron and steel the wages paid are considerably above the general average for manufacturing, which tends to make the wage ratio indicate low mechanization.

The two methods of measurement agree closely in placing among the highly mechanized industries the chemical, food, and paper and printing industries, and among the lowest in degree of mechanization, musical instruments, leather, and railroad repair shops.<sup>7</sup>

<sup>7</sup> The comparisons made above are for major industrial groups. One might expect a closer relation between the degree of mechanization shown by the two measures if the comparison is made for the some hundreds of individual industries comprising the groups. We tested this hypothesis for 338 individual industries reported in the *1925 Census of Manufactures*, by the scatter diagram method, but the relationship shown is no closer than that evidenced by the ranking in Table 28. On the hypothesis that other complicating factors would be lessened by restricting the study to one state, we made a similar study for the individual industries in New York State, but the results were equally inconclusive, showing little evidence of close correlation between the two measures.

## INVESTMENT IN BUILDINGS AND EQUIPMENT

If satisfactory data were available by industries for the investment in buildings and equipment per wage earner, or possibly per dollar of sales,<sup>a</sup> they would afford a valuable measure of differences in mechanization. However, little information of this type is available, and even when data purporting to represent investment in equipment are given, the problems created by changing prices, depreciation allowances, etc., are so complex as to make doubtful their accuracy and usefulness.

## RELATIVE NUMBER OF HAND AND MACHINE WORKERS

From the point of view of the effect of mechanization upon the worker himself, it would be desirable to know for what proportion of those engaged in each industry or, better yet, in each process of an industry, are the tempo and other conditions of their work determined by machines. In one case the machine may dominate the worker, forcing him to adapt the time and speed of his actions to the machine; in others the man may dominate the machine, using it as an aid in operations the frequency and timing of which are under his control. We have not attempted to measure the degree of mechanization in this sense.

A simpler measure of mechanization is the ratio of the number of workers engaged in machine processes to the total number of workers in the process or plant as a whole. This measure has the merit that it is a relatively realistic and direct measure of mechanization, and that it affords a

<sup>a</sup> A study by the Bureau of Foreign and Domestic Commerce puts the capital investment per dollar of sales in 1916 as only 75.3 in 35 plants making window glass by the hand method as compared with 92.9 cents in 11 cylinder-machine plants (Misc. Series No. 60, p. 77).

basis for comparison not only of an industry as a whole, but also of the separate processes within an industry. Its usefulness is limited because it may understate by a wide margin the proportion of output produced by machine methods.<sup>9</sup> Also, when machinery becomes so automatic as to need very few or no tenders the 'machine labor' ratio may understate the actual degree of mechanization. Furthermore, the necessary data are obtainable only by special survey and are not available for other periods; thus their value for comparative purposes is limited, and considerable difficulties of definition are met in deciding which workers should be classified as hand and which as machine.

For most of the industries included in the field phase of the survey, our agents obtained, partly by inquiry and partly by direct observation, data concerning the occupations of the several classes of workers in each of the major processes of the industry. The workers were divided into five groups: machine operators, workers auxiliary to machines, hand workers, supervisory workers and teamsters.

The field investigators were instructed to count as 'machine operators' all those who control the starting, stopping and movement of machines, including ordinarily the workers who control the feeding of the machine, guide it, or remove the product without conveying it far from the machine.

The group designated as 'auxiliary workers' is obviously the most difficult to define satisfactorily. Here are included those workers whose occupations are not the direct control of the stopping, starting or movement of the machine, but those whose tasks are directly contributory to machine operations. This group includes machine repairmen, oilers and cleaners; men engaged in setting up and adjusting

<sup>9</sup> See Ch. X for illustrations of ratios between production by hand and machine methods.

machines, or in feeding the machine in those rare instances where no control is exercised over it; and a long list of special occupations in the various industries, such as pneumatic drill sharpeners, crane and hoist signalmen or hitchers, hose and pipe-line men about power shovels, and men engaged in handling plank, blocking, etc., in moving the power shovel. We endeavored to include in this 'auxiliary' group that diverse list of occupations which are not clearly machine operations and yet which are essential to the operation of machines.<sup>10</sup>

The workers listed as hand workers are engaged in processing or conveying by hand or with the aid of man-powered contrivances such as wheelbarrows and hand trucks. We ordinarily included as a hand operation the conveying of products from the discharge end of the machine where the person involved does not control the machine but performs work that a mechanical conveyor could readily do; also assembling without a conveyor, or even assembling on a continuous conveyor system if the worker uses no automatic tools.<sup>11</sup> Fabrication by hand, such as has been prevalent in the cigar-making industry; wrapping or packaging goods by hand; and various miscellaneous operations, such as cleaning buildings without power tools, are among those which make up the group of manual as distinguished from machine or auxiliary-to-machine occupations.

The supervisory group includes foremen, time checkers,

<sup>10</sup> In cotton mills, for example, the following occupations were among those classified as auxiliary to machines: card grinders and cleaners, oilers, can boys, band boys, doffers, bobbin cleaners, spindle setters, helpers to drawing-in and tying-in machine operators, loom cleaners, harness men, and loom fixers.

<sup>11</sup> The reader may question whether assembling with the aid of a conveyor system should not be classified as work auxiliary to a machine. We have preferred to think of the conveyor as doing the *handling* work, and the operator as engaged in *processing* by hand.

and miscellaneous clerks in the factory department. Our survey did not cover the office force proper.

Undoubtedly there are rather wide 'twilight zones' between the three major classes listed—machine operators, workers auxiliary to machines, and hand workers; and probably not all those engaged in filling the schedules interpreted the definitions of the classes in exactly the same way. In each of the separate industries, however, the major portion of the schedules for the industry were collected by one man, or at most two or three. The writer, after careful study of the materials in the schedules and the method used in their collection, is inclined to think that, with all their limitations, they are fairly good indicators of the proportion of workers properly assignable to the several classes, and that they serve to point out more forcibly, perhaps, than any other evidence available the relatively large proportion of hand work that remains in most industries, despite the great increases in the use of mechanical equipment in recent decades.

Mechanization ratios based on occupations of the workers are presented in Table 29 for the industries to which principal attention was devoted in our field survey. In terms of the combined number of machine operators and of workers auxiliary to machines, the cotton goods industry is shown to be 86 per cent mechanized, paper 54, retail coal 49, brick and tile 40, highway construction 35, ferrous foundries 27, construction (chiefly excavation) 15, soft coal mining only 14, and stevedoring at the bottom of the list at 12 per cent.<sup>12</sup>

<sup>12</sup> The number of workers in the establishments grouped in Table 29 as 'other manufacturing' is somewhat too small to justify separate listing in a formal table, but some of the detail may be of interest. The percentage of hand workers in each of the industries included, together with the total number of workers upon which the percentages are based (in parentheses), is as follows: meat packing 74 (1,064); brass goods 57 (297); automobile 51

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TABLE 29

PROPORTION OF HAND AND MACHINE WORKERS IN SELECTED INDUSTRIES; BASED ON SAMPLE INSPECTIONS IN 1925

INDUSTRY	NUMBER OF SCHEDULES	NUMBER OF WORKERS	PERCENTAGE OF TOTAL NUMBER OF WORKERS IN INDUSTRY					
			MACHINE WORKERS			HAND		
			<i>All</i>	<i>Ma-</i>	<i>Opera-</i>	<i>Aux-</i>	WORK-	SUPER-
		<i>chine</i>	<i>tors</i>	<i>iliary</i> <sup>1</sup>	ERS	VISORS	STERS	
Total, all inspections	472	90,960	52	40	12	44	3	1
Cotton goods	50	31,396	86	67	19	12	2	2
Paper	30	5,537	54	26	28	42	4	2
Retail coal	21	467	49	43	6	46	1	4
Brick and tile	38	2,081	40	11	29	53	4	3
Other manufacturing <sup>4</sup>	58	10,173	50	36	14	45	4	1
Highway construction	68	3,269	35	26	9	42	6	17
Ferrous foundries	81	32,052	27	27	<sup>2</sup>	69	4	2
Construction, preponderately excavation	100	2,530	15	10	5	78	5	2
Bituminous coal mining	4	1,838	14	7	7	82	2	2
Stevedoring	22	1,617	12	6	6	80	8	2

<sup>1</sup> For explanation of the occupations classified as 'Auxiliary' see the accompanying text.

<sup>2</sup> None, or less than one-half of one per cent.

<sup>3</sup> In the foundry industry, because of special difficulties in classification, both 'Machine operators' and 'Auxiliary' have been grouped under 'Machine operators'.

<sup>4</sup> 'Other manufacturing' includes the following factories: automobile (1); brass (6); cement (5); cotton bleachery (1); crushed stone (2); garment (22); glass (1); machine shop (3); meat packing (5); paper pulp (4); tire (1); silk and velvet (3); woolen and worsted (4).

(3,257); rubber goods 50 (26); ladies' garments and men's clothing 48 (904); wood pulp 43 (568); cement 43 (1,287); a cotton bleachery 34 (230); machine shops 29 (207); crushed stone 25 (73); woolen and worsted 20 (395); and silk and velvet 14 (1,655). It is not our intent to suggest, of course, that these samples are sufficiently large to be accepted as fully representative of the respective industries.



Or to reverse the method of expression, the percentage of hand workers ranges from 12 for cottons to 80 for stevedoring.

This measure of mechanization tends to minimize the effect of heavy materials and to stress the influence of intricate though light machinery requiring human attention but not necessarily a great deal of power. This is one reason why, in Table 29, cotton goods rank at the top of the list, but 37 in a list of 141, in the array by horsepower per wage earner (Appendix C). Similarly, the ratios of mechanization based upon occupations show a somewhat lower degree of mechanization for foundries, and for brick and tile, than would be expected from their ranking on the basis of horsepower.

Contrary to the more or less prevalent concept of modern industry as almost entirely a machine process, these estimates of the proportion of machine workers indicate that there are, in fact, large numbers of workers in most industries whose work is essentially hand rather than machine. Something of the large potentialities for still further progress in mechanization is thus apparent.

#### PROPORTION OF HAND WORKERS, BY PROCESSES

The extent to which manual labor is prevalent in industry, and the variation in the degree to which different phases of industrial operations are mechanized, are brought out still more clearly by an analysis of mechanization by processes. For selected groups of plants in several of the industries surveyed we obtained the data essential to classify the workers in each major process as machine and hand. The results are summarized in Table 30 for inspections made in

TABLE 30

DEGREE OF MECHANIZATION, BY PROCESSES  
PERCENTAGE RATIO OF MACHINE WORKERS TO TOTAL LABOR  
FORCE IN THE SPECIFIED PROCESS<sup>1</sup>

INDUSTRY AND PROCESS	PER CENT	INDUSTRY AND PROCESS	PER CENT
<b>FERROUS FOUNDRIES (80 plants)</b>		<b>WOOD PULP (4 plants)</b>	
All departments (21,729) <sup>2</sup>	29	All departments (568)	51
Processing (15,673)	33	Maintenance and repair (67)	82
Cleaning and repairing castings (3,392)	70	Power (56)	77
Molding (6,346)	37	Pulp making (181)	65
Sand conditioning (511)	19	Wood room (88)	53
Core making (2,833)	8	Handling in yard (71)	35
Flask making (222)	5	General (31)	3
Tending furnaces and cupolas (297)	5	Conveying between processes (74)	0
Pattern making (1,254)	4	<b>NEWSPRINT (6 mills)</b>	
Shaking out (818)	4	All departments (2,137)	56
Materials handling (3,386)	28	Paper making (451)	84
Operating cranes (662)	100	Power plant (161)	83
Trucking (169)	75	Finishing and cutting (143)	78
Yard men (773)	15	Receiving logs and preparing pulp (618)	45
Charging cupolas and furnaces (621)	8	Maintenance and repair (675)	42
Shifting and cleaning (1,161)	1	Packing, conveying to carrier and shipping (89)	13
Other occupations (2,670)	11		
<b>BRICK AND TILE (38 plants)</b>		<b>PAPER MILLS (25 plants)</b>	
All departments (2,081)	40	All departments (3,402)	52
Molding (321)	74	Paper making (666)	83
Offbearing and drying (310)	55	Maintenance and repair (256)	83
Clay preparation (178)	54	Power production (286)	70
Pit and clay delivery (192)	52	Washing, beating and refin- ing (520)	58
Other (223)	47	Finishing processes (849)	45
Loading (372)	14	Preliminary preparation of stock (254)	29
Setting and burning (485)	14		

## MECHANIZATION IN INDUSTRY

TABLE 30 (cont.)

## DEGREE OF MECHANIZATION, BY PROCESSES

INDUSTRY AND PROCESS	PER CENT	INDUSTRY AND PROCESS	PER CENT
Receiving raw material and shipping product (358)	9	Sorting and arranging goods for consignee (559)	3
Conveying between processes, watchmen, cleaners and unclassified (213)	5	RURAL HIGHWAY CONSTRUCTION (61 jobs) <sup>1</sup>	
		All operations (3,164)	36
COTTON YARN AND CLOTH (50 mills)		Handling materials (962)	72
All departments (31,396) <sup>2</sup>	86	Paving (611)	39
Weaving (13,315)	95	Grading, with	
Spinning (6,377)	92	Power shovels (205)	28
Drawing and roving (3,382)	92	Elevating graders (242)	21
Carding and combing (1,516)	86	Drag or wheel scrapers (282)	10
Opening and picking (692)	81	Roadway structures (109)	18
Other yarn processes (3,261)	76	Incidental finishing (69)	12
Cloth room (1,183)	51	Fine grading (684)	7
Power, maintenance, yard handling and misc. (1,670)	36	BUILDING CONSTRUCTION (49 jobs, selected processes) <sup>1</sup>	
		All operations (1,402)	10
STEVEDORING (22 ships)		Hauling (27)	78
All operations (1,617)	12	Concrete and mortar hoisting (26)	73
Loading ships		Concrete and mortar mixing (161)	42
Delivery to side of ship (119)	3	Steel erection (41)	18
Placing in ship (38)	18	Digging (150)	3
Stowing in ship (67)	0	Concrete and mortar distribution (195)	2
Unloading ships		Carpentry (314)	1
Breaking out (554)	5	Brick and stone laying (208)	0
Removing from ship (280)	58		

<sup>1</sup> The machine workers group includes both machine operators and workers auxiliary to machines as defined in accompanying text.

<sup>2</sup> The figures in parentheses are the total number of workers in the specified process, including machine workers, hand workers, teamsters and supervisory workers. The total number of foundry workers is less than that

six manufacturing industries, stevedoring, and highway and building construction. The percentages given are ratios of machine workers to the total number in the respective process, counting as machine workers not only the direct machine-operating labor but also those whose tasks are auxiliary to machine operation.

An examination of these mechanization ratios reveals marked differences in the degree of mechanization among the several processing operations, and even more marked differences between the group of processing operations, on the one hand, and the handling operations, on the other.

In the foundry establishments surveyed, the machine workers constitute 29 per cent of the total labor force, in cleaning and repairing castings as high as 70, and in pattern and flask making as low as 4 or 5. In foundries there is no marked difference in the proportion of machine workers in processing (33 per cent) and in materials handling (28). But in brick plants, while the machine workers average 40 per cent for the force as a whole, the ratio is as high as 74 for the molding process and as low as 14 for the loading and also for the setting and burning operations. In cotton mills as a whole (Table 30) 86 per cent of the force were classified as machine workers. This percentage ranges, however, from over 90 in some of the major operations, such as spinning and weaving, to 51 in the cloth room, and even lower in the power, maintenance, yard and miscellaneous group. The ratios for the wood pulp, newsprint and other paper mills again show the preponderance of hand workers in the handling operations, both in the yard and between

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in Table 29 because of the exclusion here of the labor force of one large foundry.

\* For both highway and building construction the detailed distribution in this table covers a smaller number of jobs than the summary in Table 29.

processes in the plant. The paper-making process proper is highly mechanized—over 80 per cent—but only slightly more than half of the total labor force in the paper mill group were machine workers.

Hand workers outnumber others in many of the building operations studied (Table 30). Even steel erection, which almost always requires some machinery, is credited with only 18 per cent mechanization. The basic occupations of carpentry and bricklaying are almost completely manual. In highway construction somewhat more than a third of the workers are machine operators or helpers, the degree of mechanization being highest in the handling of paving materials and in the paving process itself, but the ratio is low in several of the other processes, notably roadway structures, incidental finishing and fine grading. In stevedoring the operations are largely manual, except that in the most highly mechanized of the several processes—that of removing goods from the ship—58 per cent of the labor force are machine operators or auxiliary workers.

To recapitulate, the evidence presented by this analysis by process stresses the wide divergence in the degree of mechanization in the several processes and also indicates a tendency for the processing operations to be more highly mechanized than the handling.

#### PROPORTION OF WORK DONE BY MACHINE

The occupation measure tends to minimize the degree of mechanization, because of the relatively greater productivity, in most instances, of labor applied with the aid of machinery. A proportion-of-work measure of mechanization, computed by determining the percentage of a given type of work or output done by machine methods, tends, con-

versely, to minimize the part performed by hand. The two measures taken together give excellent complementary pictures of the extent of mechanization. If we knew for each process in each industry, in each period, what percentage of the workers were engaged in hand operations and what part of the total output of the process resulted from their efforts, we would have intelligible and significant records of variations in the degree and progress of mechanization. Unfortunately, not only is the occupation measure not generally available, but also the proportion-of-work ratio is available for only a few industries. So far as they go, however, these few instances are noteworthy as illustrations both of tendencies and of a method of measurement.<sup>18</sup>

In terms of the proportion of work done by machine methods, there are many processes in which mechanization has reached one hundred per cent. Speaking of the immediate process, and not of various incidental occupations, the generation of electric current, the haulage of freight and passengers in rail transportation, the grinding of flour, cement and clay, the rolling of steel rails, and hundreds of other processes in manufacturing are beyond the capacity of manual power and hence are entirely mechanized. We are interested, however, chiefly in processes where the work is divided between machine and hand methods.

In coal mining in 1929, 75.4 per cent of bituminous coal and 1.6 per cent of anthracite was undercut by machine. Only 3.6 per cent of bituminous coal was loaded with self-feeding loading devices, their introduction being relatively recent. From 3 to 4 per cent of both bituminous and anthracite coal was mined by the highly mechanized process of stripping with power shovels.

<sup>18</sup> The sources for the following statements are given in Appendices A and B.

In a group of 20 iron foundries, allowing for distance and tonnage handled, we found ratios of mechanization ranging from 43 for the disposal of waste material, such as ashes, burnt sand and cupola droppings, to 93 per cent in the handling of molten materials (see Ch. V).

In a still more detailed study for 24 medium-size iron foundries, estimates for the three operations of loading, moving and unloading, in each of fifteen steps in the handling operations, were made in terms of percentage of tonnage handled by manual methods. These percentages range from 100 to zero for loading; from 86 to zero for moving; and from 100 to 31 for unloading.

In a group of 45 common brick plants, we found that about 49 per cent of the interprocess handling, assuming operation at full capacity, was done by power methods if only distance handled was considered, or 55 per cent if allowance was made for both distance and tonnage. For the separate major processes the corresponding ratios range from 12 to 96 for distance alone, and from 18 to 98 for distance and tonnage combined (see Ch. V).

In the glass industry, the percentage of window glass produced by hand had declined by 1926 to only 2 (Ch. III); for bottles and jars, it has been estimated that by 1924 or 1925 the proportion made on automatic machines had increased to 90 per cent (Table 38); and 95 per cent of all electric light bulbs are made by automatic processes.<sup>14</sup>

<sup>14</sup> B. L. S., Bul. 441, p. 6 (Ref. 36).

ESTIMATES OF EXTENT OF USE  
OF SELECTED MACHINES OR PROCESSES

The measures of mechanization that are available for many industries and periods—the ratio of horsepower per worker and the ratio of wages paid to value added in manufacture—tell us nothing about the extent to which specific labor-saving mechanical changes or processes are in use. Also, as we have just seen, the data upon the proportion of output ascribable to particular machines are quite fragmentary. Consequently, it seems appropriate and worth while to attempt a tabulation of the extent to which various labor-saving devices and methods are in use. This is done in Tables 48–55, Appendix B. In large part, the digests in Appendix B merely summarize the last stage reached in the chronological development which is shown in detail by the tables giving year-by-year data (Appendix A) and in some of the tabulations in Chapters III, IV and V.

In these summaries we have utilized the best sources of information we could find, but where precise data are unavailable, we have not hesitated to use whatever approximations we could get, indicating, however, the source of the information. Obviously they are of widely differing degrees of accuracy and usefulness. We have aimed, where exact details are lacking, to paint a picture of mechanization in broad outlines even if the margin of error or incompleteness is large in some instances. We trust the reader will not read into these estimates a greater degree of precision than they imply, but will take these tables on extent of use as a pioneer attempt to summarize the degree of mechanization in American industries, an attempt the value of which consists in part in pointing out the deficiencies in the available data.

The types of evidence we have used in compiling the



tabulations in Appendix B, ranked approximately in the order of the precision with which they indicate the degree of mechanization, are:

1. Proportion of output or work produced by the specified machine (Example: machine-made cigars, Table 38).
2. Proportion of the industry equipped with the specified device (Example: household electric appliances, Table 50).
3. Total number of machines in use (tractors on farms, Table 48).
4. Total number sold to specified date from beginning of commercial sale (Example: cigar machines, Table 55).
5. Total number sold within a specified period, not covering the entire period of introduction, by producers of the major part of the total number manufactured (Example: harvester combines, Table 48).
6. Total number sold within a specified period by a limited number of producers (Example: motorized section cars, Table 54).
7. The percentage ratio of the value of engine-power equipment sold in a specified period to the combined sale of engine- hand- or animal-power equipment for the same operations (see agricultural implements in Table 6).
8. Miscellaneous other types of information, or combinations of the above types indicative of the extent to which a device is being used.

The sources or bases of the estimates are indicated directly with the entry or in footnotes.

We shall not endeavor to review here in detail the estimates given in Appendix B. In large part the comments in those tables are self-explanatory. A few selected examples will serve to call attention to the type of material presented.

Table 48 summarizes the extent of mechanization in agriculture, with the estimates arranged in five groups pertaining, respectively, to (1) machines of relatively general

purpose use, such as the 920,000 tractors on farms in 1929; (2) devices for soil preparation, such as tractor-drawn plows and disk harrows; (3) equipment for harvesting grain, of which 68,000 combines sold in the period 1920-29 is the outstanding item; (4) equipment for handling row crops, such as the cotton picker and the corn picker; (5) equipment used chiefly in dairy and stock farming, such as the milking machine.

As illustrative of mechanization tendencies in excavation and highway construction, attention is called (Table 49) to the large number of power shovels sold by a group of leading manufacturers; to the introduction of the narrow trencher as a substitute for the unskilled laborer and his shovel; to the development of such mechanized equipment in highway construction as the subgrader, central proportioning plant, and machine finisher, all three of which are in substantially general use on the larger jobs.

The encroachment of the machine in household operation is indicated by the estimates in Tables 50 and 51. By January 1930 there were 20,400,000 wired dwellings in the United States, housing 70.5 per cent of the population. Of these wired dwellings, 98 per cent were equipped with electric irons, 44 per cent with electric vacuum cleaners, and 35 per cent with electric washing machines, but only a small percentage with electric dish washers, electric ironing machines or even electric sewing machines. Table 51, summarizing the results of a survey made in 1925-26, reveals the relatively smaller use of labor-saving appliances in rural homes.

The next compilation (Table 52) summarizes the extent of use of various mobile and fixed or semimobile types of handling equipment. In the 16 years, 1914-29, nearly 20,000 electric industrial trucks and tractors were marketed in the United States, the portable conveyor came into extensive

use, and some 3,000 or more self-feeding wagon loaders were put into competition with the manual laborer in construction, snow removal and coal-loading work. These estimates of handling equipment are supplemented by the statistics in Table 13 of the output, in dollar value, of several important types of conveying equipment in recent census years. Table 53 deals with coal mining.

Table 54 covers a diversified group of machines in non-manufacturing industries: adding and calculating machines, illustrative of the tendency towards the mechanization of office operations; motorized railway section-crew cars, representative of mechanization in railway maintenance; one or two illustrations of the encroachment of the machine on the white-garbed street cleaner; various devices for the commercial preparation of food and drink, used chiefly in hotels and restaurants; and finally, mechanical stokers for coal stoking in general and for locomotives in particular.

The final summary table contains illustrations of the extent to which selected items from the vast multitude of labor-saving devices in manufacturing are in use: the rise of machine-made glass, the relatively recent introduction of the cigar machine; the widespread use of garment pressing machines by the corner tailor and the garment manufacturing concerns. Because of the special attention to foundries in our survey, we have listed the data on extent of use for several items of equipment in this industry, and likewise for the cotton goods industry. It will be noted that the automatic loom has about reached the saturation point. By 1925 or 1926 only some 250,000 to 300,000 non-automatics were left in the cotton industry, and from a quarter to a half of these were estimated by our informants to be on work for which automatics were not suitable.<sup>15</sup> They

<sup>15</sup> The 1929 *Census of Manufactures* records 193,620 active and 25,870 idle nonautomatic looms (II, 263-4).

are concentrated chiefly in a few of the older textile centers like Fall River. The automatic loom, as one manufacturer of looms said in 1926 in an interview with the writer, is so dominant that its product fixes the market price of cotton goods; a quarter of a century earlier, the product of the non-automatic loom was the standard for price quotation. The automatic loom is also used quite extensively in worsteds and is getting into the silk field.

#### SUMMARY

The general feature of the heterogeneous material analyzed in this chapter which will, we judge, stand out most clearly to the reader, is that despite the wide variety of mechanical appliances in use and their intrusion into practically all lines of human endeavor, few have reached one hundred per cent use, and, as shown perhaps most strikingly by the data on the proportion of hand workers in various operations, in almost all types of industry, and in a substantial proportion of the separate processes in each industry, a large amount of hand work is still carried on.

We turn in the following chapter to an analysis of the characteristics of the machine-producing industries and endeavor to ascertain the extent to which the life histories of labor-saving devices conform to a more or less typical pattern.

## CHAPTER VIII

# CHARACTERISTICS OF THE MACHINE-PRODUCING INDUSTRIES

THE extent to which changes in economic conditions such as those arising from the curtailment of immigration stimulate the use of more and more machines and the expansion of the machine-producing industries is obviously in part a function of the nature of the latter. To what extent does an increase in wage rates bring a corresponding increase in the cost of machine production? What portion of the cost of machine production is labor expense? Are the workers in machine-producing industries chiefly skilled or chiefly common labor and how does the ratio between the grades of skill compare with that in other industries? Is the increasing substitution of machines for human beings in various industries accompanied by anything like a comparable expansion of the labor force engaged in making machines? Are the machine-producing industries unusually sensitive to the ups and downs of the business cycle? What bearing, if any, do the marketing methods of the machine producer have upon the rapidity with which new devices are introduced? Must the development of machines await the uncertain event of chance invention or do we have the technical facilities to develop new machines as need arises? What is the typical sequence in the development and introduction of new machines? What light do the various determinable characteristics of the machine-producing industries throw on the probable effect on their growth of

immigration restriction or other factors tending to increase or decrease materially the additions to the supply of labor? It is to these questions that the present chapter is devoted.

#### ESSENTIAL FEATURES OF A MACHINE-PRODUCING PLANT

A machine is a composite of ideas, embodied in patents, blueprints and specifications, and of materials—chiefly steel shapes, iron castings and wooden parts—arranged in accordance therewith. Consequently, the major operating departments of a machine-producing plant, aside from the engineering and planning divisions, are the foundry, machine-shop and assembling divisions. In fact, in many specialized machine plants the parts are bought in semi-finished form and the plant operations consist largely of the assembling process. We can, therefore, find good clues to the nature of the machine-producing industries by an examination of data pertaining to foundries and machine shops. The latter industries, in turn, draw their basic materials chiefly from the iron and steel industry.<sup>1</sup>

#### THE VOLUME OF EMPLOYMENT IN THE PRODUCTION OF MACHINES

It is frequently suggested that the reduction in the number of workers required in various activities arising from the substitution of machines for human beings is in large part offset by increasing employment in the industries producing the machines themselves. This makes pertinent an inquiry into the volume of employment in the machinery industries.

<sup>1</sup> See Ch. III for further discussion of the iron and steel and foundry industries.

## WAGE EARNERS IN THE MACHINERY INDUSTRIES

In analyzing the trends in mechanization, we gave a comparison, Table 21, between the number of wage earners in all manufacturing in the United States and the number in those industries which belong to the machinery group. According to the *1929 Census*, the machinery industries constituted 12.4 per cent of total manufacturing, in terms of the number of wage earners employed. Over the period 1899-1929 the proportion employed by the machinery industries varied from 8.7 to 12.4 per cent.

These ratios are about as satisfactory a measure as we have for changes in employment in the machinery industries as compared with employment in manufacturing as a whole; but they are not necessarily accurate measures of the number of wage earners engaged in the production of machines. We must distinguish between employment in the machinery industries as classified by the Census, and employment in the production of machines for domestic use. The major differences are:

1. A substantial portion of the products of the machinery industries is not machinery in the ordinary sense. In 1927, for example, their output included items such as: \$198,000,000 for 'radio apparatus and supplies'; \$210,000,000 for 'insulated wire and cable'; \$150,000,000 for batteries and parts and supplies; and \$386,000,000 for gray iron and malleable castings, not all of which go into machinery.

2. The number of wage earners in the machinery industries does not include all of the labor required in the production of materials used in the construction of machines.

3. Some machinery is made as a secondary product by establishments not classified with the machinery industries by the Census.

4. Some machinery is exported and hence does not enter into domestic use.

5. Some part of the motor-vehicle industry, and also locomotive and car-building shops, may reasonably be considered as producing machines for business and productive use.<sup>2</sup>

#### WAGE EARNERS ENGAGED IN THE PRODUCTION OF MACHINES

Instead of trying to determine the number of wage earners in the machinery industries as classified by the Census, we may estimate the number of men engaged in the production of machines by making use of the Census statistics on the value of machinery produced in the United States, in 1927, whether produced in the machinery industries or as secondary products of establishments not included in the machinery group.<sup>3</sup>

The total value of machinery produced in 1927 was \$4,904,692,000. From this we have subtracted \$2,203,854,000 for aircraft, motor cycles, bicycles and passenger vehicles; also \$509,516,000 for exported machinery of the following

<sup>2</sup> See discussion of this point in Ch. VI.

<sup>3</sup> Data for 1927 are used because at the time this section was written, the most recent *Census of Manufactures* in print was that for 1927, and although the 1929 data have subsequently become available, they do not appear to be any more suitable for this particular purpose. The Census explains the scope of the statistics of machinery as follows: "This section is not an industry report . . . but is merely a special presentation of statistics for the broad group of products covered by the general designation 'Machinery'. . . . The differences between the values of certain classes of machinery . . . and the total values of the products of the industries of which these classes of machinery are the primary products are due to the inclusion in these tables and the exclusion from the industry totals of data for the specified classes of machinery made as secondary products by establishments engaged primarily in other lines of manufacture, and to the exclusion from Tables 1 and 2 and the inclusion in the industry totals of data for miscellaneous commodities made as secondary products by establishments classified in the industries in question" (1927 *Census of Manufactures*, pp. 1081-2).



types: electrical machinery and apparatus; industrial machinery; office appliances; printing machinery; agricultural machinery and implements; and automobiles and vehicles other than passenger cars, aircraft and cycles. The net resulting figure, \$2,199,322,000, may be considered a fair approximation of the total value of machines produced in the United States in 1927 for domestic use. We estimate that of this sum, 24 per cent, or \$527,837,000, was expended for wages in the direct production of machines, and that 38.4 per cent, or \$765,364,000, covers expenditures for materials, supplies, fuel and power used in the production of the machines.<sup>4</sup> In Chapter II we estimated that about 56 per cent of the cost of materials used in manufacturing covers payments for wages of the workers engaged in the production of the materials;<sup>5</sup> 56 per cent of \$765,364,000 is \$428,604,000.

These estimates in dollar terms of the wages paid to wage earners engaged directly and indirectly in the production of machines may be translated into an estimated number of wage earners by dividing by the approximate annual earnings of the latter. Dividing the \$527,837,000 expended for wages in the direct production of machinery by \$1,453 (the 1927 average wages paid per wage earner in the machine industries) we estimate that the number of wage earners directly engaged in the production of machinery in 1927 was 363,000.

Likewise, dividing \$428,604,000 (our estimate of the wage element in the cost of materials, supplies, fuel and power) by \$1,299 (the 1927 average earnings of wage earners en-

<sup>4</sup> These percentages are the respective ratios in 1927 of wages paid and materials, etc., to the value of products in the machinery industries as compiled by the *Census of Manufactures*.

<sup>5</sup> See Table 31. Note that the estimates in this paragraph apply only to wage earners, and not to salaried workers.

gaged in all manufacturing) we estimate that the number of wage earners indirectly engaged in the production of machinery was 330,000. This makes an estimated total of about 700,000 wage earners engaged, directly or indirectly, in the production of machinery for domestic use. Workers engaged in the production of passenger vehicles are not included in this estimate. •

#### VOLUME OF EMPLOYMENT RELATIVE TO ALL MANUFACTURING

By this last estimate of wage earners in the machinery industries, we reach a figure equivalent to 8.4 per cent of the total number of wage earners in manufacturing. This is a large figure; but, it should be noted, if the change in the number of wage earners in the machinery industries proper, as defined in the preparation of Table 21, is fairly representative of the changes in the total number of workers chargeable to the production of machines, then we may conclude that the increase in the number of wage earners engaged in the production of machines from 1899 to 1927, for example, is only about 500,000. In fact, in the latter part of this period (1923-27) the number of wage earners in the machinery industries declined rather than increased. On the other hand, the constructive displacement of workers by machinery far exceeded a half million.\* For example, in the period under consideration (1899-1927) the output per wage earner in the manufacturing industries rose about 75 per cent.† Consequently, at the 1927 rate of production the 1899 volume of manufactures could have been turned out with about two million fewer wage earners than the num-

\* For further discussion of 'constructive displacement' see Ch. X.

† Estimated by chaining together index numbers of output per wage earner for three periods (1899-1914, 1914-23 and 1923-29) given in F. C. Mills, *Economic Tendencies*, pp. 38, 192, 304.

ber actually employed in 1899. Or, to turn out the 1927 volume at the 1899 rate per wage earner would have required about six million more wage earners than the number actually employed in 1927. Not all of this difference can be ascribed to improvements in machinery; but it is obvious that if we take into consideration the constructive displacement of workers by machinery in other industries as well as in manufacturing, we must reach the conclusion that the effects of new and better machines in the period 1899-1927 exceeded by a substantial margin the coincident increase in the number engaged in the production of machines.

#### GRADE OF LABOR IN THE PRODUCTION OF MACHINERY

We may conveniently distinguish three grades of manual labor: skilled, semiskilled and unskilled or common. Data purporting to classify fully the working population into these three classes are not available and the terms themselves are only loosely defined.<sup>8</sup> However, rough approximations adequate for present purposes can be made.

<sup>8</sup>In determining to which of these three classes to assign various occupations it is sometimes necessary to take the customary designation in the industry, sometimes the length of training period or experience required, and sometimes the hourly wage rates received. In our field survey we suggested to our informants that they classify workers receiving not more than 5 cents per hour in excess of the customary rate for common laborers as unskilled, and that they count as skilled workers only those in occupations that require about two years' apprenticeship or its equivalent in other training, with a rate of pay 50 per cent or more in excess of that for common labor.

The approximate interpretations placed by our informants on the terms 'skilled', 'semiskilled' and 'unskilled' are suggested by the typical rates quoted: for common laborers, 39-45 cents; semiskilled, 50-65 cents, skilled, 65-85 cents; the training period was in most instances stated to be from a few weeks to 8 months for semiskilled, and 2 or 3 years for skilled workers.

The common labor group includes workers whose occupations require little or no special training but for which strength may be a requisite, such

In the first place, in our field survey we collected data on the proportion of skilled, semiskilled and common laborers in a group of 21 machine-producing establishments. In this sample, about 10 per cent were unskilled, 59 per cent semiskilled and 31 per cent skilled.

A second estimate is derived from the United States Bureau of Labor Statistics survey of hourly earnings in 1925 in 413 foundries and 511 machine shops, chiefly engaged in the production of machinery. Classifying as semiskilled all workers receiving from 110 to 150 per cent of the hourly earnings of 'laborers', we find that 23 per cent of the male labor force was common labor, 55 per cent semiskilled, and 22 per cent skilled.

From these two sets of data, we estimate, as a rough working approximation, that in machine plants the distribution of the labor force is as follows: common or unskilled, 20 per cent; semiskilled, 55 per cent; and skilled, 25 per cent.

Similar estimates of the distribution by skill of wage earners in manufacturing as a whole have been made by us, utilizing information obtained in our field survey and data from the *Census of Occupations* and the *Census of Manufactures*, and also by applying to several other industries the method of estimation described above for foundries and

as truckers, wheelbarrow men, shovelers and cleaners. The semiskilled group includes workers whose occupations require a relatively brief period of training or experience, ranging from a few weeks to a year or so, but less than that required to establish skilled status. In this group are a large number of machine operators who work on one machine or process but who do not have all-round training as mechanics. There appears to be a strong tendency for factory executives to consider all machine operators as at least semiskilled, even though the work is very simple and the rate of pay slightly, if any, above that of common labor. The skilled group ordinarily includes, among others, 'all-round' mechanics, machine repair men, pattern makers and hand molders in foundries, and in general, workers who are trained to some trade, such as carpentry.

machine plants.<sup>9</sup> On the basis of these studies, we estimate that about one-fourth of the workers engaged in manufacturing are unskilled, about one-half semiskilled, and about one-fourth skilled.

According to the above rough estimates, the proportion of unskilled workers is somewhat less in the machinery industries than in manufacturing as a whole. Further light on the relative skill of workers in machine production is obtained by comparing the earnings per week or year in the machine-producing industries with the earnings in other industries. In 1927 the average annual earnings per wage earner in all manufacturing industries combined was only \$1,299, while in the machinery group it was \$1,453, or nearly 12 per cent higher. In fact, in 15 of the 16 industries included in the machinery group the annual earnings were in excess of the average for all industries. Only in 'typewriters and supplies' was the average below \$1,299.<sup>10</sup>

Since the monthly statistics of employment indicate that employment is, if anything, slightly less regular in the machinery industries than in manufacturing as a whole, the higher annual earnings in the machine-producing industries would seem to confirm the impression that the grade of workers employed is above the average for other manufacturing.

<sup>9</sup> The industries so analyzed are: motor vehicles, lumber, meat packing and slaughtering, iron and steel, woolens and worsteds, and pottery.

<sup>10</sup> Computed from data for wage earners and wages paid in the 1927 *Census of Manufactures*, pp. 1033-4. A tendency for earnings in the machinery industries to be higher than in manufacturing as a whole is also indicated in the data on weekly earnings by industries published in the bulletins of the labor departments of Illinois, New York and Wisconsin. In 1928 for 4 sample months, at quarterly intervals, the ratio of earnings in the 'Machinery' industry in Illinois, compared with total manufacturing, was from 106 to 111; in New York the ratio for 'Foundries and Machine Shops' was from 103 to 112; and in Wisconsin the ratio for 'Machinery' was from 121 to 135, and for 'Foundries and Machine Shops', from 114 to 121.

The comparisons just made are between the general level of skill in the machine-producing industries and in manufacturing as a whole. Comparisons between the grade of labor required in the production of particular machines and the grade of labor displaced by them are made in Chapter X, in discussing the effect of labor-saving machines upon the degree of skill required in industry.

#### DISTRIBUTION OF THE COST INVOLVED IN THE PRODUCTION OF MACHINES

If a shortage of common labor raises the relative compensation for the unskilled worker, to what extent will it also increase the cost of producing the machine that is capable of displacing him? A precise answer cannot be given, but even a rough approximation of the extent to which labor costs enter into the selling price of machines enables us to make some estimate of the effect of wage rates.

In Table 31 we give in the first column a rough estimate of the typical distribution of the total selling price of a machine which costs the user \$1,000, and in the second column estimates of the payments for wages, either directly in the production and marketing of the machine, or indirectly in the production of materials, buildings, machines, etc., used in the production of the machine and its delivery to the user. The footnotes indicate the bases, admittedly limited, upon which the estimates are made.

In Table 31 we arrive at an estimate that of the total price of a machine sold at \$1,000, on the average \$525 represents payments for wages, either to wage earners engaged in the immediate production and marketing of the machine, or to wage earners engaged in the production of the materials, buildings, etc., for the machine industries. Rounding this figure off to five hundred dollars, we may say that about

## MECHANIZATION IN INDUSTRY

TABLE 31

ESTIMATE OF THE TYPICAL DISTRIBUTION OF THE PRICE OF A MACHINE SOLD TO USER FOR \$1,000

	TOTAL	WAGE ELEMENT	SALARY ELEMENT	OTHER ELEMENTS
Materials used in producing the machine	\$320 <sup>1</sup>	\$179 <sup>2</sup>	\$54 <sup>2</sup>	\$87
Value added by manufacture				
Wages paid in factory	192 <sup>1</sup>	192	...	...
Salaries paid in factory	64 <sup>1</sup>	...	64	...
Rent, interest and profits	45 <sup>2</sup>	...	...	45
Other expenses	179 <sup>3</sup>	72 <sup>3</sup>	36 <sup>3</sup>	71
Value added by distribution	200 <sup>4</sup>	82 <sup>5</sup>	26	92
Total	\$1,000	525	180	295

<sup>1</sup> Based upon data for the machinery industries in the *Census of Manufactures, 1925*. The year 1925 was selected because it is a reasonably normal year in the center of the decade to which chief attention is given in this study.

<sup>2</sup> Based upon 1925 percentage ratios of wages, salaries, and income to entrepreneurs and other property owners, computed by us from income estimates according to Dr. W. I. King in *The National Income and Its Purchasing Power* (National Bureau of Economic Research, 1930), pp. 74, 94-5, 108, 132-3 and 138.

To illustrate the method: the estimate of \$179 (56 per cent) for the wage element in materials is a weighted average, the ratios and the weights (in parentheses) applied to them being: mining 64 (1), manufacturing 65 (2), railroads 57 (1), other industries 30 (1). By similar methods the salary element was estimated to be 17 per cent.

<sup>3</sup> 'Other expenses' is a residual item and includes depreciation, insurance, advertising, taxes and sundry factory expenses. We have estimated the wage element in 'other expenses' as 40 and the salary element as 20, these being the respective percentage ratios of wages and salaries to total realized income (excluding income imputed to the services of durable consumer goods) in all industries combined, as computed from data for 1925 given by W. I. King, *op. cit.*

<sup>4</sup> In allowing 20 per cent of the selling price for the spread between value at factory and retail price we took into consideration: (1) statements made to us by machine producers that their selling costs ran from 20 to 30 per cent of the sale price; (2) studies by the Federal Trade Commission showing that the margin between ultimate selling price and the value at factory, for 20 typical agricultural implements, was 17.5 per cent in 1916 and 15.9

per cent in 1918. *Causes of the High Prices of Farm Implements* (1920), p. 221.

<sup>5</sup> The wage element in the 'value added by distribution' item is estimated as 41 and the salary element as 13, these being the respective percentage ratios of wages and salaries to total realized income in the mercantile and railroad industries combined.

fifty cents of every dollar paid for machines represents payments to wage earners.

How much of this goes to the several classes of wage earners? We have cited evidence to indicate that in the machinery industries, about 20 per cent of the workers are unskilled, some 55 per cent semiskilled, and 25 per cent skilled. The proportion of the lower grades of skill is probably greater in the industries furnishing materials to the machinery industries than in the machinery industries proper. Consequently, let us estimate that the distribution for all workers engaged in machine production directly or indirectly is 25 per cent unskilled, 55 semiskilled, and 20 skilled. The relative hourly earnings of these three classes may be estimated as 100, 125 and 155.<sup>11</sup>

Applying these relative rates of earnings to the estimated proportions of common, semiskilled and skilled labor in the machinery industries, and remembering that we have estimated that fifty cents of each dollar paid for machines represents payments of wages to labor, we reach a final estimate that, on the average, of each dollar in the selling price of a labor-saving machine about twelve cents represents wages paid to skilled workers, twenty-eight cents to semiskilled workers and only ten cents to common labor.

Consequently, if a labor shortage brings a 20 per cent in-

<sup>11</sup> Based upon computations of average hourly earnings of workers in the several occupations in the foundry and machine-shop industries in 1925, U. S. Bureau of Labor Statistics, Bul. 422, *Wages and Hours of Labor in Foundry and Machine Shops*.



crease in the wage level for all grades of labor, it tends to increase the expense of machine production about 10 per cent. If the increase affects only one grade of labor, the increase in machine expense will be correspondingly less—some 2 or 3 per cent if it applies only to skilled labor, 5 or 6 per cent if to semiskilled labor only, and about 2 per cent if the 20 per cent increase applies to unskilled labor only.

It is true that some of the estimates made in arriving at the conclusions just stated are necessarily subject to a considerable margin of error, but even after allowing for any reasonably possible error, it would still appear true that an increase in the relative compensation for any single grade of labor will bring a relatively small increase in the expense involved in the production of labor-saving machines that are competitive with that grade of labor.

#### CHARACTERISTICS OF THE DEMAND FOR MACHINES

The machinery industries are very sensitive, expanding vigorously in boom periods and declining sharply when business as a whole suffers depression. The severity of these fluctuations may be illustrated by Table 32, which shows the typical rate of change in the sales of machine producers from one year to another. Division A comprises series constructed from the sales of single models, or a group of allied models, by individual manufacturers; Division B, on the other hand, comprises series representing a group of manufacturers producing a substantial portion of the total output of machines of the specified type. We shall designate these divisions as individual and group lines.

In the boom years of the World War both individual and group lines increased rapidly, the annual increases being from 21 to 42 per cent for individual lines, and from 16 to

TABLE 32  
YEAR-TO-YEAR FLUCTUATIONS IN VOLUME OF SALES OF  
SELECTED TYPES OF MACHINE<sup>1</sup>

YEAR	<i>Division A</i> <sup>2</sup>		<i>Division B</i>	
	SERIES REPRESENTING SALES OF SINGLE MODELS OR GROUP OF ALLIED MODELS BY SINGLE MANUFACTURERS		SERIES REPRESENTING SALES OF A GROUP OF MANUFACTURERS PRODUCING A SUBSTANTIAL POR- TION OF THE TOTAL OUTPUT OF THE SPECIFIED TYPE	
	MEDIAN PERCENTAGE CHANGE FROM PRECEDING YEAR	NUMBER OF SERIES	MEDIAN PERCENTAGE CHANGE FROM PRECEDING YEAR	NUMBER OF SERIES
1915	+24.8	24	+91.2	4
1916	+42.0	27	+55.3	4
1917	+21.6	28	+28.5	4
1918	+21.3	40	+16.4	4
1919	+ 8.4	46	+ 0.4	4
1920	+ 8.3	49	+19.6	5
1921	-49.4	54	-53.3	14
1922	+27.9	59	+60.0	16
1923	+28.3	70	+31.0	19
1924	-10.0	77	-13.5	20
1925	+12.1	77	+26.6	19
1926	+ 7.1	62	+ 6.4	21
1927	+ 0.3	52	- 5.6	25
1928	+ 0.6	31	+ 8.5	24
1929	+13.9	26	+18.3	24
1930	...	..	-37.3	12

<sup>1</sup> In a few instances the series represent shipments; in the others sales or new orders. Most of the series in Division A are in terms of number of machines sold; in Division B ten series are in terms of value; the others in number of machines.

<sup>2</sup> Division A are series of confidential data obtained from individual producers, many of which are combined in series shown in Appendix A. Division B represents 26 series, also listed in tables in Appendix A.

91 per cent for the 4 group lines for which data are available from 1915 to 1918.

In the depression of 1921 the typical decline in individual lines was 49 per cent; in group lines 53. Even in the mild

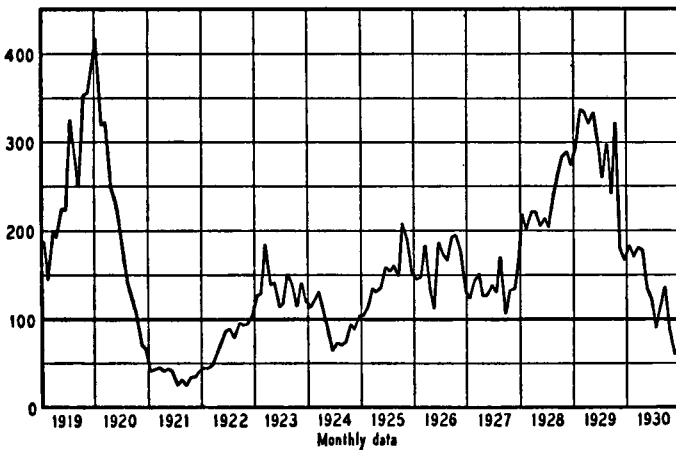
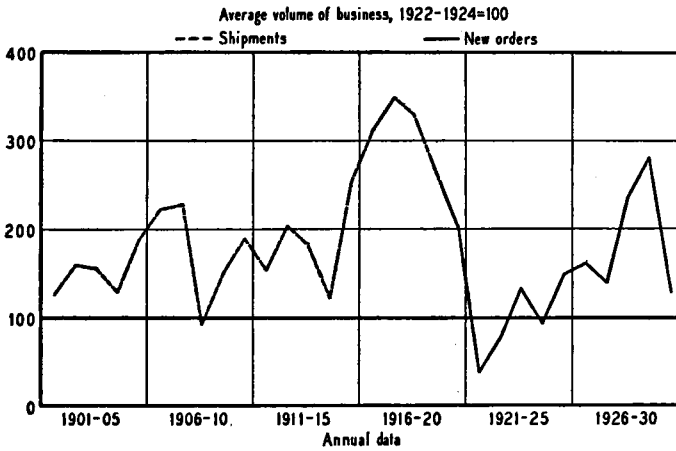
depression of 1924 individual lines declined 10 per cent and group lines 13. Likewise in 1927 individual lines registered practically no gain, while group lines declined nearly 6 per cent. Figures for the depression year 1930 are available for only 12 of the group lines, but show the expected sharp decline (37 per cent).

#### MACHINE-TOOL INDUSTRY

The susceptibility of the equipment industries to alternations of prosperity and depression is brought out sharply by a study of the machine-tool industry. The market for these 'master tools' of industry, the power-driven tools which are used in large part in the making of other machinery, affords a highly sensitive and important index of the machinery business. The course of shipments and new orders, shown in Chart 2,<sup>12</sup> reflects clearly both the major and minor depressions of the last 30 years: 1904, 1908, 1911, 1914, 1921, 1924, 1927 and 1930. This series differs from many other industrial series in showing a peak in 1917 rather than 1920. The upper part of Chart 2 shows the fluctuations in the

<sup>12</sup> The data presented in Chart 2 were compiled originally by the National Machine Tool Builders' Association and are taken from the *Survey of Current Business, Supplement, Record Book of Business Statistics, Part II, Machinery*, p. 42, for 1901-26, and *1931 Annual Supplement*, p. 92, for 1927-30. For 1901-19 the data represent shipments of 29 firms, in terms of number of machines; for 1919-30, they are based on dollar values of new orders reported by from 50 to 60 firms said to represent about one-third of the industry. We have changed the base of the shipment series and spliced it to the new orders series at 1919 to make a continuous series with the 1922-24 average as a base. Owing to the methods necessarily used in compiling the original indexes, we judge that this index cannot be taken as an accurate index for comparing the general level of machine tool sales in the earlier and later years of the period, but that it probably is a fairly accurate index of the effect of prosperity and depression upon the volume of business.

Chart 2  
 FLUCTUATIONS IN THE MACHINE-TOOL INDUSTRY, 1901-1930<sup>1</sup>



<sup>1</sup> For sources see footnote 12 to accompanying text.

annual data, 1901-30; the lower part, in the monthly data from 1919 to 1930 inclusive.

#### INELASTICITY OF DEMAND FOR MACHINES

The large cyclical fluctuations in the sales of machines can probably be ascribed in part to a marked inelasticity of demand—a relative insensitiveness of the demand for machines to changes in price. The prospective purchaser of machines is strongly influenced by his expectation of changes in the market for his products. In a period of increasing business activity he anticipates an increased demand for his own products and is apt to be ready to purchase new equipment without close scrutiny of its price. On the contrary, when business begins to slump, the reverse attitude towards the purchase of equipment becomes dominant. The machine user ceases to be overconfident of the advantages of purchasing new equipment and in fact cannot be persuaded to invest even by substantial reductions in price. As a consequence of this relative inelasticity of demand, the machine producer finds the demand for his product quite erratic—very heavy in periods of rising prosperity, very slack in periods of business depression.

#### MARKETING METHODS

The rapidity of introduction of a labor-saving device is determined in part by the marketing policy followed. Some machines are sold outright, with or without a period of free trial. Others are sold on the installment plan or on some other liberal credit basis. Some models are leased to any responsible user on a royalty basis; others, particularly certain complicated patented machines or processes, are leased

only to exclusive licensees, thus transferring the monopolistic feature of the patent to the use of the machine.

For many years the American Window Glass Company held an exclusive license for the use of the cylinder window-glass machine. Likewise the holders of the patent on the Owens automatic bottle machines have restricted their use to their own factories and to licensees who agreed to specialize in particular lines of ware. This restrictive policy has tended to retard the rate of introduction and stimulate the development of competitive devices.

The Hollerith tabulating machine, the cigar-making machine, some bag-filling machines and much of the machinery in shoe factories are installed on a royalty basis. Our field agents were informed by shoe manufacturers that in general new machinery tends to be introduced more rapidly in the shoe industry than in many other industries for the reason that most of it is leased, not bought, from the machine-producing companies, such as the United Shoe Machinery Corporation, the largest producer of shoe machinery, and hence companies are not deterred by considerations of capital expense from installing the latest and best equipment.

When machines are sold outright rather than leased, introduction is sometimes encouraged by a period of free trial or by liberal credit terms. Great quantities of household appliances have been marketed with the aid of the installment plan. Likewise, in the agricultural implement industry, when harvesting machines were perfected, the most important agricultural sections of the country were to a large extent recently settled and the farmers relatively poor; but the manufacturers speeded up the introduction of harvesters by extending credit either directly to the purchasing farmer or to the retail dealer, who in turn extended credit

to the farmer.<sup>18</sup> We understand that the credit system has been similarly effective in hastening the introduction of the harvester-thresher combines.

Occasionally purchasers of labor-saving devices have even been permitted to pay for them out of savings that resulted from their adoption. One machine producer informed us that this policy has been followed at times in selling his machines to railroads, the railroads having sufficiently accurate cost records to determine the relative costs per ton under the old and new methods.

Between a policy of allowing a machine to be paid for out of savings and restricting its use to an exclusive licensee there is a wide spread, so far as the probable effect of the marketing method on the rate of introduction is concerned. The holder of the patents for a highly effective labor-saving device may decide that the most profitable method of marketing is one that retards the rate of introduction. Producers of more freely competitive devices are more likely to seek methods that will expedite their introduction.

#### TYPICAL STAGES IN THE LIFE HISTORY OF A MACHINE TYPE

In the analysis of the typical stages in the development and adoption of labor-saving machines, let us first examine the objective evidence afforded by those series for which we have a relatively complete chronological record.

#### ANALYSIS OF 23 MACHINE SERIES

We have assembled 23 series for which data are available for periods ranging from 11 to 39 years, and, in most in-

<sup>18</sup> Federal Trade Commission, report on *High Prices of Farm Implements* (1920), p. 57.

stances, extending back to the beginning of commercial sale of the given type.<sup>14</sup> Each of these has been reduced to yearly percentages of the known or estimated maximum use attained within the period covered by the available data. The maximum use is directly indicated by those series which in their original form are in terms of the percentage of total output that is machine produced, or the percentage of total equipment units that are automatic, or the total number of machines in use each year; but for the remaining series, which are in terms of yearly sales, it was necessary to approximate the maximum number in use by estimating the average working life of each type.<sup>15</sup>

Not only are our results subject to a margin of error arising from this method of estimating the average working life, but also it was impossible to put all of the 23 series on an entirely consistent basis of expression. The coal and cigar series show for each year the proportion of the total output that was produced by machine methods, and the telephone series is in terms of the percentage of telephones that are of the dial type; but the other series are in terms of yearly ratios to the maximum number of equipment units of the given type and hence the growth of one of these series will reflect not only a proportionally increasing use of the given type of equipment but also the growth of the industry in

<sup>14</sup> Listed, with period covered, in Charts, 3, 4, 5. Sixteen series cover practically the entire sales or use of the type of machine in question; 4 cover, in the judgment of the writer, more than half of their respective types; and the remaining three (series N, Q and U), though probably covering less than half of the total, are believed to be fairly typical of trends in the type as a whole.

<sup>15</sup> For 13 series the maximum 10-year moving total of yearly sales was taken as a rough approximation of the maximum number in use at any time. The actual number in use at one date was known for the warp tying in machine and electric industrial trucks and tractors, and to get estimates agreeing with these known totals, moving totals of 12 years for the trucks and tractors, and 19 years for the tying-in machines were used.



which it is used. However, we do not believe that these differences detract seriously from comparability for our purposes.

The changing extent of use of each of the 23 series, expressed as a percentage of the estimated maximum use in any one year in the entire period covered by the data, is shown by the curves in Charts 3, 4 and 5.

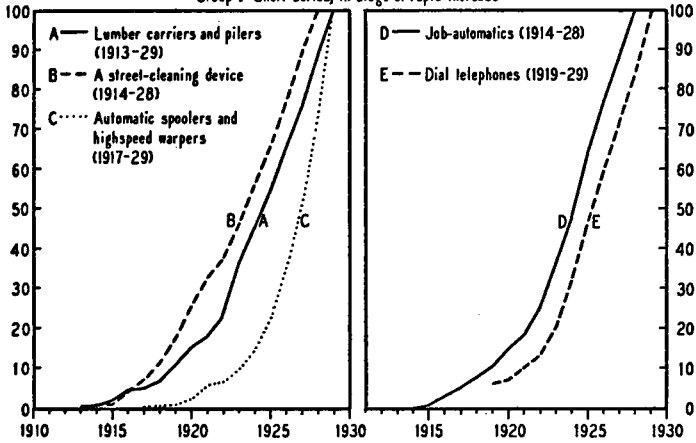
The series are arranged in six groups, two to a chart. The first two groups (Chart 3) are still in the stage of relatively rapid increase of installation. The 5 series shown in the upper part of Chart 3 are relatively short, covering only from 11 to 17 years. If these machines have not yet approximately reached maximum use, a record including later years would make the rate of growth appear less rapid. This comment also applies, but to a lesser extent, to the two series (power shovels and electric main roll drives) shown in the lower part of Chart 3. Series as long as these two have probably attained more nearly their maximum use, even though the rate of increase is still rapid at the close of the period for which data are available.

The series in Chart 4 are still increasing but in recent years usually at less than 10 per cent. Those in Group III have experienced a slackened rate of increase for less than 5 years, those in Group IV for at least 5 years. It will be noted that the introduction of pig machines and coal-undercutting machines has been relatively gradual from early in their history.

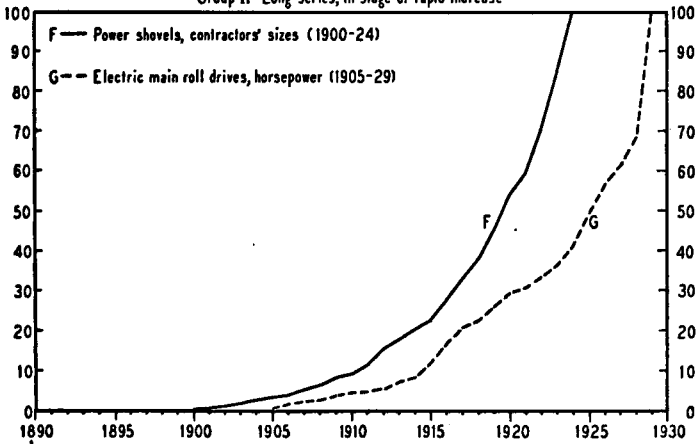
The series in Chart 5 are in the stage of decline. Those in Group V have been declining for only a few years, and it is quite possible that this is an apparent rather than a real decline, arising from errors in the estimate of the working life of the respective machines. Group VI, on the other hand, (shown in the lower half of Chart 5) have suffered a more definite and prolonged decline. The hand-molding

Chart 3  
GROWTH IN THE USE OF MACHINES<sup>1</sup>

(Estimated maximum use in period covered = 100)  
Group I—Short series, in stage of rapid increase



Group II—Long series, in stage of rapid increase



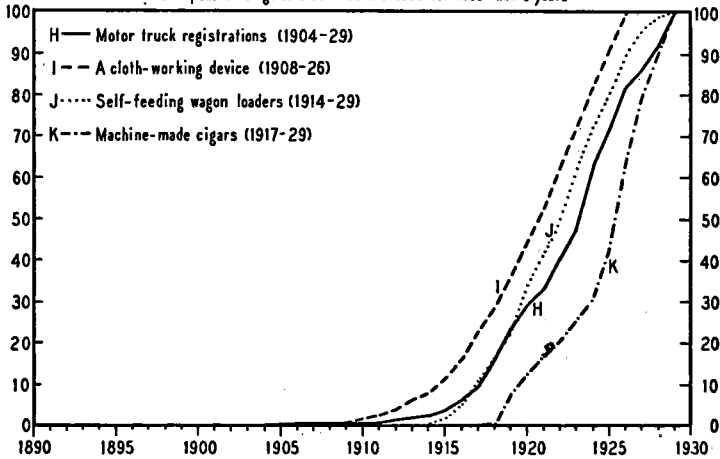
<sup>1</sup>For sources of the basic data and methods of estimating maximum use, see accompanying text.

Chart 4

GROWTH IN THE USE OF MACHINES<sup>1</sup>

(Estimated maximum use in period covered = 100)

Group III - In stage of slackened increase for less than 5 years



Group IV - In stage of slackened increase for at least 5 years

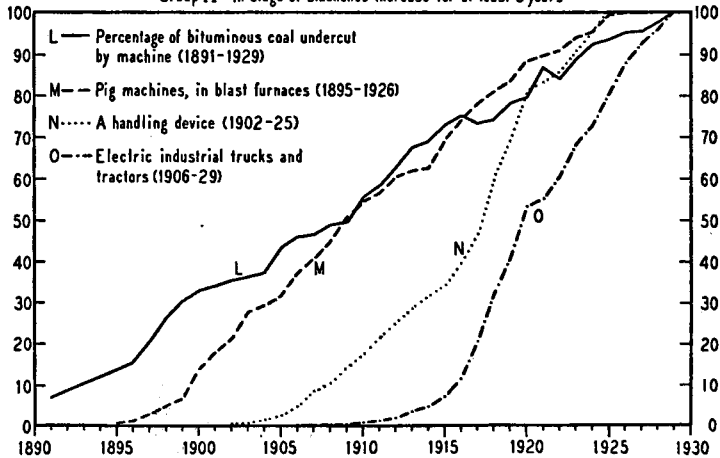
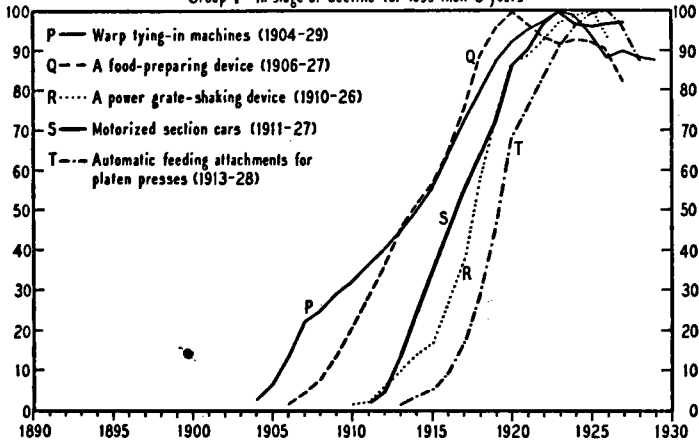
<sup>1</sup>For sources and methods of estimating maximum use, see accompanying text.

Chart 5

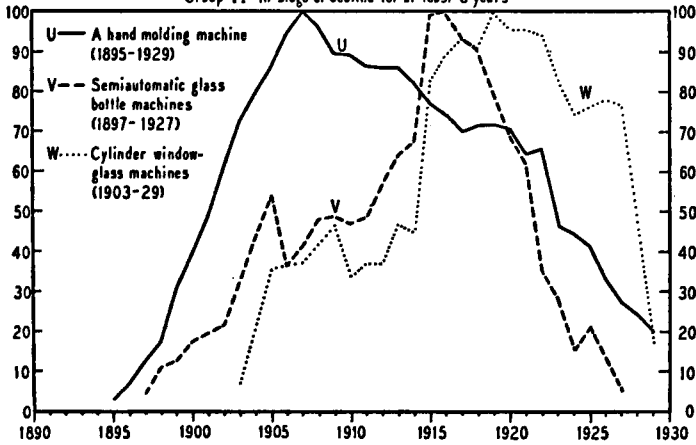
GROWTH IN THE USE OF MACHINES<sup>1</sup>

(Estimated maximum use in period covered = 100)

Group V - In stage of decline for less than 8 years



Group VI - In stage of decline for at least 8 years



<sup>1</sup>For sources and methods of estimating maximum use, see accompanying text.

machine has apparently given way to the power machine and possibly other types of hand machine; the semiautomatic glass bottle machine has yielded to the completely automatic type; and the cylinder machine is losing ground to the sheet process.

The record of these series can be used as an aid to an approximate definition of the typical stages in the life history of machine types. To this end we have tabulated in Table 33 the length of time spent in each of 4 stages or such of them as the machine has reached.<sup>16</sup> The stages are defined, somewhat arbitrarily, as: (1) commercial trial—from the beginning of commercial sale until use reaches 10 per cent of the maximum later attained; (2) rapid increase—from the close of the period of commercial trial to the date when the annual increase in use ceases to be at least 10 per cent over the level reached in the previous year; (3) slackened increase—use still increasing but at less than 10 per cent; (4) decline—use less than the maximum previously reached.

At the foot of Table 33 we have indicated the typical range of duration for each of the first three stages, defining 'typical range' as the number of years that included from 75 to 80 per cent of the total number of series. In this computation we have excluded series that have not passed entirely through the stage under consideration. The resulting approximations are: commercial trial, 3 to 11 years; rapid increase, 4 to 11 years; slackened increase, 3 to 6 years. For the period of slow increase especially, the number of series upon which conclusions must be based is, of course, unfortunately small.

While these rough estimates of the duration of the several stages afford a basis for classifying machines according to the stage they have reached when a more or less complete

<sup>16</sup> In the determination of the length of each period an exceptional year has occasionally been counted with the period even if the change for that year does not conform to the general definition of the period.

TABLE 33

DIGEST OF DURATION OF FOUR STAGES IN THE INTRODUCTION OF TWENTY-THREE TYPES OF MACHINE<sup>1</sup>

SERIES	DURATION IN YEARS				TOTAL LENGTH OF SERIES
	COMMERCIAL TRIAL	RAPID INCREASE	SLACKENED INCREASE	DECLINE	
		TRIAL	INCREASE	INCREASE	
A. Lumber carriers and pilers	7	10	4	...	17
B. A street-cleaning device	5	10	4	...	15
C. Automatic spoolers and H. S. warpers	7	6	4	...	13
D. Job automatics	6	9	4	...	15
E. Dial telephones	3 <sup>2</sup>	8	4	...	11
F. Power shovels, contractors' sizes	12	13 (1) <sup>2</sup>	4	...	25
G. Electric Main Roll Drives	11	14 (5)	4	...	25
H. Motor trucks	15	8	3	4	26
I. Cloth-working device	8	10	1	4	19
J. Self-feeding wagon loaders	4	9	3	4	16
K. Machine-made cigars	4	8	1	4	13
L. Coal undercutting	6 <sup>2</sup>	3	30 (2)	4	39
M. Pig Machines	6	3	23 (3)	4	32
N. Handling device	7	12	5	4	24
O. Electric industrial trucks and tractors	11	4	9 (2)	4	24
P. Warp-tying machines	3	12 (1)	5	6	26
Q. Food-preparing device	4	9	2	7 (1)	22
R. Power grate-shaking device	4	7	5	1	17
S. Motorized section cars	3	7	3	4 (2)	17
T. Automatic feeding attachments	5 <sup>2</sup>	4	5	2	16
U. Hand molding series	3	7	3	22 (3)	35
V. Semiautomatic glass bottle machines	2 <sup>2</sup>	7	11 (6)	11	31
W. Cylinder window-glass machines	2	11 (6)	4	10	27
Typical range for completed periods (including 75-80 per cent of cases)	3-11	4-11	3-6		

<sup>1</sup> All series except N, Q and R are computed from data given in Appendix

chronological record is available, some other basis of classification is needed for many labor-saving machines, because information concerning extent of use is available only in terms of approximations of the extent of use at one date or at most only a few dates. To make it possible to fit such data into a common classification of stages, it is necessary to delimit these stages not only in terms of the rate at which use is increasing but also in terms of the percentage of saturation reached. For this purpose we may return to the evidence presented by the series shown in Charts 3, 4 and 5 and ask what percentage of use is reached, for example, in the period of rapid increase.

For coal undercutting and pig machines the end of the period of rapid increase came early, after only about 30 per cent of the figure now attained had been reached. For semi-automatic glass bottle machines the irregularity of the series makes definition of the limit difficult but we have placed it at about 50 per cent; for the remaining 13 series that have passed through the stage of slackened introduction and then into decline, the end of the period of rapid introduction came when the series had reached between 76 and 91 per cent of the maximum later attained. With these facts as hints we have defined the approximate limit of the first three stages of commercial use in terms of percentages of maximum use as: (1) commercial trial—up to 10 per cent; (2) rapid introduction—10 to 85 per cent; (3) slackened intro-

A, or in sources there cited, by methods described in accompanying paragraphs. 1928 and 1929 data for series S were obtained only a short time before sending manuscript to printer and hence have not been included in either Table 33 or Chart 5.

<sup>2</sup> Sales of this device began before the first year for which we have data.

<sup>3</sup> Figures in parentheses indicate the number of years in the given period in which the movement is contrary to the definition of the period.

<sup>4</sup> This stage had not yet been reached in the period covered by the available data.

duction—85 to 100 per cent.<sup>17</sup> No close accuracy is claimed for these limits but they serve as convenient bases of classification even if numerous exceptions must be recognized.

While we might well wish for much more complete data, with these rough estimates of the duration of the commercial stages of use at hand we are in a somewhat better position to characterize the complete series of stages typical of the development and adoption of a new type of machine.

#### SUMMARY OF TYPICAL STAGES

While no two machines have quite the same experience, certain typical phases in the life history of the ordinary machine may be identified.<sup>18</sup>

First there is the *recognition of the need* for a machine to do certain work. Then after an interval, which may be quite long or quite brief, comes the *conception of the primary principle* or device upon which a practicable machine may be based. In the modern industrial world inventions are not left so much to chance as they were in earlier decades; and once a need is recognized, it is ordinarily not so very difficult to get a machine designed for the desired purpose, either by engineers of the factory itself or by engineering concerns which make it their business to design machines to order for particular purposes.<sup>19</sup>

<sup>17</sup> Probably those who estimate the proportion of the potential market equipped with a given device (see Appendix B) somewhat overestimate the size of the market. If so, the resulting estimates of the percentage of use attained are too low, and probably some machines now estimated to be appreciably below the suggested 85 per cent limit of the stage of rapid adoption have, in fact, passed into the stage of slackened increase in use.

<sup>18</sup> This division into periods refers to the aggregate of the several makes of a given type of machine rather than to the sales of an individual manufacturer. The sales of one maker of trucks might be declining while total sales were increasing, or *vice versa*.

<sup>19</sup> The lag between the recognition of need and the development of an



Apparently a completely automatic machine can be devised with relative ease to do any work that involves a repetitive process upon similar material and does not involve the exercise of judgment. In fact, where desired variations in the process are based upon readily measurable physical qualities of the material, the necessary adjustments may be made automatically.

Anything that enhances the economic advantages of machines speeds up the process of developing new types.<sup>20</sup> However, it should be recognized that some needs have long been obvious and as yet no completely satisfactory device has been developed. For example, we understand from the

adequate machine is probably shorter where the required machine is needed for a given motion than where a basic change in procedure is involved. Changes in productive processes may affect either the quality or the quantity of the product. Quality changes involve largely innovations in materials used, type of processing or the chemical changes to which the materials are subjected, and are with relative infrequency associated with the labor-saving aspect. One exception is standardization, which improves the product by facilitating precision and saves labor by making quantity production more feasible. Inventions designed to increase quantity, on the other hand, are essentially labor saving; and, it should be noted, deal largely with devices to perfect a machine motion or to accomplish mechanically motions formerly done manually.

The essential elements in such motions are relatively few—grasping, holding, conveying (vertical and horizontal) and releasing. The variations of these elements are multitudinous and the article may be in the process moved against a tool and processed, or the tool may be moved against the article, but the variations required would not appear to be an exceptional strain upon inventive genius. In fact, a great variety of 'motion automatics' now in use complete complicated processes without guidance by manual effort; and specialized machine shops make a business of constructing automatics to order for a special job. One such shop, visited by our field agent, constructed special machines to label filled bottles, wrap them with cardboard, add a printed advertising pamphlet and insert the bottle in its cardboard holder ready for packing. Many other examples might be cited.

<sup>20</sup> See fuller discussion of pecuniary factors affecting mechanization in Ch. IX. Doubtless some new inventions are 'sports' in the sense that economic pressure is not a major factor in their development and they are not a result of a gradual evolution from known methods.

sugar beet growers that, although for many years a \$10,000 prize has been offered for a satisfactory machine for the pulling and topping processes in harvesting beets, no reasonably satisfactory machine has been put upon the market.

Either prior to or following the patenting of a new device a considerable period of *pre-commercial experimentation* and development ordinarily elapses before commercial marketing becomes feasible. This period is rarely less than two years, and often it is much longer. For a complicated device the developmental period is apt to be long and involve expenditures amounting to hundreds of thousands and even millions of dollars.<sup>21</sup>

Even after commercial marketing begins there is ordinarily a period of *commercial trial* during which adoptions are relatively slow and machines undergo various modifications to meet difficulties developed in the course of practical operation. While no sweeping generalizations can be made, the study of the history of many successful labor-saving devices, some of which are mentioned more at length in other parts of this report, indicates that a developmental period of from 3 to 10 or 12 years may ordinarily be expected between the first commercial introduction of a device and the development to the stage where it is clearly accepted as practicable from both an engineering and an economic point of view. We have defined this stage as including the years required for use to reach 10 per cent of the maximum later attained.<sup>22</sup>

<sup>21</sup> Many years and very heavy expenditures were required before the cylinder glass machine was perfected so it could produce commercial window glass successfully. The perfection of the sheet glass method bankrupted the original company and cost the purchasers of the patents at sheriff's sale heavy additional expenditures. The manufacturers of the AutoBrik machine state in their advertisements that "more than two hundred thousand dollars were expended in perfecting it".

<sup>22</sup> See Table 33. Examples of machines in this stage are cited in a subsequent paragraph.

Following the period of commercial trial comes that of more general introduction, finally culminating in substantial saturation of the market. This period of extensive introduction, that is, from the time the machine is generally recognized as commercially practicable to the point of substantial saturation, may be long or short, depending largely upon whether the machine effects a large saving over alternative methods. If the margin of saving is not great, if much other equipment must first be scrapped, or if the industry is not in an active state of development, the introduction of even a very good new device may be quite slow. Under reverse conditions, the introduction may be very rapid. In Chapter IX we discuss more in detail the various influences that determine the rapidity with which new methods or equipment are introduced.

Examination of the histories of various types of machine, some of which have been discussed in preceding chapters or analyzed in the preceding section of this chapter, leads to the hypothesis that the period of extensive introduction following the period of commercial trial may be divided appropriately into two subperiods, each several years in length, the first characterized by a relatively rapid rate of increase in use, and the second by a continuing increase but at a slower rate.<sup>28</sup> The period of *rapid increase* appears to be from 4 to 11 years in the majority of instances, and, as a rough approximation, it is estimated that during the stage of rapid increase the extent of use rises from 10 to around 85 per cent of the total potential market.

A few revolutionary innovations, such as the talking movies with their synchronization of the musical score with the spoken words, pass through the stage of rapid increase to substantial saturation in a shorter period than the above

<sup>28</sup> See Table 33 and accompanying discussion.

summary of the general record of machines would suggest (see Ch. IV).

The period of *slackened increase* in use may, for purposes of rough approximation, be defined as the period in which the customary yearly gain is less than 10 per cent of the level previously reached, and the percentage of use from 85 to 100 per cent of the total potential market. The evidence at hand indicates a typical duration of 3 to 6 years for this period, with some marked exceptions.

The stage of *saturation*, when the machine is in use in the greater part of the work for which it is adapted, is reached towards the close of this second period of increasing use; hence most sales are to replace worn-out machines, to equip new plants, or for uses not previously recognized as part of the market. As generally there is probably a margin between what is ordinarily considered the potential market for a machine and the maximum use that will actually be reached, we are defining the saturation stage as existing whenever 90 per cent or more of what is ordinarily considered the market for the machine is equipped with it.

The attainment of a state of substantial saturation may be followed by a period of *declining use*. Either the industry in which the machine is used may decline, or because of the rise of competitive devices, the machine enters a period of *increasing obsolescence* until ultimately its use ceases entirely (see Group VI, Chart 5).

#### CONTINUOUS TECHNICAL DEVELOPMENT

It should not be assumed that the machine remains unchanged after the beginning of the period of commercial trial. On the contrary, it often undergoes radical alterations in this period and through the subsequent periods. Even if major changes in design do not occur, the machine is likely

to become steadily more rugged, larger, and have various attachments added or modifications made to adapt it to particular uses. The evolution of the electric industrial truck from a simple load-carrying device to various special forms of tiering machines and crane trucks is a case in point. Because of such developments, the statistical record of sales, in number of machines, ordinarily understates the use of the machine. The cycles in the rise and decline of these special modifications of machine types will ordinarily be shorter than the cycles for the more broadly defined classes which we have been discussing in estimating the duration of the several stages in the life history of a machine type.

#### MACHINES IN THE SEVERAL STAGES

In addition to the machines whose more or less complete chronological record is graphed in Charts 3, 4 and 5, sufficient data are available for many of the other types mentioned in previous chapters to make possible an approximation of their stage of introduction. Without attempting to give anything approaching a complete list of the devices that might be assigned to the several commercial stages in the typical life history of a machine, we will list a number of those of especial interest. These illustrations are largely from the tables on extent of use in Appendixes A and B, and rest necessarily upon a wide variety of evidence. Consequently they must be considered as representing conclusions based upon the author's judgment of the evidence rather than upon rigid adherence to the classification suggested in this chapter applied with the aid of objective criteria which can be fully presented and which all readers would consider adequate. Doubtless another analyst would reclassify these illustrations in many details.

We shall single out no particular illustrations of machines

in the pre-commercial stage of experimentation. Information concerning developments in process in this pioneer stage is not as readily available as for devices that have reached the commercial stage. Each year there are thousands of additions to the patents for mechanical devices, and many experiments in progress that have not yet reached the patent stage. Some of these are destined to emerge in a few years into the early commercial stages. The introduction of labor-saving machinery is a never-ending process, sometimes accelerated by favorable conditions, sometimes retarded, but always proceeding at innumerable points in the industrial structure. We might, of course, mention such conjectural possibilities as increases in the sources of generated power through harnessing the tides or exploding the atom, but when we speak of processes in the experimental stage it is not such faint, though potentially far-reaching possibilities that we have in mind, but rather the multitude of more modest innovations which in the course of a few years may be expected to encroach on the domain now held by hand processes or accepted mechanical devices.

The writer would judge that among the devices that may properly be classified as being in the stage of commercial trial at the close of the 'twenties are such relatively recent innovations as the use of electric welding in construction work, the application of self-feeding loading devices in coal mining (Table 40), the corn picker in the Corn Belt, and cotton sleds and pickers for cotton harvesting and the rotary hoe in row crop cultivation.<sup>24</sup> Among home appliances, we may mention the electric dish washer.

Machines that have become well known as labor-saving devices, and of sufficient importance so that adequate statis-

<sup>24</sup> The citations in parentheses in this and the following paragraphs are to tables where some numerical data are given concerning the specified device.

tical data concerning the extent of their use are available, are likely to have advanced at least to the stage of rapid introduction. In addition to the series graphed in Chart 3, many of the shorter series in Appendix A belong in this group, and also many other labor-saving devices mentioned in Chapters III, IV or V, or for which fragmentary data are given in Appendix B (Extent of Use). Among those which may be mentioned are: tractors of the tracklaying type (Table 39); harvester-thresher combines and milking machines; narrow trench excavators; installed handling systems in other than the automotive and tire industries (where they have apparently reached a still more advanced stage); and a number of labor-saving appliances for the home, such as electric ironing machines and possibly electric washing machines and vacuum cleaners, though the latter two series are well advanced in the period of rapid adoption and are approaching the period of slackened increase.

Numerous important labor-saving devices for which data are available are sufficiently advanced so that they appear to have entered the stage of slackened increase and in some instances are close to the saturation point. In addition to the series shown in Chart 4, the writer would classify in this group such extensively used farm appliances as the stationary gas engine; such factory labor savers as installed conveying systems in the automotive industries, automatic proportioning in the newsprint industry, the sheet type of window-glass machine and the continuous process for plate glass, the automatic cotton loom, and power-molding and core-making machines in the larger foundries. In household appliances, the rate of increase in the use of electric irons seems to be slackening, and possibly the same statement applies to electric washing machines and vacuum cleaners.

If we classified our machines by individual models rather than general types, we should find innumerable examples

of types that are in the declining stage, as they are superseded by new and improved models. In general the enumeration for this class is the converse of the list of types that are increasing. With the rise of the automatic bottle machine, the semiautomatic machine has gone into a stage of increasing obsolescence, the number of machines in use rapidly declining (see Chart 5); with the rise of the automatic loom, the non-automatic loom begins to pass out of the picture;<sup>25</sup> with the rise of the electric washer and sewing machine, the hand wringer and the foot-power sewing machine have probably passed their peak; the increasing dominance of the sheet machines in window-glass production is evidenced by the decline of the cylinder type (Chart 5), and the discontinuous process for plate glass yields to the continuous process.

Processes and types of equipment suffer declines for long periods before they pass completely out of use. They linger on in small plants and for special uses long after they have been replaced by new processes or equipment in the industry generally. There are many casualties in the ceaseless battle of machines against machines but few result in quick extinction.<sup>26</sup>

<sup>25</sup> At the time of our inspection in the cotton industry (1925) the non-automatic loom was still in use in an appreciable portion of the New England mills, but some of the machinery factories that had produced such looms had stopped production entirely and others were engaged largely on production only for partial replacement, that is, for sale to plants that were not ready to scrap their whole equipment of non-automatics and hence from time to time wished to replace a few as they wore out with new non-automatics in order to keep their equipment all of one type.

<sup>26</sup> The hand processes for window glass and glass tubing in use earlier in this century are now reported as virtually extinct (Ref. 36).



## SUMMARY

The material presented in the preceding sections makes certain aspects of the machinery industries fairly obvious. The industry is highly sensitive to the ups and downs of business conditions. It employs several hundred thousand men in the production of machines, but the changes in the volume of this employment have not been closely commensurate with the labor-replacing power of machines produced. Of the total expense of machine production only some 20 to 30 per cent can be ascribed to wages directly, and even if the labor embodied in the materials used is included, probably not more than 50 to 55 per cent represents wages.

Furthermore, of this labor cost not more than about 20 per cent represents expenditures for common labor. Consequently it is obvious that if immigration restriction, or any other influence, tends to increase the relative expense of hiring common labor it will at the same time tend to bring a greater increase in the expense of activities in which common labor is the chief cost than in the production expenses of the machine-producing industries. This differential would presumably be a force tending to accelerate the speed of machine substitution.

When we turn to the life histories of various machines for light on the rapidity with which machines are introduced, we find that not only are there always new devices coming upon the market, but also that the effect of any special impetus to the use of labor-saving machines, such as a scarcity of types of labor competitive to the machine, apparently does not show its full influence until after the lapse of a considerable period. Most machines require several years to get beyond the period of experimentation and trial, several more to reach wide adoption, and then continue to increase in use more slowly for several additional years.

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Examining the available evidence, fragmentary it is true, we find numerous labor-saving machines still in the trial or rapid introduction periods; and we have every reason to believe that other types will arise to take their place as these move on into the periods of saturation and decline.

We turn in Chapter IX to an inquiry into the influences that determine the rate of adoption of labor-saving machines.

## CHAPTER IX

### FACTORS DETERMINING

### THE RAPIDITY OF MECHANIZATION

IN CHAPTER X we analyze the effects of the process of mechanization. These effects themselves are among the major factors conditioning the rapidity of mechanization, but it is also pertinent to our purpose to review first the other influences that may be expected to hasten or retard the advance of mechanization.

These influences are diverse and numerous. Some are always prevalent and do not fluctuate greatly in their potency; others are peculiar to the present status of industry or at least are more potent under existing conditions. Some are susceptible of objective treatment; others are less tangible though perhaps no less significant. By what means, for example, can we express in quantitative terms the part played by the reluctance of executives to abandon familiar methods or the force of labor opposition arising from the fear of machine competition? Nevertheless, our picture will be more complete if we mention the various factors involved, even though in some instances we must rest our statement with little more than a mere enumeration or at best a few illustrative examples.

Mechanization is not completely synonymous with the factory system, but there is so close an alliance between a highly mechanized industry and a well-developed factory system that we may initiate our review of the factors conditioning mechanization by asking what are the primary

requisites for the development of an extensive factory system.

First, before there will be adequate inducement for those in control of investment funds to hazard them in industrial enterprises, any excessive element of risk must be eliminated. Second, there must be an entrepreneurial class with sufficient initiative and ability to organize factory operations and adapt them to a relatively complicated labor and market situation. Also there must be a laboring class with a somewhat flexible standard of living, that is, a group of workers sufficiently discontented with their status to be willing to subject themselves to the factory regime in the hope of bettering their conditions.<sup>1</sup> Third, there must be a relatively extensive market.

However, since we are concerned primarily not so much with the conditions requisite for the inauguration of the factory system and the introduction of power-driven machinery as with the forces affecting their further development from the stage now reached in the United States, it is not unreasonable to assume the existence of the primary requisites for the factory system—subject possibly to qualifications for particular industries or sections of the country—and to state the problem in terms of the conditions that tend to accelerate or retard the process of mechanization.

For convenience in discussion we may classify the influences that tend to affect the degree of mechanization or changes therein as technological, pecuniary and psychological. An operation may continue to be manually performed because the technicians have not developed a satisfactory

<sup>1</sup> On this point, J. E. Orchard, in *Japan's Economic Position*, says: "It is one of the paradoxes of the Orient, of India and China as well as of Japan, that manufacturing industry suffers from a scarcity of labor. . . . The farms are overpopulated, but the people are attached to the land and labor is reluctant to enter the factory" (340).

mechanical device. Or the mechanized procedure, though technologically adequate, may be too expensive. Or, despite the availability of adequate mechanical devices, at costs not prohibitive, use may be limited because of the inertia, ignorance, distrust or active hostility of employers, workers or the public.

Obviously, the technological, pecuniary and psychological factors are not independent or mutually exclusive. If expense could be ignored, there are very few operations for which a technologically adequate machine could not be developed. Furthermore, such resistance to the use of labor-saving equipment as arises from non-pecuniary factors may operate to lessen the pecuniary gains to be expected from its adoption.

#### TECHNOLOGICAL FACTORS LIMITING MECHANIZATION

There is, as above noted, no sharp cleavage between technological and pecuniary obstacles to mechanization, for many of the existing technological difficulties can be overcome if expense is ignored. However, frequently the chief reason for not substituting mechanical methods is that some particular technical difficulty has not been overcome. In fact, the balance between alternative methods of production is constantly being disturbed by technical improvements in mechanical devices. Some take the form of revolutionary changes in process which surmount a difficulty by substituting an entirely new method of attack. Others consist in the perfection of mechanical devices for carrying out a known procedure.

Under modern conditions most technical improvements probably are not accidental but are the result of continuous experimentation, partly by the users of machines themselves and partly by machine producers who maintain a technical

staff whose primary function is to design special machines to meet requirements prescribed by the prospective user. It is scarcely too much to say that a machine can be manufactured to special order to perform almost any series of operations when the need becomes sufficient to justify the expense.

#### LIMITED SELECTIVE ABILITY

One difficulty that frequently stands in the way of mechanization is the limited selective ability of the machine. For example, machines have not been developed to supplant domestic labor in the care of children, to pick strawberries or to read addresses in the Post Office. Other illustrations are found in the sugar beet industry. Beets are planted in continuous rows and later 'blocked' with a hand hoe to leave a bunch every ten or twelve inches; then each bunch is thinned by hand to one plant. For neither of these operations have mechanical devices proved satisfactory. A blocking machine does not allow for the lack of a perfect stand and the use of judgment in shifting the block, and the machine must move too rapidly to enable the operator to make the necessary shifting. Likewise there is no obvious prospect of developing a machine for thinning beets. In the seed ball there are from two to four germs. These sprout together and, if allowed to grow together, would twist around one another, making small, imperfect beets. Therefore, we must pull out by hand all the beets of the bunch but one, leaving a single beet to continue its growth. Furthermore, no toppler has been invented for use in harvesting beets that can cope with the vagaries in growth to which the toppler must be adapted.

## TEMPORARY AND LOCAL TECHNOLOGICAL LIMITATIONS

Many technological difficulties are temporary and will be surmounted through experimentation.<sup>2</sup> Other difficulties, peculiar to certain plants, may be overcome by reconstruction.<sup>3</sup>

There are two prerequisites for changes in industrial technique. First, certain scientific and engineering principles must be evolved; second, their application must be commercially feasible. Occasionally, an invention is perfected before economic conditions are ripe for it. On the other hand, occasionally an urgent or unusual economic situation concentrates attention on a technological problem and hastens its solution. Witness the impetus given to the development of mechanical cotton harvesting by the situation existing in some years in sections of the South where profitable harvesting was impossible by the customary hand picking methods.

<sup>2</sup> For example, formerly the inability of electric trucks to make steep grades on docks limited their use, but now, we understand, there are trucks that can negotiate the steepest grade fully loaded. Likewise, in the initial stages of our survey, the opinion was expressed by one mine operator that loading machines were probably then practicable in mines with adequate height in rooms, but would have to wait several years for general use until machines adapted to lower ceilings and more cramped quarters in general were developed. As indicated in Ch. IV, with their increasing adaptation to special mining conditions, the use of loading machines has been making substantial progress in recent years.

<sup>3</sup> For example, in the older cotton mills the portable type of tying-in machines, which is necessary for Jacquard looms, sometimes cannot be used because of narrow aisles. In the older foundries some roofs are too low to admit the installation of satisfactory overhead conveying systems. In one foundry surveyed the roof of the main building was so low that there was no overhead room for heavy-work cranes; consequently, large pit castings had to be dragged out. Likewise, at the time of our inspections, many piers along the lower East River, New York, were plank floored and very uneven, making the use of electric trucks difficult if not inadvisable on account of load shifting.

## PECUNIARY FACTORS

We have noted in the preceding chapter that even after a machine has become clearly practicable from an engineering point of view, many years may pass before its use becomes general in the industry; that ordinarily there is a considerable margin between the fullest use of a mechanical device that is feasible from an engineering point of view and the actual extent of use. Technical progress far outruns actual practice.

This margin of non-use is in part due to non-pecuniary factors but the major explanation is simply that, on the whole, industry must be conducted with profits as the immediate goal; hence the first and major consideration in any choice of method is not merely, will it do the work, but also will it pay?

Numerous collateral questions arise. What existing plant and equipment must be scrapped or reconstructed? What new capital will be required and how difficult will it be to obtain the necessary funds? What overhead expense will the machine add, especially in times of plant idleness? Is the market that may be counted upon of sufficient extent to justify the scale of production essential to make the use of the machines economical? How high is the wage level in relation to the costs of the other factors in production and what changes are taking place in the rates of wages for workers required in the production of machines as compared with those displaced by them?

Let us consider first the issues arising from the larger overhead expense of mechanized processes.



## OVERHEAD EXPENSE

The adoption of a more highly mechanized procedure usually involves a larger investment in equipment,<sup>4</sup> and often also in plant structures, particularly if the machines are very heavy. For example, in its investigation of the window-glass industry in 1916 the Bureau of Foreign and Domestic Commerce found that the 37 hand plants surveyed employed only \$0.74 of capital for each \$1.00 of sales, while the 12 machine plants averaged \$0.93 of capital for each \$1.00 of sales.<sup>5</sup>

Dr. D. D. Kennedy cites examples of marked increases in overhead expense due to mechanization in the ice and coke industries.<sup>6</sup> He found that depreciation constituted only 8 per cent of the expense of producing natural ice and 26 per cent for artificial ice. Likewise, in the coke industry the transition from the almost completely manual methods of the old beehive process, first to the machine beehive and then to the by-products method, has brought sharp increases in overhead costs. "A forty-oven battery of the old beehive type would be valued at about \$20,000, while a machine-operated battery would cost between \$80,000 and \$100,000." In a by-product coke plant, depreciation alone is found to constitute 21 per cent of total costs.

Where the adoption of mechanized methods requires a carefully planned reorganization of a factory, as is often the

<sup>4</sup> "Ability to make heavy capital investment has enabled the modern baking companies to install machinery whose price is prohibitive to the corner bakery, and which enables great savings in cost when bread is made in large enough quantities—though the price to the consumer is little reduced, if at all." George Soule, *New Republic*, April 4, 1928, pp. 210-1.

<sup>5</sup> *The Glass Industry*, Misc. Series No. 60, p. 43.

<sup>6</sup> Ref. 14, Ch. III, *The Increased Importance of Overhead Costs*, pp. 33-43. These estimates are based upon the records of a small number of individual plants.

case, for example, where an adequate system of mechanized handling of materials is introduced, the necessarily large outlay for engineering and reconstruction costs is feasible only when the capital market is favorable.

#### RELUCTANCE TO SCRAP EXISTING EQUIPMENT

Frequently the factory executive is deterred from introducing a machine, recognized as more efficient, because of a reluctance to scrap the existing equipment, which, though perhaps obsolete, still functions after a fashion. We were informed by various cotton mill executives that they were still using a considerable proportion of non-automatic looms because of the capital investment that would be required if these looms were scrapped before they had worn out physically.<sup>7</sup>

As the old machines wear out and it becomes necessary to discard them, this obstacle to the introduction of the newer device is, of course, removed. Meanwhile, however, average equipment lags far behind technical progress. The slow adoption of the automatic telephone may be cited as an illustration.

Difficulties arising from the nature of the existing equip-

<sup>7</sup> Mr. George O. May suggests the possibility that one cause for the greater tendency here to discard equipment than is noticeable in Europe may be an inadequate analysis of the advantages and costs of change. "Certainly for many years and in many fields there was a tendency to capitalize both the cost of original equipment and the cost of superseding equipment; for instance, it was notorious that the capital accounts of many street railways included the cost of original horse-car equipment; the cost of conversion to cable or electric cars, or perhaps to both in turn and possibly also a change first to an overhead and then to an underground electrical system. It is hardly surprising that ultimately the industry proved unable to stand the strain of such accumulated capitalization, and I have often wondered how far sound accounting would have had the effect of checking the rate of change in this and in other cases."

ment may be illustrated by reference to the conditions long prevailing in the handling facilities in the Port of New York. These, it has been pointed out, to a large extent just grew instead of being planned with a view to future conditions; consequently the design of the structures was such that without building new piers it was impracticable to equip them with the most efficient handling devices. As the old piers had many years of useful life under the then existing conditions of operation, it was difficult to prove the economic justification of new piers, even if physical conditions made possible the increased size. In brief, it appeared that the more complete mechanization of the cargo handling facilities of the Port of New York might be delayed until the useful life of the existing structures was exhausted.<sup>8</sup>

#### EASE OF FINANCING NEW EQUIPMENT

A device may save labor, and in the experience of other producers, also save money in the long run, but for various reasons it may be difficult for the management to arrange for the financing necessary to cover the purchase cost of the new equipment.<sup>9</sup> This is likely to be true particularly of industries for which the future is somewhat uncertain. The conditions of ownership may be one of the factors limiting

<sup>8</sup> See discussion of this point in an article by James A. Jackson as late as 1927; *Mechanical Engineering*, May 1927, pp. 411-3.

<sup>9</sup> A pertinent comment on this point appears in the report of a Subcommittee of Civil Research (with reference to the British cotton industry and known as the 'Government Cotton Inquiry'), as quoted in the *Manchester Guardian*, July 5, 1930: "One important reason why the question of improved methods and equipment has not received adequate examination is that many of the firms engaged in the spinning and manufacturing sections are financially weak."

ability and readiness to make additional investments in equipment.<sup>10</sup>

It has been suggested that the ability of vertical combinations like Ford and the United States Steel Corporation to finance new inventions was one factor furthering the mechanization of coal mining in the post-War period and helped to give the new non-union fields an advantage over the old fields.<sup>11</sup>

It may be noted that old plants for which the financing of reconstruction may be difficult or inadvisable and which have become so inefficient that their operation has ceased to yield a return sufficient to maintain the property and cover interest on the investment, may still continue to operate "as long as they will run without repair, in order to liquidate as much of the investment as possible."<sup>12</sup>

A major factor contributing to the era of post-War expansion in equipment was the availability of an unusually large volume of funds at low rates. "Probably never before in this country had such a volume of funds been available at such low rates for such a long period." Government debt reductions contributed to an abundant supply of capital. A substantial portion of the high corporate earnings was used for plant and equipment expansion. The net volume of domestic new capital issues increased at an annual rate of 7.7 per cent, or from \$3,669 million in 1922 to \$6,294 million in 1929.<sup>13</sup> An indication of the easy market

<sup>10</sup> In New England there are a number of old family mills; we understand that in some cases there has been a tendency for the family to expect regular dividends whether currently earned or not, and in their payment surplus has been exhausted, leaving no funds for needed investment in new equipment.

<sup>11</sup> C. B. Fowler, *Soft Coal and Hard Facts*, *Survey*, March 15, 1927, pp. 773-4.

<sup>12</sup> B. L. S. in merchant blast furnace study, Ref. 37, p. 66.

<sup>13</sup> F. C. Mills, *Economic Tendencies*, pp. 423-61.

for such securities is given by the decline in the average yield of 60 high-grade bonds, as computed by the Standard Statistics Company, from 4.98 in 1923 to a low point of 4.47 in 1927. With new capital available at low rates and wages relatively high, the financial incentives to mechanization were unusually strong in the years following the recovery from the depression of 1920-22.

#### REGULARIZATION OF PRODUCTION

Irregularity of production, a short operating season<sup>14</sup> and the availability of casual labor tend to discourage investment in machinery. The machine cannot be discharged in slack periods, but human labor can and is. We are not, of course, overlooking the very commendable efforts to regularize industry by progressive and farseeing employers, or the possibility that pressure for steady employment may be brought through special unemployment reserves or insurance schemes or provision for compensation for job severance; nevertheless it remains true that in periods of business depression executives believe it necessary and find it possible to make substantial cuts in their expenses by decreases in the number of their employees. Hence the executive who contemplates the substitution of machinery for manual methods will obviously take into consideration the fact that certain elements in his machine expense, such as interest and insurance, will continue through periods of idleness.<sup>15</sup> Consequently, forces that tend to reduce either

<sup>14</sup> An illustration is found in summer resort hotels. The manager of one, employing ten women and four men and having no vacuum cleaning units, wrote us as follows: "This is a resort hotel . . . our season is short, nine weeks, and capital charges must therefore be watched closely. We do not, therefore, use machinery except in a very limited way."

<sup>15</sup> The uncertainty of net saving when overhead during periods of idleness was taken into consideration was the reason mentioned to the writer by one

cyclical or seasonal irregularities in industrial operation are favorable to mechanization.<sup>16</sup>

The effort to reduce seasonal irregularity in the building and other industries affects the supply of labor in a twofold way. First, to the extent that the movement towards regularization is successful it economizes the existing supply of labor by a more uniform distribution throughout the year; second, by lengthening the working period it encourages the substitution of machinery for manual effort. Some of the modern developments in building in the way of mechanized production, such as the use of structural steel, also further the reduction of seasonal irregularities by increasing the amount of fabrication prior to erection (Ch. IV).

The intermittent nature of stevedoring operations partly accounts for the large amount of manual work in marine terminals. On docks speedy handling is imperative and it is cheaper to take on, for a short time, a force sufficiently large to load or unload the freight quickly by manual methods than to keep ready adequate mechanical equipment.

large steel foundry executive to explain the fact that his plant has less labor-saving machinery than is commonly found in large foundries.

<sup>16</sup>In one way, cyclical irregularity may hasten the adoption of improved methods by the ruthless but effective procedure of eliminating the weaker units. Depressions sometimes eliminate obsolete plants or processes. For example, during the 1903-04 depression, the few remaining pot furnaces in the window-glass industry were driven out of business (*Tariff Information Series*, No. 5, U. S. Tariff Commission, 1918, p. 49).

On the other hand, it has been suggested that the realization of technical improvements is deferred during recessions; that the installation of new equipment probably awaits the beginning of revival and the subsequent acceleration of production; that, as business begins to pick up, "the accumulated technical improvements of several years may be vitalized." See Ch. X for discussion of the effect of mechanization on seasonal and cyclical irregularity of operation.

## SHORTENING THE WORKING DAY

Unless the number of shifts is increased, a decrease in the length of the working day increases the expense of machine operation by spreading the overhead over fewer hours.<sup>17</sup>

## LARGE-SCALE PRODUCTION

The relatively large initial expense of mechanized equipment, and the facts that in small plants there may not be sufficient work to keep a machine busy and that machines cannot ordinarily be transferred from one type of work to another without adjustments and additional expense, make high mechanization dependent in considerable part upon mass production. Hand methods survive chiefly where variety and distinction, quality and individuality are the primary considerations.

Numerous examples of the necessity for large-scale production if heavy investments are to be made in highly-mechanized equipment could be given. For example, one manufacturer of brick machinery writes us:

"Unless the product desired reaches about 6,000 brick per hour the plant will hardly justify the employment of the modern mechanical methods of digging clay and preparing it for moulding" . . . and "in the Chicago district unless the product is close to 300,000 per day the manufacturer can hardly afford to employ the labor-saving equipment necessary to compete in that market."

Even if a single plant is operated on a relatively large

<sup>17</sup> Mr. W. M. Carpenter points out with respect to the performance of factory machinery operating on purchased power in New York State (outside New York City, Niagara Falls and Massene, the last two of which are excluded because of the electro-chemical load) that the average load factor declined from 22.8 per cent in 1909 to 21.2 per cent in 1919, or about two-thirds of the percentage decline in average hours per week (*Electrical World*, June 14, 1924, pp. 1232-4)

scale, it may be handicapped because there are not many other plants producing similar goods. Because of the small market automatic machinery would have to be custom built, and hence would be more expensive than if relatively standardized machinery could be used.

There may be a tendency towards larger plants irrespective of any increase in the total size of the industry.<sup>18</sup> On the whole, these larger units can make more economical use of labor-saving devices than the smaller units.

Similarly, the increasing use of expensive machinery—the elevating grader and other mechanical devices—in highway construction in recent years has been due largely to the tendency for hard-surface highway construction to be taken over by the state and federal governments, with the result that contracts are let on a larger scale than when under the jurisdiction of local governments. The same principle applies in the mechanization of agriculture. Mechanization is furthered by large-scale farming.<sup>19</sup>

Industries subject to frequent style changes invest in labor-saving machinery with less certainty of adequate return on the investment. For example, it was suggested to our field investigator that the relatively slow adoption of automatic looms in the New Bedford branch of the cotton industry is ascribable to the circumstance that these mills specialize in quality goods subject to many changes in style.

<sup>18</sup> Cf. Ch. VI, section on Size of Establishments.

<sup>19</sup> A correspondent engaged in the production of sugar beets in America advises us that although a satisfactory machine for pulling and topping beets has not been developed for use in America, "they have a machine in Germany which does fairly good work but it is only adaptable to the very large farms that they have there, the Estate farms. This is pulled back and forth across the field by a cable attached to two engines sitting on each end of the field and driving winding drums in the manner of the Fowler plow . . . These are very expensive machines, only to be applied to very large acreages, and are not very completely practical even there."



As a rule, the small-scale production incident to a diversity of product is a serious handicap to the extensive use of machine methods. For example, one of the reasons for the rather slow development of machinery in the pressed-ware branch of the glass industry, in contrast to the window- and plate-glass branches, is the multiplicity of products.<sup>20</sup> Since the hand plants could not compete with the machine in turning out quantities of common tumblers they are specializing in better quality, emphasizing etchings and decorations to appeal to individual tastes.<sup>21</sup> Likewise, in the manufacture of light bulbs,

"hand production has been retained to make such of the large sizes and oddly shaped and colored bulbs as cannot be economically produced on the machine, partly because the molds are too expensive, but chiefly because such bulbs are produced in very small quantities. For this purpose and for the purpose of experimentation, which can be better controlled when the bulbs are made by hand, hand production, even if only a small fraction of the whole industry, will survive no matter what strides are made by the automatic machines."<sup>22</sup>

Also, where diversity in procedure is essential the simpler hand device may be preferred. For example, in freight handling the sorting of packages to different consignees is more easily done when hand trucks with small loads are used. Likewise, repair work, such as automobile and street repairing, presents too diversified conditions to make completely automatic machinery practicable, although even here semiautomatics are used to an increasing extent. For example, often on the never-ending process of repairing city streets, the old pavement is torn up with pneumatic drill or pavement plow.

We have previously noted that there is a tendency for

<sup>20</sup> B. L. S., Ref. 36, p. 88.

<sup>21</sup> *Ibid.*, p. 135.

<sup>22</sup> *Ibid.*, p. 127.

the size of the machine unit to increase (Ch. VI). This sometimes necessitates the mechanization of associated operations. For example, as the average size of the locomotive has increased it has become less feasible to shake the grates by hand.

In general, then, large-scale production, both for single plants and for an industry as a whole, favors a high degree of mechanization. What conditions favor large-scale production?

#### AN EXTENSIVE MARKET

The primary essential for large-scale production is an extensive market, as a keen foreign observer has well stated: "The most important point in the philosophy of American production is the home market of nearly 120,000,000 people . . ." With free trade within our borders "mass production is the logical result".<sup>23</sup>

#### STANDARDIZATION

Any influence that furthers standardization within the great domestic market for American manufactures accelerates the tendency to mass production and mechanized methods. A 'stereotyped clientele' enables producers to profit readily by manufacturing standardized goods. Standardized production necessitates standardized consumption, to which an impetus is given by national advertising, furthered in part through chain broadcasting systems. Mass distribution is the next step in providing an adequate market for the products of large-scale industry. The remarkable growth of chain stores in many lines of retailing intensifies,

<sup>23</sup> André Siegfried, *America Comes of Age*, p. 166.

suggests George Soule, the tendency to standardized mass production.<sup>24</sup>

The post-War standardization campaign is not restricted to consumption goods. In recent years the agitation for simplified procedure initiated during the War and later encouraged by the Department of Commerce has as its object the reduction of the multiplicity of types and sizes, not only in consumption goods, such as bedsteads, but also in production goods, such as bricks and screws. To the standardization of consumption goods, opposition may arise on aesthetic grounds, but objection to the standardization of production goods is less valid. In any event, it seems a justifiable assumption that the standardization movement will continue and thus offer increasing facility for large-scale production.

#### AGE OF THE INDUSTRY OR PLANT

In general new industries and enterprises are more susceptible to mechanization than those which have long been established. Automobile and tire plants, though among the youngest of the important industries, are noted for their highly-mechanized operations. On the other hand, the clay products industry, as old as history and long accustomed to the use of hand labor, has had difficulty, like other old industries, in divorcing itself from old processes. The lesser susceptibility of the older industries is due in part to the force of accumulated tradition, in part to reluctance to scrap existing equipment. Moreover, the newer industries are expanding industries. Under circumstances of expansion there is greater opportunity and encouragement for mechanization: new buildings can be more readily adapted

<sup>24</sup> *New Republic*, April 4, 1928, pp. 210-2.

to automatic processing machinery and efficient conveying systems, each plant can ordinarily absorb at least some of its machine-displaced labor, and hence both executives and employees are apt to be less concerned about the effect of machines on job security.

On the other hand, in an industry that is declining or for some reason is in a relative slump for the time being, the management is likely to try to retain as many of its staff as it can, and, with more men than it really needs, has little incentive to seek labor-saving changes.<sup>25</sup> When an industry is obviously on a permanent decline, as is the lamp-chimney industry, the owners hesitate to invest the additional capital required for further mechanization.

Older types of labor-saving machinery retard the distribution of new models. For example, when electric sewing machines for home use were introduced, many homes were already equipped with hand- or foot-power sewing machines giving sufficient satisfaction to make the acquisition of the electric type not urgent.

#### RAPIDITY OF EXPANSION

It is reasonable to presume, as noted above, that the impetus towards mechanization is greatest in the industries that are expanding most rapidly. Undoubtedly, for example, the rapid growth of the automobile and tire industries has greatly stimulated the development of mechanized conveying systems and other efficiency devices. However, technical

<sup>25</sup> The manager of a leather plant described his situation thus: "Shortly after the close of the war the country contained a large oversupply of leather of most all kinds . . . hence the business of those engaged in the cutting and manufacture of, for example, sole leather cut products had been considerably reduced." Consequently they had had a surplus of help which, however, they did not care to give up, expecting that the business would soon right itself and they would need their organization.

changes are so varied and their incidence so widely distributed throughout industry that it is difficult to find quantitative proof of the correlation between rapidity of mechanization and rate of growth. To test this relationship, we prepared scatter diagrams for 101 industries, comparing the rate of growth from 1899 to 1925 with the percentage increase in horsepower per wage earner.<sup>26</sup> In one comparison, the percentage increase in the number of wage earners was taken as the measure of the rate of growth; in the other, the percentage increase in the value added by manufacture. In neither case was there any discernible tendency towards correlation between rapidity of mechanization and the rate at which the industry had expanded. Either there is no close correlation or, as seems likely, the relationship is obscured by other influences.

#### LEVEL OF WAGE RATES RELATIVE TO OTHER COSTS

The relative economy of machine and manual methods is affected both by the level of wage rates compared with the prices of the other factors in production and by the relative wage rates for different grades of workers. Other things being equal, high wages encourage the use of machines and stimulate efforts to perfect them, while cheap labor retards mechanization. To this fact the extensive use of machinery in the United States and the prevalence of hand methods in such countries as China have been largely attributed. Likewise, some observed differences in the use of machinery as among the various geographical districts in the United States have been attributed to wage differ-

<sup>26</sup> The percentage increases in horsepower per worker were computed from the data in Appendix C; those for the percentage increase in the number of wage earners and in value added were taken from Day and Thomas (Ref. 27), pp. 130, 141 ff.

entials. Thus, cheaper labor in the South has made it advantageous for most southern blast furnace plants to continue to maintain the old methods of sand-casting (sometimes with the aid of a mechanical pig breaker) rather than adopt the more expensive but labor-saving pig machine. In general, new labor-saving machinery was introduced less rapidly after the War years of 1917-18 in the southern iron-producing districts, and productivity increased less in this district than elsewhere because of the plentiful supply of negro labor.<sup>27</sup>

Likewise, this difference in wage levels may help to account for the greater number of helpers used with drawing-in and tying-in machines in cotton mills in the South and in England than in New England. On the other hand, the more recent construction of southern mills, as compared with many of the New England mills, has been a factor favoring the installation of more automatic machinery. In 1929, for example, 80 per cent of the plain cotton looms in the southern mills, but only 59 per cent of those in the New England mills were automatic.<sup>28</sup>

Dr. Alfred Briggs, in an unpublished manuscript on the development of the glass industry, says that the success with which the skilled window-glass trades, because of their strength, were able to maintain a very high wage level compared with other crafts went far to stimulate interest in the perfection of glass-making machines and to hasten their introduction. However, even where wage levels are very low, labor may not be sufficiently cheap to prevent the introduction of some mechanical equipment. For example, in the low-wage Oriental countries we find an increasing

<sup>27</sup> B. L. S., Ref. 37, p. 15. Also see Ch. VII, Chart 1, and accompanying discussion for comparison of relative wage rates and mechanization.

<sup>28</sup> Computed from data in *15th Census of the United States—Manufactures: 1929*, II, 263.

use of mechanical devices, evidenced in part by our exports of machinery to Japan.

#### CHANGES IN THE RELATIVE WAGE LEVEL

The trend towards mechanization is accentuated by a rising wage level such as was experienced in the years following 1921. In the period 1922-29 Carl Snyder's composite index of wages shows, in terms of current dollars, a 22 per cent increase; likewise, the average annual earnings of wage earners in manufacturing increased 17 per cent. In the same period, the prices of goods entering into capital equipment declined 3 per cent.<sup>29</sup> With wages rising in terms of both money and purchasing power, the prices of materials for capital equipment declining, and funds for investment in equipment available in abundance and at low rates, the situation was unusually favorable for extensive installations of capital equipment.

#### CHANGES IN WAGE DIFFERENTIALS

The introduction of machinery may be hastened or retarded by shifts in the relative wage rates for workers engaged in machine production and for those which the machines are capable of displacing. This possibility may be illustrated by a hypothetical example. Assume a machine that displaces unskilled workers and requires \$100 per day for all direct and indirect expense, including operating labor, supervision, oil, power, repairs and maintenance, interest on investment, amortization of original cost and any other expenses due to it. Of this \$100, assume \$60 represents payment directly or indirectly for labor and that

<sup>29</sup> F. C. Mills, *op. cit.*, pp. 364, 502.

one quarter of the \$60 is for unskilled labor. Assume further that at the beginning of the period under consideration there is a perfect equality between the expense of using the machine and hiring unskilled laborers to do the same work.

Under such conditions, how much margin of advantage will accrue to the machine use from (1) a 10 per cent increase in wage rates for each grade of workers, and (2) an average 10 per cent increase (\$6 in amount) distributed \$3, or a 6.7 per cent increase, to the skilled workers, and \$3, or a 20 per cent increase, to the unskilled?

The expense of the two methods, before and after the increase in wages, will be:

	MACHINE METHOD	MANUAL METHOD
Daily expense before change	\$100	\$100
After an increase of 10 per cent to both skilled and unskilled workers	106	110
After an increase of 6.7 per cent to skilled and 20 per cent to unskilled workers	106	120

Under the conditions assumed, it is obvious that any increase in wage costs greater than the increase in other items of expense (assumed to remain constant in the above example) creates a differential in favor of the machine method, and this differential is widened if the increase is proportionately greater for the unskilled worker.

In like manner, any actual shift in the relative wage rates or in the relative costs of labor and the other factors in production may disturb the previous differential between hand and machine methods. For example, it seems reasonable to believe that, other things being equal, the immigration restriction that has been in force, either by reason of war conditions or by legislative enactment, for the greater part of two decades, would, by decreasing the annual additions to the number of relatively unskilled laborers, tend



to increase the inducements for a greater use of those machines which are capable of doing the work for which immigrant laborers are adapted. True, any tendency that such restrictive measures may have to create a relative shortage of common laborers will to some extent increase the expense of producing machines, but the increase in the cost of the alternative methods of production will be still greater, for not all the expense of producing machines is labor expense. Furthermore, in the machine-producing industry a substantial part of total wages is for labor of a grade with which the greater part of immigrant workers do not come in direct competition.<sup>30</sup>

What actually did happen to the differential between the wage rates of skilled and unskilled laborers in the post-War period? As stated in *Recent Economic Changes* (p. 439), "the margins between the wage rates of skilled and unskilled labor narrowed considerably from 1914 to 1920 and then tended to widen, but were left somewhat narrower in 1927 than they were before the war." This conclusion of the National Bureau of Economic Research is supported by wage statistics computed by the National Industrial Conference Board from data published by the United States Department of Labor. The percentage ratio of the hourly earnings of male unskilled workers to those of male skilled and semiskilled workers, in manufacturing, declined from 76.8 in 1920 to 72.8 in 1929, the low point in the intervening period being 70.7 per cent in 1925. Likewise, the percentage ratio of the hourly union rates for building laborers

<sup>30</sup> We have estimated that expense for labor constitutes about 25 per cent of the total sale price of machines if we include only the labor directly in the factory, and about 50 per cent if we include the labor required in marketing the machine or embodied in the materials and equipment used in the machine-producing industry; furthermore, that of this expense for labor about 20 per cent is for the services of unskilled workers (Ch. VIII).

to those for bricklayers declined from 62.4 in 1920 to 52.0 in 1929. Similarly in important cities—Chicago, Cincinnati, Detroit, New York—the high point in the ratio of unskilled rates to the rates for bricklayers was reached in the early post-War years. In Boston the ratio increased from 54 in 1913 to a peak of 67.5 in 1920–22, inclusive, then declined to 53 in 1930.

On the whole, despite the check to immigration, there is no clear tendency in the decade of the 'twenties for the wages of unskilled workers to increase more rapidly than those of the more skilled groups. In fact, in the series examined, the ratio was highest in 1920 or 1921. The implication is not necessarily that immigration restriction has had no effect upon the relative supply of unskilled labor. It is entirely probable that had immigration not been restricted the ratio would have declined even more than it did; furthermore, to the extent that the check to immigration has set in motion counteracting forces such as an increased use of labor-saving equipment, these counteracting forces have tended to offset any influence that immigration restrictions might otherwise have had in increasing the relative rates for unskilled workers.

A further factor—somewhat hard to ascertain but nevertheless significant—is the probability that, by reason of immigration restriction, machine producers have been encouraged to develop plants adequate to manufacture, on a quantity basis, standardized machines such as trench diggers and wagon loaders that can do the work of unskilled labor.

#### MARKETING POLICIES AND COMPETITION

The pressure for mechanization varies with the type and degree of competition that prevails in the manufacture and sale of the machine in question and also with the competi-

tive conditions in the machine-using industries, though it is admittedly difficult to generalize on the precise effect of such differences. If all the machines suitable for a given task are well covered by patents and their control centered in one organization, it is quite possible, under such monopolistic control, that a rise in wages due to an increasing scarcity of labor would merely result in an increase, by the machine manufacturer, of the price of the machine sufficient to absorb most of the potential increase in gain that might otherwise have accrued to the user. In such an event, the labor shortage, whatever its cause, would have little influence in accelerating the speed of mechanization. Under competitive conditions, however, producers will find that they must pass on to users more of the savings made possible by the machine, and this should accelerate its introduction. It is pertinent to note, therefore, that the machines which more clearly are a monopoly are ordinarily those which supplant more or less skilled workers, while the materials-handling devices, conveyors, ditch diggers, wagon loaders, etc., which replace unskilled workers, although sometimes patented in details, are in active competition with other machines for the same type of work.

Sales policies may affect the rate of introduction. The holders of the patent of the cylinder machine used by the American Window Glass Company followed the policy of issuing an exclusive license for its use. Some producers lease their machines; others sell outright. Leasing would seem to require less original capital investment; but purchase may be made to appear less burdensome by a liberal credit policy.<sup>81</sup>

Intensity of competition in machine-using industries ordinarily accelerates mechanization. If competition takes the

<sup>81</sup> See further discussion, Ch. VIII, section on Marketing Methods.

form of a struggle for a larger share in an expanding market, the producer is encouraged to adopt devices that promise to enable him to expand his output. This is a primary explanation of the boom in machine sales in periods of expanding prosperity. If competition, on the other hand, takes a form that necessitates close attention to the reduction of unit costs, the purchase of new machinery may not be encouraged but there is a strong stimulus to the search for procedures which most effectively utilize what machinery is at hand.

Industries with a localized market are shielded somewhat from intensive competition, and this may account in part for the slow mechanization of such localized industries as building and the manufacture of brick. We found several brick plants producing only for local markets that were still using quite antiquated methods. But, with increasing size of plants and increasing standardization of consumption, markets are widening and competition is probably growing keener, both as between producers of the same commodities and as between commodities. Radios and automobiles, for example, compete with food and clothing for greater shares of the consumers' income.

Increasing competition, however, does not always accelerate mechanization. If a new competitor arises with a differential advantage, such as a lower wage scale, the older producer may not modernize his plant as rapidly as technologically possible, for he and his bankers may hesitate to make investments in equipment in view of the uncertain future. It has been suggested that the backwardness of some of the New England cotton mills engaged in the production of plain grades of cloth may be due to the rising competition of the southern cotton mills.

On the whole, the pressure for mechanization is greatest when there is a large volume of new capital entering into

competition with the established plants. As stated by Mr. George E. Roberts:

"There is no competition so irrepressible as that of new capital with the old. The stream of new capital which is always coming upon the market is bound to force itself into employment somewhere, and it has an advantage over the old investments in being able to utilize the very latest offerings of science and invention. In these days, when the frontiers of scientific knowledge are being rapidly extended, when the facilities for research are daily increasing, and when improvements in industry are constantly producing a flow of new capital, it may be expected that the industrial pace will be faster in every succeeding decade" (Address before American Manufacturers' Association, December 26, 1927).

Thus the force of improved technology is cumulative, creating new capital which in turn brings pressure for further improvements.

We may sum up our discussion of the pecuniary factors by the somewhat obvious statement that the rapidity of invention and development of labor-saving machines varies directly with economic pressure. A few inventions may be the result of 'spontaneous combustion' but the adaptation of labor-saving devices is likely to proceed largely under pressure of a recognized need. If the employer finds the cost of a manual process rising, he will be stimulated to cast around for an automatic substitute, and mechanics will be hired directly or through specialized machine shops to work out the desired contrivances. Invention is becoming systematized.

Hence an increasing shortage of a given type of labor may be expected not only to bring available alternative mechanical devices into more common use, but also to stimulate the perfection of new devices.

#### PSYCHOLOGICAL FACTORS

To distinguish certain other factors from the technological and pecuniary difficulties, we use the term

'psychological', although it is none too accurate. These 'psychological' influences that affect the rate at which machines are introduced are many and diverse. For example, not infrequently overzealousness in pushing a machine in its early stages acts as a boomerang. When equipment is introduced before it has been technically perfected, where it is not suited to the particular requirements of the situation, or for which there is not an adequate amount of work to be done to make its use economical, the results may well be so unsatisfactory as to create a prejudice which retards its introduction even where its use would be distinctly economical.

Occasionally, also, there is opposition to a machine not only on the part of the workers directly involved but also on the part of the public, ordinarily expressed either through the press or legislation. In recent winters there has been some opposition voiced in the press to the use of machinery in snow cleaning, on the ground that unemployed men might do the work. Legislative restriction pertains chiefly to the use of equipment considered dangerous to the health of the workers. There has been, for example, some agitation to restrict the use of compressed-air guns in painting and regulations limiting their use have been put in force in several states. Also, in the current depression, some proposals have been advanced for the special taxation of automatic labor-saving machinery. But all the 'psychological' factors are not inimical to the progress of mechanization. Thus it is probable that sometimes the desire to reduce points of friction with workers leads an employer to "substitute docile machines for more vociferous units of human labor".

Also it doubtless happens frequently that pride in having as good equipment as competitors speeds up the process of mechanization and even leads to the use of machines

when alternative methods would be more economical. If one farmer plows with a tractor, his neighbor may imitate his example without full consideration of the pecuniary costs. It is in part this element of pride, of imitative action, that explains the waves of innovation characteristic of periods of active expansion in production.

#### ATTITUDE OF EMPLOYERS

The readiness with which a labor-saving device is introduced may be retarded by the slowness of executives in becoming cognizant of its merits; by a tendency, more or less inherent in human nature, to cling to old practices; and, in some instances, by a reluctance to make such reductions in labor force as may be necessary if an improvement in equipment is unaccompanied by a proportionate expansion in the market and increase in the total output of a plant.<sup>82</sup> Especially when a machine has been rather recently introduced, many entrepreneurs are inclined to wait for fuller demonstration before they themselves experiment with the new device. A great deal of educational work must

<sup>82</sup> For example, the manager of a rubber shoe plant explained that in half of his plant improved methods were in use but that he was awaiting an expansion of the market before changing the other half of the plant over to the new methods. The attitude of the employers in this case was probably influenced by the fact that the plant is in a rural community where the workers are almost entirely dependent upon the one plant for jobs.

An executive of a pencil factory stated that machines could be obtained for doing the packing work upon which considerable numbers of employees were engaged, but that they were not much faster; moreover, many of these workers were old employees whom he hesitated to discharge.

The sales manager of a power truck factory explained to our field representative that one reason they had had difficulty in getting their trucks installed in one of the cotton-handling docks was that the prevalent system was to let the handling contract out to small contractors who in turn hired a group of their friends to do the work. These small contractors did not wish to put in machinery and discharge their friends.

be done by those who attempt to introduce machinery that requires radical changes in method. Notably in the opinion of many observers there is a pronounced reluctance to hazard new methods in old industries that have been reasonably successful, and the management of which has continued in the hands of the same individuals or of the same family for long periods.

It has been suggested that the failure of executives to recognize quickly the merits of new improvements is especially pronounced with respect to improvements that are designed to decrease the expense of handling rather than of processing. Handling is ordinarily designated in factory accounting as 'unproductive' labor, and there seems to be some tendency for greater attention to be centered on the reduction of the costs of 'productive' labor.

#### LABOR OPPOSITION

The opposition of the worker to the advance of mechanization arises from an apprehension of its effect on his job. He fears it may oust him entirely or at least make serious inroads on his earnings. This hostility is likely to be especially keen when the machine threatens to destroy a substantial wage differential enjoyed by a group of skilled workers. On the other hand, the unskilled ditch digger, for example, threatened with the competition of the mechanical trencher, is not quite so likely to look upon the machine as depriving him of his best means of earning a livelihood. He may, rather, hope for a better job running the machine, or, at least, since his training is little specialized, he may expect to find elsewhere an equally good job. In any event, the unskilled worker is ordinarily not sufficiently well organized to make effective any antagonism he may feel.

The position taken by labor towards the introduction of



the machine has, in fact, varied over a wide range, from vigorous attempts to prevent its adoption and use, through discouraged indifference to its progress or acceptance qualified by restrictive control measures, to reluctant acquiescence, and, finally, to the stage of cooperation for efficiency where the worker not only acquiesces in but even helps to initiate innovations, with the hope of sharing in the resulting gains.

The actual measures designed to prevent the use of the machine may take the form of unorganized sabotage, treating the machine as a 'scab' and refusing to permit union members to operate it or endeavoring to boycott the machine-made products.<sup>83</sup> The union may make an indirect effort to prevent work going to machine plants by accepting wage reductions for hand workers. This was done in several instances in the glass trades. Sabotage probably occurs chiefly in the early stages of the introduction of a machine.<sup>84</sup> For example, when trucks have been introduced in dock handling, a few have been run into the harbor; and the introduction of the tying-in machine in cotton mills is said to have been retarded somewhat at first by occasional sabotage. On the whole, however, the impression received by the writer in numerous interviews with machine producers was that they do not consider sabotage a major factor in retarding the introduction of their products.

A refusal on the part of unions to permit their members

<sup>83</sup> For a discussion of the efforts of the cigarmakers to boycott machine-made cigars and in other ways to discourage the use of machines, see: John P. Troxell, *Machinery and the Cigarmakers*, *Quarterly Journal of Economics*, February 1934, pp. 338-47.

<sup>84</sup> One manufacturer of tiering machines reported to us that most of the workers' opposition to their machines took the form of minor sabotaging designed to discredit the machines. There were instances of repeated tinkering with the same machine, and one year when they kept an informal record, about 5 per cent of their installations were affected by some such sabotage.

to operate machines has rarely been effective for any considerable period. For example, when the machine was first being tried in the window-glass industry, the American Association of the four skilled window-glass trades passed resolutions clearly designed to prevent the window-glass manufacturers from introducing the machines, but by the time the machine was perfected and came to be of commercial importance, the four crafts had quarreled among themselves, and a great number of the cutters and flatteners had formed independent associations. These did not hesitate to sign up with the American Window Glass Company for the flattening and cutting of machine-made glass, and the hand workers soon found themselves under the necessity of accepting wage reductions in order that the hand industry might remain alive and compete with the machine producers.

From the standpoint both of their retarding influence and their effects on the position of the worker, measures designed directly to prevent the adoption of new machinery have probably been less important than the frequent measures designed to prescribe the conditions under which the machine may be used. Such restrictions have taken many forms—insistence that the former hand workers be employed as operators on the machine, limitations on the total output,<sup>85</sup> and stipulations that the size of the crew be not reduced and that the former level of earnings, or even, in extreme cases, the same piece rates as on hand work, be maintained.

<sup>85</sup> Barnett states that the use of the semiautomatic in the manufacture of small packers' jars, begun experimentally in 1891 in the Ripley factory, was discontinued because the Flint Glass Workers, who controlled the Ripley factory, insisted that the amount that might be made by a workman in a half day be fixed. The net result of the limit set was "that the machine labor cost was to be identical with the cost of hand manufacture" (Ref. 3, pp. 74, 143).

*Cooperation for efficiency*

When employer and employee can cooperate unreservedly for efficiency, conditions are highly favorable for rapid progress in mechanization and in efficiency in general. That goal may be far distant, but in recent years various steps have been taken towards it. The B & O plan has indicated some of the possibilities in cooperation for efficiency; the job severance compensation provision in a few trade agreements provides another method of lessening the worker's dread of the effects of increasing efficiency;<sup>36</sup> and finally, the so-called 'new wage statement' of the American Federation of Labor in 1925 indicated, to say the least, a growing recognition of the importance of productivity. In its convention at Atlantic City in 1925, the Federation approved a report by its Executive Council in which was formulated what was hailed in the contemporary press comment as a "new policy to meet the 'superpower' age". The essential features were a declaration that

"the best interests of wage earners as well as the whole social group are served by increasing production in quality as well as quantity and by high wage standards which assure sustained purchasing power to the workers . . ."

This statement was accompanied by a recommendation of "cooperation in study of waste in production".<sup>37</sup> This is, in

<sup>36</sup> Any policy that so arranges a change that the workers are not reduced in earning power should tend to lessen their opposition. There has been, for example, considerable development in this respect in the clothing industry. See article by W. G. Haber in *Journal of Political Economy*, August 1925; also agreement made between Hart Schaffner and Marx and the Chicago Joint Board of Amalgamated Clothing Workers for compensation to cutters displaced as the result of improved methods instituted by the company; *Unemployment in the United States*, Hearings before the Senate Committee on Education and Labor, 70th Cong., 2d Sess., p. 241.

<sup>37</sup> *Proceedings of the 45th Annual Convention, American Federation of Labor*, Monday morning session, pp. 231-3, 271.

essence, a declaration that labor should strive both to gain a just share in the advantages accruing from this era of power development and the constant substitution of mechanical for manual labor in industry and to cooperate with employers in increasing this advantage by studying wastes in production.

This resolution pointed the way to a constructive solution and gave some promise of a lessening in the opposition of labor to industrial change. To the degree that the policy of cooperation for efficiency becomes effective in the conduct of union activities it tends to lower the barrier that each innovation must hurdle. How high is this hurdle? How effective is labor opposition to new methods?

#### *Effectiveness of workers' opposition*

In summarizing his studies of the introduction of machinery in the stone planing and glass industries, Professor George E. Barnett states:

"Experience has convinced the greater part of well-informed trade union leaders that the introduction of important labor-saving machinery cannot be permanently halted by trade union action" (Ref. 3, p. 141).

However, speaking of the opposition to the introduction of the stone-planer and of the attempt of the Flint Glass Workers' Union of America to stop the introduction of the semiautomatic bottle machine, Barnett concludes "that the opposition of these unions did retard the introduction of the machines is undoubted".<sup>88</sup> The general conclusions of these two quotations are borne out by the history of the introduction of other machines. In general, opposition is rarely if ever permanently effective, but probably in many instances it has some retarding influence. The press assistants'

<sup>88</sup> Ref. 3, p. 144.

union in the commercial printing industry in New York City is strongly entrenched, and Dr. Baker (Ref. 5) reaches the conclusion that "their bargaining power has been a retarding factor in the displacement of their men"; but despite their strength the press assistants lost 3.2 men to each 100 presses in the five-year period ended in the winter of 1928-29. When the undercutting machine was introduced in the coal mining industry, the union restricted its use by setting a machine differential and limiting the loaders, but W. E. Atkins and H. D. Lasswell say:

"the machines were invincible; their use has steadily increased even in the union districts until most of the coal is today machine mined."<sup>89</sup>

The effectiveness of labor opposition varies with the strength of the union. This is one reason assigned for the slow introduction of improved machinery in the British cotton mills. As stated in the 1930 "Cotton Report",

"One important reason why the question of improved methods and equipment has not received adequate examination . . . is that such improvements necessitate adjustment of hardly won and long-established agreements between employers and employed" (*Report of the Subcommittee of Civil Research*, published as supplement to the *Manchester Guardian*, July 5, 1930).

Conditions relatively favorable for effective opposition to technological change are found where there is a strong local union in a localized industry. For example, R. E. Montgomery, in his study of *Industrial Relations in the Chicago Building Trades* (p. 154), concludes:

"It is not improbable that throughout industry in general wage-earners are coming to regard opposition to technological change as being, in the long run, futile. But this attitude will be long in penetrating the Chicago construction locals. The essentially localized character of the industry is likely to mean that the workers will be in a position to enforce, to an extent

<sup>89</sup> *Labor Attitudes and Problems*, pp. 38-9.

See Table 40 for the growth and present extent of machine undercutting.

at least, their own demands regarding the use of machinery and the doing of work on the job instead of in the shop for some time after such opposition has—if it ever does—become a discarded part of the program of unionism in general.”

On the other hand, in local operations such as highway construction, where there are no strong union organizations, it is probable that the highway contractor experiences little effective labor opposition to the introduction of new machinery, because he does not have a more or less fixed labor force with a feeling of vested interest in their jobs.

Opposition to the introduction of machinery, even if not completely or permanently effective, may result in deflecting the line of technological development. An illustration is found in the difference between the English and American cotton mills with respect to the speeds at which looms are ordinarily run. In England union opposition to the automatic loom has made it difficult for manufacturers to increase the number of looms per weaver as has been done in the United States, but they have made up for this in part by running the looms at higher speeds than are customary in the United States. Another probable effect of union opposition is to stiffen the resistance of employers to recognition of the union. The rules regulating the use of undercutting machines in coal mining have been one of the reasons assigned for the fact that the newer mining fields of West Virginia, Alabama and Colorado are predominantly non-union.<sup>40</sup>

#### *Methods of lessening opposition*

The natural opposition of workers to technological change may be lessened by a twofold process of education, that is, by educating the workers to see clearly the ultimate gains

<sup>40</sup> W. E. Atkins and H. D. Lasswell, *op. cit.*, pp. 38-9.

from improved efficiency, and by educating the public and the employer to recognize the importance of so managing a change that its immediate effects on the worker are not adverse. Care to see that, where feasible, a displaced worker is assigned other equally satisfactory work in the same organization; care to make changes chiefly when markets are expanding; provision for compensation for those who cannot be retained in the organization after changes are made; provision for reeducation of workers in declining trades; the revision of wage scales so that the worker shares in the gains—these are steps which should lessen the opposition to technological improvements.<sup>41</sup> Likewise, the movement for a shorter day or week is closely associated in the mind of the worker with the effect of technological improvements. For example, in the discussion of the 'new policy' of the American Federation of Labor in its 1925 convention, some apprehension of the danger that improved efficiency would increase unemployment was evident, and the desirability of offsetting this tendency by shorter hours was emphasized. This point of view was voiced by Delegate Lynch of the International Typographical Union and reiterated by him in an editorial in the *American Federationist* (Vol. 33, 1926, p. 292) in the phrase, "continual shortening of the working day is the only practical plan for solving this problem". In fact, in recent years the emphasis in the labor press has been upon the danger of machine-made unemployment, and the necessity of shortening the working day and week as an essential step in spreading a decreasing volume of work, rather than upon the possibilities of increasing pro-

<sup>41</sup> See a short article by O. S. Beyer, Jr. in *Factory* (February 1926, pp. 266-7), citing constructive measures which facilitated the introduction of machine molding, the substitution of welding for riveting, and the use of larger locomotives, by enabling the workers affected to maintain or even increase their earnings.

ductivity through labor-management cooperation in joint research for waste reduction and improved efficiency.

#### SUMMARY

The primary factors that retard or hasten the development of new machinery and technique are technological difficulties, pecuniary considerations and mental attitudes not entirely determined by pecuniary considerations. Of the many factors listed in these three groups, which are of special interest to our present problem? Which may be considered as declining or increasing in influence? What is the net tendency?

Generalization concerning technological difficulties is hazardous, but with the larger stock of scientific knowledge and increasing attention to industrial research evidenced in recent decades, it would appear probable that technical difficulties will be hurdled with greater and greater ease.

A pecuniary factor favoring further mechanization in the future is the drive for standardization and the apparent tendency in some industries for continued concentration into larger units.

The psychological factors are even more difficult to weigh. On the one hand is the encouraging influence of some successful examples of cooperation for efficiency and the announcement by the American Federation of Labor of the 'new wage statement' in 1925. As the technique of cooperation develops this 'new policy' should become more and more effective. On the other hand, in recent years there has been a growing emphasis on the existence, real or fancied, of a great volume of technological unemployment. That this will tend to stiffen the resistance to technological changes is quite probable.

The net balance of the changing importance of the



favorable and unfavorable factors is, in the judgment of the writer, on the side of a renewal of the trend towards higher mechanization, at a moderate rate at least, when prosperity returns and where there is still considerable room for further reduction of manual operations. A major consideration leading to this conclusion is that the increasing mechanization and emphasis on efficiency in the post-War decade has given such an impetus to the search for new methods and the adoption of tried devices that the movement may be expected to continue of its own momentum even if other conditions are not predominantly favorable. The adoption of machinery in one process leads to the mechanization of complementary processes; the installation of machinery by one user leads to its adoption by others.

## CHAPTER X

### THE EFFECTS OF MECHANIZATION

IN APPRAISING the effects of mechanization it must be kept in mind that we are not here considering contrasts between modern mechanized methods and handicraft methods of earlier centuries or in distant and undeveloped countries. We are asking, rather, what are the effects of further mechanization here and now in industries most of which are already in a relatively advanced stage of mechanization.

Our primary concern in this study is with the effects upon the quantity of labor required in industrial processes. It is pertinent, however, to inquire also into the other effects of mechanization, for these other effects, aside from their general industrial and social significance, are important factors in determining the rapidity with which mechanized processes are introduced. To cite one example: to the extent that spray-gun painting is believed to be harmful to the worker, it involves expense for protective devices and may arouse legislative or union action to curtail its use. To the extent that it is believed to save material or result in a better job of painting, its use is encouraged. Similar examples could be multiplied indefinitely.

#### EFFECTS UPON THE QUANTITY OF LABOR

In analyzing the effect of labor-saving changes upon the quantity of labor required, the major questions, in order of their consideration in this chapter, are: (1) What are the typical reductions in crew arising from various devices

mentioned in previous chapters? (2) Can the total labor-saving effect of some be estimated, either for the aggregate number of total installations already made, or even of the possible total effect if more or less completely introduced in the sphere of work for which they are adapted? (3) What may we learn by summarizing the labor-saving changes reported to us by factory executives? Do these suggest that the typical change affects many or few men? And is there ordinarily a marked difference between labor-saving effects when we measure only the actual reductions in crew or when we also allow for any increase in the total output of the crew? (4) Turning to the more comprehensive statistics of employment and occupations, what estimates have been made of the total effect of all sorts of technical improvements in the decade of the 'twenties—what estimates, in other words, as to how much of the total change in employment can be ascribed to improvements in productivity, whatever the cause, and how much to changes in the total volume of output? (5) Passing to the more human side of the problem, is there reason to believe that the increasing use of machines not only reduces the amount of labor required for a given volume of production but also that it causes at least temporary unemployment of the individual worker? What evidence upon this question of technological unemployment is afforded by the several studies that have been made of employment histories of individual workers, or of the unemployment in the total membership of given trades or occupations? Does the available evidence suggest that the typical effect of technological improvements is at least a temporary increase in the volume of unemployment? (6) Are the arguments and evidence for the alleged tendency of the machine to create a permanent increase in the volume of unemployment adequate and convincing?

Not all of these questions were subjects of direct inquiry

in the field phase of our survey. We did not attempt, for example, to trace the subsequent employment histories of the men displaced by changes in the factories inspected. Nor is the evidence from any source adequate for a convincing answer to some of these questions. It is pertinent to our problem, however, to indicate the nature and purport of such evidence as is available.

#### SELECTED MACHINES

An attempt at anything approaching a complete enumeration of labor-saving improvements is impracticable and unnecessary. A relatively small number of illustrations must suffice. The reductions stated are in most instances only in the crew on the specified operation, not for the total labor force of the plant (unless so designated), and refer to the effect upon the labor directly required, with no allowance for indirect effects such as a possible increase in repair or supervisory labor.<sup>1</sup> The citations in parentheses are to the numbered references in Appendix D.

In agriculture, the harvester-thresher combine is estimated to reduce the labor required for harvesting and threshing wheat 84 per cent as compared with the use of binders and stationary threshers; and 80 per cent as compared with the use of headers and stationary threshers.<sup>2</sup> In the mining of bituminous coal, mechanical loading devices are estimated to reduce the labor in loading some 25 to 50 per cent.<sup>3</sup> A similar reduction was accomplished in

<sup>1</sup> Cf. discussion, in Ch. II, of 'productivity', 'labor displacement' and the 'labor-saving ratio'. For additional examples of reductions in labor required, see Ref. 61.

<sup>2</sup> R. A. Reynoldson, *et al.*, *The Combined Harvester Thresher in the Great Plains*, U. S. Department of Agriculture, Technical Bulletin No. 70 (1928), p. 23.

<sup>3</sup> Ref. 2, p. 35. For 4 mines with fully mechanized loading, the Bureau of

the labor required to deliver materials to the paver in highway construction when central proportioning plants replaced the roadside dump and wheelbarrow proportioning method.<sup>4</sup> The finishing machine for cement highways is estimated to save from 2 to 7 men, or 40 to 60 per cent of the labor on finishing. In the painting of buildings, where the paint-spray gun can be used, it is credited with a capacity to reduce the labor required from 80 to 85 per cent (Haber, Ref. 13, p. 43). In the field of commercial amusements, the introduction of the 'talkie' with synchronized musical score reduced the employment of musicians in the moving picture theaters about 50 per cent (Ch. IV, and Ref. 44 and 46).

Passing to the handling phase of the manufacturing industries, we find that the electric storage battery trucks introduced by our informants eliminated on the average about 3 men per machine. Savings by other types of handling equipment are also very important but cannot be as readily reduced to significant statements of average effects.

For the processing operations in manufacturing, numerous examples may be cited. In two factories reporting to us labor savings by the introduction of the cigar machine, the reduction was 50 to 60 per cent.<sup>5</sup> In window glass manufacture, the cylinder machine reduced the labor cost in dollars about 57 per cent for single-strength glass and about 42 for double-strength; the Fourcault sheet machine, about 62 per cent for single and 56 for double (B.L.S., Ref. 36, p. 159). In the glass bottle industry, the semiautomatic machine, compared with the most efficient hand process,

Labor Statistics found the reduction in labor required to be nearly 40 per cent when mechanical loading methods were introduced (Ref. 63, pp. 267-8).

<sup>4</sup> From information obtained by us from users of the given method or machine.

<sup>5</sup> About the same labor reduction ratio is ascribed to the cigar machine by Mary Anderson, Director, Women's Bureau, U. S. Department of Labor, in *When Machines Make Cigars*, *American Federationist*, 1932, pp. 1375-81.

accomplished a reduction of from 29 to 71 per cent, and the automatic machine from 86 to 97 (B.L.S., Ref. 36, pp. 49-54). For the pressed-ware branch, the most efficient machine for various selected types effects a reduction of from 80 to 92 per cent; in the blown-ware branch, of from 30 to 97 (B.L.S., Ref. 36, p. 7). In the foundry industry, the instances coming to our attention indicated a saving of from 3 to 4 men by the installations of sand-cutting and mixing equipment, and of from 4 to 5 men by molding machines of the roll-over and sand-slinging type. In cotton cloth manufacture, the automatic looms seem to require a crew about two-thirds as large as that needed for non-automatic.\* The warp-tying machine was credited by our informants with a reduction of from 10 to 15 workers per machine; the drawing-in machine with from 3 to 5. The high speed spooler and warper combination apparently saves about 50 to 55 per cent of the labor required in the warping operation (Ch. III). In the commercial printing industry, Dr. Baker found that "the automatic feeder accelerates the speed of printing some 20 per cent—to 1,200 to 1,300 impressions per hour as compared with some 1,000 by hand" (Baker, Ref. 5, p. 447). In the small group of establishments in the clothing industry surveyed by us, machines reduced the labor involved in pressing by from 50 to 60 per cent. In his survey of a group of representative automobile tire plants, Boris Stern found that the change from regular mixing mills to Banbury mixers reduced labor requirements in the mixing and compounding divisions about one-half; and in tube manufacture, "the man-hour output of the watchcase method is over four times that of the pot heaters", nevertheless, the transition to the watch-

\* Based upon a comparison of the looms per weaver in 5 non-automatic and 8 automatic-loom mills producing substantially similar types of cloth.

case system has been very slow because of the expense of scrapping the old equipment.<sup>7</sup>

In compiling the above illustrations we have selected equipment changes of substantial labor-saving significance but have tried to avoid exceptional and spectacular instances which are likely to create an exaggerated impression of the actual or potential labor saving. In this way we hope to make the estimates fairly representative of what may be expected in the ordinary run of installations. Even so, these estimates should not be interpreted as purporting to have the precision essential as a guide, for example, to the wheat grower who is considering whether to purchase a combine, or the manufacturer who is weighing the relative advantages of hand-power and electric trucks for indoor haulage. Such decisions require intimate knowledge of the special conditions pertaining to the particular establishment. What we have endeavored to give are the best possible estimates of average tendencies—estimates which may be used for reasonably accurate approximations of the probable effects of a relatively widespread adoption of the given device.

#### *Total installations*<sup>8</sup>

We have just cited examples of the approximate typical reduction in labor ascribable to selected types of labor-saving machines. Many of these types do not lend themselves to an estimate of their total effect, but some suggestion of the aggregate influence may be afforded by estimates for a selected few. Taking the number of units installed by the

<sup>7</sup> U. S. Bureau of Labor Statistics, Bul. 585, *Labor Productivity in the Automobile Tire Industry*, 1933, pp. 41, 60.

<sup>8</sup> For estimates of constructive displacement in various industries arising from the combined effect of all changes affecting productivity see subsequent section, *Aggregate Constructive Displacement*.

specified date, and multiplying this number by the approximate average number of men displaced per unit, we reach estimates that the 12,000 electric trucks in use in June 1928 represent the constructive displacement of about 36,000 men; the cigar-making machines installed by the close of 1929, 16,800 workers, the 900 warp-tying machines, 10,800, and the 140 sandslinging machines about 700.\*

These estimates are, of course, for constructive rather than actual displacement. That is, if the industry has expanded, they merely represent jobs that might otherwise have been filled by additions to the number of manual workers. If the industry has not expanded in total output, they presumably indicate an actual reduction in the number of workers employed on the operations upon which the machine is used.

#### *Potential further displacement*

In the immediately preceding paragraphs, we have presented estimates of the constructive man-power displacement of the aggregate installations of various machines.

\* In view of the fact that the discussion of the labor-saving qualities of selected machines in the immediately preceding paragraphs, and of total installations in this section, runs in terms of the reductions in operating workers on the immediate processes affected, it may well be reiterated at this point that labor saving in one process may increase the demand for other kinds of labor—in the making of machines and their repair and maintenance, and in still more indirect ways. See, for example, the distinctions in Ch. II between 'operating, auxiliary, embodied, and indirectly required labor'. These indirect effects give rise to differences in the appraisal of the result of a given change according to whether the unit considered is merely the single process, the plant as a whole, manufacturing industry as a whole (including the production of the machine), or even the entire industrial process from the acquisition of the raw material to the placing of the finished goods in the hands of the consumer. See Ch. VI for discussion of the labor involved in the production of machines.



Estimates of potential additional displacement are much more difficult. However, one or two tentative approximations may be of interest as suggesting a type of estimate that may become of increasing usefulness as our knowledge of industrial organization, occupational distribution and mechanization procedure becomes more adequate as a basis for the appraisal of future developments.

A combination of machines known as the 'automatic spooler and high speed warper' has been introduced in some cotton mills as a substitute for older and slower types of machine for the warping and spooling processes. About 7 per cent of the labor force in the cotton mills included in our survey were engaged in these processes. The labor reduction attributable to the new machine we estimate to be about 50 per cent (see Ch. III). If we assume that in about one-fifth of the mills these machines have already been introduced or cannot be used to advantage, we reach an estimate that a general introduction of the 'automatic spooler and high speed warper' would accomplish a further labor reduction of about 2.8 per cent of the total mill force, or some 12,500 workers for the industry as a whole.

This illustration is relatively unimportant in itself but it serves to call attention to the type of information needed as a basis for a reasonable approximation of the labor displacement to be expected upon general adoption of a new machine—the number of persons in the occupation affected, the reduction ratio attributable to the machine, and the percentage of plants in which the use<sup>o</sup> of the machine is feasible.

#### LABOR REDUCTIONS IN THE PLANTS SURVEYED

Summaries of the labor-saving changes reported to us are presented in Tables 34 and 35. In Table 34, the classifica-

tion is by number of men saved per plant; in Table 35 by the number of men saved per reported change. In each table the data are presented on two bases, the second giving a constructive rather than an actual displacement.

In popular discussion of labor saving, attention is apt to be centered only on the spectacular instances of large reductions. These are, of course, important, but it is also noteworthy that in nearly two-thirds of the 356 instances of labor saving tabulated in Table 35, the crew reductions were less than 10 men.<sup>10</sup> Even on the plant basis (Table 34) it is still true that over half of the reported changes effected reductions of less than 10 men. It would appear that a substantial part of the total reductions of labor requirements in an industry takes place by this gradual process of nibbling away at the size of the staff required.<sup>11</sup>

Substantial differences between the results derived on Basis A and on Basis B will be noted. The total number of men reported as 'saved' by the 356 labor-saving changes is 5,572 if no allowance is made for increased output but rises

<sup>10</sup> The importance of relatively small but numerous changes in method is stressed by Boris Stern, who has devoted several years to the conduct of productivity studies for the Bureau of Labor Statistics (see *American Statistical Association Journal*, March 1933, *Supplement*, p. 42). In the electric lamp industry, for example, the minor changes are probably more important in the aggregate than the relatively few major changes (Ref. 65, p. 1216). Even in the tire industry, while there have been some revolutionary changes, notably the introduction of the flat-drum process in 1926, "the increased productivity of labor was due more to the so-called evolutionary small changes in production than to any revolutionary change in the process of tire manufacturing" (Ref. 62, p. 1264).

<sup>11</sup> The number of men saved and the total labor force in the reporting plants could be compared but we do not believe this comparison should be stressed too much, for certainly in some plants not all the labor-saving changes actually made were reported. In Group I the reported savings were equal to 4.6 per cent of the total labor force if no allowance is made for increased output, or 5.1 with such allowance. The corresponding percentages for Group II are 3.0 and 8.6 respectively.

TABLE 34

REPORTED LABOR SAVINGS, CLASSIFIED BY NUMBER OF MEN  
SAVED PER PLANT<sup>1</sup>

*All changes reported for a single plant combined and counted as one change  
Basis A: no allowance made for increase in total output of crew*

NUMBER OF MEN SAVED	NUMBER OF CASES			TOTAL NUMBER OF MEN SAVED		
	ALL	GROUP	GROUP	ALL	GROUP	GROUP
	GROUPS	I	II	GROUPS	I	II
Total, all plants	246	177	69	5574	4117	1457
Under 10 men	132	93	39	498	365	133
10 to 19 men	50	41	9	686	568	118
20 to 49 men	40	29	11	1135	842	293
50 to 99 men	15	8	7	916	485	431
100 or more men	9	6	3	2339	1857	482

<sup>1</sup> See footnotes to Table 35 for sources of data in this table.

to approximately 8,633 if such allowance is made. The former figure represents the immediate impact of the changes on the crews; the latter figure gives a more complete indication of the probable effects on labor requirements in the industries as a whole. One plant may introduce a labor-saving device, but, by capturing a larger share of the market and increasing its total output, may avoid reducing the crew; obviously, however, this cannot be done in all plants in the industry unless there is an increase in the total market for the given product.

AGGREGATE CONSTRUCTIVE DISPLACEMENT IN  
SELECTED INDUSTRIES

We have cited examples of the labor saving per unit for various machines, and for some, estimated the labor displacement attributable to the aggregate installations made; also, we have noted the extent of labor-saving changes re-

TABLE 34 (cont.)

REPORTED LABOR SAVINGS, CLASSIFIED BY NUMBER OF MEN  
SAVED PER PLANT

*All changes reported for a single plant combined and counted as one change*

*Basis B: allowance made for increase in total output of crew*

NUMBER OF CASES			TOTAL			NUMBER OF MEN SAVED
ALL GROUPS	GROUP I	GROUP II	ALL GROUPS	GROUP I	GROUP II	
246	177	69	8625	4363	4262	Total, all plants
123	92	31	500	370	130	Under 10 men
49	39	10	661	539	122	10 to 19 men
43	30	13	1286	889	397	20 to 49 men
16	9	7	1015	541	474	50 to 99 men
15	7	8	5163	2024	3139	100 or more men

ported by the establishments included in our survey; but it is obvious that because of the diversity in form and effect of labor-saving changes, not to mention the lack of detailed information for a great many types, it is impossible to build up from the estimates of the effect of individual types of machine anything approaching a close estimate of the aggregate effects of the totality of labor-saving changes in any given period. We must resort to an analysis of the data for total employment and total output by industries in order to secure a rough approximation of the joint effect of the aggregate of forces which in the post-War period have been brought to bear upon the industrial utilization of human labor.

Estimates of constructive displacement will vary according to whether we make comparisons on a fixed base year or from year to year, and also whether we estimate the displacement by applying the differential between current and base-year productivity rates to the current-year output or to

TABLE 35

REPORTED LABOR SAVINGS, CLASSIFIED BY NUMBER OF MEN  
SAVED PER INDIVIDUAL CHANGE<sup>1</sup>

*Basis A: no allowance made for increase in total output of crew*

NUMBER OF MEN SAVED	NUMBER OF CASES			TOTAL NUMBER OF MEN SAVED		
	ALL	GROUP	GROUP	ALL	GROUP	GROUP
	GROUPS	I <sup>2</sup>	II <sup>2</sup>	GROUPS	I	II
Total, all cases	356	287	69	5572	4115	1457
Under 10 men	219	180	39	928	795	133
10 to 19 men	75	66	9	1031	913	118
20 to 49 men	40	29	11	1172	879	293
50 to 99 men	13	6	7	807	376	431
100 or more men	9	6	3	1634	1152	482

<sup>1</sup> If a plant reported more than one labor-saving change, the changes have not been combined but are treated as separate instances. Part A represents the results in the way of reduction in the size of crew, when no allowance is made for change in the crew output. Part B represents the difference between the crew at the time of reporting and the crew that would have been required under the former method to equal the output of the actual crew under the new method.

the base-year output. Combinations of these alternatives give us four basic methods of estimate:<sup>12</sup>

<sup>12</sup> We may state these four methods algebraically thus:

$$\text{Method A: } T = P_1 (L_1 - L_0)$$

$$\text{Method B: } T = P_0 (L_1 - L_0)$$

$$\text{Method C: } T = \Sigma [P_1 (L_1 - L_0)]$$

$$\text{Method D: } T = \Sigma [P_0 (L_1 - L_0)]$$

Where,

T = the constructive technological change in the volume of employment (expressed in number of workers or man-years, man-weeks, man-days, or man-hours, as the case may be).

P<sub>1</sub> = total output in physical units in the current year; P<sub>0</sub>, in the base year.

L<sub>1</sub> = the labor requirement ratio in the current year (labor per unit of output); L<sub>0</sub>, in the base year.

TABLE 35 (cont.)

REPORTED LABOR SAVINGS, CLASSIFIED BY NUMBER OF MEN  
SAVED PER INDIVIDUAL CHANGE*Basis B: allowance made for increase in total output of crew*

NUMBER OF CASES			TOTAL NUMBER OF MEN SAVED			NUMBER OF MEN SAVED
ALL GROUPS	GROUP I	GROUP II	ALL GROUPS	GROUP I	GROUP II	
356	287	69	8633	4371	4262	Total, all cases
210	179	31	936	806	130	Under 10 men
73	63	10	990	868	122	10 to 19 men
46	33	13	1566	1169	397	20 to 49 men
13	6	7	850	376	474	50 to 99 men
14	6	8	4291	1152	3139	100 or more men

\* Group I represents chiefly inspections (with a few mail inquiries) made in the summer of 1925. Group II represents replies to an inquiry made by mail in 1928. In Group I an effort was made to obtain all labor-saving changes. In Group II, only "the single change made since 1920 which resulted in the greatest saving of labor" was asked for.

*Method A, the fixed-base, current-year-output method,*

answers the question: How much less labor did it require to produce the current output than would be required at the productivity rate of the base year?

*Method B, the fixed-base, base-year-output method,*

answers the question: How much less labor would be required to produce the base-year output at the current productivity rate than actually was required at the base-year productivity rate?

*Method C, the year-to-year, current-year-output method,*

answers the question: What is the cumulative constructive displacement when the displacement for each year is com-

puted by multiplying the current year output by the differential between the labor requirement ratios of the current and the immediately preceding year?

*Method D, the year-to-year, preceding-year-output method,* answers the question: What is the cumulative constructive displacement when the displacement for each year is computed by multiplying the output of the preceding year by the differential between the labor requirement ratios of the current and the immediately preceding year?

A simple hypothetical example may help to make clearer the differences in these four methods. Assume that in 1927 an industry employing on the average 100 workers had an output of 1,000 units and hence a labor requirement ratio of 0.1 worker per unit. The corresponding data for 1928 are 100 workers, 2,000 units of output, and a labor-requirement ratio of 0.05 workers per unit; and for 1929, 150 workers, 6,000 units of output and a labor-requirement ratio of 0.025 workers per unit.

Under the conditions assumed, the constructive labor displacement in 1929 is 450 if the differential in 1927 and 1929 in the labor-requirement ratios is applied to the 1929 output (Method A), but only 75 if it is applied to the 1927 output (Method B). But if the year-to-year method is applied by first estimating the displacement from 1927 to 1928, and then from 1928 to 1929, and cumulating the two results, the displacement is 250 if the labor-requirement differential is applied to the current year output in each instance (Method C), but only 100 if it is applied to the preceding year output (Method D).

If there have been changes in the length of the working week or working day in the period covered, their effect is

included with the other forces determining the labor-requirement ratio.

Which of these four methods is most logical? Ordinarily the year-to-year method is preferable and nearer to reality than comparisons with a distant base. In the first place, the year-to-year changes in employment due to technological improvements are probably more important than the relatively long-time or possibly permanent displacement effects.<sup>13</sup> Furthermore, the significance of estimates of the constructive displacement of labor is obscured by any degree of interdependence between changes in total output and in productivity rates. If total output and productivity are independent of each other over a long period, then the fixed-base method may be reasonably accurate; but if, as is more often true, the trend in the total output of the industry is in part both effect and cause of changes in the rate of productivity, then of the two methods, the comparisons with the preceding year as a base are the less likely to be distorted by the interdependence of changes in total output and in productivity rates.<sup>14</sup>

Also, when using the year-to-year method the arguments for applying the labor-requirement differential to the output of the current year are in most instances more cogent than those for applying it to the preceding year output. As suggested by the Bureau of Labor Statistics, "in the larger industries, such as the electric-lamp industry, the volume of production in any given year is determined primarily, not by any decrease in labor cost during the year, but by the actual or estimated demand for the product".<sup>15</sup>

When we turn to the available estimates of constructive

<sup>13</sup> Cf. discussion of the Volume of Permanent Unemployment in a subsequent paragraph.

<sup>14</sup> Cf. B. L. S., Bul. 585, p. 15.

<sup>15</sup> Ref. 65, p. 1220.



displacement in the several industries we find no one of these methods used exclusively, although resort is had most frequently to Method A, that is, to estimates of the greater amount of labor that would be required to produce the current output at the productivity rate of some one earlier year.

Thus it is estimated that in 1929, 16,797 more workers would have been required in the cigar industry if the machine output of that year had been made by hand.<sup>16</sup> In the Bell telephone system, because of expanding volume of business, the number of operators actually increased from 118,470 in 1921 to 143,979 in 1930 despite the increase in the number of stations served by dial telephones; but it is estimated that 69,421 additional operators would have been required to handle the 1930 volume of business at the 1921 output-per-operator rate.<sup>17</sup> The volume of business handled in 1931 by 8,460 operators with the printer telegraph in 'functional' offices of the commercial branch of the telegraph industry would have required 16,926 Morse manual operators or approximately twice as many.<sup>18</sup> Likewise, it is estimated that the work of the printer operators in the principal news agencies in 1931 was equivalent to only 243 full-time positions, and that to operate these and the 2,317 receiving positions which they serve, with a complete Morse manual system, would require 3,737 Morse operators.<sup>19</sup> The number of employment opportunities lost, 1924-1929, because of the installation of automatic signals on grade crossings is estimated at 39,258, and the constructive displacement ascribable to grade separations at 2,631 workers.<sup>20</sup>

<sup>16</sup> B. L. S., Ref. 47, p. 1277.

<sup>17</sup> B. L. S., Ref. 50, p. 243.

<sup>18</sup> B. L. S., Ref. 51, p. 510.

<sup>19</sup> B. L. S., Ref. 52.

<sup>20</sup> B. L. S., Ref. 53, p. 766.

All the above estimates are obtained by applying the differential in labor requirements to the current output, and are expressly or by implication comparisons on a fixed base. Estimates for the postal service and agriculture illustrate the second method of estimate—computations of the constructive reduction in the labor required to produce the base-year output if current productivity rates are applied. By 1929 the efficiency of the postal service had increased so much since 1908 that the output of that year (1908) could have been handled with 193,093 less full-time workers, or a loss of 41.5 per cent.<sup>21</sup> The Bureau of Labor Statistics estimates a constructive technological labor displacement in agriculture of 2,530,000 workers, 1919–27, offset by sufficient increase in the total output so that the actual decline was only about 800,000.<sup>22</sup>

In electric-lamp assembly plants, the total reduction in full-time workers ascribable to improvements in productivity, 1920–29, is estimated as 22,931 by direct comparison between the two years, 1920 and 1929, but only 14,787 if computed on the year-to-year basis.<sup>23</sup>

The application of all four methods of estimating constructive displacement may be illustrated with the aid of data in the above-mentioned study of the tire industry by Boris Stern. The statistics cover output and man-hours, 1922–31, in six representative plants producing from 45 to 60 per cent of the total output of pneumatic tires in this country in those years. Direct comparisons between 1922 and 1929 indicate a constructive displacement of 35,888 workers if the labor-requirement differential between these two years is applied to the 1929 output, but only 13,215 if applied to the 1922 output. If constructive displacement is

<sup>21</sup> B. L. S., Ref. 59, p. 759.

<sup>22</sup> B. L. S., Ref. 45, pp. 778–9.

<sup>23</sup> B. L. S., Ref. 65, p. 1219.

computed for each year in comparison with the preceding year, and the results cumulated for the years 1922-29, we reach an estimate of 23,826 men displaced if the differential in productivity is applied to the current-year output in each instance, but only 20,684 if it is applied to the previous year output. The divergence in the results obtained by the four methods is substantial for an industry like the manufacture of tires which has been changing rapidly in total volume and output per worker or man-hour.

For manufacturing as a whole David Weintraub estimates that in the period 1920-29, 32 men out of each 100 required in 1920 were made unnecessary by increases in output per man, but of that number increases in the total output absorbed 27 (Ref. 23). Using the year-to-year method and summing for the period 1920-29, his estimates indicate that improvements in efficiency in this period had displaced 2,832,000 men or 416,000 more than had been reabsorbed into manufacturing by shortening the working week and increases in total output. Likewise for Class I steam railroads, 1920-29, Weintraub estimates, using the year-to-year method, that 345,000 workers "were displaced by increased technological and managerial efficiency". The corresponding technological displacement in the bituminous and anthracite industries he places at 95,000. For all four of these major industries—manufacturing, Class I railroads, bituminous and anthracite coal mining—Weintraub estimates a decline, 1920-29, arising from changes in productivity, of 3,272,000; meanwhile, 2,269,000 more men were required to handle the increases in the physical volume of output, leaving a net decline in employment in these industries of 1,003,000.<sup>24</sup>

These estimates afford a striking illustration of the wide-

<sup>24</sup> The effects of shortening the working week are lumped with the effects of factors increasing the productivity per hour, but the decline in the length of the working week was relatively small in the years 1920-29.

spread effect of improvements in efficiency in the 'twenties. However, to avoid a possible misinterpretation of their significance it must be noted that they tell us nothing about what part of the constructive gains ascribed to changes in productivity arise from (a) new equipment, (b) chemical and other non-mechanical changes in processing, (c) the elimination of inefficient plants, personnel economies facilitated by mergers or by better organization and management in any respect, (d) improvements in the skill or energy of the workers.

Estimates of constructive displacement, or even estimates of the actual net change in employment resulting from the combined effects of technological change and expansion or contraction in specified industries, do not indicate whether the identical workers who were made unnecessary by gains in efficiency are those who have been absorbed by increases in output. Furthermore, they do not explain to what extent changes in employment have absorbed the increases in population of working age. Nor do they tell us to what extent and how quickly the net losses in manufacturing, railroading and mining have been offset by the expansion of other occupations such as the distribution and service industries.

#### CONDITIONS FAVORABLE TO A LAG IN ABSORPTION

There is, in fact, considerable evidence to indicate a substantial lag in the absorption by industry of workers displaced by improvements in technique.

Weintraub estimates for manufacturing that during the period 1920-29 "the process of absorption, when not impeded by cyclical recession, lasted approximately one and one-half years". Furthermore, the absorption here mentioned is of the same number of workers, not necessarily the same workers.

Moreover, Dr. F. C. Mills calls attention to the significant circumstance that the figures for aggregate employment in manufacturing, for example, conceal the fact that some industries may be employing fewer men while others are employing more. Hence the total separations in a period may be much greater than the change in total employment suggests.<sup>25</sup> If the average number employed in an individual industry between two census dates is 100,000 and declines 25,000 between these dates, this industry has net separations of 25,000, or a separation rate of 25 per cent. Comparing such separation rates for identical individual industries in the three five-year census periods from 1899 to 1914 and the three post-War census periods from 1923 to 1929, Dr. Mills finds that

the average separation rate was 4.9 per cent between 1923 and 1929. During each two-year period, on the average, between 1923 and 1929, 49 men out of every thousand employees withdrew or were forced out of the industry in which they were working, as compared with 21 men out of every thousand during a five-year pre-War period (p. 422).

These industrial separation rates measure the minimum demands placed upon manufacturing employees for finding employment in other industries. True, some of these separations are from death or voluntary resignation but it must be remembered that the separations are given as net. An industry may have 100,000 employees at the beginning of a period and 100,000 at the end and yet have forced 20,000 men out and taken in another 20,000.<sup>26</sup> Furthermore, these census statistics give no indication of how much shifting takes place between factories in the same industry.

<sup>25</sup> *Economic Tendencies*, pp. 419-23.

<sup>26</sup> Each year, in addition to new immigrants, young men and women by the hundreds of thousands come of working age and are available for positions in industry. Also, it is well known that often an older workman is replaced by a younger one. Such replacements would not appear in the total of separations as computed by Dr. Mills from the census statistics.

To assume that the actual mobility between plants and industries is sufficient to make possible the degree of shifting that is known to occur without creating at least some temporary technological unemployment is not reasonable in view of what is known concerning the crudity of the industrial mechanism for facilitating mobility and the personal factors which militate against prompt and perfect adjustment.

#### DIRECT EVIDENCE OF TECHNOLOGICAL UNEMPLOYMENT

It is regrettable, from the point of view of our present inquiry, that a census of unemployment was not taken near the peak of industrial expansion in the late 'twenties. By the time of the census taking in April 1930, the depression was in progress and the 'technological' element in unemployment, difficult to isolate at best, was still further concealed by the cyclical decline.<sup>27</sup> Of the total number of persons reporting gainful occupations in 1930, 5 per cent or 2,429,062 workers were "out of a job, able to work and looking for a job" on the day preceding the enumeration. In addition to this 'Class A' unemployment, 758,585 or 1.6 per cent of the gainful workers were "persons having jobs but on lay-off without pay, excluding those sick or voluntarily idle".

It would seem reasonable to assume that most of the unemployment that could be ascribed directly to changes in technique would appear as part of the 'Class A' type unemployment. Inquiries were made concerning the reason for being out of a job or for losing the last job held; but only 4.2 per cent of 'Class A' and 1.5 of 'Class B' (or 113,573 in all) gave reasons which fell in the category of 'industrial

<sup>27</sup> Dr. Baker suggests 'technocultural unemployment' as a more adequate phrase than 'technological unemployment' (Ref. 4, p. viii).

policy'. One of the causes included under this caption was 'machines introduced or replaced'. These figures doubtless fall short of an adequate indication of unemployment arising from 'industrial policy'. In the first place, over a third gave immediate or superficial reasons, such as 'no work'. Furthermore, the released worker is often not in a position to know just what caused his release.

More tangible evidence is afforded by various studies of the subsequent history of displaced men by R. J. Myers, Isador Lubin, and Ewan Clague and R. J. Couper.<sup>28</sup> These studies reveal the difficulties of prompt adjustment and support the argument that technological changes frequently create at least temporary unemployment of sufficient length to create a serious problem.<sup>29</sup>

Furthermore, while some of the displaced men included in these three studies obtained employment at higher rates than in their former trades, a large proportion had to accept lower wages in their new employment.<sup>30</sup> Further evidence of actual experience in technological unemployment is afforded by Dr. Baker's study of the commercial printing industry and the experience of musicians after the introduction of the sound movie as reported by the Bureau of Labor Statistics.<sup>31</sup>

In brief, the evidence at hand would seem to indicate a

<sup>28</sup> Myers, Ref. 18; Lubin, Ref. 16; Clague and Couper, Ref. 9.

<sup>29</sup> The phenomenon of 'technological' unemployment is not new. Its actual or threatened existence has been decried ever since the industrial revolution began. It was mentioned, for example, in the United States Census of 1900. The situation in recent years is unique only in that the changes seem to have been more rapid than usual; and, fortunately, there appears to be a greater public consciousness of the existence and significance of the evil.

<sup>30</sup> Lubin ascertained that 46 per cent of the displaced workers earned at least as much on their new jobs as on their old; Myers, about 54 per cent; Clague and Couper, an even smaller proportion, especially of women.

<sup>31</sup> Baker, Ref. 4; B. L. S., Ref. 44 and 46.

tendency for technological changes to result in a substantial period of unemployment for the men displaced and frequently to necessitate their taking employment at a lowered wage. The difficulty of adjustment without loss probably varies, other things being equal, directly with the rapidity with which the innovation is adopted and with the height of the skill differential of the persons displaced.

On the other hand, it has been suggested that the burden of efficiency gains has fallen in large part upon the less efficient worker; that the employer has learned the importance of maintaining a stable well-paid efficient force, and hence when improvements have made reductions in his force possible, he has let go the less efficient workers and it has become increasingly difficult for them to find remunerative occupations.<sup>22</sup>

#### VOLUME OF PERMANENT UNEMPLOYMENT

In general, the writer does not find convincing the evidence or theoretical arguments sometimes advanced to demonstrate an inherent tendency for mechanization to create an ever larger permanent body of unemployed. We know that, offsetting the check to expansion in certain industries like manufacturing and steam railroad transportation, there has been a substantial expansion of employment in other occupations, such as the distribution and service industries, and the successive censuses of occupations do not furnish evidence of a significant decline in the proportion of the total population reporting gainful occupations.<sup>23</sup>

<sup>22</sup> See Margaret H. Hogg, *The Incidence of Work Shortage* (Russell Sage Foundation, 1932), pp. 26-30, for relation between age and unemployment in New Haven: "the rate of idleness from lack of work for men appears to increase at a nearly uniform rate from the late 'thirties onward."

<sup>23</sup> See an analysis of this point by Dr. W. I. King, Ref. 15; also see Ch.



The element of truth in this charge against the machine lies in the fact that there is a lag in absorption; and consequently the more rapid the displacement, the greater, probably, is the pool of at least temporarily unemployed workers. It may be a pool made up of ever changing individuals but even at that it represents in a sense a more or less permanent addition to the volume of unemployment.

Furthermore, it is quite possible that increasing mechanization has some bearing upon the magnitude of elements in unemployment other than the 'technological' factor. Let us consider, then, the relation between mechanization and regularity of operations.

#### EFFECT ON CYCLICAL IRREGULARITY OF OPERATIONS

Some students of the business cycle trace a close relationship between innovations and alternations in prosperity. Thus Professor Josef Schumpeter holds that innovations begun by a few able minds and followed by many imitators stimulate prosperity, which in turn stimulates more inventions.<sup>84</sup> A. B. Adams likewise suggests that the introduction of new competitively superior capital equipment may help to initiate a business cycle.<sup>85</sup>

VI, Shifting Occupational Patterns, in *Recent Social Trends*. For divergent interpretations of the theoretical possibility of permanent technological unemployment, see: Paul H. Douglas, Technological Unemployment, *American Federationist*, August 1930, pp. 923-50; and Alvin H. Hansen, *Economic Stabilization in an Unbalanced World*, Ch. X, Institutional Frictions and Technological Unemployment. Douglas expounds the optimistic expectation that decreased requirements for labor arising from technological change merely shift purchasing power to other uses where equivalent new employment opportunities will be created. Hansen stresses the possibility that the institutional controls of the present-day industrial organization, notably those which help to account for the relative rigidity of wages, are likely to create lags in the absorption process and, under certain conditions, may even result in a failure to reabsorb displaced workers.

<sup>84</sup> *Theorie der wirtschaftlichen Entwicklung*, 2d ed. (1926), Ch. VI.

<sup>85</sup> *Economics of Business Cycles*, pp. 138-50.

It does appear possible that the increased productive capacity accompanying an improvement of plant equipment may intensify competition, and by that very intensity tend to periodic irregularity in operation. For example, the press has been, at times, filled with ominous hints of an impending price war in a struggle for the market between leading automobile producers whose combined full capacity, it is urged, far exceeds any demand that may reasonably be expected.

Also, advances in mechanization lengthen the chain of productive processes intervening between the raw materials and the final use of goods and thus increase the possibilities of misadjustment of production to effective consumer demand.

Furthermore, whatever may be the causes of cyclical fluctuations, the production of capital goods is one of the highly variable elements in the productive process. As computed by Dr. Mills, the index of instability of growth in the period 1922-29 was 1.4 for non-durable consumption goods, 2.7 for semi-durable consumption goods, 6.2 for durable consumption goods and 6.6 for machinery.<sup>28</sup> The expansion in the machinery industries which accompanies increasing mechanization is an expansion of a highly variable element in the industrial system.

On the other hand, so far as the interests of the user of machinery are concerned, a high mechanization of his processes involves heavy overhead costs and increases the incentive for maintaining in all possible ways regularity of operation. Men may be laid off without pay, but machines may be stopped only at the expense of their owner.

<sup>28</sup> *Op. cit.*, pp. 270-8; see also Ch. VIII *supra*.

## SEASONAL IRREGULARITIES

In construction work mechanization helps to iron out seasonal irregularities by furthering cold weather operation. A power shovel can be used for excavation in temperatures that would make hand shovels impracticable. Likewise, other changes in the building industry, such as the use of structural steel, have made it possible to do much of the work in the shop prior to erection, thus lessening human exposure and furthering winter work.<sup>87</sup> In the window-glass industry the introduction of the machine has made possible operation throughout the hot summer months. The substitution of steam-pipe-rack driers for open-air 'summer yards' in brick making has lengthened the operating season for brick yards. Manufactured ice may be made the year round; natural ice is frozen only in winter.

An interesting example of a possible increase in the seasonality of operation through further mechanization arises in the sugar beet industry. The invention of a practical beet puller and topper for use in the autumn harvesting is rendered less desirable by the necessity of using hand labor—largely migratory Mexican workers—in the summer in thinning the beets. As the same workers are used in the autumn work of pulling and topping, the mechanization of this autumn work would make the hand work in the beet fields more seasonal than it now is, increasing the present difficulty of securing an adequate force for the thinning period.

<sup>87</sup> Cf. discussion of this point in the report of the committee of the President's Conference on Unemployment, *Seasonal Operation in the Construction Industries, Report of the Industrial Commissioners (New York State), 1928*, p. 164; Ralph J. Watkins, *The Construction Industry in Ohio*, p. 148.

## EFFECT ON SKILL

We are primarily concerned here with manual as distinguished from clerical, managerial and professional workers. Manual workers may conveniently be classified as skilled, semiskilled, and unskilled or common laborers.<sup>38</sup> Skill is a quality which is not precisely defined, and the available quantitative evidence concerning the relation between the progress of mechanization and changes in the degree of skill in industry is relatively scant and fragmentary. However, on the basis of information collected in our interviews and correspondence with factory executives or presented in the literature dealing with industrial change, we can submit at least tentative formulations of the effects of mechanization on skill.

It is quite possible that a new device may lower the grade of labor in the operation directly affected but raise the general average because of the skilled labor required in the production, maintenance and repair of the machine. Hence, we can more readily appraise the net effect of the progress of mechanization if we direct our attention to three aspects: (1) the amount and grade of labor in the production of machines; (2) the amount of skilled labor engaged in machine repair work; and (3) the effects of mechanization on operating labor.

## LABOR IN THE PRODUCTION OF MACHINES

In the post-War decade about one million men were employed in the production of machines (Table 21, Ch. VI). In Chapter VIII we cited evidence to indicate that the grade of skill in machinery factories is somewhat higher

<sup>38</sup> The customary significance of these terms is analyzed in Ch. VIII, section on Grade of Labor in Machine Production.

than that in the manufacturing industries as a whole, and also estimated that on the average the percentage distribution of all workers engaged in machine production, directly or indirectly, is: unskilled 25, semiskilled 55, and skilled 20.

Obviously, the machine which displaces only one type of worker will reduce the proportion of that type in industry as a whole but will raise the proportion of the other two types, to the extent that workers of those types are employed in the production and repair of the machine.

#### LABOR IN MACHINE REPAIR WORK

The use of more machinery or of more intricate devices doubtless, as a rule, increases the proportion of repair and maintenance labor, both by decreasing the amount of operating labor and by increasing the repair and maintenance labor. For example, the number of looms to each loom fixer in cotton mills is ordinarily less for automatic than for non-automatic looms; and automatic telephone switchboards require more maintenance labor than the manual type.

However, the reverse—a decrease in repair labor—is sometimes one of the incentives for the installation of new types of equipment. Some of our informants stated, for example, that one reason for their adoption of the individual motor drive was that it requires less maintenance and repair labor. Also, early models of a new type of machine often get out of repair more readily than later, more ruggedly constructed models. However, though the progress of mechanization sometimes reduces the absolute amount of repair labor, probably even in such instances it ordinarily increases the proportion of repair to direct operating labor.

The repairing and adjusting of machines requires a relatively high degree of skill. We estimate, roughly, that in the typical factory 3 to 5 per cent of the labor force are

skilled men on machine repair work. This estimate is based on replies to a special inquiry received from 88 of the establishments included in our survey (Ref. 20-a). These establishments manufactured a wide variety of products, in which textiles, furniture, secondary iron and steel products, brass goods, motor vehicles and smelting and refining predominated. Their replies showed that 4 per cent of their total labor force of 42,348, or approximately 15 per cent of the total number of their skilled workmen, were on machine repair work.

The wording of the repair question differed slightly in the several industries, and as a result it is likely that a small amount of building repair work is included in these figures. Nevertheless, the percentage shown is probably an understatement, because some machine repair work is done by men whose primary job is the operation of machines; also, especially in large cities, much repair work is done by service men in the employ of the machine manufacturers. Doubtless in some industries, particularly those which are highly mechanized, the proportion of repair labor is substantially higher than indicated by the above estimate.

#### EFFECTS ON OPERATING LABOR

To minimize the chance of misleading generalizations, we shall discuss in turn four types of labor-saving changes: 1. innovations in handling methods that do not materially alter the nature of the processing operations or the facility with which they are carried on; 2. handling changes that by reducing the flow of materials to orderly sequence tend to systematize and standardize the processing operations and hence may alter both the grade and amount of processing labor; 3. changes in the processing operations that directly displace handicraft procedures by mechanical devices; 4.

changes in the processing operations that merely introduce improved mechanical devices or methods in operations already mechanized.

*Modifications in handling methods only*

The workers engaged in the handling or transportation of materials in the factory are relatively unskilled, particularly where such operations are manually performed (Ch. V). Hence, in the case of those handling changes which do not also modify or speed up the processing operations, the substitution of mechanical for manual handling tends to increase the proportion of relatively skilled workers, both by decreasing the total number of workers engaged in handling, most of whom are unskilled, and by increasing the number of semiskilled and, in some instances, even of skilled workers. The operator of the industrial truck, the power conveyor or the overhead traveling crane would ordinarily be classed as at least a high-grade common laborer or as a semiskilled worker and in some instances as a skilled worker.

For 31 instances of labor-saving innovations in handling reported to us (Ref. 20-a), the data enable us to compute the change in the number of workers of each grade. The aggregate reduction was from 535 to 134, or about 75 per cent of the total force engaged in the specified handling operations. The number of unskilled workers was reduced from 523 to 64, the number of semiskilled was increased from 56 to 61, and the number of skilled from 7 to 9.

In addition to the indicated increase in the proportion of semiskilled and skilled laborers directly on the handling operations, the use of machines for handling necessitates some relatively skilled labor for their initial construction,<sup>89</sup>

<sup>89</sup> The following summaries of the grade of labor in three plants producing handling and excavating machines that displace common labor serve

for their maintenance and repair, and for the production of the power used; hence it would seem to be quite well established that the type of handling device which affects only handling operations tends to widen the market for high-grade labor.

*Handling innovations that systematize the processing operations*

Some improvements in handling facilitate labor saving in the processing as well as in the handling operations. A basic feature of much of our modern mass production is the serialization of machines and processes in such a way as to reduce handling to a minimum and arrange the assembling and other processing operations along a continuously or intermittently moving conveyor, with the processes highly subdivided and standardized.<sup>40</sup> Such changes in handling

to illustrate the tendency for such machines to require a higher grade of labor in their production than that displaced by them.

Plant No. 1 produces industrial electric trucks. The manager of this plant stated that he employs very few common laborers and that about 90 per cent of his force is skilled.

Plant No. 2 produces bucket loaders, narrow trench diggers and other machines that do the work of unskilled labor. As it buys its castings, the labor cost directly in the plant is only a small percentage of the cost to consumers; but 47 per cent of its labor is skilled, 45 per cent semiskilled and only 8 per cent unskilled.

Plant No. 3 produces a narrow trench digger that takes the place of hand-shovel labor. About 25 per cent of its force is common labor, the remainder semiskilled and skilled.

<sup>40</sup> See also Ch. V. It may be noted that the tendency towards greater subdivision of work is not necessarily associated with increased mechanization. For example, in the manufacture of cotton cloth, some plants in recent years have introduced a higher division of labor, assigning, for example, more looms to a weaver, but delegating his less specialized tasks to less skilled and lower-wage workers, thus lowering the general average of skill required in the weave-room force—all without necessarily making major changes in the mechanical equipment. See also the discussion of subdivision of labor in a rubber shoe plant, Ch. III, Shoes, footnote 57.



methods not only reduce the amount of handling labor, but also tend to make possible the use of more narrowly specialized workers on the assembling and processing operations. They encourage the production of standardized products such as interchangeable parts, and, in general, further the substitution of production planned and systematized in detail by engineers and executed by semiskilled workers for production dependent upon the artisanship of high-grade mechanics.

In changes of this type there may be a two-fold reduction in the direct demand for skilled workers on the immediate processing operations: the work can be done by less skilled operators and the output per man is increased.

There are mitigating factors. The introduction of this type of operation has largely been in the rapidly growing industries, such as automobiles and tires, and hence has not meant the actual displacement of skilled workers to the extent that would be involved in a similar change in industries expanding less rapidly. Also, the effect on operating labor is, of course, as in other developments in mechanization, partly offset by the increases in the use of skilled labor in machine production, maintenance and repair.

#### *Displacement of manual by machine processing*

Where the mechanization of a process involves the substitution of a processing machine directly for the hand-craftsman, it is probable that the typical effect, even after allowing for indirect as well as direct effects, is a net decrease in the grade of skill required.

This tendency to decrease the need for specialized skill finds classic illustrations in the history, as recorded by Professor George E. Barnett, in his *Machinery and Labor*, of the introduction of the stone planer and the semiautomatic

and automatic bottle machines. The glass industry affords other examples of the relatively recent supplanting of skilled labor by machines. The cylinder machine for window glass displaced the two highly skilled trades of gathering and blowing, and the semiskilled trade of snapping. True, it introduced a few new crafts requiring considerable skill, but they involve only a few workers. The introduction of machine molding likewise tends to enable semiskilled workers to do the work of an even larger number of skilled workers, and the casting method of making sanitary ware, which has come into extensive use since 1922, lessens the dependence on the skilled potter as compared with the hand pressing method which it supplants. The evolution of the cigar industry from completely manual processes to almost completely automatic machines has been marked by the substitution of semiskilled workers for the skilled cigar maker and has increased remarkably the proportion of women and children in the industry.<sup>41</sup>

The potential displacement of skilled labor by the further substitution of machine methods for hand processing is limited by the fact that, while there are still many hand workers in industry, the number engaged in hand crafts that are of a distinctly skilled type is relatively small, especially if we exclude the building industries; hence any further reduction in the demand for skilled labor due to the direct substitution of machines in skilled hand crafts is apparently not the major problem in judging the probable effect of further mechanization upon skill requirements.

The transition to mechanical processing does not always affect the level of skill adversely. If the displaced manual

<sup>41</sup> John P. Troxell, *Machinery and the Cigarmakers*, *Quarterly Journal of Economics*, February 1934, pp. 338-47.

methods require only semiskilled or even common labor, then mechanization tends to raise the proportion of skilled workmen. For example, the warp tying-in machine, used in cotton weaving, enables a skilled machine operator, with an assistant, to do work formerly requiring 12 to 18 tying-in girls. Their work required considerable adeptness and experience, but not a degree of skill comparable with that required of the machine operator. The following examples from our factory inspections will serve as illustrations of innovations that displace semiskilled rather than skilled workers:

Plant No. 54, high-grade sporting guns. One man of the semiskilled grade operating a sanding machine does work that formerly required 5 men of the same grade.

Plant No. 103, machine screw products. One semiskilled woman operating a screw-sorting machine does work formerly requiring 10 semiskilled women.

Plant No. 105, typewriter ribbons. With a ribbon-reeling machine, 3 semiskilled men do work formerly requiring 9 semiskilled.

In a group of 8 plants, 14 semiskilled workers operating various wrapping, packaging, nailing and labeling machines do work formerly requiring 74 semiskilled workers.

Also, if operations which have already been reduced to progressive assembly or progressive processing advance to a more highly mechanized stage where mechanical devices displace some of the manual workers along the assembly line, the change is likely to reduce the number of semi-skilled operatives, and tends, on the whole, to increase the demand for skilled workers and trained technicians in the construction and planning departments.

For example, a factory as highly mechanized as the A. O. Smith Corporation automatic automobile-frame plant requires much skilled labor in the planning and engineering departments but relatively few workers in the immediate operation of the machinery.<sup>42</sup>

<sup>42</sup>L. R. Smith, *We Build a Plant to Run Without Men*, *Magazine of Business*, February 1929, pp. 135-8, 200.

*Improvements in processes already mechanized*

The effect of those labor-saving changes that involve the substitution of one mechanical method for another is most difficult to appraise. Some improvements change the character of the remaining work and thus alter the qualifications required of the operating workers; more frequently they merely reduce the number required. In general, minor improvements in the equipment used in operations already mechanized, such as increases due to faster machinery or larger units, and to automatic feeding devices, rather than to essential changes in the type of equipment or process, reduce the relative demand for the particular grade of operator required, and in the majority of instances this is the semiskilled type.<sup>48</sup> For example, the 'automatic spooler and high speed warper', now being introduced into the cotton goods industry cuts the requirements for spoolers and warpers, who are semiskilled operatives, approximately in half.

A clue to the net effect when we consider not only the operating labor but also the labor involved in the production of the machines that displace semiskilled labor is afforded by the following examples from our inspections:

Plant No. 4 produces textile labor-saving machinery that displaces semiskilled workers. Of a total of 850 workers, 450 are skilled, 350 semiskilled and 50 are common laborers.

Plant No. 5 produces automatic textile looms that increase the output of a relatively high grade of semiskilled workers. The percentage distribution of the labor force is: skilled 25, semiskilled 65, and common labor 10.

Plant No. 6 also produces automatic looms. In the machine shop and

<sup>48</sup> The net effect of the technical changes in the pressrooms of commercial printing establishments in recent years, chiefly in the introduction of high-speed, self-feeding, 'job-automatics' and the addition of mechanical feeding attachments to other types of presses, has been to increase the proportion of the highly skilled pressmen to the less skilled assistants (Baker, Ref. 5).

foundry combined about 40 per cent of the workers are skilled, and 60 per cent semiskilled or unskilled.

In each instance a substantial proportion of skilled workers is required in the production of these machines, but they displace almost entirely semiskilled labor.

When we take into consideration the proportion of skilled workers in machine construction and repair, it seems probable that, on the whole, improvements in processing operations already mechanized increase the total demand for skilled workers.

#### SUMMARY OF EFFECT ON SKILL

Any conclusion as to the net effect on skill of further mechanization, when all of the several types just discussed are lumped together, is necessarily a more or less impressionistic judgment based on a totality of observations, not all of which can be reduced to tangible form. If we compare industry in its present stage with manufacturing prior to 1900, when a period of apprenticeship was the customary gateway to an occupation, it is possible that the average skill and initiative required of the worker has declined. On the other hand, with industry mechanized to the extent that it was in this country by the close of the World War, the net effect of the changes of the last decade is not so clearly one-sided. The numerical evidence, admittedly limited, assembled in our survey indicates that the mechanization of handling has tended to reduce the proportion of unskilled workers in industry; that in the direct displacement of handicrafts the mechanization of processing has ordinarily reduced the demand for certain types of skilled workers; but that the innovations in processing operations have in many industries made no sweeping changes in the proportions between common, semiskilled

and skilled labor. Probably the aggregate effect may be accurately described as a leveling process producing fewer highly skilled jobs but also few really unskilled jobs.

From executives of 101 manufacturing establishments we obtained answers to the following question: "For the single change made since 1920 which resulted in the greatest saving of labor . . . was the labor saved of the unskilled, semiskilled or skilled grade?"<sup>44</sup> The reduction was effected in the skilled grade in 25 per cent of the total number of reports, in the semiskilled in 43 and in the common labor grade in 32. The percentage with reductions in skilled labor was 36 for the processing operations and only 10 for the handling operations. On the other hand, changes resulting in reductions in common labor constituted only 18 per cent in the processing operations and 52 in the handling.

Evidence in a slightly different form is afforded by 114 labor-saving innovations for which we obtained information adequate to enable us to determine whether they lowered, raised, or made no change in the grade of operating labor required (Ref. 20-a). In 69 instances the change did not alter the type of labor required.<sup>45</sup> About four-fifths of the instances of lowered skill were reductions from the skilled to the semiskilled grade. The advances in skill were chiefly substitutions of semiskilled workers for common labor. Of 39 labor-saving changes in handling equipment and methods for which our informants stated the grade of labor before and after the change, 3 lowered the grade required, 24 made no substantial change, and 12 raised the skill re-

<sup>44</sup> The definition of these terms was left to the judgment of the informant. For discussion of the meanings ordinarily assigned by factory executives, see Ch. VIII, section on "Grade of labor in machine production".

<sup>45</sup> In the operations involved in these 69 changes, skilled labor was employed in 8, semiskilled in 28 and common in 14. The information at hand is inadequate to classify the labor in the remaining 19.

quirements for all or part of the crew, chiefly by substituting semiskilled workers for unskilled.

On the other hand, in 45 labor-saving changes affecting the processing operations and involving an aggregate reduction in force from 965 to 355, the number of common laborers was reduced from 36 to 6, semiskilled from 698 to 331, and skilled from 231 to 8. Here the proportionate reduction was relatively greatest for the skilled group, although numerically greater in the semiskilled. This sample was rather heavily weighted with the foundry industry, and most of the reductions in the demand for skilled workers was in foundries. In the non-foundry plants, the changes in processing methods affected the three grades of workers in about the same proportion.

The evidence afforded by these two samples suggests that a large proportion of labor-saving changes reduce the number in the given operation without altering the grade of labor required, and that innovations reducing the grade occur chiefly in the processing changes; those raising the grade, in the handling changes.

As to the effect on skill of further mechanization in the future, with our industries in their present state of mechanization there is considerable reason to believe that the effect of further changes will be to raise the average skill required. The construction, installation, repair, maintenance and adjustment of machines (including automobiles) is requiring an ever-increasing army of relatively skilled men; the number of skilled men still engaged in hand processes, aside from the building operations, is relatively small; a further displacement of unskilled workers by mechanical handling may be expected; and so large a proportion of other workers in industry are now semiskilled that the principal effect of further mechanization of the processing operations will be to decrease the demand for semiskilled

workers. The effects will, of course, be diverse, some changes lowering the skill requirements, others raising them. On the whole, the shift will continue to be from emphasis on the trade skill typical of the handicraftsman to, on the one hand, the alertness and intelligence required in handling fast and intricate machinery and, on the other, to the more formal training required in the engineering and production planning departments. In the machine repair men we shall continue to have an approximation of the type of training and skill required of the old-style all-round mechanic.

In this section we have been discussing primarily the effect of mechanization upon the general average of skill in industry. Nothing here said should be construed as overlooking the obvious fact that even a change which raises the general level of skill may result in skill obsolescence and pecuniary losses for the particular individuals trained in the out-moded methods.

#### OTHER EFFECTS OF INCREASING MECHANIZATION

We have noted above the effects of labor-saving improvements upon skill requirements. In the course of our examination of the facts of mechanization, our informants have called our attention to various other savings which they attribute to particular labor-saving changes in equipment or methods.

In all, 148 instances of effects of labor-saving changes other than the direct effect on the quantity or grade of workers employed were reported to us. In 34 instances, the quality of the final product or of semi-finished goods at some stage was improved; in 25, the capacity of the plant was enlarged by increasing the output of 'bottle-neck' departments (12 instances), by reduction of stoppages (7), and in various other ways. In 24 instances, working condi-



tions were improved by lightening the tasks, by making possible cleaner or safer working conditions, and in other ways. Space requirements were reduced in 13 instances, fuel or power saved in 9, the breakage or waste of materials reduced in 17, and repairs and maintenance in 16. Reduction in the volume of work required in departments other than the one in which the equipment change occurred, and miscellaneous other savings complete the list.

Obviously the instances cited are not quantitatively adequate to indicate whether the tendencies listed are generally associated with the progress of mechanization; but they will serve to call attention to the great diversity of factors which must be taken into consideration in appraising the totality of effects resulting from changes in equipment or processes.

#### CONDITIONS OF WORK: MACHINES AND INDUSTRIAL HEALTH

That machinery is responsible for a substantial proportion of industrial accidents will be granted. For example, in New York State in the year ending June 30, 1927, 13 per cent of all accidents were attributed to machinery, and the burden of machine accidents was particularly heavy for boys—22 per cent.<sup>46</sup>

However, where increases in accidents have occurred, the increase has not been restricted to machine accidents; in fact, in New York State

"in the five years ended June 30, 1927, machine accidents increased 28 per cent, but all types of permanent injuries to eyes, hands, feet, etc. . . . increased 80 per cent. In two types of machines where the hazard and the resulting injury were greatest the greatest improvement was evident. This was in power presses and buzz saws."<sup>47</sup>

<sup>46</sup> *Industrial Bulletin*, N. Y., June 1928, p. 276, Machinery the Chief Cause of Accidents to Minors.

<sup>47</sup> N. Y. State Department of Labor, *Report of the Industrial Commissioner*, 1928, p. 3.

The bearing of increasing mechanization upon safety in industry is analyzed in the report of the American Engineering Council on *Safety and Production* (Ref. 1). As this report points out, we are confronted with the apparent paradox that while on the one hand the most efficient operation of a plant depends on continuous operation, which in turn is contingent on safety, yet in fact the critical situation which led to the study consisted essentially in the circumstance that the intensive development of industry in the post-War period appeared to have been accompanied by an increase in the number and severity of accidents. In the introductory statement of the report, Mr. Whitney suggests that mechanization undoubtedly affects the accident situation in many ways, some of the effects being favorable, some unfavorable. Among the unfavorable factors he suggests (pp. 5-6):

"1. The introduction of machinery has, in many cases, displaced hand-work that was comparatively safe. Even though the change may have resulted in accomplishing the work in question with less sacrifice of life and limb, the hazard per worker, because of the greatly decreased number of workers, is, in general, greater. Not only is the number of machine accidents per worker greater, but the severity is greater than under non-mechanized conditions."

"2. The introduction of automatic machinery has, in general, had the effect of displacing operators that were working under standardized conditions at machines that could be thoroughly guarded. The man-power that is needed on automatic machinery, on the other hand, is largely for repair work. Such work is intrinsically dangerous and is scarcely capable of being standardized."

"3. Under mechanized conditions the speed with which material goes through the process of manufacture is increased and the exposure to accident, other things being equal, is proportionately greater."

This report makes comparisons between production and accident rates in 1922 and 1925 of 359 companies in 34 industries and employing 254,529 workers. About 80 per cent of the companies showed an increase in the rate of production and a decrease in both the frequency and severity of accidents

in 1925 as compared with 1922; but for the group as a whole it was found that:

1. productivity increased 14.4 per cent;
2. accident frequency per man-hour decreased 10.4 per cent;
3. accident severity per man-hour increased 2.5 per cent.

It may be that the increase in severity observed in the period studied is due primarily to the higher degree of mechanization reached; but in the judgment of the writer it should be ascribed in greater part to the rate of change in this period, as a temporary increase that may be cancelled when a slackening in the rate of change gives the safety movement a better opportunity to catch up. Certain it is that industrial hazard is not solely a machine phenomenon, nor are the more hazardous occupations restricted to the mechanized tasks.<sup>48</sup> In fact, in some instances an increase in the degree of mechanization reduces the health hazard.<sup>49</sup> Doubtless, however, the development of adequate protective devices and methods frequently lags behind the development of new processes or new equipment, and the knowledge or fear of this lag in some degree retards the introduction of new devices.

#### ARDUOUSNESS OF MACHINE LABOR

Mechanization has been charged with making the life of the factory worker well-nigh intolerable, and credited with lifting the heaviest burdens from his back. In the steel mills,

<sup>48</sup> Compare the discussion of this point and other phases of the relation of mechanization to health in Stuart Chase, *Men and Machines*, pp. 148-55.

<sup>49</sup> For example, a paint factory included in our survey has substituted the mechanical handling of litharge under cover for manual handling primarily as a means of avoiding the danger of lead poisoning. Likewise, it is claimed for some of the newer developments in materials handling in construction and factory operations that they reduce the accident hazard.

according to the conditions described by John Fitch, machinery is doing much of the heavy drudgery, but the legacy of this development has been a terrific din of machinery and an unremitting nervous strain in handling the mechanical devices with due care and precision.<sup>50</sup> Much could be said with respect to these two sides of the problem.

We shall not attempt here to strike a balance between modern machine industry and a complete handicraft system. We are concerned rather with relatively recent and impending changes in the degree of mechanization. The writer is inclined to believe that the net effect of these changes is to improve the conditions of work and lighten the physical burden of the worker. In the course of our survey various examples of a conscious effort on the part of many executives—apparently an increasing effort—to eliminate hand processes involving excessively arduous or disagreeable work have come to our attention.<sup>51</sup>

The tendency to substitute oil for coal as fuel, or electric power for steam power has reduced the number of laborers engaged in the arduous work of stoking furnaces; and the extensive introduction of mechanical handling devices has shifted to the machine much of the heavier trucking and lifting work of the factory. Likewise, many special developments in processing machines tend to reduce the task of the operator to that of merely seeing that the machine is functioning properly.

Against such gains it is urged that the tendency towards standardization of machine processes, such as is exemplified in the continuous-assembly-belt system, introduces or in-

<sup>50</sup> *The Steel Workers*, p. 58.

<sup>51</sup> The manager of a ship and engine company mentioned that the introduction of the electric furnace in their foundry has improved conditions sufficiently to make it appreciably easier to get American workmen who formerly avoided the foundry.

tensifies the element of fatiguing monotony. Even here, however, the tendency is to minimize the exertion of strength and the exposure required of the worker.

#### EFFECTS ON QUALITY

The effects of increasing mechanization on the quality of products is admittedly a moot question in many instances, and no all-inclusive generalization can be made.

In general, where standardization is desirable, the machine product is more satisfactory than the hand-made. The superiority of the machine is especially marked where the adherence of a large number of units to minute specifications is required. The output of modern machine tools, for example, can be held to a precision unattainable in handicraft work; and in many even less exacting cases of standardization the superiority of the machine is conclusive. For example, automatic weighing and packaging devices make possible greater uniformity in content.

Improvements in quality mentioned by informants interviewed in the course of our field survey include, among others, the following pertinent instances:

The system of automatic control for mixing pulp for newsprint paper adopted in recent years is said to result in a more uniform product than from the former manual control of mixing. In cotton cloth manufacture the work of the machines in drawing-in and tying-in is said to average more uniformly good than hand drawing-in or twisting-in; there are always some poor hand workers. In highway construction the subgrade can be shaped more accurately with the mechanical subgrader than by hand. In demolishing sections of hard-surface pavement for repair purposes, it is claimed that with the pneumatic hammer, the cutting tool can be set to cut uniformly to a desired depth and also that cutting

to a line can be more readily done. The substitution of power for hand irons in pressing the edges of coats in the manufacture of men's garments is reported to result in a more accurate pressing of the unfinished garments and consequently better work in the subsequent stages. The introduction of mechanical screening plants in retail coal yards has, in the several cases reported, made possible a more satisfactory sorting of the fine coal and its sale at better prices. In several instances, machine molding equipment was reported to give a more uniform casting. An automatic rim-grinding machine on car wheels resulted in a more uniform job. Mechanical sanding devices on wood operations were reported to improve the quality of the product; and the use of automatic distributors to cotton lapping machines results in more even laps than from hand feeding.

"The very great improvement in the quality of tubing effected by the machine," when combined with a large increase in man-hour output and a decrease in labor costs, has "resulted in the almost complete elimination of hand production in favor of the machine."<sup>52</sup>

Where the process involves pressure somewhat too high for easy manipulation by hand, the use of mechanical devices is likely to result in a more uniform product. Thus it is claimed that the automatic dumping device on molding machines improves the product as compared with the hand-dump because a stiffer mud may be used. Likewise, in the production of floor and wall tile the tile press compresses the damp granular clay much more compactly and more uniformly than the hand press, raising the quality of the finished tile.

But the story is not at all one-sided. Doubtless many machines are sub-marginal because of their wastage of ma-

<sup>52</sup> B. L. S., Ref. 36, pp. 137 ff.

terial or the poor quality of their products, and are pushed into the class of economical devices only by changes in the price of the product,<sup>53</sup> in wage costs or in other major elements in the cost of production. Whenever high quality rests not upon standardization but upon adaptation of a process to a constantly changing and wide variety of conditions, the odds in favor of the machine materially decrease or disappear.

For this reason, in the growing of sugar beets the mechanical beet blocker and the mechanical beet topper still cannot compete satisfactorily with hand work, and for similar reasons in such industries as meat packing, where the work consists largely of the dismembering of carcasses, each one varying somewhat from those immediately preceding and following, a large proportion of handwork survives. One obstacle to the development of mechanical cotton picking has been that machines of the simpler and relatively inexpensive types do not gather only the ripe bolls but harvest the entire crop at one time indiscriminately. It is claimed that the hand-made lamp-chimney is of better quality than the machine product because of greater facility in incorporating a variation in the thickness of the glass in the various parts of the chimney.<sup>54</sup>

The advantage of the machine, and the standardization associated with it, is less clear in consumption than in production goods, and undoubtedly a preference exists, sometimes well-founded, sometimes perhaps not, for hand-made products. Frequently a machine-made product, whether a pro-

<sup>53</sup> A sharp impetus was given the use of the cotton 'sled' or stripper in northwest Texas when in the season of 1926 the cotton farmers found themselves confronted with an unusually large crop, high wages and declining cotton prices. See D. L. Jones, *et al.*, *Mechanical Harvesting of Cotton in Northwest Texas*, Circular No. 52, Texas Agricultural Experiment Station, p. 26.

<sup>54</sup> B. L. S., Ref. 36, p. 114.

ducers' or consumers' good, encounters a prejudice in the early stages of its introduction which later decreases. This prejudice arises in part from the crudity often characteristic of machine products in the early stages and in part from a traditional prejudice in favor of the hand-made product.

For example, the effects of mechanization in the window-glass industry is a matter of dispute so far as quality is concerned, but the belief, at least, seems to have persisted for some time that the mechanical processes resulted in a larger proportion of poor glass, making difficult the cutting of an equal number of large pieces from a specified output. Likewise, in the use of milking machines in New Zealand, H. L. Russell and Theodore Macklin report that "when the machines were first introduced, considerable trouble was experienced in keeping the teat cups and the releaser pipes in a thoroughly sanitary condition", with a resulting "dish water taint" in the milk, but that later "this obstacle has been met by the use of electricity to heat wash water to the boiling point."<sup>85</sup>

It may be impossible to strike a balance on the score of quality; however, we shall not be far wrong if we generalize by saying that the superiority of machine products intended for use in further production in standardized processes is quite readily recognized, but that the introduction of machine products to replace hand-made goods in the field of consumers' articles will ordinarily be limited or retarded by a preference, fully justified or not, in favor of the hand-made product. We are not overlooking the fact, of course, that in many lines, particularly commodities like sugar, salt and many other foodstuffs, machine-made products virtually monopolize the field. We speak rather of the prejudice to be expected when a machine product invades a new field.

<sup>85</sup> *Intensive Dairying in New Zealand and Wisconsin*, Bul. 377, Agricultural Experiment Station, University of Wisconsin, 1925, pp. 16-7.



## EFFECT ON SPACE REQUIREMENTS

Small-scale fabrication frequently can be carried on by hand in shops that would be too small for the minimum economical size of a machine-equipped plant; and a certain minimum width of aisles and height of rooms is frequently essential to machine operation. But, particularly for operations on any considerable scale, machines usually require less space than is essential to turn out the equivalent product by hand methods.

Further reduction of space requirements with increasing efficiency in type or operation of machines occurs along two lines. First, the speeding up of machines without any essential change in their type or size results in a greater output with essentially no change in floor space except as required for handling and storing the increased output. Second, while many of the improved models of machines are larger units, they are likely to require less space than the several smaller units which they replace.

Let us note a few illustrations of the tendency frequently evidenced for mechanization to reduce space requirements:

1. The extensive introduction in recent years of mobile power trucks and of overhead conveying systems for handling materials has in numerous instances relieved the congestion in floor space, particularly in aisles, caused by the numerous hand trucks and the piles of material accumulated for them.
2. The machine piling of lumber and the mechanical handling of bricks make feasible higher piles and thus reduce the required yard space.
3. Power screening plants for handling retail coal were reported to us as saving ground space.
4. The use of tractor power, instead of horses, in highway construction is said to lessen the confusion and crowding on the subgrade.

5. The increasing substitution of oil for coal as boiler fuel is reducing the required yard storage space.
6. The increasing substitution of individual motor drives or purchased current for steam power and shaft drives is making possible a more compact machine arrangement.
7. Frequently, new models of machines are less bulky and clumsy than earlier models. The latest model of the Westlake machine for electric light bulbs involves changes that appreciably reduce its weight and bulk; output is thereby increased owing to the consequent higher speed of rotation.<sup>56</sup> The substitution of the new-style 'automatic spooler and high speed warper' for the older and slower styles of spoolers and warpers has resulted, we understand, in a reduction of required floor space of about one-half.

#### OTHER FACTORS WEIGHED BY THE FACTORY MANAGER

While we may not assume that the factory manager is always actuated solely by economic motives in adopting or rejecting a new machine or process, yet it is reasonable to assume that any anticipated effect of the innovation upon pecuniary returns will be taken into consideration. Hence, in addition to the effects already mentioned in this chapter, his decision will rest in part on whether he believes the new machine will require more or less power, waste more or less material, require more repairs and maintenance, increase or decrease his labor turnover, make possible a speedier completion or a more certain completion of tasks on scheduled time or, perhaps, make possible a fuller utilization of other equipment by minimizing stoppages or by enlarging capacity at a particular 'bottle neck' in the process—that is, a department with capacity not adequate to feed material properly to subsequent departments.

<sup>56</sup> B. L. S., Ref. 36, p. 125.

*Fuel or power requirements*

The initial substitution of mechanical methods for handcraft work obviously increases the requirements for fuel and power; but as machine methods are improved these requirements are frequently decreased. This is particularly true in the use of fuel in the production of power itself. The reports of the Geological Survey indicate a substantial decrease in recent years in the quantity of coal required to turn out a kilowatt of power. In fact throughout industry we find various instances of improvements tending to reduce the quantity of fuel or power required. Here we may class the introduction of waste-heat boilers in cement plants, and the introduction of continuous annealing ovens and brick kilns.

*Waste of materials*

The introduction of a new process is sometimes retarded by the belief that it would cause more materials to be wasted. On the other hand, numerous instances can be cited where improved methods of processing or of conveying materials reduce the amount of breakage and wastage involved. It is claimed for the mechanical vegetable peelers that they reduce the waste on potatoes as compared with hand peeling some 60 per cent; and that the mechanical handling of brick reduces breakage. A furniture factory reported a 50 per cent saving in lumber in certain operations by the introduction of mechanical molders and planers. A foundry reported that the substitution of straightening presses for the drop hammer method in straightening castings reduced the loss of castings.

*Repairs and maintenance*

We have elsewhere discussed the diverse effects of modern mechanization tendencies upon the amount of repairs. On

the one hand, the increasing intricacy of machinery increases the amount of repair labor. On the other, the observed tendency towards the development of more rugged models decreases the maintenance requirements. On the whole, a substantial degree of ruggedness is an essential for the extensive commercial adoption of most mechanical contrivances; and the ability of new devices to ensure more regular operation is always a strong factor in their favor.<sup>57</sup>

#### *Control of production schedule*

Does the increasing mechanization of factories make the employer more certain of the completion of an order on schedule time? In certain instances this seems clearly to be true. It was pointed out to the writer, for example, by executives of some of the factories inspected, that the installation of a machine in place of a group of hand workers on a key job decreases the dependence on labor, in the sense that the chance of mill stoppage due to a strike at the key point is much less. In other words, a machine operator or two are less likely to go on strike than a group of 20 or 25 workers engaged on a common occupation and with common interests. Likewise, some road contractors gave as the reason for the purchase of additional machinery the desire to make more certain the completion of work within the contracted period. The machine does not quit in search of higher wages elsewhere; hence, if ruggedly built, it promises somewhat more continuous operation.

<sup>57</sup> The makers of steam grate shakers claim, for example, that grates of locomotives in terminal ash pits can be shaken more quickly by steam than by hand; consequently, the engines may be kept more constantly in active operation. Likewise, wagon loaders save the time of trucks when loading materials from ground storage and thus facilitate a more economical use of the trucks.

*Increase in the capacity of other departments*

Frequently a mechanical change in a given department not only increases the output of that department but by causing a better balance of equipment increases as well the effective capacity of other departments or of the plant as a whole. Among the labor savings reported to us were a number of instances of such expansion due to the improvement in a 'bottle-neck' department.

## OTHER CONSIDERATIONS

Obviously, the preceding discussion of the effects of mechanization does not even touch upon many of the ways in which the increasing use of machines alters for better or worse the social and cultural life of the modern world. Even on the economic side, there are many additional questions which may appropriately be mentioned, although no attempt is made to answer them in this monograph. Does mechanization tend to reduce labor turnover? Is the ability of American manufacturers to compete in world markets largely due to the development of mechanical devices which supplant expensive and laborious manual effort? Is the increasing productivity arising from mechanized mass production really as great as it seems; to what extent is it true that the development of mass production, with its dependence upon extensive markets, brings with it indirect expenditures of labor which are not ordinarily allowed for in computing the changing efficiency of industry? To what extent, in other words, are manufacturing economies offset by increasing distribution costs? Will increasing mechanization, by lessening the labor force required, facilitate the deurbanization of industry and make it less dependent on a floating labor supply? Does the increasing use in recent years of individual electric motors,

driven largely by purchased power, encourage such decentralization of industry or its greater concentration in industrial centers? Is it probable that, just as the urban civilization of the last century or so has been built upon mechanical power, the inventions and developments of the present century may reverse the process and bring the restoration of an industrial rural life and the revitalization of the small community?

These suggestions of a few of the broader aspects of mechanization are presented here without any attempt to marshal the evidence bearing upon the validity of their implications. An adequate treatment would require a complete analysis of our economic and social system.<sup>58</sup> But it seems pertinent to cite these problems as part of the considerations to be weighed in any judgment upon the aggregate effects of the increasing resort to machines.

<sup>58</sup> For stimulating discussions of many of the economic and cultural aspects of the increasing mechanization of industry see: C. A. Beard, ed., *Toward Civilization*; Stuart Chase, *Men and Machines*; H. S. Dennison, *Some Economic and Social Accompaniments of the Mechanization of Industry*; E. Mayo, *The Human Effect of Mechanization*, and E. G. Nourse, *Some Economic and Social Accompaniments of the Mechanization of Agriculture*, in *American Economic Review, Supplement*, March 1930; and Glenn Frank, *Thunder and Dawn*.

APPENDIX A

MACHINE SALES AND OTHER  
MEASURES OF MECHANIZATION,  
BY YEARS

(For similar data, see also text tables 5, 6, 7, 8 and 13)

TABLE 36  
IRON AND STEEL: 1911-31

YEAR	MACHINE CASTING OF PIG IRON						
	NUMBER OF MACHINES INSTALLED BY LEADING MANU- FACTURERS <sup>1</sup>	PERCENTAGE OF OUT- PUT MACHINE CAST			PERCENTAGE OF STACKS MECHANI- CALLY CHARGED <sup>4</sup>	NEW IN- STALLATIONS OF ELECTRIC MAIN ROLL DRIVES (HORSE- POWER) <sup>5</sup>	GROWTH OF THE CONTINUOUS PROCESS <sup>6</sup>
		MERCHANT BLAST FURNACES <sup>2</sup>	IRON NOT DELIVERED	MOLTEN <sup>3</sup>			
1911	5	45	7	57	3,100	7	
1912	6	50	47	57	27,700	7	
1913	3	42	47	56	37,650	79.7	
1914	1	31	51	64	42,775	76.7	
1915	13	31	54	75	96,980	81.5	
1916	8	50	51	73	158,660	83.5	
1917	7	50	50	49	98,525	87.9	
1918	5	56	54	54	37,900	85.8	
1919	4	58	62	56	107,750	83.3	
1920	9	63	63	56	102,420	87.1	
1921	2	71	83	68	31,300	78.4	
1922	3	75	73	73	80,555	88.0	
1923	5	72	74	71	94,800	86.1	
1924	3	75	79	84	120,350	85.2	
1925	7	82	81	88	243,975	88.8	
1926	1	85	83	87	198,440	87.9	

## MECHANIZATION IN INDUSTRY

TABLE 36 (cont.)  
IRON AND STEEL: 1911-31

YEAR	MACHINE CASTING OF PIG IRON						
	NUMBER OF MACHINES INSTALLED BY LEADING MANU- FACTURERS <sup>1</sup>	PERCENTAGE OF OUT- PUT MACHINE CAST			PERCENTAGE OF STACKS MECHANI- CALLY CHARGED <sup>4</sup>	NEW IN- STALLATIONS OF ELECTRIC MAIN ROLL DRIVES (HORSE- POWER) <sup>5</sup>	GROWTH OF THE CONTINUOUS PROCESS <sup>6</sup>
		MERCHANT BLAST FURNACES <sup>2</sup>	IRON NOT DELIVERED MOLTEN <sup>3</sup>	ALL PIG IRON			
1927	7	81	85	91	134,150	87.8	
1928	7	7	85	7	188,150	89.5	
1929	7	7	89	7	890,600	91.1	
1930	7	7	91	7	146,740	87.5	
1931	7	7	93	7	95,325	91.7	

<sup>1</sup> Based on U. S. *Census of Manufactures* for 1914 and 1919, and lists of installations by manufacturers. The installations in the successive years 1895-1910 were: 1, 1, 3, 3, 4, 13, 7, 6, 12, 3, 4, 10, 6, 7, 10, 7. The average number of strands per listed installation varied from 2.0 to 2.4 in the period 1898-1916, and from 1.7 to 1.9 in the period 1917-26.

<sup>2</sup> Based upon survey reported in Bul. 474 (Ref. 37). The list of plants included is not completely identical from year to year. In 1890 no pig machines were used.

<sup>3</sup> Computed from data in *Statistical Reports* of the American Iron and Steel Institute. The percentage was zero in 1890; 40 in 1904.

<sup>4</sup> Same source of information as <sup>2</sup>.

<sup>5</sup> Computed from lists published in January issues, 1926-32, of *Iron and Steel Engineer*. Corresponding figures for the successive years 1905-10 are: 10,600, 25,640, 26,600, 8,050, 27,450, 30,700.

<sup>6</sup> The measure of growth utilized is the percentage of steel-making pig iron used by makers which is cast in molten condition. Computed from *Statistical Reports* of the American Iron and Steel Institute.

7 No data available.



## SALES BY YEARS

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**TABLE 37**  
**COMMERCIAL PRINTING: 1913-28**<sup>1</sup>

YEAR	NUMBER SOLD		RATIO OF CUMULATIVE SALES OF MACHINE- FED PRESSES TO TOTAL PRESSES SOLD, 1913-28 <sup>4</sup>
	JOB- AUTOMATICS <sup>2</sup>	AUTOMATIC FEEDING ATTACHMENTS <sup>3</sup>	
1913	. . .	328	8.7
1914	14	490	11.8
1915	82	555	14.9
1916	209	938	19.6
1917	271	1,924	28.2
1918	259	2,857	41.3
1919	277	3,948	53.6
1920	499	5,163	64.6
1921	325	2,021	64.7
1922	685	2,060	62.8
1923	1,199	2,238	62.5
1924	1,133	1,915	63.2
1925	1,738	1,348	63.7
1926	1,542	1,215	64.5
1927	1,461	1,217	65.7
1928	1,439	1,048	66.8

<sup>1</sup> Baker (Ref. 4), pp. 201, 204.

<sup>2</sup> Computed from cumulative annual sales as compiled by Dr. Baker, pp. 201, 204.

<sup>3</sup> Automatic feeding attachments for platen and flat-bed cylinder presses.

<sup>4</sup> Includes platens, job-automatics, small and large cylinders, and two-color and perfecting presses. For cumulative annual sales of each type see Ref. 4, p. 201.

This computation does not cover presses sold prior to 1913.

TABLE 38  
SELECTED MANUFACTURING EQUIPMENT: 1914-1929

## I

YEAR	FOUNDRY EQUIPMENT			MACHINE TOOLS <sup>3</sup> (NUMBER IN 1925: 100)	WOOD-WORKING MACHINERY (SHIPMENTS) <sup>4</sup>		YARN-WORKING MACHINES (NUMBER SOLD) <sup>5</sup>		
	ALL TYPES <sup>1</sup> (SHIPMENTS, VALUE IN 1925: 100)	MOLDING MACHINES <sup>2</sup> (NUMBER)			VALUE		WARP TYING	AUTOMATIC SPOOLERS	HIGH SPEED WARPERS
		HAND	POWER		(THOUSAND	NUMBER			
		TYPE	TYPE		DOLLARS)				
1914	6	364	6	81	6	6	43	7	7
1915	6	435	6	167	6	6	50	...	...
1916	6	886	6	209	6	6	71	...	...
1917	6	640	6	233	6	6	66	1	1
1918	6	380	200	219	6	6	67	1	1
1919	6	567	710	174	14,798	6	67	2	1
1920	6	707	625	135	21,320	6	38	8	4
1921	27	112	65	25	10,595	6	26	16	8
1922	70	180	304	51	15,644	6	18	5	3
1923	100	282	351	89	19,913	18,173	43	14	7
1924	79	136	119	63	18,179	13,725	22	22	15
1925	100	142	107	100	19,213	13,697	23	33	23
1926	106	127	79	108	19,004	14,521	24	53	45
1927	94	53	24	92	15,504	12,243	35	63	56
1928	131	89	31	158	16,212	12,022	22	75	69
1929	148	112	52	187	19,316	13,488	20	101	99

<sup>1</sup> Obtained by converting to 1925 base an index on 1922-24 base given in the *1932 Annual Supplement, Survey of Current Business*, p. 218. The series is said to represent from 65 to 70 per cent of the industry.

<sup>2</sup> The foundry molding machine data represent sales of single manufacturers, the hand series being of the plain squeezer type, for use on the lighter classes of work; the power series, the squeezer and jolt-squeezer types operated by compressed air.

<sup>3</sup> Index of number of machines, based on shipments, 1914-19, and new orders, 1919-28. The data were compiled by the National Machine Tool Builders' Association, and are published in the *Survey of Current Business*. The shipments were "reported by 29 firms representing about 20 per cent of the membership and believed to be fairly typical of the industry, as standard machines and the larger firms are represented". The data on 'new orders' include quantity reports "from between 50 and 60 firms, said to represent about one-third of the industry". We have spliced the two index numbers at 1919 and converted the resulting series to a 1925 base.

<sup>4</sup> From *1932 Annual Supplement, Survey of Current Business*, pp. 222-3; originally compiled by the Association of Manufacturers of Wood Working Machinery from reports of its members, averaging about 23 each month and varying from 20 to 27. The total shipments for 1925 represented 48 per cent of the value of wood-working machinery produced that year, according to the *Census of Manufactures*.

<sup>5</sup> Data from Barber-Colman Company, the sole manufacturers of these three types. Sales of the warp-tying machine in the successive years 1904-13 were: 24, 31, 64, 72, 21, 35, 27, 21, 44 and 40.

<sup>6</sup> No data for these years.

<sup>7</sup> No sales prior to 1917.

## MECHANIZATION IN INDUSTRY

TABLE 38 (cont.)

## SELECTED MANUFACTURING EQUIPMENT: 1914-1929

II 8

(number sold in 1925: 100)

YEAR	CLOTH AND GARMENT- WORKING MACHINES <sup>9</sup>				CRUSHING, MIXING, AND FILTERING EQUIPMENT <sup>10</sup>				PACKING AND FILLING MACHINES <sup>11</sup>			
	SERIES	SERIES	SERIES	SERIES	SERIES	SERIES	SERIES	SERIES	SERIES	SERIES	SERIES	SERIES
	A	B	C	D	E	F	G	H				
1914	17	...	4	31	13	13	13	...				
1915	29	...	15	46	13	13	13	...				
1916	39	...	54	62	13	13	13	...				
1917	53	<sup>12</sup>	80	100	17	126	13	...				
1918	46	14	96	116	34	130	13	...				
1919	66	0	104	58	45	126	13	...				
1920	74	43	174	112	44	122	13	...				
1921	70	0	39	38	43	56	13	...				
1922	89	43	73	44	62	52	151	<sup>12</sup>				
1923	90	100	127	72	62	108	127	16				
1924	95	57	83	52	82	80	105	32				
1925	100	100	100	100	100	100	100	100				
1926	109	114	130	121	112	104	122	100				
1927	116 <sup>15</sup>	100	125	118	160	<sup>14</sup>	100	111				
1928	<sup>14</sup>	86	144	116	212	<sup>14</sup>	100	<sup>14</sup>				
1929	88 <sup>15</sup>	29	158	134	191	<sup>14</sup>	102	14				

<sup>8</sup> Each series in this division is based on the sales of only one or two establishments.

<sup>9</sup> The comparable figures for 1908-13 for Series A are: 3, 5, 7, 7, 10 and 15.

<sup>10</sup> Series B, C and D represent, respectively, a type of heavy crushing machinery, sand mixers, and continuous filtering systems.

<sup>11</sup> Series E, F, G and H represent, respectively, filling and capping machines for milk bottles, labeling and casing machines for cylindrical containers, bag-filling machines, and butter-wrapping and cartoning machines.

<sup>12</sup> No sales made prior to the first year for which data are given.

<sup>13</sup> Sales began before 1914 but data for the early years are not available.

<sup>14</sup> Data not available for these years.

<sup>15</sup> Estimated from value of machines of this type as reported in *Census of Manufactures*.

SALES BY YEARS

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TABLE 38 (cont.)  
SELECTED MANUFACTURING EQUIPMENT: 1914-1929

III

YEAR	PERCENTAGE RATIO OF MACHINE- MADE CIGARS TO TOTAL <sup>16</sup>	NUMBER SOLD IN 1925: 100		GLASS BOTTLE MACHINES	
		TOBACCO- PREPARING MACHINERY <sup>18</sup>	AUTOMATIC PAPER-STOCK PROPORTIONING AND METER- ING SYSTEM	ESTIMATED	
				SEMI- AUTOMATICS <sup>20</sup>	PERCENTAGE OF JARS MADE ON AUTOMATICS <sup>21</sup>
1914	...	84	...	22	22
1915	...	119	...	22	22
1916	...	94	...	459	22
1917	<sup>17</sup>	135	...	428	50
1918	0.1	287	...	417	22
1919	2.6	387	...	22	22
1920	4.6	219	...	315	22
1921	6.0	132	<sup>19</sup>	288	22
1922	7.1	177	74	164	80
1923	9.1	155	105	130	22
1924	10.9	152	95	72	90
1925	14.8	100	100	98	22
1926	22.3	181	89	22	22
1927	28.0	171	121	26	22
1928	32.0	123	53	22	22
1929	35.1	126	42	22	22

<sup>16</sup> Computed from total production of cigars weighing more than 3 pounds per thousand and estimated production of machine-made cigars (Ref. 47). The ratio was 47.0 in 1930.

<sup>17</sup> Less than one-tenth of one per cent.

<sup>18</sup> Five series. Sales of these types began before 1914.

<sup>19</sup> Few or no sales made prior to 1922.

<sup>20</sup> The number of machines in use as reported by the union, which had practically complete control over these machines. Data for 1897-1924 from Barnett (Ref. 3, p. 110); for 1925 and 1927 from annual proceedings of the Glass Bottle Blowers Association. We are informed by the secretary of the Association that by 1929 there were none in use (letter to the writer, January 23, 1934). See Ch. III, especially Table 5, for other data pertaining to machines in the glass industries.

<sup>21</sup> Barnett (Ref. 3), p. 85. Estimates are for production years 1917, 1922-23 and 1924-25, respectively.

<sup>22</sup> Data not available for these years.

TABLE 39  
DOMESTIC SALES OF SELECTED TYPES OF FARM EQUIPMENT:  
1920-1929<sup>1</sup>

	<i>(number in thousands)</i>									
	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929
<i>Tractors</i>	163.0	4	101.2 <sup>6</sup>	117.7 <sup>6</sup>	99.0 <sup>6</sup>	122.0 <sup>6</sup>	126.7 <sup>7</sup>	160.7 <sup>7</sup>	103.9 <sup>7</sup>	160.0 <sup>7</sup>
Wheel <sup>2</sup>	4	4	96.4	110.7	92.2	114.2	116.9	147.1	86.9	136.3
Tracklaying <sup>3</sup>	4	4	3.7	4.4	4.4	4.6	6.0	8.8	12.9	19.0
<i>Tractor-drawn equipment</i>										
Moldboard plows	122.0	24.7	52.4	54.1	40.7	53.9	66.2	70.7	79.8	90.9
Disk plows	22.6	6.2	7.5	7.4	7.3	10.7	11.2	11.8	15.9	26.1
Listers	2.2	.7	1.3	1.0	2.5	2.7	6.5	8.0	8.9	4
Grain drills	3.2	.9	.9	.4	.2	.7	2.4	5.9	9.2	15.8
Disk harrows	59.7	28.6	27.3	30.3	26.0	29.8	39.8	39.8	44.3	46.0
<i>Other power equipment</i>										
Internal-combustion engines	216.1	116.6 <sup>5</sup>	90.6	129.0	104.1	147.8	141.7	106.8	105.7	111.8
Corn shellers	6.5	3.3	5.3	5.5	3.3	3.4	3.	3.7	3.5	3.7
Hay presses	4.3	1.6	2.5	2.0	2.2	1.7	1.8	1.8	1.2	1.7
Feed grinders and crushers	52.3	15.4	46.0	49.5	32.5	35.3	41.8	37.4	44.4	46.8
Spraying outfits	10.7	2.2	10.7	10.4	8.0	8.8	10.0	11.3	11.9	10.7
Water systems	4	4	29.5	20.7	58.5	98.2	91.2	101.2	126.0	130.7
Milking machines	28.1	8	9.4	11.1	11.2	14.3	14.5	15.3	19.9	21.3
<i>Other equipment<sup>4</sup></i>										
Combines (harvester-thresher)	2.7	2.3	1.6	1.1	1.6	3.6	6.3	11.2	18.0	19.7
Corn huskers and shredders	5.1	3.0	3.3	3.5	1.6	3.8	2.8	1.5	1.7	1.0
Potato diggers, plow type	6.8	3.2	5.1	2.6	2.5	2.6	2.7	3.4	3.5	3.0

Potato diggers, elevator type	10.5	7.4	14.2	8.1	5.8	4.9	7.8	10.9	13.7	7.9
Farm elevators, portable and stationary	10.3	.6	4.9	7.5	4.6	7.0	6.6	7.0	11.3	11.0
Ensilage and fodder cutters	23.9	10.6	13.8	13.9	12.1	13.0	13.5	13.9	12.7	10.8
Overhead feed and litter carriers	14.3	.9	6.8	9.9	8.4	9.9	8.3	9.7	9.6	9.8

<sup>1</sup> Based upon data contained in (1) U. S. Bureau of Public Roads, Circular 212, *The Manufacture and Sale of Farm Equipment in 1920*; (2) U. S. Bureau of the Census, *Census of Manufactures, 1921*, and annual bulletins entitled *Manufacture and Sale of Farm Equipment, 1922-29*, inclusive. Although the number of reporting concerns varies somewhat, it is believed that each year all but a small part of the total production is included.

<sup>2</sup> Not including garden tractors and motor cultivators.

<sup>3</sup> Not including tracklaying attachments (used to convert the wheel type to the tracklaying type). In 1926, 2,234 were sold in the United States.

<sup>4</sup> No data available.

<sup>5</sup> These figures are the number manufactured, rather than sold, and probably exceed the domestic sales.

<sup>6</sup> Includes the garden type tractor.

<sup>7</sup> Includes the garden type tractor and motor cultivators.

<sup>8</sup> Data for domestic sales not available.

<sup>9</sup> All power driven.

SALES BY YEARS

## MECHANIZATION IN INDUSTRY

TABLE 40  
COAL MINING: 1914-1929

YEAR	UNDERCUTTING MACHINES <sup>1</sup>				PERCENTAGE OF TONNAGE MINED BY STRIPPING WITH POWER SHOVELS <sup>1</sup>		PERCENTAGE OF BITUMINOUS COAL LOADED WITH SELF-FEEDING DEVICES <sup>2</sup>
	NUMBER IN USE		PERCENTAGE UNDERCUT BY MACHINE		ANTHRA-CITE	BITUMI-NOUS	
	BITUMI-NOUS	ANTHRA-CITE	BITUMI-NOUS	ANTHRA-CITE <sup>3</sup>			
1914	16,507	<sup>4</sup>	51.7	<sup>4</sup>	<sup>4</sup>	0.3	...
1915	15,692	<sup>4</sup>	55.0	<sup>4</sup>	<sup>4</sup>	0.6	...
1916	16,198	<sup>4</sup>	56.5	<sup>4</sup>	1.4	0.8	...
1917	17,235	<sup>4</sup>	55.5	<sup>4</sup>	2.5	1.0	...
1918	18,463	176	55.9	2.1	2.6	1.4	...
1919	18,959	<sup>4</sup>	59.2	1.9	2.4	1.2	...
1920	19,103	139	59.8	1.1	2.5	1.5	...
1921	19,618	114	65.6	1.1	2.3	1.2	...
1922	20,436	82	63.2	1.0	1.9	2.4	...
1923	21,229	162	66.9	1.4	2.7	2.1	0.3
1924	18,660	212	69.5	1.7	2.2	2.8	0.7
1925	17,551	159	70.6	1.6	2.7	3.2	1.2
1926	17,466	90	71.7	1.2	3.0	3.0	1.8
1927	17,388	138	72.2	1.5	2.8	3.6	<sup>4</sup>
1928	15,261	193	73.8	1.8	3.4	4.0	2.9
1929	14,731	137	75.4	1.6	2.7	3.8	3.6

<sup>1</sup> Data for undercutting machines and stripping operations from *Mineral Resources* (Ref. 32), Pt. II: 1923, p. 582; 1927, pp. 374-5; 1929, pp. 751-5.

<sup>2</sup> Computed from coal production and tonnage of coal mechanically loaded as reported in *Mineral Resources of the United States* (Ref. 32) 1929, II, 701, 758-9. In 1930 the percentage mechanically loaded was 5.0; in 1931, 5.9 (computed from data in U. S. Bureau of Mines *Coal in 1931*), pp. 427, 451.

Mechanically loaded coal includes that "loaded by mobile machines, scrapers, and duckbills and other self-loading conveyors" but not coal loaded by hand-fed pit-car loaders and other hand-loaded conveyors or by power shovels in strip pits.

<sup>3</sup> Percentage of fresh mined coal.

<sup>4</sup> No data available.



SALES BY YEARS

TABLE 41  
SELECTED NON-MANUFACTURING EQUIPMENT: 1914-1929

I

YEAR	PRODUCTION OF POWER AND HEAT					
	EXCAVATING AND GRADING		HEAVY INDUSTRIAL STOKERS <sup>3</sup> (NEW ORDERS)		LOCOMOTIVE	SPECIAL
	POWER SHOVELS <sup>1</sup>	NARROW TRENCHERS <sup>2</sup>	NUMBER	TOTAL HORSE-POWER	STOKERS <sup>4</sup> sold in 1925: 100)	ANNEALING AND DRYING SYSTEMS <sup>5</sup>
	(number sold)	(number sold in 1925: 100)		(thousands)	(number sold)	(number sold)
1914	181	...	...	...	23	...
1915	197	...	...	...	36	2
1916	366	...	...	...	86	3
1917	431	...	...	...	100	9
1918	392	...	...	...	171	8
1919	536	...	2,809	633	19	20
1920	641	...	2,195	791	122	22
1921	465	...	871	327	9	4
1922	876	...	1,563	725	130	12
1923	1,147	14	1,464	730	179	16
1924	1,105	33	1,128	514	100	15
1925	6	100	1,348	553	100	16
1926	6	114	1,361	546	164	19
1927	6	109	1,374	484	6	14
1928	6	82	1,490	509	6	7
1929	6	94	1,716	600	6	9

<sup>1</sup> Power shovels of contractors' sizes, 1/2 to 1 3/4 yd., of steam, gasoline and electric types, sold by a group of manufacturers including 3 firms in 1914; 5 in 1915; 6 in 1921; 8 in 1922; and 10 in 1924. In each instance the increase in numbers represents establishments just beginning the manufacture of this type of shovels in the given year. The sales in earlier years are:

1900	14	1904	45	1908*	69	1912	195
1901	16	1905	49	1909	95	1913	165
1902	27	1906	45	1910	105		
1903	35	1907	90	1911	147		

<sup>2</sup> Data from manufacturers of narrow trenchers.

## MECHANIZATION IN INDUSTRY

TABLE 41 (cont.)

## SELECTED NON-MANUFACTURING EQUIPMENT: 1914-1929

## II

YEAR	AUTOMATIC TELEPHONE SWITCHBOARDS <sup>7</sup>		MOTORIZED RAILWAY SECTION-CREW CARS <sup>8</sup>	STREET AND CATCH-BASIN CLEANING MACHINES <sup>9</sup>
	NUMBER OF STATIONS SERVED	PERCENTAGE OF TOTAL STATIONS	(number sold by reporting manufacturers)	
	(thousands)			
1914	10	10	3,103	4
1915	10	10	2,971	7
1916	10	10	2,706	19
1917	10	10	2,885	22
1918	10	10	2,447	33
1919	130	1.7	2,735	49
1920	157	1.9	3,634	53
1921	236	2.7	1,808	47
1922	338	3.6	2,541	33
1923	575	5.5	3,227	68
1924	969	8.6	2,429	68
1925	1,496	12.4	2,596	74
1926	1,975	15.4	2,954	107
1927	2,550	18.6	2,941	104
1928	3,147	21.7	3,776	106
1929	4,014	26.0	4,119	10

<sup>8</sup> From 1919 through 1922 compiled by the Stoker Manufacturers' Association; thereafter by the Bureau of the Census, U. S. Department of Commerce, and published in the *Survey of Current Business* and mimeographed press releases. In the latter the data are classified as installed under fire-tube or water-tube boilers. The series represents practically the entire industry, changes in the number of plants being due, apparently, to consolidations. The 1929 compilations cover ten plants.

<sup>4</sup> Data from two manufacturers.

<sup>5</sup> Six series covering metal annealing furnaces and clay-burning kilns of the continuous tunnel type and automatic drying systems for clay products.

<sup>6</sup> Comparable data not available for these years.

<sup>7</sup> The telephone data cover Bell-owned stations, as of the close of the specified year, and are furnished by the American Telephone and Telegraph Company.

<sup>8</sup> From three manufacturers. The exact distribution by years of about 600

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cars sold, 1914-17, is an estimate. A relatively small number of cars used for inspection purposes is included. Comparable data for 1911, 1912 and 1913 are 600, 900 and 2,294 respectively.

<sup>9</sup> Two types.

<sup>10</sup> No data available.

TABLE 42

EQUIPMENT FOR THE COMMERCIAL PREPARATION OF FOOD AND DRINK: 1914-1929<sup>1</sup>

(number sold by reporting establishments in 1925: 100)

YEAR	BOTTLE- WASHING MACHINES	BREAD- AND CAKE-MIXING MACHINES	DISH- WASHING MACHINES	VEGETABLE- PARING MACHINES
1914	92	<sup>3</sup>	<sup>2</sup>	22
1915	102	...	...	19
1916	81	...	...	37
1917	66	...	...	51
1918	87	...	58	74
1919	121	79	63	61
1920	129	82	67	70
1921	71	86	65	53
1922	66	97	76	60
1923	76	98	85	82
1924	88	93	79	93
1925	100	100	100	100
1926	80	109	111	90
1927	<sup>4</sup>	114	111	86
1928	<sup>4</sup>	112	138	<sup>4</sup>
1929	<sup>4</sup>	102	143	<sup>4</sup>

<sup>1</sup> The index for bottle-washing machines covers five models sold by three manufacturers, the total number in 1925 being 548; the index for bread- and cake-mixing machines covers the sales of two manufacturers; for dish-washing machines, one manufacturer; for vegetable-paring machines, six models sold by two manufacturers.

<sup>2</sup> On market prior to 1918, but data not available.

<sup>3</sup> Sales in this series began before 1914 but are available only for 1919-29.

<sup>4</sup> No data available for these years.

## MECHANIZATION IN INDUSTRY

TABLE 43  
NUMBER OF ELECTRIC HOUSEHOLD APPLIANCES SOLD, BY  
SELECTED TYPES: 1923-1930<sup>1</sup>

(thousands)

ELECTRIC APPLIANCE	1923	1924	1925	1926	1927	1928	1929	1930
Irons	2,250		<sup>2</sup> 2,750	3,000	3,000	3,000	3,150	2,363
Vacuum cleaners	1,016	904	958	1,065	1,195	1,219	1,253	978
Washing machines <sup>2</sup>	554	612	733	844	790	810	956	802
Ironing machines	50		<sup>2</sup> 40	60	68	92	126	100
Sewing machines	625		<sup>2</sup> 170	200	350	380	399	319
Floor polishers	<sup>2</sup>	<sup>2</sup>	50	90	47	49	53	33
Dishwashers	<sup>2</sup>	<sup>2</sup>	4	7	9	10	12	15

<sup>1</sup> Except where otherwise stated, the estimates in this table are compiled from the issues of *Electrical World* for March 1, 1924, p. 461, and April 2, 1927, p. 736, and of *Electrical Merchandising* for January 1927, p. 77; 1928, p. 70; 1929, p. 62; 1930, p. 52; and 1931, p. 22. The data for vacuum cleaners were originally compiled by the Vacuum Cleaner Manufacturers' Association.

<sup>2</sup> According to a letter from the American Washing Machine Manufacturers' Association, February 23, 1928, the sales of the electric washing machine industry in the United States and Canada were 566,000 in 1920; 289,000 in 1921; and 423,000 in 1922. They also report the number of engine-driven washing machines (in thousands) as follows:

1920	58	1922	20	1924	17	1926	67
1921	16	1923	20	1925	36	1927	85

<sup>2</sup> No data available.

TABLE 44  
NUMBER OF USERS OF ELECTRIC HOUSEHOLD APPLIANCES, BY  
SELECTED TYPES: 1924-1930<sup>1</sup>

(estimates as of December 31, in thousands)

ELECTRIC APPLIANCE	1924	1926	1927	1928	1929	1930
Irons	10,200	12,800	15,300	17,700	18,538	20,001
Vacuum cleaners	5,000	5,900	6,828	7,700	8,600	9,086
Washing machines	3,500	4,250	5,000	5,735	6,585	7,185
Ranges	268	480	590	725	875	1,000
Cookers	<sup>2</sup>	750	950	1,050	1,175	<sup>2</sup>
Ironing machines	210	280	348	480	580	680

<sup>1</sup> Compiled from the files of *Electrical Merchandising* and supplements, 1925 to 1931.

<sup>2</sup> No data available.

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TABLE 45  
PERCENTAGE OF WIRED HOMES EQUIPPED WITH SPECIFIED  
ELECTRIC APPLIANCES: 1924-30<sup>1</sup>

(estimates as of December 31)

ELECTRIC APPLIANCE	1924	1926 <sup>2</sup>	1927	1928	1929	1930
Irons	77.0	80.0	87.0	93.0	94.0	97.8
Vacuum cleaners	37.7	37.1	38.8	40.7	43.6	44.4
Washing machines	26.4	26.7	28.4	30.2	33.4	35.1
Ranges	2.0	3.0	3.4	3.8	4.4	4.8
Cookers	<sup>3</sup>	4.7	5.4	5.5	5.9	<sup>3</sup>
Ironing machines	1.6	1.7	2.0	2.5	2.9	3.3

<sup>1</sup> Compiled from the files of *Electrical Merchandising*: February 1925 (supplement); January 1928, p. 71; January 1929, p. 63; January 1930, p. 53; and January 1931, p. 24.

<sup>2</sup> The year 1925 is omitted because the available data do not appear to be comparable with the data for the other years.

<sup>3</sup> No data available.

TABLE 46  
HANDLING EQUIPMENT, MOBILE TYPES: 1914-1929

YEAR	MOTOR TRUCKS		ELECTRIC			LUMBER
	NUMBER PRODUCED IN THE U. S. <sup>1</sup>	REGISTRATIONS <sup>2</sup>	INDUSTRIAL TRUCKS AND TRACTORS, <sup>3</sup>	PORTABLE CON-VEYORS	SELF-FEED-ING WAGON LOADERS <sup>4</sup>	CARRIERS AND PILERS <sup>5</sup>
			DOMESTIC SHIPMENTS (NUMBER)	(NUMBER SOLD BY REPORTING FIRMS IN 1925: 100)	(NUMBER SOLD BY REPORTING FIRMS)	
1914	25,375	85,600	200	20	4	3
1915	74,000	136,000	350	23	16	16
1916	92,130	215,000	750	25	31	24
1917	128,157	326,000	1300	46	51	9
1918	227,250	525,000	1800	106	54	18
1919	275,943	794,372	1300	88	73	46
1920	321,789	1,006,082	1914	119	111	47
1921	143,712	1,118,520	351	60	67	23
1922	269,991	1,375,725	793	91	88	54
1923	409,295	1,612,569	1340	100	125	139
1924	416,659	2,134,724	849	103	98	99

## MECHANIZATION IN INDUSTRY

TABLE 46 (cont.)

HANDLING EQUIPMENT, MOBILE TYPES: 1914-1929

YEAR	MOTOR TRUCKS		ELECTRIC INDUSTRIAL TRUCKS AND TRACTORS, <sup>3</sup> DOMESTIC SHIPMENTS (NUMBER)	PORTABLE CON- VEYORS (NUMBER SOLD BY REPORTING FIRMS IN 1925: 100)	SELF-FEED- ING WAGON LOADERS <sup>4</sup> (NUMBER SOLD BY REPORTING FIRMS)	LUMBER CARRIERS AND PILERS <sup>5</sup> (NUMBER SOLD BY REPORTING FIRMS)
	NUMBER PRODUCED IN THE U. S. <sup>1</sup>	REGISTRA- TIONS <sup>2</sup>				
	1925	530,659				
1926	516,947	2,764,222	1317	107	125	136
1927	464,793	2,914,019	1129	104	113	112
1928	543,342	3,113,999	1321	95	82	160
1929	771,020	3,379,854	1857	101	80	156

<sup>1</sup> *Survey of Current Business*, June 1927, p. 22, and 1932 *Annual Supplement*, pp. 274-5. The figures for 1922-29 include foreign assemblies.

<sup>2</sup> Registrations from Ref. 19, 1931, p. 16.

<sup>3</sup> Data for 1914-19 are rough estimates based on reports from establishments producing about 50 per cent of the total number in 1920. It is assumed that the fraction produced by these establishments decreased gradually from 1914 to 1920. Data for 1920-24, from the Industrial Truck Association; for subsequent years, from press releases of the U. S. Department of Commerce, based upon reports from the 9 to 11 leading manufacturers. Similar estimates for the successive years 1906-13 are: 5, 10, 10, 25, 45, 75, 130, 200.

<sup>4</sup> Three models, comprising the major portion of the industry. These machines pick up loose material such as sand, gravel or snow and convey it to the box of wagon or truck.

<sup>5</sup> Four models, gasoline and electric types. The total number sold to 1929, inclusive, was 1,151.

**TABLE 47**  
**HANDLING EQUIPMENT, FIXED AND SEMIMOBILE TYPES: 1920-1929**  
*(annual value in thousands of dollars)*

YEAR	ELECTRIC HOISTS (NEW ORDERS) <sup>1</sup>	ELECTRIC OVERHEAD CRANES <sup>2</sup>		ELECTRIC INDUSTRIAL LOCOMOTIVES <sup>3</sup>		ELECTRIC MINING LOCOMOTIVES <sup>3</sup>		INSTALLED HANDLING SYSTEMS, SAMPLE <sup>4</sup>
		SHIPMENTS	NEW ORDERS	TROLLEY	STORAGE BATTERY	TROLLEY	STORAGE BATTERY	(VALUE IN 1925: 100)
1920	3,194	...	...	...	...	...	...	114
1921	1,590	6,893	2,708	...	...	...	...	26
1922	1,590	3,796	6,898	...	...	...	...	68
1923	2,118	10,567	9,168	...	...	...	...	81
1924	1,673	9,420	8,900	...	...	...	...	82
1925	2,016	9,742	10,770	...	...	...	...	100
1926	1,920	11,722	11,688	286	305	3,210	752	119
1927	1,620	9,308	7,976	190	329	2,867	805	95
1928	2,448	7,126	7,598	796	436	1,718	518	143
1929	3,102	12,290	14,619	1,344	267	2,720	806	129

<sup>1</sup> Compiled by the Electric Hoist Manufacturers' Association from the reports of nine firms. Data for 1925-30 in *Survey of Current Business*, August 1929, p. 42, and February 1931, p. 26. Issues of the *Survey* since March 1931 have carried revised and larger figures for this series, without explanation of the revision. We have used the unrevised figures as probably more comparable with the data for the years prior to 1925.

<sup>2</sup> "Compiled by the Electric Overhead Crane Institute, from reports of eleven manufacturers, estimated to cover 98 per cent of the output of electric overhead cranes for factories, etc." Published in *Survey of Current Business*, 1932 *Annual Supplement*, pp. 218-19.

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\* Shipments as reported to the U. S. Department of Commerce by ten firms, comprising practically the entire industry. Mimeographed press releases, March 2, 1929 and January 17, 1930. Number of locomotives also given. In 1929, there were shipped 56 industrial locomotives of the trolley type and 13 storage battery type; 468 mining locomotives of trolley type and 288 storage battery.

\* Based on reports from a small number of firms, whose total installations ranged from \$1,500,000 to \$2,000,000 in the peak years. The effect of changes in the list of reporting firms has been eliminated so far as possible by constructing the index from year-to-year percentage changes in installations of identical firms.



**APPENDIX B**

**ESTIMATES OF THE EXTENT OF USE IN  
THE UNITED STATES OF SELECTED  
LABOR-SAVING DEVICES**

*Explanation of abbreviations and footnote references*

**MD** = Data furnished by one or more manufacturers of the specified device and believed to be exact or approximately so

**ME** = Estimates by one or more manufacturers of the specified equipment and believed to be reasonably accurate

**MRE** = Estimates by one or more manufacturers of the specified equipment and believed to have a wide margin of possible error

**RE** = Rough estimate

**T** = Based upon data given in the specified table in this report or in the sources from which it was prepared

The numbered references are to footnotes to the respective tables, with the exception that those prefaced with 'Ref.' refer to the serially numbered bibliography in Appendix D.

**TABLE 48**

**AGRICULTURE**

**I. GENERAL PURPOSE EQUIPMENT**

<b>TYPE</b>	<b>EXTENT OF USE IN THE UNITED STATES, YEAR TO WHICH ESTIMATE APPLIES AND SOURCE OF INFORMATION</b>	<b>1920</b>	<b>1930</b>
<b>Motor trucks</b>	Number on farms <sup>1</sup>	139,169	900,385
	Percentage of farms reporting trucks	2.0	13.4
<b>Automobiles</b>	Number on farms <sup>1</sup>	2,146,362	4,134,675
	Percentage of farms reporting automobiles	30.7	58.0

## MECHANIZATION IN INDUSTRY

TABLE 48 (cont.)

## AGRICULTURE

## I. GENERAL PURPOSE EQUIPMENT (cont.)

TYPE	EXTENT OF USE IN THE UNITED STATES, YEAR TO WHICH ESTIMATE APPLIES AND SOURCE OF INFORMATION	
	1920	1930
Tractors	Number on farms <sup>1</sup> (1925, 505,933) <sup>4</sup>	246,083 920,021
	Percentage of farms reporting tractors	3.6 13.5
	Domestic sales of tractors, 1922-29, (for both agricultural and industrial uses): all types, 991,000; tracklaying type, 64,000. <sup>5</sup>	
	Percentage ratio of value of tractors to all farm equipment sold in 1929, 33.9 (T. 6)	
Stationary gas engines	Number on farms <sup>1</sup>	7 1,131,108
	Percentage of farms reporting gas engines	7 15.0
	Total domestic sales, 1920-29, 1,270,309 (sales in 1921 not known but estimated as equal to the number produced, T. 39)	
Electrification	Electric motors on farms <sup>1</sup>	7 386,191
	Percentage of farms reporting electric motors	7 4.1
	Farm dwellings lighted by electricity (including those lighted by gas in 1920):	
	Number	452,620 841,310
	Percentage	7.0 13.4
	In 1931, of approximately 1,000,000 farms using electricity, 644,500 had high-line service, and between 300,000 and 400,000 had independent or unit farm-lighting plants (Ref. 24, p. 449). Of a group of farms surveyed in 1925-26, 23 per cent had stationary engine power, 28.5 per cent had electric power available	

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TABLE 48 (cont.)

AGRICULTURE

I. GENERAL PURPOSE EQUIPMENT (cont.)

EXTENT OF USE IN THE UNITED STATES, YEAR TO WHICH ESTIMATE APPLIES AND SOURCE OF INFORMATION

and 16 per cent of the reporting farms without electricity were within one mile of a transmission line (T. 51).

II. SOIL PREPARATION AND GRAIN HARVESTING

TYPE OF EQUIPMENT	EXTENT OF USE, YEAR TO WHICH ESTIMATE APPLIES AND SOURCE OF INFORMATION
Tractor-drawn plows	<p>Total domestic sales (for use in the U. S.), 1920-29: moldboard, 655,319; disk, 126,822 (T. 39).                      Percentage of total value of moldboard plows sold which are tractor-drawn (1929) 66; of disk plows, 83. No pronounced trend in these ratios (T. 6).                      In 1928 on 25 per cent of Illinois farms surveyed most of the plowing was done with tractor-drawn plows.<sup>2</sup></p>
Tractor-drawn disk harrows	<p>Total domestic sales (1920-29) 371,513 (T. 39).                      Percentage ratio to dollar value of all disk harrows sold (1929) 60. No pronounced trend in this ratio.                      28 per cent of Illinois farms had tractor-drawn disk harrows in 1928.<sup>2</sup></p>
Harvester-thresher combines	<p>Total number, domestic sales (1920-29), 68,013.                      Percentage ratio to dollar value of all harvesting machinery sold (1929), 51.9. Sharp increases in this ratio in 1926, 1927 and 1928.                      Estimated that 30 per cent of wheat acreage in Kansas was harvested with combines in 1926.<sup>2</sup></p>
Tractor-drawn binders	<p>Used on only 0.2 per cent of Illinois farms (1928).                      13 per cent of Illinois farms used tractor-drawn binders in 1928; 62 per cent used the horse-drawn type.<sup>2</sup></p>
Small-size threshing machines	<p>On 63 per cent of Illinois farms (1928) threshing was hired, but 11 per cent of threshing machines were farmer-owned, 77 per cent of these being 28-inch cylinders or less (most of which can be powered by tractors sufficiently small for field work). 88 per cent of separators sold in 1929 were 28-inch or less, as compared with 73 per cent in 1921.</p>

TABLE 48 (cont.)

## III. ROW CROPS

TYPE OF EQUIPMENT	EXTENT OF USE, YEAR TO WHICH ESTIMATE APPLIES AND SOURCE OF INFORMATION
Tractor-drawn listers	Total number, domestic sales, 1920-29, over 37,000. Percentage ratio to dollar value of all listers sold: 14.2 in 1920; 34.9 in 1928. Sharp increases in this ratio in 1926, 1927 and 1928 (T. 6).
Tractor-drawn cultivators	Percentage ratio to dollar value of all cultivators sold: 16.6 in 1929. Sharp increases in this ratio in 1927, 1928 and 1929.
Motor cultivators	Not extensively used. It is estimated that most of the cultivation was done with motor cultivators on only 0.7 per cent of Illinois farms in 1928. <sup>2</sup>
Rotary hoes	Use relatively small but increasing. Domestic sales in 1929 were 14,504. Used for most of the cultivation on 4.3 per cent of Illinois farms in 1928.
Multiple-row corn planters	Use of more than two-row planters limited. For example, in 1928, 87 per cent of Illinois farms had two-row planters; 0.2 per cent, three-row; and 0.02 per cent, four-row.
Mechanical corn pickers	Use small but increasing. Domestic sales of mechanical picker-huskers totalled 25,381 in 1927-29. In 1928, they were in use on 11,000 Illinois farms or 4.9 per cent of farms over 50 acres.
Corn huskers and shredders (usually belt-driven at barn)	Practically all power. Sales stationary or declining (T. 39). Used on 9.4 per cent of Illinois farms in 1928.
Cotton sleds and pickers	Cotton sleds used for a portion of the crop in western Texas and Oklahoma in late 'twenties, especially when prices were low. Also there has been some experimental use of mechanical cotton pickers.
Potato diggers	Total domestic sales, 1920-29: plow type, 35,343; elevator type, 91,130.

EXTENT OF USE

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TABLE 48 (cont.)

IV. STOCK AND DAIRY FARMING

TYPE OF EQUIPMENT	EXTENT OF USE, YEAR TO WHICH ESTIMATE APPLIES AND SOURCE OF INFORMATION
Milking machines	<p>Total domestic sales (1920-29), 188,415, assuming domestic sales in 1921 were the same as the number manufactured (T. 39).</p> <p>In use on 3.1 per cent of Illinois farms of over 50 acres (1928), and on 9 per cent of Wisconsin farms (1928).<sup>3</sup> Sampling surveys found milking machines on 10 per cent of 204 farms in southeastern Pennsylvania; on 23.6 per cent of 318 farms in northeastern New Jersey (1930-31); on 23.2 per cent of 414 farms in Grafton County, N. H. (1930); on 34.5 per cent of 863 farms in Connecticut; and on 50.6 per cent of 83 farms in Coos County, N. H. (1931).<sup>6</sup></p>
Cream separators	<p>Percentage ratio of value of power-driven separators to value of all cream separators sold (1928), 7.4 (T. 6). No distinct trend in this ratio, 1922-28.</p>
Water systems	<p>Total domestic sales (1922-28), 655,976, mostly power operated.</p> <p>Percentage of farms with water piped into the dwelling house: 10.0 in 1920; 15.8 in 1930.</p> <p>Percentage of farms in Wisconsin with running water in barns (1927), 30.<sup>5</sup></p> <p>Mechanically operated water systems on Illinois farms (1928): electric on 5.7, gas engine on 12.2 and wind-mills on 16.1 per cent of the number of farms.<sup>2</sup></p>
Overhead feed and litter carriers	<p>Total domestic sales (1920-29), 87,528.</p>
Power hay presses	<p>Constituted 71 to 84 per cent of value of all hay presses sold, each year 1920-29. No marked trend.</p>
Power feed grinders and crushers	<p>Total domestic sales (1920-29), 401,539. In value, over 90 per cent of all feed grinders sold. No distinct trend.</p>
Ensilage and fodder cutters	<p>Total domestic sales (1920-29), 137,993.</p>
Power corn shellers	<p>83 per cent of all corn shellers sold (1929) were power-driven. No trend in this ratio, 1920-29.</p>
Power spraying outfits	<p>Percentage ratio of power type to total value of all spraying outfits sold (1929), 69.0. No marked trend.</p>

## MECHANIZATION IN INDUSTRY

TABLE 48 (cont.)

## IV. STOCK AND DAIRY FARMING (cont.)

TYPE OF EQUIPMENT	EXTENT OF USE, YEAR TO WHICH ESTIMATE APPLIES AND SOURCE OF INFORMATION
Farm elevators, portable and stationary	Total domestic sales (1920-29), 70,244.

<sup>1</sup> U. S. Bureau of the Census, *15th Census of the U. S., 1930, Agriculture*, Vol. II, Pt. 1.

<sup>2</sup> All data given for Illinois in Table 48 are from mimeographed report of estimates based on a survey made by A. J. Surratt and R. K. Smith, *Illinois Farm Equipment Survey*, and are for 1928.

<sup>3</sup> All data for Wisconsin in Table 48 are from Bulletin No. 90, U. S. Department of Agriculture and Wisconsin Department of Agriculture, *Wisconsin Agriculture—A Statistical Atlas, 1926-27*.

<sup>4</sup> U. S. Bureau of the Census, *Census of Agriculture, 1925*.

<sup>5</sup> Based upon data in Table 39 or given in the sources listed in footnote <sup>1</sup> thereto. Unless otherwise specified, the sales data in Table 48 are in terms of the number of machines sold for use in the U. S.

<sup>6</sup> U. S. Department of Agriculture, *Yearbook of Agriculture, 1932*.

<sup>7</sup> Comparable data for 1920 not available.

TABLE 49

EXCAVATING AND HIGHWAY CONSTRUCTION <sup>1</sup>

EQUIPMENT OR PROCESS	EXTENT OF USE, YEAR TO WHICH ESTIMATE APPLIES AND SOURCE OF INFORMATION
Power shovels, contractors' sizes (½-1¼ yds.)	Widely used in excavation for buildings and in deep cuts for highway grading. Number sold, 1900-13, by 2 leading manufacturers, 1,097; 1914-24, by 3 to 10 manufacturers, 6,337 (MD). Total production in census years 1925, 1927 and 1929: \$102,063,000 (T. 13).
Trenching	Large ditching almost entirely a machine process. Total production of trench excavators in 1925, 1927 and 1929: \$9,068,584 (T. 13). Narrow trenchers for pipe lines, gas mains, telephone conduits, etc., relatively new. 1,089 machines sold by leading manufacturers, probably representing at least 50 per cent of the industry, 1923-29. By 1925

TABLE 49 (cont.)

EXCAVATING AND HIGHWAY CONSTRUCTION <sup>1</sup>

EQUIPMENT OR PROCESS	EXTENT OF USE, YEAR TO WHICH ESTIMATE APPLIES AND SOURCE OF INFORMATION
Central proportioning plants	about 30. per cent of work for which they are adapted was handled by these machines; by 1929, about 70 per cent (MRE). In general use on larger highway jobs by 1925, as a substitute for wheelbarrow proportioning at point of construction (Ref. 20-a).
Subgrader, in highway construction	Introduced in 1920. In 1926 in use on 80 to 90 per cent of larger jobs, where its use is most clearly advantageous (MRE). In use on 79 per cent of those construction operations inspected in 1925 where the subgrader was feasible (Ref. 20-a).
Machine finishers on cement highway construction	Used on 80 to 90 per cent of larger jobs (1926, MRE). In use on 84 per cent of 1925 field inspections (Ref. 20-a).

<sup>1</sup> For further detail concerning sales of selected types of excavating machinery, see Tables 13 and 41.

TABLE 50

SELECTED HOUSEHOLD APPLIANCES <sup>1</sup>

EQUIPMENT OR PROCESS	EXTENT OF USE, YEAR TO WHICH ESTIMATE APPLIES AND SOURCE OF INFORMATION
<i>Availability of power</i> (see also Table 48, I)	Number of wired homes, December 1930, 20,438,774, with 70.5 per cent of the total population in dwellings with electric current. <sup>2</sup>
<i>Laundrying</i>	
Electric washing machines	7,185,000 users, December 1930; in 35 per cent of wired homes (T. 44 and 45).
Gasoline-power washing machines	Number sold, 1920-27, 318,000 (T. 43, footnote).
Electric irons	Users, December 1930, 20,000,000; in 98 per cent of wired homes (T. 44 and 45).
Electric ironing machines (flat work)	Users, December 1930, 680,000; in 3.3 per cent of wired homes (T. 44 and 45).
Stationary laundry tubs	Percentage of dwellings equipped, 1925-26: urban, 28; rural, 6 (T. 51).

## MECHANIZATION IN INDUSTRY

TABLE 50 (cont.)  
SELECTED HOUSEHOLD APPLIANCES<sup>1</sup>

EQUIPMENT OR PROCESS	EXTENT OF USE, YEAR TO WHICH ESTIMATE APPLIES AND SOURCE OF INFORMATION
<i>House cleaning</i>	
Electric vacuum cleaners	Users, December 1930, 9,086,000; in 44.4 per cent of wired homes (T. 44 and 45).
Electric floor polishers	Number sold, 1925-30, 322,000 (T. 43).
<i>Sewing</i>	Electric sewing machines, number sold, 1925-30, 1,818,000 (T. 43). In 1925-26, 4 per cent of urban and 2 per cent of rural reporting homes had electric ma- chines; 80 per cent of rural homes had hand or power type (T. 51, note).
<i>Food preparation</i>	
Electric dishwashers	Number sold, 1925-30, 57,000 (T. 43); in 1925 used in less than one per cent of urban homes (T. 51).
Electric cookers	Users, December 1929, 1,175,000; in 5.9 per cent of wired homes (T. 44, 45).
Electric ranges	Users, December 1930, 1,000,000; in 4.8 per cent of wired homes (T. 44, 45).
Electric refrigerators	Users, December 1930, 2,625,000; in 12.8 per cent of wired homes. <sup>4</sup>
Bread mixers	Percentage of reporting farm homes equipped, 1926, 8.9 (WCS). <sup>3</sup>
<i>Heating</i>	Estimated number of oil burners in homes, 1928, 600,000 to 650,000. <sup>5</sup> Sales of mechanical stokers of the residential type totalled 6,915 in 1931, 6,783 in 1932 and 9,507 in 1933. <sup>6</sup>

<sup>1</sup> For further detail concerning the extent of use of household appliances, see Tables 43, 44, 45 and 51.

<sup>2</sup> *Electrical World*, January 3, 1931.

<sup>3</sup> WCS = Women's Club Survey (see T. 51).

<sup>4</sup> *Electrical Merchandising*, January 1931, p. 24.

<sup>5</sup> Letter to author from H. F. Tapp, Assistant Secretary, American Oil Burner Association, March 12, 1928.

<sup>6</sup> U. S. Department of Commerce press release, *Mechanical Stokers*, December, 1933.



TABLE 51  
 PERCENTAGE OF RURAL AND URBAN HOMES EQUIPPED WITH  
 SPECIFIED LABOR-SAVING DEVICES

(based on a sampling survey made in 1925-1926)<sup>1</sup>

TYPE OF EQUIPMENT	PERCENTAGE OF REPORTING HOMES EQUIPPED WITH SPECIFIED DEVICE	
	RURAL	URBAN
Electricity available		
Central station service	19.6	<sup>2</sup>
Individual plant	8.9	<sup>2</sup>
Electric or gas lighting	30.6	87.0
Laundry equipment		
Electric washing machines <sup>2</sup>	13.1	23.0
Hand washing machines	17.5	<sup>2</sup>
Other power washing machines	11.7	<sup>2</sup>
Electric irons	20.3	63.6
Gas irons	7.4	<sup>2</sup>
Flat-work ironers	<sup>2</sup>	1.9
Laundry tubs	6.0	28.3
Vacuum cleaners, electric <sup>2</sup>	9.1	34.6
hand	8.4	<sup>2</sup>
Sewing machines, electric <sup>2</sup>	2.0	4.0
foot	72.1	<sup>2</sup>
Electric dish washers	<sup>2</sup>	0.5
Heating, furnaces other than oil oil-burning furnaces	12.9 <sup>2</sup>	46.8 1.8
Water and sanitary equipment		
Water piped to house	47.2	<sup>2</sup>
Stationary kitchen sink	33.3	83.9
Stationary wash bowl	16.3	71.3
Stationary bath tub	21.3	68.3

<sup>1</sup> Based on mimeographed reports of surveys made under the direction of the Industrial Survey and Research Service for the General Federation of Women's Clubs, one covering urban home equipment (1925-26), the other farm home equipment (1926).

<sup>2</sup> No information given.

<sup>3</sup> Of the rural homes for which reports on washing machines were obtained, 44.3 per cent in all had some type of washing machine, though only 42.3 per cent specified whether the machines were hand, electric or other power. Likewise, the percentages for vacuum cleaners and sewing machines, irrespective of whether hand or electric types, were 18.3 and 80.1.

TABLE 52  
HANDLING EQUIPMENT

## I. MOBILE TYPES

EQUIPMENT	EXTENT OF USE, YEAR TO WHICH ESTIMATE APPLIES AND SOURCE OF INFORMATION
Electric industrial trucks and tractors	Shipments, domestic, 1914-29, 19,742 (T. 46). Number in use, June 1928, 14,103, including 2,133 tractors (T. 12). Leading users: metal products, marine and railway terminals, iron and steel mills, automotive industries (T. 11). Used in one-fourth to one-half of potential market (MRE, 1926).
Gasoline tractors in industrial use	About 50,000 to 70,000 sold for non-farm uses by 1926 (MRE).
Lumber carriers and pilers, electric and gasoline	Total number sold, four models, 1914-29, 1,151 (MD). In the Northwest, used for probably 75 per cent of lumber cut and by 90 per cent of mills where use is feasible. Probably used for 65 per cent of lumbering in South and on West Coast (MRE, 1929).
Portable conveyors	Use in large wholesale and retail yards increasing rapidly. Number of users, 1929, about 11,000 (MRE). Estimated percentage of total work for which they are adapted actually done with aid of these machines: 1920, 15; 1925, 30; 1929, 40 (MRE).
Portable elevators or tiering machines, hand and power	Widely used in such industries as wholesale paper, large newspapers, oil in barrels, etc. for from 15 to 20 years. One firm sold over 2,000 (1921-25); peak in sales 1917-20 (MD). Increasing demand for power types.
Hand lift trucks	Estimated 30,000 users, or 50 per cent of potential market (MRE, 1926).
Motor trucks	Registrations, 1929, 3,380,000. Number produced in the United States, 1914-29, 5,211,000 (T. 46).
Self-feeding wagon or truck loaders for	Use in bituminous coal mines small but increasing; 3.6 per cent of output so handled.

TABLE 52 (cont.)  
HANDLING EQUIPMENT

EQUIPMENT	EXTENT OF USE, YEAR TO WHICH ESTIMATE APPLIES AND SOURCE OF INFORMATION
handling loose materials in piles	in 1929 (T. 40). Percentage ratio of actual to potential use in fields for which its practical feasibility had been demonstrated: 1920, 10; 1925, 40; 1930, 25. The 1930 decline arises, not from less extensive use, but from a widened field as the machine was improved (MRE, 1930). Over 3,000 of 3 models sold, 1914-29 (MD).
<b>II. FIXED AND SEMIMOBILE TYPES</b>	
EQUIPMENT	EXTENT OF USE, YEAR TO WHICH ESTIMATE APPLIES AND SOURCE OF INFORMATION
Electric hoists	About 44,300 sold, 1920-29. <sup>1</sup> Dollar value of new orders, 1920-29, 9 firms, over \$21,000,000.
Electric overhead cranes	Shipments and new orders, for about 98 per cent of total output, each over \$80,000,000, 1921-29. Peak in 1929 (T. 47).
Cupola charging hoists, for foundries	In use in a small proportion of work for which suitable (MRE, 1926).
Electric locomotives (See also Table 53)	Shipments, 1926-29, by 10 firms, representing the bulk of the industry (T. 47): For industrial use Trolley type, aggregate value \$2,600,000 Storage battery type, aggregate value \$1,300,000. For mining use Trolley type, aggregate value \$10,500,000 Storage battery type, aggregate value \$2,900,000.
Installed handling systems	Installations by 3 reporting firms, chiefly in the automotive and tire industries, totalled \$6,800,000, 1922-25 (MD). Not over 25 per cent of potential market for package conveyors equipped (MRE, 1926). For conveyors of all types, see T. 13.

<sup>1</sup> Letter to author from Secretary of Electric Hoist Manufacturers' Association, March 10, 1930.

## MECHANIZATION IN INDUSTRY

TABLE 53

## COAL MINING

PROCESS	EXTENT OF USE, YEAR TO WHICH ESTIMATE APPLIES AND SOURCE OF INFORMATION
<i>Bituminous coal</i> Stripping	Percentage of total tonnage produced by stripping with power shovels: 1.5 in 1920; 3.8 in 1929, varying from below 1 per cent in some Pennsylvania counties to 100 per cent in Wallace County, Georgia (Ref. 32).
Undercutting	Percentage of total tonnage undercut by machine: 59.8 in 1920; 75.4 in 1929 (T. 40). Percentage of tonnage of underground mines undercut by machine varied, in 1929, from 2.1 in Texas to 97.9 in Michigan (Ref. 32).
Loading into mine cars	Percentage of total tonnage loaded with self-feeding loading devices: 0.3 in 1923; 3.6 in 1929; 5.9 in 1931 (T. 40). Percentage handled on pit-car loaders and hand-loaded conveyors: 3.5 in 1929. Percentage of product of underground mines loaded by machine varied in 1929 from 0.8 in Kentucky to 39.9 in Wyoming (Ref. 32).
Drilling shot holes	Power drilling of shot holes with portable electric drills being rapidly introduced (Ref. 32, 1928, Pt. II, p. 482). In a sample group of 100 mines surveyed in 1929, 94 were using electric or compressed-air drills (Ref. 2, pp. 122-24).
Underground haulage	"Mines equipped with one or more electric locomotives now supply 85 per cent of the output, and 33 per cent is produced by mines in which even the gathering is done electrically and no animals whatever are employed" (Ref. 32, 1928, Pt. II, pp. 481-2). In 1925 percentage of deep-mined bituminous coal moved by animal haulage only, 12.0; locomotives only, 34.1; locomotives and animal haulage, 53.9 (U. S. Bureau of Mines, <i>Coal in 1925</i> , p. 445).
Cleaning	Percentage of total tonnage cleaned mechani-

TABLE 53 (cont.)

## COAL MINING

PROCESS	EXTENT OF USE, YEAR TO WHICH ESTIMATE APPLIES AND SOURCE OF INFORMATION
<i>Anthracite coal</i>	<p>ally by wet washing or pneumatic methods: 3.3 in 1920; 6.2 in 1929 (Ref. 32).</p> <p>Percentage mined by stripping with power shovels: 2.5 in 1920; 2.7 in 1929 (T. 40).</p> <p>Percentage of tonnage undercut by machine: 1.1 in 1920; 1.6 in 1929.</p> <p>Percentage mechanically loaded: about 3 in 1928 (Ref. 2, p. 47).</p> <p>Tonnage cleaned mechanically: very large, and additional mechanical cleaning facilities total- ling almost 8,200 tons per hour were under construction in 1929 (Ref. 32).</p>

TABLE 54

## OTHER NON-MANUFACTURING INDUSTRIES

EQUIPMENT OR PROCESS	EXTENT OF USE, YEAR TO WHICH ESTIMATE APPLIES AND SOURCE OF INFORMATION						
Adding and calculating machines (See also T. 7)	<p>Number manufactured by principal manu- facturers to March 1928<sup>1</sup></p> <table border="1"> <tr> <td>Full keyboard types</td> <td>1,707,400</td> </tr> <tr> <td>10-key keyboard types</td> <td>326,500</td> </tr> <tr> <td>Miscellaneous non-listers</td> <td>314,000</td> </tr> </table>	Full keyboard types	1,707,400	10-key keyboard types	326,500	Miscellaneous non-listers	314,000
Full keyboard types	1,707,400						
10-key keyboard types	326,500						
Miscellaneous non-listers	314,000						
Motorized railway section-crew cars	<p>Number sold by 3 makers, 1914-29, 49,727 (MD). In 1927, approximately 55,000 were in use, representing about 83 per cent motori- zation of railway section cars (special inquiry by makers). Used in practically all cases where conditions are suitable.</p>						
Street cleaning	<p>Motorization increasing. Over 700 of one type of motorized sweeper sold, 1914-28, with highest sales in 1926-28 (MD).</p> <p>Sales of mechanical catch-basin cleaners, 1922- 28, reached peak in 1928 (MD).</p>						
Automatic equipment in the commercial preparation of food	<p>Bottle-washing machines have long been used. Sales of 5 models totalled 6,348 in 1914-26 (MD).</p>						

## MECHANIZATION IN INDUSTRY

TABLE 54 (cont.)

## OTHER NON-MANUFACTURING INDUSTRIES

EQUIPMENT OR PROCESS	EXTENT OF USE, YEAR TO WHICH ESTIMATE APPLIES AND SOURCE OF INFORMATION
<i>Note: in these estimates of use, an estimated total of 8,500 hotels over 50 rooms in size, and 120,000 restaurants, is taken as 100 per cent, as of 1928<sup>2</sup></i>	Dish-washing machines extensively used; in about 50 per cent of the larger hotels and 20 per cent of restaurants in 1928 (RE). Total number sold, 1918-29, about 44,000, with heaviest sales in 1929 (MRE). Aggregate production of dish-washing machinery in the census years 1925, 1927 and 1929: \$6,915,500 (T. 8).
	Dish-drying machine, for blowing water off dishes, just entering commercial marketing in 1926 (MD).
	Vegetable peelers: used in about 40 per cent of the larger hotels and 15 per cent of restaurants (RE). Total sales of 2 makers, 1914-27, over 16,500, power and hand types (MD).
	Slicers used in about 60 per cent of the larger hotels and 30 per cent of restaurants (RE).
	Fruit-juice extractors used in 25 per cent of the larger hotels and 30 per cent of restaurants (RE).
	Dough mixers used in about 45 per cent of the larger hotels and 20 per cent of restaurants (RE). Total sales of 2 makers, 1919-29, over 54,000, with peak in 1927 (MD).
Coal stoking	Heavy industrial mechanical stokers: total new orders, 1919-29, over 17,000, with 6,412,000 horsepower (T. 41).
	Locomotive stokers: sales of 2 makers, 1922-26, over 5,000 (MD).
	Steam grate shakers: introduction began in 1914 and was rapid in 1916-20.
Automatic signals at railway grade crossings	"Automatically controlled crossings constituted 61.3 per cent of all protected grade crossings in 1930" (Ref. 61, p. 1,050).
Retail merchandising by coin device. vending machines	Value of vending machines produced in the census years 1919 to 1929: \$27,971,000 (T.8). "It is said that 25 million dollars worth of cigarettes are sold through coin machines

TABLE 54 (cont.)

## OTHER NON-MANUFACTURING INDUSTRIES

EQUIPMENT OR PROCESS	EXTENT OF USE, YEAR TO WHICH ESTIMATE APPLIES AND SOURCE OF INFORMATION
	each year; that Automat restaurants feed 500,000 people a day in New York, Philadelphia and other cities; that there are 10,000 handkerchief vending machines in the United States; and it is well known that hundreds of millions of pieces of gum and candy are sold in this way." <sup>3</sup>

<sup>1</sup> Estimates made available by courtesy of Equipment-Research Corporation, Chicago, publishers of *The Business Machines and Equipment Digest*.

<sup>2</sup> Rough estimates of extent of use suggested by J. O. Dahl, Manager, Service Department, Ahrens Publishing Company, Inc., in letter to the author, February 23, 1928.

<sup>3</sup> L. D. H. Weld, *The Cost of Marketing, Taylor Society Bulletin*, April 1933, pp. 26-30.

TABLE 55

## MANUFACTURING INDUSTRIES

## I

EQUIPMENT OR PROCESS	EXTENT OF USE, YEAR TO WHICH ESTIMATE APPLIES AND SOURCE OF INFORMATION
Glass manufacture	98 per cent of window glass was machine-made in 1926 (Ch. III, footnote 39). 90 per cent of bottles and jars were made on automatics in 1924 (T. 38). 95 per cent of electric light bulbs were made by automatic processes by 1926 (Ref. 36, p. 6).
Continuous kilns in clay products industries	Used in the production of approximately 50 per cent of high-grade clay products, but for only 3 to 5 per cent of crude clay products (MRE, 1929).
Automatic cigar machines	Used by most or all large cigar manufacturers (ME). Over 4,400 machines installed or ordered by principal manufacturers, 1918-29.

## MECHANIZATION IN INDUSTRY

TABLE 55 (cont.)

## MANUFACTURING INDUSTRIES

## I

EQUIPMENT OR PROCESS	EXTENT OF USE, YEAR TO WHICH ESTIMATE APPLIES AND SOURCE OF INFORMATION
Automatic paper-stock proportioning and metering system, in paper mills	35 per cent of cigars were machine-made in 1929 (T. 38). In use for about 90 per cent of newsprint production, as a substitute for the intermittent-batch method (1929, ME). Most new mills equipped.
Continuous filters, in place of the intermittent type, for separation of liquids and solids	Used for from 50 to 70 per cent of materials in beet sugar factories and 100 per cent in wood-pulp mills (1928, ME), and for from 20 to 30 per cent of materials in the heavy chemicals industry (MRE). Over 5,000 sold by 1929.
Garment pressing machines, used in garment manufacturing and by tailors in pressing	Probably over 100,000 sold 1921-29 (author's estimate, based upon data for a substantial fraction of the industry). Aggregate value of machines produced in 1925, 1927 and 1929 was \$24,702,800 (T. 8).
<i>Metal and wood-working equipment</i>	
Blast furnaces	81 per cent of output of merchant blast furnaces and 85 per cent of all pig iron not delivered molten was machine-cast (1927, T. 36); and 91 per cent of merchant blast furnace stacks were mechanically charged (1927, T. 36).
Machine tools	Ceaseless change in types and uses. Peak of production, 1917 and 1918 (Chart 2). Aggregate production in the census years 1925, 1927 and 1929: \$383,075,000 (T. 8).
Wood-working machines	Shipments by reporting group of manufacturers, 1918-29, totalled approximately \$190,000,000; and the number shipped 1923-29, 97,568 (T. 38).
Electric portable drills and valve grinders	It is estimated that 360,000 were sold in 1924-26 ( <i>Electrical Merchandising</i> , January, 1928).



EXTENT OF USE

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TABLE 55 (cont.)  
MANUFACTURING INDUSTRIES

I

EQUIPMENT OR PROCESS	EXTENT OF USE, YEAR TO WHICH ESTIMATE APPLIES AND SOURCE OF INFORMATION
Tire building	The core process predominated prior to 1926, the flat-drum process thereafter (U. S. Bur. of Labor Statistics, <i>Bul.</i> 585, p. 7).
Job printing presses	Two-thirds of presses sold, 1913-28, were machine-fed (T. 37).

II

EQUIPMENT OR PROCESS	EXTENT OF USE, YEAR TO WHICH ESTIMATE APPLIES AND SOURCE OF INFORMATION
<i>Foundry equipment</i>	
Molding machines	37 per cent of workers in the molding process in 80 foundries inspected were machine workers, 68 of 77 foundries inspected had some power molding machines, 9 had hand molding only (1925, Ref. 20-a).
Power types in general	In use for 50-100 per cent of small, and for 90 per cent of the medium and heavy work for which power machines are suitable (MRE, 1926).
Sandslinger type	Over 140 units installed, in 65 or more plants, by close of 1924. Used in 7 of 79 plants inspected (T. 3).
Hand types	One maker sold 1,900 to 2,000 of the hand squeezer type, 1920-29 (3,300 in the 6 preceding years), but chiefly as replacements or for new foundries rather than in displacement of other methods (T. 38). In 1927, molding machines constituted, in value, three-sevenths of total foundry equipment produced (1929 <i>Census of Manufactures</i> , p. 1100).
Core-making machines for cores, 3/8" to 7", hand and power	Used for about 80 per cent of suitable work (MRE, 1926). 23 of 79 foundries inspected reported their use. One maker sold about 5,000 in the quarter century ending 1925.

TABLE 55 (cont.)

## MANUFACTURING INDUSTRIES

## II

EQUIPMENT OR PROCESS	EXTENT OF USE, YEAR TO WHICH ESTIMATE APPLIES AND SOURCE OF INFORMATION
Sand mixers	Core and facing-sand mixers used for 75 per cent of suitable work (MRE, 1926). 61 of 79 foundries had power sand-conditioning equipment (1925, Ref. 20-a).
<i>Textile equipment</i> Automatic looms Cotton goods	Plain cotton goods made mostly on automatics, except in a few localities. In 1925, in the sample of New England mills inspected, 52 per cent of looms of all types were automatic; in the southern sample, 79 per cent (Ref. 20-a). In 1929, 74 per cent of plain looms were automatic; of fancy, 47. In the southern cotton states, 80 per cent of plain looms were automatic; in the New England states, 59 per cent (1929 <i>Census of Manufactures</i> ).
Other textiles	Used quite extensively in worsteds, and getting into the silk field (1926, ME).
Tying-in and drawing-in machines, in cotton goods manufacturing	808 tying-in machines in use at end of 1925; about 100 more sold, 1926-29 (MD). Approximately 450-460 drawing-in machines in use, 1919; about 100 sold, 1920-25 (MD). Possibly 80 per cent of cotton goods market equipped. A few used on finer grades of worsteds (ME, 1926).
Automatic spoolers and high speed warpers	Total number sold, 1917-29: 394 spoolers and 332 warpers. Only a small fraction of potential market equipped (ME).
Hand knotters, in spooling	Used in the majority of cotton mills by 1910; about 50,000 of one make sold in the quarter century after introduction in 1900 (ME).

APPENDIX C

HORSEPOWER PER WAGE EARNER IN MANUFACTURING,  
CENSUS YEARS 1899-1929

HORSEPOWER PER WAGE EARNER IN MANUFACTURING, CENSUS YEARS 1899-1929, FOR INDUSTRIAL  
GROUPS AND INDIVIDUAL INDUSTRIES, ARRAYED IN ORDER OF HORSEPOWER  
PER WAGE EARNER IN 1925 <sup>1a</sup>

1925 RANK	1929	1927	1925	1923	1919 ADJUST- UNAD- ED <sup>1a</sup> JUSTED <sup>1a</sup>		1914	1909	1904	1899	HORSEPOWER PER WAGE EARNER  455	
1 Blast furnaces		<sup>5</sup>	<sup>5</sup> 47.29*	45.94	37.28	36.78	41.64	30.53	22.04	12.67		
2 Ice, manufactured	33.47	43.68	37.07	31.41	19.06	18.97	20.09	19.74	18.98	14.55		
3 Cement	35.48	29.46	22.70	18.31	19.17	19.17	17.58	13.87	8.55	<sup>1</sup>		
4 Flour-mill and grain-mill products	23.73	21.39	20.93	20.17	19.33	19.26	20.72	21.61*	19.83	20.83		
5 Paper and wood pulp	23.18	21.42	19.60	18.05	16.25	16.26	18.32	17.16	16.57	15.36		
6 Coke	19.13	21.42	17.66	11.71	7.68	7.68	5.55	2.14	3.51	2.05		
7 Minerals and earths, ground or otherwise treated	<sup>2</sup>	14.08	14.50*	9.60	8.83	8.83	9.38	10.45	7.86	8.76		
8 Smelting and refining	17.49	14.33	13.21	13.65	11.11	11.18	7.28	6.81	4.81	3.84		
9 Steel works and rolling mills	<sup>5</sup>	<sup>5</sup>	12.85*	11.11	10.18	10.99	10.88	8.75	7.95	6.01		
10 Oils	16.58	12.91	12.51	13.39	9.64	9.66	10.88	10.33	9.04	6.16		
11 Malt liquors, including cereal beverages	<sup>2</sup>	<sup>2</sup>	12.28 <sup>8</sup>	13.97* <sup>8</sup>	9.39	9.46	6.54	6.37	5.53	5.01		
12 Sugar, beet and cane, and its refining	13.14	12.26	12.16	11.28	7.81	7.81	10.46	10.52	10.06	10.37		
13 Paving materials, other than brick or granite	12.80	13.67	11.59	10.17	12.20	11.89	7.08	4.14	2.74	<sup>1</sup>		

HORSEPOWER PER WAGE EARNER IN MANUFACTURING, CENSUS YEARS 1899-1929, FOR INDUSTRIAL GROUPS AND INDIVIDUAL INDUSTRIES, ARRAYED IN ORDER OF HORSEPOWER PER WAGE EARNER IN 1925

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1925 RANK	1929	1927	1925	1923	1919 ADJUST- UNAD- ED 12 JUSTED 12		1914	1909	1904	1899
14 Glucose and starch	12.58	11.57	11.17	9.97	6.67	6.77	9.24	5.90	7.66	4.51
15 Chemicals and acids <sup>a</sup>	13.74	11.02	9.44	7.66	6.24	6.24	8.68	8.28	6.18	5.16
16 Gas, manufactured, illuminating and heating	12.63	10.23	9.11	8.48	5.57	5.56	4.87	3.45	2.39	1.41
17 Locomotives, not made by railroad companies	8.92	11.46	8.92	2.97	3.61	3.64	2.90	2.36	1.20	1
18 Cereal preparations	10.22	8.50	8.48	9.58	6.18	6.24	4.96	1	1	1
19 Chocolate and cocoa products other than confectionery	10.12	9.80	8.21	6.84	3.67	3.67	4.69	3.79	2.48	2.15
20 Fertilizers	7.98	8.40	7.76	8.70*	4.79	4.79	5.01	3.54	3.38	3.34
21 Condensed and evaporated milk	12.07	8.65	7.59	5.82	3.59	3.59	3.33	2.76	1.76	1
22 Wire	6.69	7.68	7.45	5.82	6.04	6.05	4.77	3.98	5.46	6.22
23 CHEMICAL AND ALLIED PRODUCTS— Group	8.80	7.89	7.40	6.68	4.79	4.78	4.90	3.84	3.21	2.34
24 Butter and cheese	8.41	7.07	6.97	6.04	5.53	5.54	6.48	6.28	7.20	6.88 <sup>b</sup>
25 Shipbuilding, steel	1	1	6.78*	5.39	1.38	1.38	2.50	2.05	1.39	1.26
26 IRON AND STEEL AND THEIR PROD- UCTS—Group	7.58	7.50	6.76	5.85	5.10	5.10	5.22	4.44	3.83	2.94
27 STONE, CLAY AND GLASS PRODUCTS— Group	8.79	7.80	6.70	5.52	5.29	5.26	4.46	3.62	2.72	2.20
28 Explosives	9.19	6.59	6.63	5.50	5.61	5.61	7.27	4.54	5.12	4.27
29 Marble and stone work	8.09	7.29	6.56	5.31	5.24	5.18	3.78	2.86	2.01	1.99 <sup>b</sup>
30 Petroleum refining	9.80	7.76	6.03	5.86	4.06	4.06	5.06	6.50	2.74	2.96

MECHANIZATION IN INDUSTRY

31 Brass, bronze and copper products	6.39	6.30	5.74	4.73	3.54	3.54	3.04	2.61	2.09	1.74
32 PAPER AND PRINTING—Group	6.45	6.12	5.70	5.21	4.67	4.61	4.53	4.02	3.72	3.06
33 Other rubber goods *	7.41	7.41	5.63	5.19	3.02	2.96	3.02	2.98	2.28	2.00
34 Paint and varnish	6.17	5.81	5.61	5.01	3.94	3.96	4.38	3.96	3.56	3.13
35 Lumber and planing-mill products not in planing mills connected with sawmills	7.52	6.53	5.36	4.79	4.83	4.79 <sup>a</sup>	4.26 <sup>a</sup>	3.66 <sup>a</sup>	3.17 <sup>a</sup>	3.11 <sup>a</sup>
36 Cordage and twine	5.04	4.96	5.04*	4.41	3.78	3.78	3.51	3.24	2.81	2.57
37 Cotton goods and cotton lace	5.28	5.00	4.97	4.52	4.22	4.23	4.07	3.46	3.15	2.65
38 Tires and inner tubes	5.56	5.77	4.94	5.01	1	1	1	1	1	1
39 Cars, steam and electric railroad	5.96	6.22	4.84	3.10	3.03	3.03	2	2	2	2
40 RUBBER PRODUCTS—Group	5.52	5.58	4.65	4.39	2.71	2.71	2.70	2.49	1.98	1.95
41 FOOD AND KINDRED PRODUCTS—Group	4.94	4.82	4.64	4.41	4.05	4.04	4.32	4.44	4.15	4.03
42 Engines, steam, gas and water	4.69	4.45	4.39	3.40	2.45	2.45	2.12	1	1	1
43 Lumber and timber products, n.e.s.	4.74	4.30	4.39	3.90	5.02	4.90*	4.57	4.23	3.68	3.33
44 Structural and ornamental ironwork	4.84	4.80	4.38	3.98	3.76	3.76	2.32	2.00	1.65	0.79
45 Aluminum manufactures	5.08	4.86	4.33	3.58	2.65	2.66	2.67	1	1	1
46 Carriages and wagons <sup>10</sup>	5.19	5.35	4.25	3.26	2.29 <sup>10</sup>	2.25 <sup>10</sup>	1.80 <sup>10</sup>	1.50 <sup>10</sup>	1.04 <sup>10</sup>	.89 <sup>10</sup>
47 ALL INDUSTRIES—combined	4.86	4.65	4.27	3.77	3.25	3.24	3.19	2.82	2.47	2.11
48 Roofing materials, n.e.s.	5.61	5.71	4.12	5.14	4.40	4.42	2.85	3.76	2.61	2.39
49 Boxes, wooden packing, except cigar boxes	4.49	4.40	4.12	3.81	3.39	3.40	3.29	3.18	2.84	2.50
50 Leather, tanned, curried, and finished	4.60	4.17	4.12	3.86	3.00	3.01	3.09	2.38	2.05	1.71
51 Brick, tile, pottery, and other clay products <sup>a</sup>	4.66	4.28	4.09	3.78	4.19	4.17	3.70	3.40	3.04	2.39
52 Phonographs	2.67	3.42	4.05*	2.01	1.40	1.40	1.24	1.23	0.74	0.85
53 Agricultural implements	3.08	3.54	4.02*	3.94	2.36	2.36	2.50	1.99	1.89	1.52
54 MISCELLANEOUS INDUSTRIES—Group	3.91	4.22	3.98	3.51	2.25	2.25	2.32	2.10	1.79	1.22
55 NON-FERROUS METALS AND THEIR PRODUCTS—Group	4.76	4.22	3.96	3.70	2.90	2.91	2.19	1.86	1.46	1.33
56 Glass	5.06	4.84	3.91	3.28	2.67	2.68	2.19	1.79	1.43	1.00

HORSEPOWER PER WAGE EARNER

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HORSEPOWER PER WAGE EARNER IN MANUFACTURING, CENSUS YEARS 1899-1929, FOR INDUSTRIAL GROUPS AND INDIVIDUAL INDUSTRIES, ARRAYED IN ORDER OF HORSEPOWER PER WAGE EARNER IN 1925

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1925 RANK	1929	1927	1925	1923	1919 ADJUST- ED 12	UNAD- JUSTED 12	1914	1909	1904	1899
57 LUMBER AND ITS REMANUFACTURES— Group	4.39	4.02	3.88	3.71	4.11	4.07	3.82	3.56	3.02	3.15
58 Machine tools	2.99	3.73	3.86*	3.27	1.89	1	1	1	1	1
59 Shipbuilding, wooden, including boat building	1	1	3.70*	3.62	1.79	1.80	2.87	2.45	1.94	1.45
60 Soap	4.59	4.63	3.68	4.40	1.65	1.65	2.51	2.18	1.84	1.84 <sup>8</sup>
61 Slaughtering and meat packing, wholesale	4.29	4.11	3.67	2.88	2.23	2.23	2.56	2.30	1.56	1.24
62 Foundry and machine-shop products 7	3.97	3.87 <sup>7</sup>	3.58	2.75	2.16	2.12	2.12	1.70	1.40	1.08
63 Dyeing and finishing textiles	3.83	3.89	3.57	3.22	2.86	2.86	2.68	2.45	2.38	2.32
64 Photographic materials 11	3.44	2.78	3.56*	3.08	1.68	1.68	1.90	1.65	1.34	1.00
65 Woolen and worsted goods	3.86	3.60	3.45	2.77	2.79	2.81	2.40	2.13	1.95	1.86
66 Screw machine products	3.26	3.18	3.39*	3.19	2.28	2.28	2.22	1.94	1.60	.88
67 Confectionery, chewing gum, and ice cream	4.01	3.73	3.35	3.02	1.89	1.88	1.58	.80 <sup>8</sup>	.67 <sup>8</sup>	.72 <sup>8</sup>
68 Mineral and soda waters	2	2	3.33	3.58*	2.50	2.40	1.62	1.48	1.12	.91
69 Pumps	3.57	3.46	3.16	2.62	2.01	2.02	2.07	1	1	1
70 Cutlery, not including silverware and plated cutlery	3.33	2.52	3.15	2.59	1.95	1.96	2.10	1.89	2.23	2.21
71 Tools, not elsewhere specified	3.42	3.41	3.11	2.58	1.91	1.92	2.28	2.26	1.90	1.55
72 Motor cycles, bicycles and parts	2.53	2.77	3.00*	2.24	1.32	1.36	1.31	1.34 <sup>8</sup>	1.73	1.13
73 Ammunition and related products	2.36	2.26	2.99*	2.21	1.71	1.71	.99	1.18	.69	.58
74 Automobile bodies and parts	3.73	3.04	2.90	2.60	1.94	1.94	1.44	1.02	1.39	1
75 Cooperage	3.17	2.92	2.68	2.79	2.34	2.32	2.24	2.18	1.85	1.39

MECHANIZATION IN INDUSTRY

76 Paper goods, n.e.s.	3.32	2.90	2.63	2.57	2.51	2.52	2.03	1.72	1.34	1.30
77 Automobiles	3.16	3.86	2.58	1.80	1.34	1.36	1.32	.99	.74	1.45
78 Plumbers' supplies, n.e.s.	3.61	3.09	2.54	2.20	2.18	2.19	1.53	1.35	1.17	.95
79 Coffins, burial cases, and undertakers' goods	3.04	2.66	2.54	2.35	1.86	1.87	2.00	1.77	1.55	1.31
80 VEHICLES FOR LAND TRANSPORTATION INCLUDING RAILROAD REPAIR SHOPS	3.30	3.14	2.53	1.95	1.50	1.51	1.48	1.29	.94	.79
81 Steam fittings, steam and hot water heating apparatus	3.47	3.09	2.52	2.06	1.84	1.84	1.46	1.41	.91	.70
82 TEXTILES AND THEIR PRODUCTS-- Group	2.43	2.47	2.46	2.21	2.03	2.03	1.82	1.58	1.50	1.36
83 Electrical machinery, apparatus and supplies	2.72	2.74	2.46	2.04	2.06	2.06	1.93	1.82	1.74	1.04
84 Cast iron pipe	3.53	2.76	2.38	2.19	2.28	2.28	2.06	1.53	1	1
85 Boots and shoes, rubber	2.44	2.55	2.38	1.91	1.50	1.50	1.32	1.47	1.37	1.74
86 Mattresses and bed springs, n.e.s.	2.94	2.44	2.28	2.15	1.87	1.86	1.78	1.57	1.27	1.05
87 Pickles, preserves and sauces	1	1	2.27	2.38*	1.35	1.36	1.49	1.33	1.20	.92
88 Sewing machines and attachments, including cases	2.83	3.56	2.26	1.68	1.67	1.67	1.34	1.00	1.00	.75
89 Furniture	2.61	2.39	2.22	2.05	1.89	1.90	1.88	1.71	1.49	1.31
90 Textile machinery and parts	2.46	2.46	2.21	1.58	1.31	1	1	1	1	1
91 Steam-railroad repair shops	2.92	2.61	2.20	1.51	1.22	1.23	1.28	1.04	.71	.55
92 Electric-railroad repair shops	2.59	2.32	2.17	1.79	1.72	1.72	1.70	1.60	1.12	.91
93 Stamped and enameled ware, n.e.s.	2.45	2.33	2.16	1.94	1.50	1.50	1.21	1.09	.74	1.66
94 Stoves and hot-air furnaces	1	1	2.16*	1.98	1.50	1.50	1.40	1.25	.96	1
95 Canning and preserving fruits and vegetables	1	1	2.16	2.43*	2.21	2.17	1.76	1.48	1.11	.72
96 Printing and publishing newspapers and periodicals	2.56	2.40	2.03	1.76	1.69	1.61	1.59	1.60	.98	.74
97 Hardware, n.e.s.	2.15	2.09	1.88	1.58	1.58	1.59	1.30	1.08	1.05	.86

HORSEPOWER PER WAGE EARNER

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HORSEPOWER PER WAGE EARNER IN MANUFACTURING, CENSUS YEARS 1899-1929, FOR INDUSTRIAL GROUPS AND INDIVIDUAL INDUSTRIES, ARRAYED IN ORDER OF HORSEPOWER PER WAGE EARNER IN 1925

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1925 RANK	1929	1927	1925	1923	1919 ADJUST- ED 12	UNAD- JUSTED 12	1914	1909	1904	1899
98 Canning and preserving—fish and oysters	1.59	1.46	1.86	1.93	2.08	2.09*	1.15	.85	.73	.40
99 Boot and shoe cut stock	1.67	1.59	1.86*	1.80	.87	.93	.87	.72	.76	.52
100 Carpets and rugs, wool other than rag	2.00	2.01	1.86	1.53	1.64 <sup>4</sup>	1.67	1.40	1.16	1.02	.94
101 Stoves, gas and oil	1	1	1.79*	1.33	1.07	1.07	1.02	1.06	.97	.68
102 Druggists' preparations, patent medicines, perfumery and cosmetics	1.99	1.79	1.72	1.51	1.20	1.19	1.27	1.22	.93	.88
103 Lithographing	1.87	1.75	1.68	1.65	1.19	1.19	1.00	.87	.65	.55
104 Tinware, n.e.s.	2.46	2.15	1.63	1.35	.88 <sup>3</sup>	.89 <sup>3</sup>	.84	.79	.53	.1
105 Silk goods, including throwsters	1.69	1.73	1.60	1.64	1.37	1.39	1.08	.99	.90	.88
106 Toys and games	1.54	1.29	1.46	1.11	1.02	1.01	.86	1.00	1.12	.97
107 Instruments, professional and scientific	1.35	1.56	1.45	1.32	.82	.82	.96	1.02	.62	.89
108 Bread and other bakery products	1.77	1.65	1.42	1.19	1.18	1.17	.87	.65	.46	.37
109 Copper, tin, sheet-iron work, including galvanized iron, n.e.s.	1.88	1.46 <sup>3</sup>	1.41 <sup>3</sup>	1.18	.89	.87	.74	.66	.50	.43 <sup>3</sup>
110 Buttons	1.62	1.66	1.37	1.29	1.02	1.04	.99	.78	.66	.48
111 Musical instruments, pianos	2.73	1.79	1.34	1.21	1.25	1.25	1.09	.91	.83	.98 <sup>3</sup>
112 Bags other than paper	1.62	1.41	1.34	1.21	.85	.84	1.11	.86	.79	.46
113 Boxes, paper and other, n.e.s.	1.44	1.44	1.33	1.08	.98	.98	.84	.59	.47	.34
114 Cash registers, adding and calculating machines	1.68	1.53	1.32	1.99*	.88	.89	1.18	.92	1.00	.62
115 LEATHER AND ITS FINISHED PROD- UCTS—Group	1.37	1.32	1.31	1.20	1.10	1.11	1.04	.91	.77	.64

MECHANIZATION IN INDUSTRY



116 Optical goods	1.61	1.63 <sup>*</sup>	1.28	1.10	1.06	1.07	.99	.89	.79	.68
117 Printing and publishing, book and job	1.40	1.37	1.27	1.17	1.08	1.07	1.01	.90	.64	.55
118 Hats, fur felt	1.20	1.29	1.18	1.11	1.10	1.10	.98	.76	.75	.62
119 Tobacco, chewing and smoking, and snuff	1.43	1.27	1.17	1.14	1.03	1.03	.82	.71	.77	.61
120 Saddlery and harness	1.41	1.22	1.09	1.18	.82	.79	.80	1.18	.49	.42
121 Typewriters and supplies	1.38	1.07	1.04	.77	.84	.83	.98	.71	.72	.53
122 Stationery goods, n.e.s.	1.04 <sup>3</sup>	.99 <sup>3</sup>	.96 <sup>3</sup>	.86	.74	.73	.74	1.10	.79	.57
123 Knit goods	.87	.93	.94	.94 <sup>*</sup>	.87	.88	.84	.80	.76	.68
124 Watches and watch movements	.94	.77	.88	.64	.45	.45	.53	.52	.30	.26
125 Signs and advertising novelties	.98	.90	.83	.91	.75	.74	.77	.69	<sup>1</sup>	<sup>1</sup>
126 Trunks, suitcases and bags	.90	.87	.77	.64	.68	.67	.77	.62	.55	.47
127 Bookbinding and blank-book making	.88	.87	.77	.75	.55	.54	.52	.51	.32	.29
128 Jewelry	.98	.71	.73	.64	.49	.53	.55	.37	.36	.33
129 Boots and shoes, other than rubber	.68	.68	.67	.57	.55	.57	.52	.46	.37	.35
130 Fancy articles, n.e.s.	.59	.64	.62	.60	.62	.64	.62	.48	.52	.46
131 Collars and cuffs, men's	.43	.94	.62	.48	.47	.47	.39	.26	.22	.13
132 Corsets	.44	.56	.58 <sup>*</sup>	.37	.38	.39	.35	.26	.30	.29
133 TOBACCO MANUFACTURES—Group	.56	.40	.32	.30	.28	.28	.20	.17	.15	.17
134 Fur goods	.35	.34	.30	.30	.39	.39 <sup>*</sup>	.36	.18	.21	.12
135 Furnishing goods, men's	.30	.32	.29	.31	.32	.32	.26	.25	.19	.10
136 Shirts	.28	.26	.28	.27	.38 <sup>*</sup>	.38 <sup>*</sup>	.34	.26	.24	.19
137 Clothing, men's, n.e.s.	.28	.24	.26	.27	.23	.23	.20	.16	.15	.11
138 Millinery and lace goods, n.e.s.	.34	.30	.22	.29	.25	.24	.28	.20	.17	.11
139 Tobacco, cigars and cigarettes	.47	.31	.21	.19	.18	.18	.09	.07	.04	.04
140 Clothing, women's, n.e.s.	.19	.20	.19	.21 <sup>*</sup>	.20	.20	.17	.14	.13	.12
141 Turpentine and rosin	.05	.08	.10	.06	.08	.08	.07	.10 <sup>*</sup>	.04	.02

\*=maximum, if prior to 1927.

n.e.s.=not elsewhere specified.

<sup>1</sup> Not shown separately.

<sup>2</sup> Not canvassed, or comparable statistics not available.

<sup>3</sup> Scope of industry in these years not strictly comparable with other years.

<sup>4</sup> Includes wage earners in establishments with value of product under \$5,000.

<sup>5</sup> Because the power equipment is sometimes common to blast furnaces and rolling mills under common ownership, in the 1927 and 1929 Censuses of Manufactures, the horsepower in blast furnaces and rolling mills is combined, though at the former censuses it was distributed by means of estimates.

<sup>6</sup> Data for 'Other Rubber Goods' in 1923, 1925, 1927 and 1929 not comparable with the data for earlier years because tires and inner tubes were included prior to 1921.

<sup>7</sup> The following industries are included in 'Foundry and machine-shop products' only at the stated censuses, and thereafter treated as separate industries or omitted: 'Machine tools', 'Steel barrels, drums, and tanks', 'Textile machinery and parts', and the tempering and welding of iron and steel—prior to 1919; 'Engines—steam, gas, and water', and 'Pumps, steam and power', prior to 1914; 'Automobile repairing'—in 1909 and 1904; 'Iron and steel—cast iron pipe', prior to 1909; 'Locomotives', and 'Stoves and furnaces', prior to 1904.

<sup>8</sup> Includes sand-lime brick.

<sup>9</sup> 'Coal-tar products' and 'Ferro-alloys' included.

<sup>10</sup> Repairing included prior to 1923.

<sup>11</sup> Includes 'Photographic apparatus' and 'motion pictures'.

<sup>12</sup> The 1919 'unadjusted' figures cover plants with value of product \$500 or more, and include rented power other than electric; the 1919 'adjusted' figures are based upon wage earners in plants with value of product \$5,000 or more, and exclude rented power other than electric. The 'unadjusted' data are comparable with those for the earlier censuses; the 'adjusted' figures have been made comparable as far as possible with the subsequent censuses, but the horsepower data used still include the small amount of power in establishments with products less than \$5,000.

<sup>13</sup> Computed from horsepower and wage-earner data originally compiled in the *Censuses of Manufactures*, and rearranged by Day and Thomas in *The Growth of Manufactures*, Tables 29 and 30 for 1899–1923, and Table 43 for 1925. The data for 1927 and 1929 are taken directly from the *Census of Manufactures for 1927 and 1929*, respectively; and the data for 1925, 1927 and 1929 are adjusted to make the classifications comparable as far as possible with those for 1923 and earlier years.

## APPENDIX D

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