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CHAPTER III

CHANGES IN MECHANIZATION IN SELECTED MANUFACTURING INDUSTRIES

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

SOURCES OF INFORMATION

These summaries are based chiefly upon three sources of information: (1) the labor-saving changes reported to us in our survey of several hundred manufacturing and other industrial operations (see Table 1); (2) records of annual sales or installations of labor-saving devices (detailed in Appendix A); (3) government reports and other special industrial studies listed in the Bibliography, Appendix D.

Labor-saving Changes in Establishments Surveyed

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

Annual Sales of Labor-saving Equipment

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

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

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

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

In presenting this material we are limited because we cannot fully explain the nature of some of the series without violating the conditions under which we were given confidential data on the machine sales of individual manufacturers. For this reason it has been necessary in a few instances to give titles to series that do not make fully obvious their importance as labor-saving machines.

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

SUMMARY OF IMPORTANT CHANGES IN MECHANIZATION

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

Iron and Steel (Blast Furnaces and Steel Works) [2]

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

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

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

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

In the '80's blast furnace workers comprised about 25 per cent of the total number of wage earners in the industry. In 1920 only 10 per cent of the workers were found in this department, and during the depression of the '30's this proportion dropped to about 5 per cent. This change is explained in part by the relatively more rapid increase of productivity in smelting, by the increased use of scrap in steel-making, and by the diversification of product in the rolling and finishing departments, with a consequent increase in employment in those branches of the industry. Since the '80's American blast furnaces have been the most efficient in the world and have steadily increased in productivity. Average daily output per mineral fuel blast furnace in the United States in 1884 was 54 tons; in 1930 it was 584 tons, more than ten times as much. A corresponding increase in the average output per wage earner has taken place. In 1849 the output of pig iron per worker in the United States was only 24 tons per year, in 1869 it had reached 70 tons. In succeeding decades production per worker in the mineral fuel furnaces has increased more than tenfold, from 170 tons in 1884 to over 1,700 tons in 1929. The advance during the post-War years was especially marked. Meanwhile the number of necessary positions in blast furnace crews has fluctuated within narrow limits. Approximately the same direct operating crews are required for large furnaces as for small, although the output per worker may differ manyfold. Approximate computations by the writer indicate that the average mineral fuel stack required 116 men in 1884, 185 men in 1908 and about 120 men in 1929. Direct labor displacement over this period of several decades has kept pace with the steady increase in tonnage to be handled.

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

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

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

In the smelting and refining processes the steady reduction of the number of workers per ton of product is due to continual improvement in control of combustion and temperature, the construction of ever larger furnaces, the universal adoption of standard labor-saving methods which in the main had been devised before 1911, and constant eliminations and combinations of occupations, especially under the stimulus of the three-shift system generally inaugurated in 1923.

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

Straight-line production and automatic control have reached their highest development in the rolling mills. Here the most important aspect of recent change has been the electrification of drives and controls. Steam-driven mills were clumsy, mechanically inefficient, subject to frequent breakdown, and required relatively large numbers of operators and attendants. The labor-saving significance of electrification cannot be estimated with accuracy but the effect has been enormous. The introduction of highly-developed automatic specialty mills has been made possible by standardization of shapes and chemical specifications. In the continuous mills the hot ingot is taken from the soaking pits (the metal never having cooled since leaving the blast furnace) and is transformed into finished shapes by passage through a series of automatic rolls arranged in tandem. In 1905 there were only five electric main roll drives in the industry; in 1920 there were 674, and in 1931, 1,806, with a rated capacity of 3,000,000 horsepower out of a total horsepower of little more than twice this figure for all branches of the industry.

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

The most significant single change in steel manufacturing in recent years was the introduction in 1927 of a remarkable process of continuous strip-sheet rolling. Since the early days in Wales it had been inconceivable that steel sheets could be rolled directly from the ingot. In the United States the bulk of the product has been produced on simple hand rolls, and in 1929 there were roughly 1,400 mills of the traditional type in the industry, with an aggregate annual capacity of 7,500,000 gross tons of sheets. A single continuous mill of the new type can now produce more than 400,000 gross tons of sheets of uniform gauge, equivalent to the normal output of 40 or 50 of the old-style mills. For the sheet steel industry as a whole, the complete adoption of strip-sheet rolling will mean the displacement of ten thousand men and the concentration of sheet and tin plate production in the hands of a few dominant concerns.

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

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

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

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

[3] See also section on Metal Mining in Ch. IV.

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

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

Ferrous Foundries

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

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

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

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

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

TABLE 3

INSTALLATIONS OF LABOR-SAVING EQUIPMENT IN FOUNDRIES

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

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

TABLE 3 *(cont.)*

INSTALLATIONS OF LABOR-SAVING EQUIPMENT IN FOUNDRIES

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

[1] These data include the experience of one very large foundry, and hence can scarcely be considered typical.

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

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

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

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

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

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

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

The Manufacture of Brick

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

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

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

[7] See Ch. VII for degree of mechanization by processes.

handling, including loading the brick from the kilns to the common carrier.[8]

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

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

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

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

EQUIPMENT CHANGES IN PLANTS INSPECTED [10]

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

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

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

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

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

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

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

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

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

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

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

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

The other reported changes in handling included the

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

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

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

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

DECLINE IN NUMBER OF ESTABLISHMENTS

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

[17] For discussion of volume of handling in brick plants, see Ch. V.

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

POTTERY [18]

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

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

CHANGES IN EQUIPMENT AND PROCESSES

Aside from those incessant minor changes which take place

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

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

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

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

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

The extensive use of the continuous kiln in the pottery industry is a relatively new development. A report of a survey made in 1925 by the Bureau of Labor Statistics of the tableware branch of the pottery industry states that, "there are only two or three tunnel kilns in operation in this country" (Ref. 35). In response to inquiries by mail concerning their most important labor-saving change since 1920, we were advised by two manufacturers of tableware that the substitution in 1927 of continuous tunnel kilns for upright periodic kilns resulted in a direct and indirect saving of semiskilled and skilled labor, one plant reporting that with no change in the crew the output was increased, and the other that 6 men are now able to turn out the same amount of work as 11 men prior to the change. We understand that the continuous tunnel kiln is especially suited for steady quantity production.

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

We also understand that the use of artificial drying instead

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

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

Portland Cement

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

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

Cotton Yarn and Cloth [22]

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

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

22 Our inspections covered 53 cotton mills, 48 of which were both spinning

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

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

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

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

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

THE AUTOMATIC LOOM

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

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

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

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

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

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

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

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

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

REORGANIZATION OF WORK

By the end of the War too large a proportion of looms were already automatic to afford great scope for savings by changes of the type just listed. However, several mills reported that they had saved labor by greater specialization of occupations in the weave room. By the assignment of various incidental duties to less skilled workers, the weavers were freed to devote their entire attention to watching the looms and mending breaks, and thus were able to tend more looms. Changes in the duties of the weaver and the number of looms tended were ordinarily associated with concurrent improvements in the quality of materials used and better maintenance of machines, so that it is difficult to determine the exact amount of labor saved by such 'doubling-up', but the following summaries of savings reported in the mills inspected are of interest as indicative of tendencies.[23]

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

[23] For a brief description of the introduction of the 'multiple loom and frame' system in a New England mill and its marked effect on the size of the labor force, see *Monthly Labor Review*, October 1926, pp. 701–12.

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

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

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

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

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

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

TYING-IN AND DRAWING-IN MACHINES

Power equipment had been developed for the major processes of spinning and weaving for decades before inventive ingenuity solved the problem of mechanically tying a new set of warp threads to the old set in the loom. The first Barber-Colman warp-tying machine was installed on an experimental basis in 1904. The tying-in machine can be used to advantage when the pattern does not have to be altered and, provided there is no change in the number of threads, even pattern alterations are possible. The modern models tie about 250 threads a minute in non-stop operation. The economies of this machine gained rapid recognition, and 1907 sales reached a peak of 72 machines.[24] Then sales fell off, never rising above 50 until War demands induced a second boom in 1916–19. This machine, it is claimed, will do the work of about 15 hand operators. Three users estimated the number of hand workers displaced by each machine to be 11, 14 and 16 respectively. It can be run by one tender; frequently, though, there is a helper for every one or two machines.

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

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

24 The annual sales of tying-in machines, 1904–29, are presented in Table 38.

AUTOMATIC SPOOLER AND HIGH SPEED WARPER

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

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

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

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

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

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

Garment Industries

Important centers of the garment industries are found in New York, Chicago and Philadelphia. In New York, where our inspections were made, much of the work is done in relatively small shops. In a limited sample of 11 men's and 7 ladies' garment establishments surveyed in New York, employing a total of 904 workers, half were machine operators or helpers, though probably not engaged on machines all their working time. Half of the 18 establishments surveyed had made no labor-saving changes in equipment since 1920. Seven had substituted steam pressing machines for the hand-iron and sponge method. Six of these reported an aggregate reduction in labor requirements for the pressing operations from 74 to 38 workers, or 49 per cent. Three establishments replaced 1600-, 2200- and 2300-stitch per minute sewing machines with 2300-, 3200- and 4000-stitch machines, respectively, and reported labor reductions of 15 to 20 per cent. Two establishments substituted rotary cutting machines for hand cutting, with a reduction in crews from 22 to 8. An increase of multiple-ply cutting with the aid of these cutting machines has been one of the important developments in the industry since 1920.[26]

Pulp and Paper

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

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

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

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

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

[27] See Table 4 for power used, and Table 30 for degree of mechanization by occupations.

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

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

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

INCREASING SIZE OF EQUIPMENT UNITS

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

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

TABLE 4

CHANGES IN CAPACITY OF MECHANICAL EQUIPMENT: PULP AND PAPER[1]

Unit: one short ton (2,000 pounds)

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

1 *Census of Manufactures,* for the respective years.

2 Data not available.

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

REPORTED LABOR-SAVING CHANGES[28]

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

28 The inspections of pulp and paper mills by our representatives in 1929 covered 35 establishments in six states, employing 6,905 persons, or about 4.5 per cent of the total number of establishments and 5.6 per cent of the total number of wage earners in the industry. This sample covered about 79 per cent of the wage earners in the industry in Connecticut, but only from 4 to 12 per cent in the other 5 states. Four of the 35 schedules are for mills or departments making pulp only; 6, both pulp and newsprint; and 1

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

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

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

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

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

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

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

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

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

[29] See Tables 38 and 55.

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

Commercial Printing

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

The progress and effects of mechanization in the pressroom department since 1912 have been surveyed by Dr. Elizabeth F. Baker of Columbia University.[30] Her conclusions rest in part upon records of printing press sales from 1913 to 1928, and in part upon a study of the changes in a group of plants in New York City in the five-year period from the winter of 1923 to the winter of 1928. In all, 53 establishments were surveyed, but the detailed analysis pertains chiefly to 36 medium-size union plants, employing from 5 to 20 men in their pressrooms.

The two outstanding technical changes in commercial

30 See Bibliography, Ref. 4, 5 and 6.

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

Newspaper Printing[32]

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

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

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

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

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

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

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

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

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

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

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

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

Despite the lack of sweeping innovations, there were sub stantial gains in productivity in newspaper printing betweer 1916 and 1926; [34] but as in previous periods, their potentia effect on the volume of employment has been offset to a larg extent by expansion in the total volume of newspaper print ing, due chiefly to the remarkable growth in the circulatior and size of the daily newspaper. The total number of news papers, however, has decreased since 1909, and especiall since 1919.

The Glass Industry [35]

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

[34] The increase in output per man-hour for composition, stereotyping an presswork on 10,000 copies of a 4-page section of a representative newspape 1916–29, was estimated as 36.5 per cent, the smallest increase, 7.8, being i the presswork, and the largest, 40.7, in composition (Ref. 38, p. 19).

[35] In the glass industry we have not relied primarily upon field inspe tions, although Mr. Alfred Briggs, who prepared for our use a report o

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

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

WINDOW GLASS

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

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

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

[36] The snapper was the least skilled of the five and is hereinafter considered a semiskilled worker.

Cylinder machine

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

Sheet process

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

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

[37] *National Glass Budget,* June 3, 1905.

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

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

Decline of the hand branch

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

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

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

TABLE 5

EQUIPMENT IN THE WINDOW-GLASS INDUSTRY: 1903–1929

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

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

[1] Sources of information:

1903, *National Glass Budget,* January 17, 1903;

1905, *1905 Census of Manufactures,* p. 846;

1907, *National Glass Budget,* June 29, 1907;

1909, A. B. Morton, Machinery in the Window Glass Trade, *The Johns Hopkins University Circular,* April 1910, No. 4, p. 43. This figure seems high even though it was reported by Morton to be "estimated by a competent authority";

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

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

Another version of the decline of the hand branch is afforded by the following estimates of the percentage of window glass produced by the hand process: [39]

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

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

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

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

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

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

PLATE GLASS

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

The principal technological difference that affects the quantity of labor required is between the discontinuous and continuous processes of casting and finishing. In the older, discontinuous process, the raw materials are melted in large pots in furnaces, the pot is removed and the molten contents poured upon a casting table, smoothed to a large sheet by a heavy roller and immediately placed in an annealing lehr. When cooled, the defects are cut out and the glass ground smooth and polished. In contrast to the intermittent casting of one pot at a time, in the continuous process, which first came into use in 1921, there is an uninterrupted flow of the glass from a tank to the rollers and then through the lehr. In addition, after it is annealed there is a continuous passing of the ribbon of glass under a series of grinding and polishing machines, in contrast to the old process where circular tables are moved about from one machine to another.

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

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

GLASS CONTAINERS [40]

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

[40] This section is based chiefly upon the studies by Barnett (Ref. 3) and Stern (Ref. 36).

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

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

> "1. From 1898 to 1905, semi-automatic machines, requiring for their effective working skilled workmen, largely displaced hand blowers in the manufacture of wide-mouth ware.
>
> 2. From 1905 to 1917, the Owens automatic machine, which required only supervision and the amount of whose product was independent of the speed of the watcher, was the chief factor in the displacement of hand blowers and of the skilled operatives of semi-automatic machines. Contemporaneous with the introduction of the Owens was the appearance of semi-automatic machines for making narrow-mouth ware.
>
> 3. From 1917 to 1924, the trade has again been revolutionized by the introduction of 'feed and flow' devices which, while requiring more attention than the Owens machine, produce more ware than the semi-automatics. The attendants, moreover, need not be skilled workers, although the question of the relative superiority of skilled and unskilled workmen as attendants is still in dispute."

The semiautomatics substituted a combination of machine pressing and blowing for hand mold-blowing. Following a period of slow development in the experimental stage the number of these machines in use for wide-mouth jars rose rapidly from about 20 in 1897 to some 250 in 1905. Barnett estimates that these 250 represented a potential displacement of about 1,500 hand blowers; but that, in fact, almost no displacement occurred, because concurrently with their introduction the demand for bottles had so increased that the potential displacement of hand blowers could be met successfully in two ways: " (1) by the conversion of jar blowers into blowers of other forms of ware unaffected by the machine; (2) by placing hand blowers in positions as machine workers" (Ref. 3, p. 71). The first method proved the more effective.

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

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

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

[41] For estimates of comparative productivity of hand, semiautomatic and automatic machines, see Stern, Ref. 36.

Extent of introduction of automatic machinery

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

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

PRESSED WARE [45]

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

[42] Ref. 3, p. 85.

[43] *Ibid., p.* 93.

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

[45] The paragraphs on pressed and blown ware are based largely upon Stern, Ref. 36.

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

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

BLOWN WARE

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

"Since 1917 hand production has been almost entirely displaced—first by the semiautomatic Empire E machine and more recently by the completely automatic Westlake machine and the Empire F machine operated with an automatic feeder. At present more than 95 per cent of all the electric bulbs are made by the two automatic processes. The semiautomatic machine has been almost completely abandoned, while a few hand shops have been retained for experimental purposes or for the purpose of making oddly shaped and colored electric bulbs" (Stern, Ref. 36, p. 6).

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

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

ELECTRIC-LAMP INDUSTRY [46]

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

A. The group or unit system of manufacture.

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

[46] *Monthly Labor Review*, Ref. 65, especially pp. 1213–4.

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

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

Lumber Manufacture and Wood-Working Industries

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

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

[47] See Table 46, for annual sales of four models of carriers and high lumber pilers, and Table 52 for estimates of extent of use.

in the primary manufacture of lumber for which productivity and equipment records are available, 1916–17.[48]

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

WOOD FURNITURE

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

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

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

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

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

A similar situation holds with respect to mouldings:

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

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

MOTOR-VEHICLE INDUSTRY

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

RUBBER TIRES AND TUBES

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

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

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

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

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

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

[52] See also list for two plants in *Monthly Labor Review* (Ref. 62, p. 1266).

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

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

Leather

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

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

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

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

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

SHOES [55]

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

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

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

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

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

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

Beet Sugar

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

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

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

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

Slaughtering and Meat Packing

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

[59] See Ethelbert Stewart, Labor Productivity in Slaughtering, *Monthly Labor Review,* 18: 488–95, and Productivity of Labor in Slaughtering and Meat Packing. . ., *ibid.,* 23: 954–8.

methods difficult except in the conveying and packaging phases.[60]

TOBACCO MANUFACTURE

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

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

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

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

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

After the cigar has been formed, it is usually wrapped in cellophane and banded. Wrapping machines for this purpose are now quite generally used by all cigar manufacturers and most of the larger machine factories are now operating cellophane-wrapping machines and banding machines as a unit. "Some cigars are banded only, while others are first banded and then wrapped in cellophane. However, the usual method now employed is to first cellophane the cigar and then band it" (Ref. 47, p. 1, 278).