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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 i production. But comparisons of the ratio of wages paid t other production expense at a definite time are less ope to this objection, though they may still lack adequate accu racy because of geographical or industrial differences i wage rates for the same grade of skill.

Furthermore, some measures or indexes of mechanizatio which are not available at regular intervals are availabl at one or two periods. This is largely true, for example, c the statistics we have compiled of the ratio of machin workers to the total labor force, for these were obtaine by direct observation and interview, and are not perioc ically compiled.

We have distinguished five more or less general measure of mechanization: the rated-capacity-of-power-equipmer ratio (horsepower per wage earner); the labor expense rati (notably the ratio of wages to value added in manufacture the machine worker ratio; the machine output ratio; an the investment-in-equipment ratio (dollar investment i equipment per wage earner). We shall first note the cor tribution that each of these measures makes to an unde standing of the differences in mechanization between indu tries and then turn to the evidence afforded by the le general measures, that is, data showing the extent to whic tractors, harvester combines, automatic telephones, sel feeding wagon loaders, or other particular labor-savin devices are in use.

Horsepower per Wage Earner

by industries

Despite the limitations on its usefulness as a measure c mechanization,[1] the ratio of horsepower to wage earne

[1] 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 [1]

INDUSTRIAL GROUP	HORSEPOWER PER WAGE EARNER		
	1919 [2]	*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

[1] 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.

[2] 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 interrelated 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[1]

(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

[1] 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.[2] By this procedure we aimed to minimize the

[2] 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

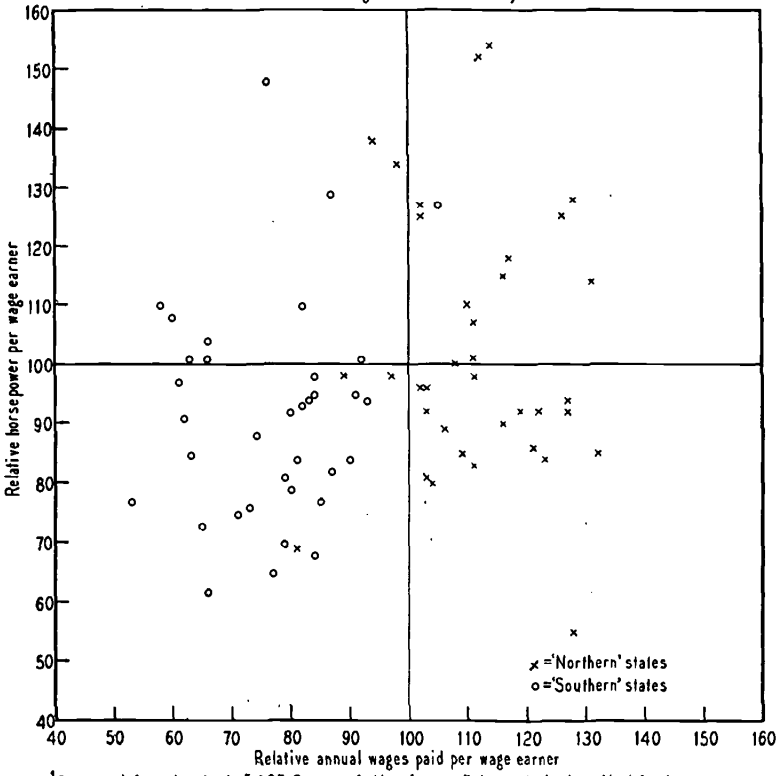
Chart I raises a presumption in favor of assuming an association between high wage levels and high mechanization, although the relationship exhibited cannot be said to be extremely close. In three-fourths of the instances where the wage ratio is below the average (100) for the industry as a whole, the 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[1]

(United States average in selected industry = 100)



[1]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[1]

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

[1] 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.[3] 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

[3] *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.[4] 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.[5] 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

[4] 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.

[5] 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.[6] Value

[6] 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.

TABLE 28

RANKING OF THE SIXTEEN INDUSTRIAL GROUPS IN MANUFACTURING, BY TWO MEASURES OF MECHANIZATION: 1925 [1]

INDUSTRY	PERCENTAGE RATIO OF WAGES PAID TO VALUE ADDED BY MANUFACTURE		HORSEPOWER PER WAGE EARNER		DIFFERENCE 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

[1] 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.[7]

[7] 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,[8] 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

[8] 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.[9] 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

[9] 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.[10]

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.[11] 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,

[10] 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.

[11] 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.[12]

[12] 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

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 WORKERS	SUPERVISORS	TEAMSTERS
			All Machine	*Operators*	*Auxiliary*[1]			
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[4]	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	[3]	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

[1] For explanation of the occupations classified as 'Auxiliary' see the accompanying text.

[2] None, or less than one-half of one per cent.

[3] In the foundry industry, because of special difficulties in classification, both 'Machine operators' and 'Auxiliary' have been grouped under 'Machine operators'.

[4] '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 [1]

INDUSTRY AND PROCESS	PER CENT
FERROUS FOUNDRIES (80 plants)	
All departments (21,729) [2]	29
Processing (15,673)	33
Cleaning and repairing castings (3,392)	70
Molding (6,346)	37
Sand conditioning (511)	19
Core making (2,833)	8
Flask making (222)	5
Tending furnaces and cupolas (297)	5
Pattern making (1,254)	4
Shaking out (818)	4
Materials handling (3,386)	28
Operating cranes (662)	100
Trucking (169)	75
Yard men (773)	15
Charging cupolas and furnaces (621)	8
Shifting and cleaning (1,161)	1
Other occupations (2,670)	11
BRICK AND TILE (38 plants)	
All departments (2,081)	40
Molding (321)	74
Offbearing and drying (310)	55
Clay preparation (178)	54
Pit and clay delivery (192)	52
Other (223)	47
Loading (372)	14
Setting and burning (485)	14
WOOD PULP (4 plants)	
All departments (568)	51
Maintenance and repair (67)	82
Power (56)	77
Pulp making (181)	65
Wood room (88)	53
Handling in yard (71)	35
General (31)	3
Conveying between processes (74)	0
NEWSPRINT (6 mills)	
All departments (2,137)	56
Paper making (451)	84
Power plant (161)	83
Finishing and cutting (143)	78
Receiving logs and preparing pulp (618)	45
Maintenance and repair (675)	42
Packing, conveying to carrier and shipping (89)	13
PAPER MILLS (25 plants)	
All departments (3,402)	52
Paper making (666)	83
Maintenance and repair (256)	83
Power production (286)	70
Washing, beating and refining (520)	58
Finishing processes (849)	45
Preliminary preparation of stock (254)	29

TABLE 30 *(cont.)*

DEGREE OF MECHANIZATION, BY PROCESSES

INDUSTRY AND PROCESS	PER CENT
Receiving raw material and shipping product (358)	9
Conveying between processes, watchmen, cleaners and unclassified (213)	5
COTTON YARN AND CLOTH (50 mills)	
All departments (31,396) [2]	86
Weaving (13,315)	95
Spinning (6,377)	92
Drawing and roving (3,382)	92
Carding and combing (1,516)	86
Opening and picking (692)	81
Other yarn processes (3,261)	76
Cloth room (1,183)	51
Power, maintenance, yard handling and misc. (1,670)	36
STEVEDORING (22 ships)	
All operations (1,617)	12
Loading ships	
Delivery to side of ship (119)	3
Placing in ship (38)	18
Stowing in ship (67)	0
Unloading ships	
Breaking out (554)	5
Removing from ship (280)	58
Sorting and arranging goods for consignee (559)	3
RURAL HIGHWAY CONSTRUCTION (61 jobs) [3]	
All operations (3,164)	36
Handling materials (962)	72
Paving (611)	39
Grading, with	
Power shovels (205)	28
Elevating graders (242)	21
Drag or wheel scrapers (282)	10
Roadway structures (109)	18
Incidental finishing (69)	12
Fine grading (684)	7
BUILDING CONSTRUCTION (49 jobs, selected processes) [3]	
All operations (1,402)	10
Hauling (27)	78
Concrete and mortar hoisting (26)	73
Concrete and mortar mixing (161)	42
Steel erection (41)	18
Digging (150)	3
Concrete and mortar distribution (195)	2
Carpentry (314)	1
Brick and stone laying (208)	0

[1] The machine workers group includes both machine operators and workers auxiliary to machines as defined in accompanying text.

[2] 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.

[3] 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.[13]

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.

[13] 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.[14]

[14] 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 nonmanufacturing 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.[15] They

[15] 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.