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.[1]

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.

[1] 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.[2]

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.[3]

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

[2] See discussion of this point in Ch. VI.

[3] 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.[4] 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; [5] 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-

[4] 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*.

[5] 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.[6] For example, in the period under consideration (1899–1927) the output per wage earner in the manufacturing industries rose about 75 per cent.[7] 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-

[6] For further discussion of 'constructive displacement' see Ch. X.

[7] 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.[8] However, rough approximations adequate for present purposes can be made.

[8] 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.[9] 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.[10]

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.

[9] The industries so analyzed are: motor vehicles, lumber, meat packing and slaughtering, iron and steel, woolens and worsteds, and pottery.

[10] 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

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 [1]	$179 [2]	$54 [2]	$87
Value added by manufacture				
Wages paid in factory	192 [1]	192	...	...
Salaries paid in factory	64 [1]	...	64	...
Rent, interest and profits	45 [2]	...	...	45
Other expenses	179 [3]	72 [3]	36 [3]	71
Value added by distribution	200 [4]	82 [5]	26	92
Total	$1,000	525	180	295

[1] 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.

[2] 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.

[3] '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.*

[4] 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.

[5] 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.[11]

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-

[11] 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[1]

YEAR	*Division A*[2] SERIES REPRESENTING SALES OF SINGLE MODELS OR GROUP OF ALLIED MODELS BY SINGLE MANUFACTURERS		*Division B* SERIES REPRESENTING SALES OF A GROUP OF MANUFACTURERS PRODUCING A SUBSTANTIAL PORTION 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

[1] 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.

[2] 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).

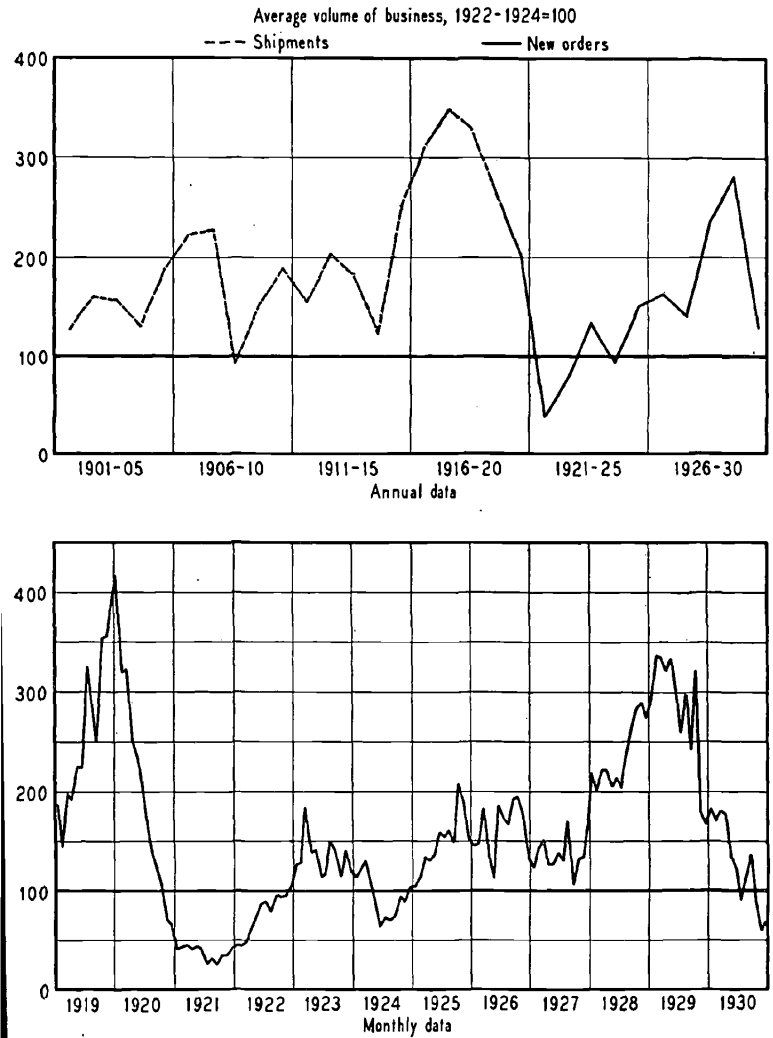
MACHINE-TOOL INDUSTRY

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,[12] 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

[12] 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[1]



1 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.[13] 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-

[13] 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.[14] 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.[15]

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

[14] 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.

[15] 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.

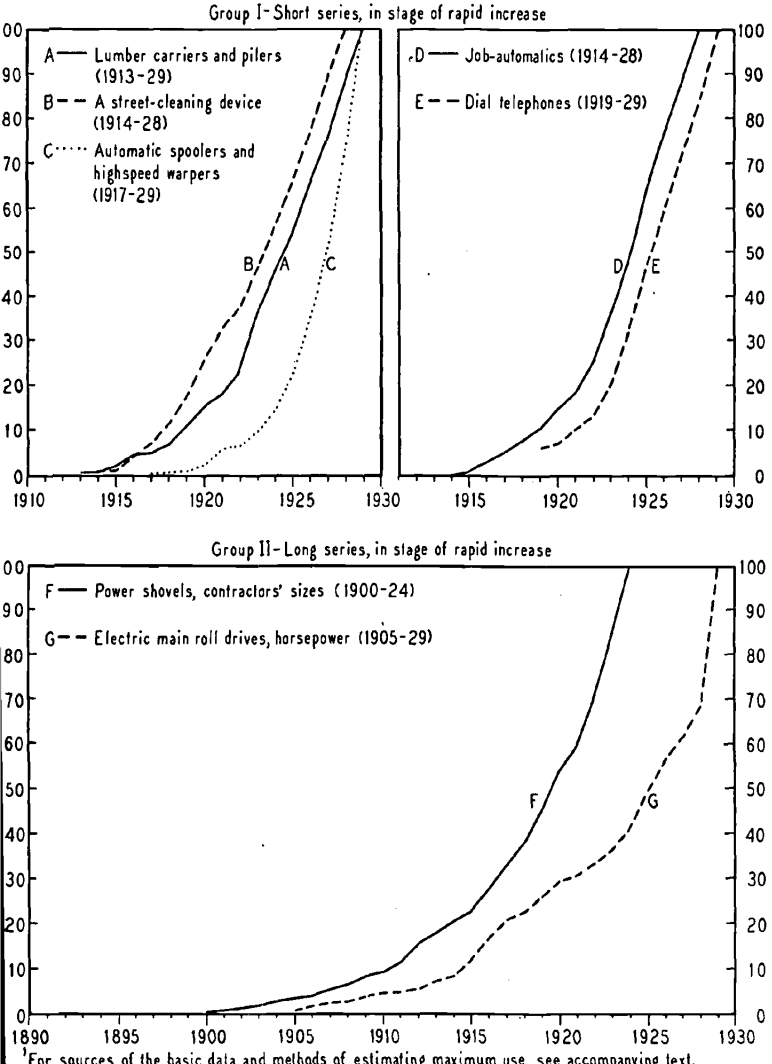
The series in Chart 4 are still increasing but in recent years usually at less than 10 per cent. Those in Group III have experienced a slackened rate of increase for less than 5 years, those in Group IV for at least 5 years. It will be noted that the introduction of pig machines and coal-undercutting 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[1]

(Estimated maximum use in period covered = 100)

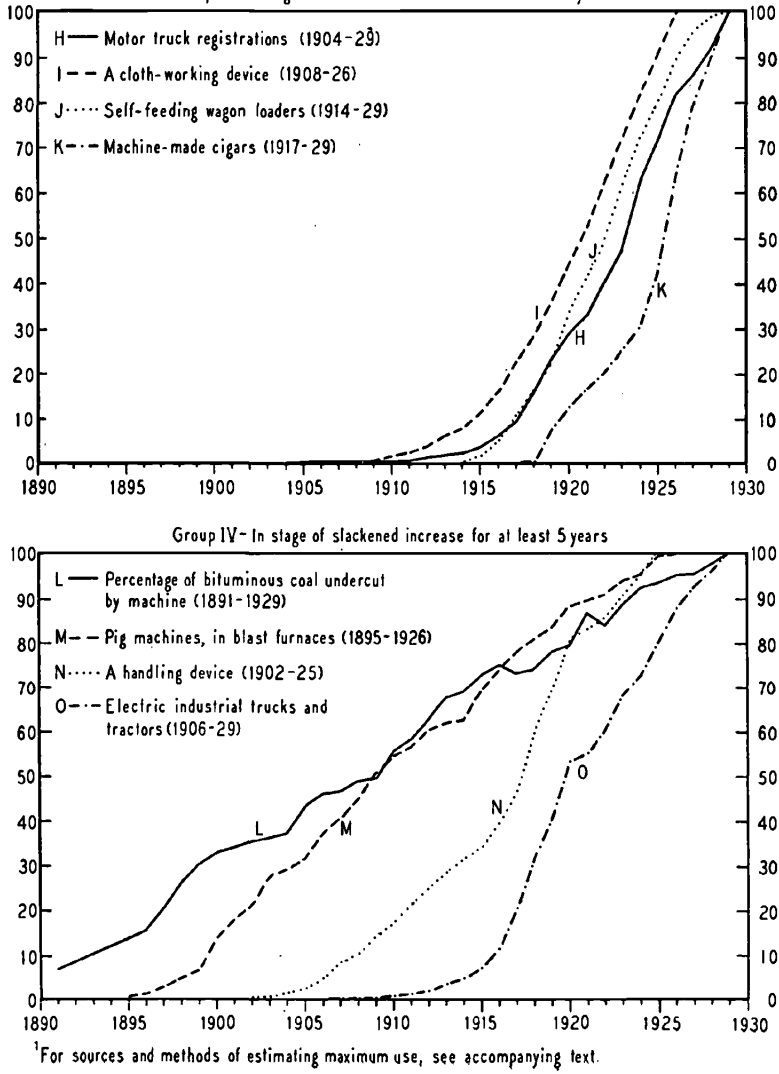


[1]For sources of the basic data and methods of estimating maximum use, see accompanying text.

Chart 4

GROWTH IN THE USE OF MACHINES[1]

(Estimated maximum use in period covered = 100)

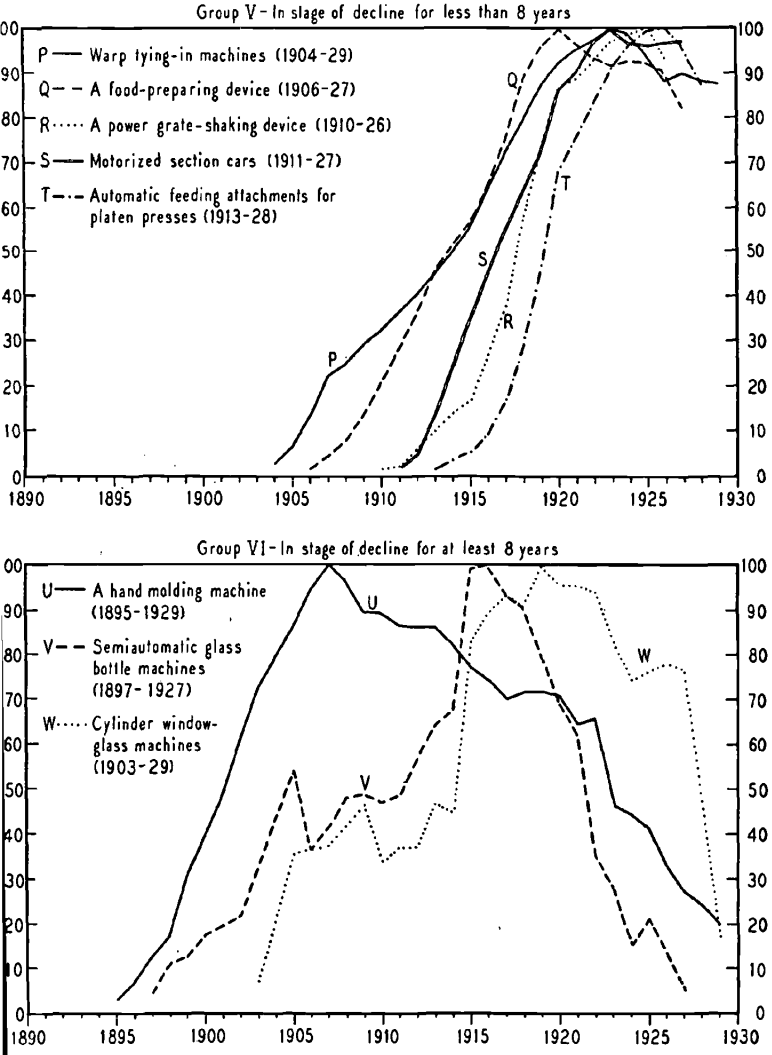


[1] For sources and methods of estimating maximum use, see accompanying text.

Chart 5

GROWTH IN THE USE OF MACHINES[1]

(Estimated maximum use in period covered = 100)



[1]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.[16] 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

[16] 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 [1]

SERIES	DURATION IN YEARS: COMMERCIAL TRIAL	RAPID INCREASE	SLACKENED INCREASE	DECLINE	TOTAL LENGTH OF SERIES
. Lumber carriers and pilers	7	10	4	...	17
. A street-cleaning device	5	10	4	...	15
. Automatic spoolers and H. S. warpers	7	6	4	...	13
. Job automatics	6	9	4	...	15
. Dial telephones	3[2]	8	4	...	11
. Power shovels, contractors' sizes	12	13 (1)[3]	4	...	25
. Electric Main Roll Drives	11	14 (5)	4	...	25
. Motor trucks	15	8	3	4	26
. Cloth-working device	8	10	1	4	19
. Self-feeding wagon loaders	4	9	3	4	16
. Machine-made cigars	4	8	1	4	13
. Coal undercutting	6[2]	3	30 (2)	4	39
. Pig Machines	6	3	23 (3)	4	32
. Handling device	7	12	5	4	24
. Electric industrial trucks and tractors	11	4	9 (2)	4	24
. Warp-tying machines	3	12 (1)	5	6	26
. Food-preparing device	4	9	2	7 (1)	22
. Power grate-shaking device	4	7	5	1	17
. Motorized section cars	3	7	3	4 (2)	17
. Automatic feeding attachments	5[2]	4	5	2	16
. Hand molding series	3	7	3	22 (3)	35
. Semiautomatic glass bottle machines	2[2]	7	11 (6)	11	31
. 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		

[1] 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 define limit 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 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 hint 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.

[2] Sales of this device began before the first year for which we have data

[3] Figures in parentheses indicate the number of years in the given period in which the movement is contrary to the definition of the period.

[4] This stage had not yet been reached in the period covered by the available data.

uction—85 to 100 per cent.[17] No close accuracy is claimed or these limits but they serve as convenient bases of classi-cation even if numerous exceptions must be recognized.

While we might well wish for much more complete data, ith these rough estimates of the duration of the commer-ial stages of use at hand we are in a somewhat better posi-ion to characterize the complete series of stages typical of ne development and adoption of a new type of machine.

UMMARY OF TYPICAL STAGES

While no two machines have quite the same experience, ertain typical phases in the life history of the ordinary nachine may be identified.[18]

First there is the *recognition of the need* for a machine to o certain work. Then after an interval, which may be quite ong or quite brief, comes the *conception of the primary rinciple* or device upon which a practicable machine may e based. In the modern industrial world inventions are not eft so much to chance as they were in earlier decades; and nce a need is recognized, it is ordinarily not so very diffi-ult to get a machine designed for the desired purpose, ither by engineers of the factory itself or by engineering oncerns which make it their business to design machines o order for particular purposes.[19]

[17] Probably those who estimate the proportion of the potential market quipped with a given device (see Appendix B) somewhat overestimate the ze of the market. If so, the resulting estimates of the percentage of use ttained are too low, and probably some machines now estimated to be ppreciably below the suggested 85 per cent limit of the stage of rapid doption have, in fact, passed into the stage of slackened increase in use.

[18] This division into periods refers to the aggregate of the several makes f a given type of machine rather than to the sales of an individual manu-cturer. The sales of one maker of trucks might be declining while total les were increasing, or *vice versa*.

[19] The lag between the recognition of need and the development of an

Apparently a completely automatic machine can be d
vised with relative ease to do any work that involves
repetitive process upon similar material and does not involv
the exercise of judgment. In fact, where desired variatio
in the process are based upon readily measurable physic
qualities of the material, the necessary adjustments may b
made automatically.

Anything that enhances the economic advantages of m
chines speeds up the process of developing new types.[20] Ho
ever, it should be recognized that some needs have lon
been obvious and as yet no completely satisfactory devic
has been developed. For example, we understand from th

adequate machine is probably shorter where the required machine is need
for a given motion than where a basic change in procedure is involve
Changes in productive processes may affect either the quality or the quanti
of the product. Quality changes involve largely innovations in materials use
type of processing or the chemical changes to which the materials are su
jected, and are with relative infrequency associated with the labor-savi
aspect. One exception is standardization, which improves the product b
facilitating precision and saves labor by making quantity production mo
feasible. Inventions designed to increase quantity, on the other hand, a
essentially labor saving; and, it should be noted, deal largely with devic
to perfect a machine motion or to accomplish mechanically motions former
done manually.

The essential elements in such motions are relatively few—grasping, hol
ing, conveying (vertical and horizontal) and releasing. The variations
these elements are multitudinous and the article may be in the proce
moved against a tool and processed, or the tool may be moved against th
article, but the variations required would not appear to be an exception
strain upon inventive genius. In fact, a great variety of 'motion automati
now in use complete complicated processes without guidance by manu
effort; and specialized machine shops make a business of constructing aut
matics to order for a special job. One such shop, visited by our field agen
constructed special machines to label filled bottles, wrap them with car
board, add a printed advertising pamphlet and insert the bottle in i
cardboard holder ready for packing. Many other examples might be cited

[20] See fuller discussion of pecuniary factors affecting mechanization in C
IX. Doubtless some new inventions are 'sports' in the sense that econom
pressure is not a major factor in their development and they are not
result of a gradual evolution from known methods.

ugar beet growers that, although for many years a $10,000 rize has been offered for a satisfactory machine for the ulling and topping processes in harvesting beets, no reasonbly satisfactory machine has been put upon the market.

Either prior to or following the patenting of a new device considerable period of *pre-commercial experimentation* nd development ordinarily elapses before commercial mareting becomes feasible. This period is rarely less than two ears, and often it is much longer. For a complicated device ne developmental period is apt to be long and involve xpenditures amounting to hundreds of thousands and even illions of dollars.[21]

Even after commercial marketing begins there is ordiarily a period of *commercial trial* during which adoptions re relatively slow and machines undergo various modificaons to meet difficulties developed in the course of practical peration. While no sweeping generalizations can be made, ne study of the history of many successful labor-saving deices, some of which are mentioned more at length in other arts of this report, indicates that a developmental period f from 3 to 10 or 12 years may ordinarily be expected etween the first commercial introduction of a device and ne development to the stage where it is clearly accepted as racticable from both an engineering and an economic point f view. We have defined this stage as including the years equired for use to reach 10 per cent of the maximum ıter attained.[22]

[21] Many years and very heavy expenditures were required before the linder glass machine was perfected so it could produce commercial window ass successfully. The perfection of the sheet glass method bankrupted the riginal company and cost the purchasers of the patents at sheriff's sale eavy additional expenditures. The manufacturers of the AutoBrik machine ate in their advertisements that "more than two hundred thousand dollars ere expended in perfecting it".

[22] See Table 33. Examples of machines in this stage are cited in a subquent paragraph.

Following the period of commercial trial comes that
more general introduction, finally culminating in substa
tial saturation of the market. This period of extensive intr
duction, that is, from the time the machine is general
recognized as commercially practicable to the point of su
stantial saturation, may be long or short, depending large
upon whether the machine effects a large saving over alte
native methods. If the margin of saving is not great, if muc
other equipment must first be scrapped, or if the industr
is not in an active state of development, the introduction
even a very good new device may be quite slow. Under r
verse conditions, the introduction may be very rapid. I
Chapter IX we discuss more in detail the various influenc
that determine the rapidity with which new methods
equipment are introduced.

Examination of the histories of various types of machin
some of which have been discussed in preceding chapters
analyzed in the preceding section of this chapter, leads t
the hypothesis that the period of extensive introduction fo
lowing the period of commercial trial may be divided a
propriately into two subperiods, each several years in lengt
the first characterized by a relatively rapid rate of increas
in use, and the second by a continuing increase but at
slower rate.[23] The period of *rapid increase* appears to b
from 4 to 11 years in the majority of instances, and, as
rough approximation, it is estimated that during the stage
rapid increase the extent of use rises from 10 to around 8
per cent of the total potential market.

A few revolutionary innovations, such as the talkin
movies with their synchronization of the musical score wit
the spoken words, pass through the stage of rapid increase t
substantial saturation in a shorter period than the abov

[28] See Table 33 and accompanying discussion.

ummary of the general record of machines would suggest see Ch. IV).

The period of *slackened increase* in use may, for purposes rough approximation, be defined as the period in which ne customary yearly gain is less than 10 per cent of the vel previously reached, and the percentage of use from 85 100 per cent of the total potential market. The evidence hand indicates a typical duration of 3 to 6 years for this eriod, with some marked exceptions.

The stage of *saturation,* when the machine is in use in the reater part of the work for which it is adapted, is reached owards the close of this second period of increasing use; ence most sales are to replace worn-out machines, to equip ew plants, or for uses not previously recognized as part of ne market. As generally there is probably a margin between hat is ordinarily considered the potential market for a nachine and the maximum use that will actually be reached, e are defining the saturation stage as existing whenever 90 er cent or more of what is ordinarily considered the market or the machine is equipped with it.

The attainment of a state of substantial saturation may e followed by a period of *declining use.* Either the indus- y in which the machine is used may decline, or because of ne rise of competitive devices, the machine enters a period *increasing obsolescence* until ultimately its use ceases en- rely (see Group VI, Chart 5).

ONTINUOUS TECHNICAL DEVELOPMENT

It should not be assumed that the machine remains un- nanged after the beginning of the period of commercial ial. On the contrary, it often undergoes radical alterations this period and through the subsequent periods. Even if ajor changes in design do not occur, the machine is likely

to become steadily more rugged, larger, and have variou attachments added or modifications made to adapt it t particular uses. The evolution of the electric industri truck from a simple load-carrying device to various speci forms of tiering machines and crane trucks is a case in poin Because of such developments, the statistical record of sale in number of machines, ordinarily understates the use o the machine. The cycles in the rise and decline of thes special modifications of machine types will ordinarily b shorter than the cycles for the more broadly defined class which we have been discussing in estimating the duratio 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 complet chronological record is graphed in Charts 3, 4 and 5, suff cient data are available for many of the other type mentioned in previous chapters to make possible an appro imation of their stage of introduction. Without attemptin to give anything approaching a complete list of the devic that might be assigned to the several commercial stages i the typical life history of a machine, we will list a numbe of those of especial interest. These illustrations are large from the tables on extent of use in Appendixes A and B and rest necessarily upon a wide variety of evidence. Cons quently they must be considered as representing conclusion based upon the author's judgment of the evidence rathe than upon rigid adherence to the classification suggested i this chapter applied with the aid of objective criteria whic can be fully presented and which all readers would consid adequate. Doubtless another analyst would reclassify thes illustrations in many details.

We shall single out no particular illustrations of machin

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.[24] 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-

[24] 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; [25] 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.[26]

[25] 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.

[26] 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.

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.