Volume Title: Recent Economic Changes in the United States, Volumes 1 and 2

Volume Author/Editor: Committee on Recent Economic Changes of the President's Conference on Unemployment

Volume Publisher: NBER

Volume ISBN: 0-87014-012-4

Volume URL: http://www.nber.org/books/comm29-1

Publication Date: 1929

Chapter Title: Industry: Part 2 - Technical Changes in Manufacturing Industries

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Chapter URL: http://www.nber.org/chapters/c4954

Chapter pages in book: (p. 96 - 166)

PART 2.—TECHNICAL CHANGES IN MANUFACTURING INDUSTRIES

By L. P. Alford

I. NATIONAL CHANGES IN TECHNICAL PRODUCTION FACTORS

The key to an understanding of recent technical changes in manufacturing is the increase in productivity, or the increase in output per worker. Therefore, the other factors will be studied in relation to the changes in productivity. Those which are capable of quantitative study on a national basis are:

1. Physical volume of production.
2. Number of wage earners.
3. Wages paid.
4. Cost of materials for manufacture.
5. Prime cost.
6. Primary power.
7. Value of manufacturing buildings.
8. Value of manufacturing machinery.
9. Hours per week.
10. Weekly wage rate.

In addition, two derived unit factors are discussed, as well as individual productivity, making three in all.

1. Productivity per wage earner.
2. Unit prime cost.
3. Primary power per wage earner.

Table 1 gives index numbers of those factors for American manufacturing industry as a whole, for the period 1899 to the date of latest available statistics.[1]

These data have been plotted in various relationships on Charts 1 to 7, inclusive, to visualize the changes that have taken place. Semilogarithmic (or ratio) co-ordinates have been used.

[1] Data included in this table were secured from the following sources: *United States Census of Manufactures*, 1925; "The Economic Significance of the Increased Efficiency of American Industry," by Woodlief Thomas, *American Economic Review*, Supplement, March, 1928; "A Theory of Production," by Charles W. Cobb and Paul H. Douglas, *American Economic Review*, Supplement, March, 1928; *Wages in the United States, 1914–1926*, published by the National Industrial Conference Board.

TABLE 1.—INDEX NUMBERS FOR 13 PRODUCTION FACTORS FOR PERIOD 1899 TO DATE OF LATEST AVAILABLE STATISTICS

(1899 base year, except for columns 10 and 11, for which 1914 is base year)

1	2	3	4	5	6	7	8	9	10	11	12	13	14
Year	Physical production	Number of wage earners	Wages paid	Cost of materials for manufacture	Prime cost	Primary power	Value of manufacturing buildings	Value of manufacturing machinery	Hours per week	Weekly wage rate	Productivity per wage earner	Unit prime cost	Primary power per wage earner
1899[a]	100	100	100	100	100	100	100	100	...	...	100	100	100
1904[a]	122	117	130	129	130	134	139	138	...	...	104	106	115
1909[a]	159	145	171	183	181	185	187	187	...	...	110	114	132
1914[a]	169	156	203	215	212	222	221	223	100	100	108	125	151
1918	220	210	...	...	...	...	225	230	...	...	...	...	...
1919[a]	214	204	522	563	553	292	...	...	...	...	104	258	152
1920	222	205	...	...	...	...	...	...	95	234	...	...	...
1921[a]	170	158	410	383	388	...	...	...	88	188	107	228	...
1922	223	173	...	...	...	...	285	296	96	192	...	...	...
1923[a]	261	197	550	524	528	330	...	...	96	212	132	202	176
1924	246	188	...	...	...	...	...	...	91	210	...	...	...
1925[a]	275	188	536	547	545	356	...	...	94	214	147	198	199
1926	285	189	...	...	...	...	...	...	94	216	...	...	...
1927	280	187	...	...	...	...	...	...	...	...	[b]151–5	...	...

[a] Census years. [b] Estimated by Woodlief Thomas.

Sources: Columns 2, 3, 7, and 12 from "The Economic Significance of the Increased Efficiency of American Industry," by Woodlief Thomas, *American Economic Review*, Supplement, March, 1928. Columns 4 and 5 from *United States Census of Manufactures*, 1925. Columns 8 and 9 from "A Theory of Production," by Charles W. Cobb and Paul H. Douglas, *American Economic Review*, Supplement, March, 1928. Columns 10 and 11 from *Wages in the United States, 1914–1926*, National Industrial Conference Board.

Chart 1 shows unit productivity and unit prime cost. The first has increased from 1919 on; the second has decreased steadily from that same year.

CHART 1.—RELATIONSHIP OF PRODUCTIVITY PER WAGE EARNER AND UNIT PRIME COST

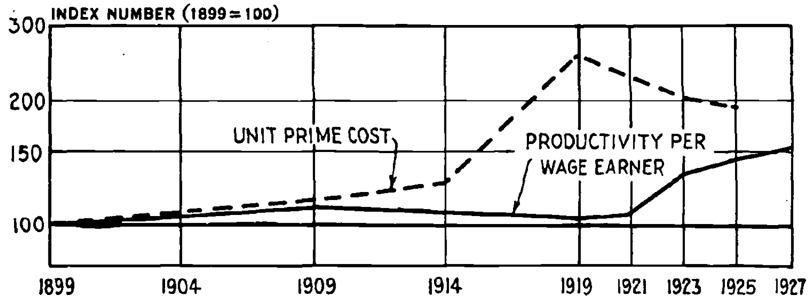


Chart 2 has three curves—physical volume of production, number of wage earners, and productivity per wage earner. The third, point by point, plots as index numbers the quotient of the first divided by the second.

CHART 2.—RELATIONSHIP OF PHYSICAL VOLUME OF PRODUCTION, NUMBER OF WAGE EARNERS, AND PRODUCTIVITY PER WAGE EARNER

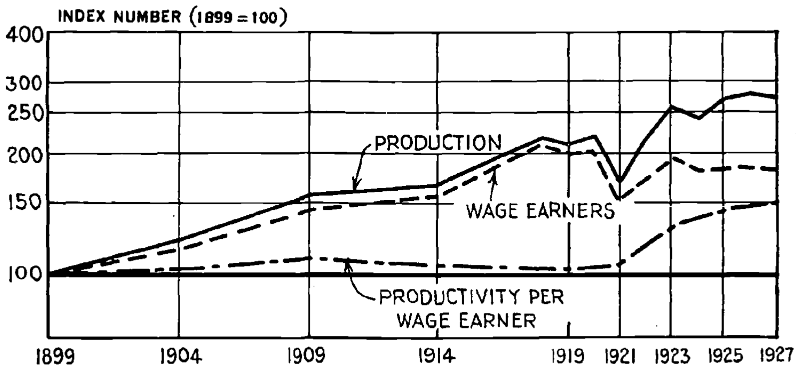


Chart 3 shows the cost of materials, wages paid, and physical volume of production. The first two are the cost elements which added together give prime cost.

Chart 4 also has three curves—prime cost, physical volume of production, and unit prime cost. The relationship between them is that unit prime cost is the quotient of prime cost divided by production.

CHART 3.—RELATIONSHIP OF COST OF MATERIALS, WAGES PAID, AND PHYSICAL VOLUME OF PRODUCTION

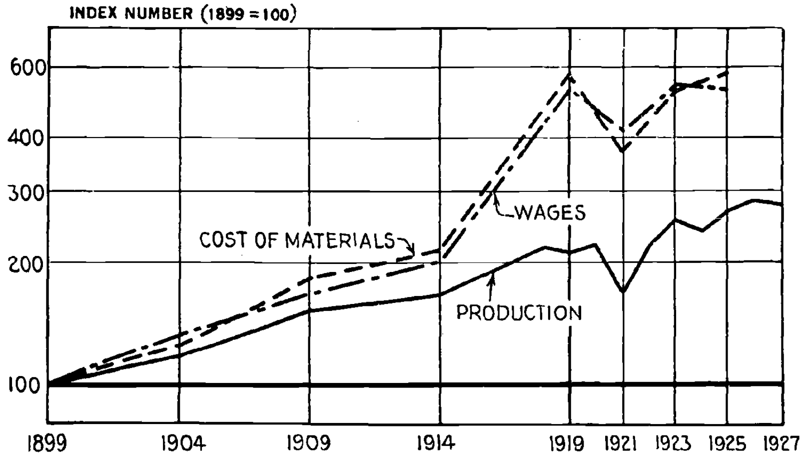


CHART 4.—RELATIONSHIP OF PRIME COST, PHYSICAL VOLUME OF PRODUCTION, AND UNIT PRIME COST

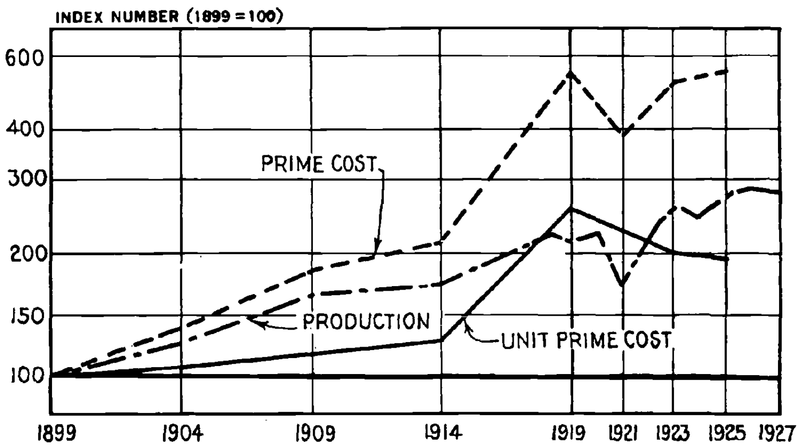


Chart 5 visualizes in comparison the changes in primary power, values of manufacturing buildings and machinery corrected for fluctuations in dollar value on the 1899 basis, and physical volume of production.

Chart 6 graphically compares the weekly wage rate, hours worked per week, and the unit prime cost. Wages paid, the product of hours worked multiplied by rate per hour, is one of the cost elements in prime cost.

Chart 7 has three curves—primary power, number of wage earners, and primary power per wage earner. The values for the first divided by the values for the second give those of the third.

CHART 5.—RELATIONSHIP OF PRIMARY POWER, VALUE OF MANUFACTURING BUILDINGS AND MACHINERY, AND PHYSICAL VOLUME OF PRODUCTION

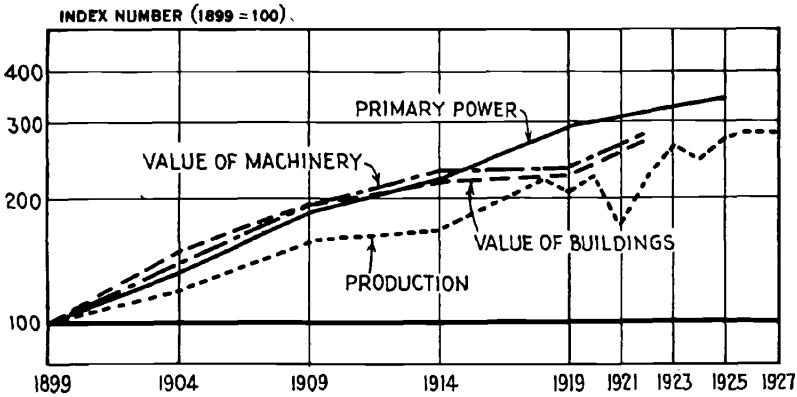


CHART 6.—RELATIONSHIP OF WEEKLY WAGE RATE, HOURS WORKED PER WEEK, AND UNIT PRIME COST

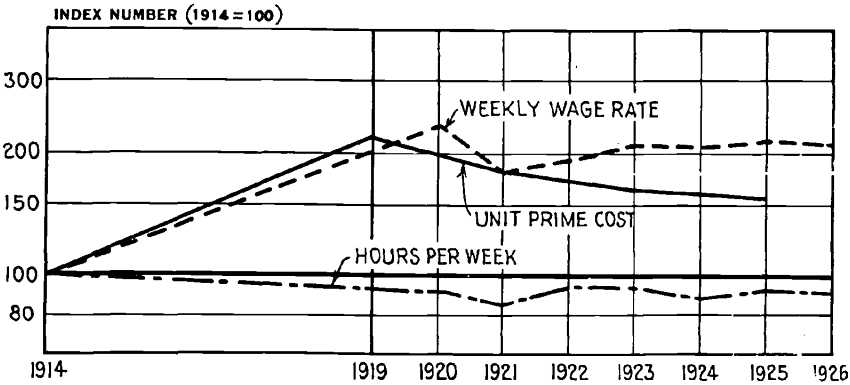


CHART 7.—RELATIONSHIP OF PRIMARY POWER, NUMBER OF WAGE EARNERS, AND PRIMARY POWER PER WAGE EARNER

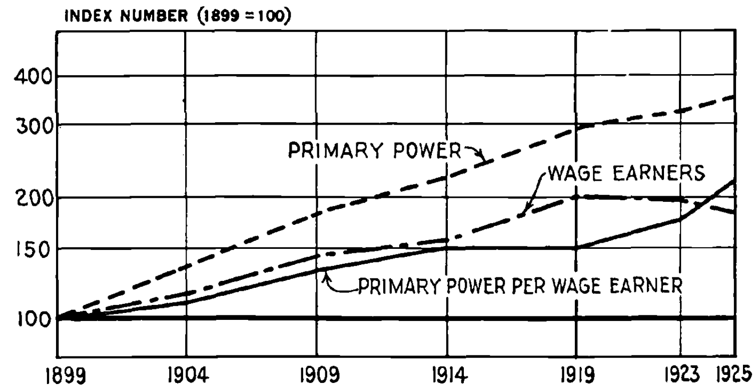


Table 2 gives for each of these 13 factors the terminal percentage change for both periods, 1899–1919 and 1919 to date of latest available statistics, and the average annual percentage change for each of these periods.

TABLE 2.—PERCENTAGE CHANGES FOR 13 PRODUCTION FACTORS

(Computed by method of least squares)

Factor	Percentage changes (increases except where otherwise noted)			
	Total	Annual	Total	Annual
	1899 to 1919	1899 to 1919	1919 to year shown	1919 to year shown
Production	112	5.6	46.5 (1927)	5.81 (1927)
Wage earners	103	5.15	−2.9 (1927)	−0.36 (1927)
Productivity	4.7	0.24	53.5 (1927)	6.69 (1927)
Primary power	205	10.25	22 (1925)	3.67 (1925)
Primary power per wage earner	47	2.35	30.9 (1925)	7 (1925)
Cost of materials	1,135	56.75	9.7 (1925)	1.62 (1925)
Wages paid	878	43.9	11.4 (1925)	1.9 (1925)
Value of buildings	123	6.15	26.7 (1922)	8.9 (1922)
Value of machinery	129	6.45	28.7 (1922)	9.6 (1922)
Prime cost	1,050	52.5	7.2 (1925)	1.2 (1925)
Unit prime cost	182	9.1	−24.5 (1925)	−4.08 (1925)
	1914–1920	1914–1920	1920–1926	1920–1926
Hours worked per week	−5	−0.83	0.9	0.15
Weekly wage rate	134	22.33	1.04	0.17

Physical Volume of Production.—The physical volume of product turned out by American manufacturing industry has increased steadily since 1899. There has been but one year of marked drop, namely, 1921. The year of greatest production was 1926, with a falling off of about 2 per cent from that year's volume in 1927. The percentage increase, taken from Table 2, from 1899 to 1919 is 112 per cent; the increase from 1919 to 1927 is 46.5 per cent. It is evident both from the statistics and charts that the sudden increase in production corresponds with the increase in productivity.

Number of Wage Earners.—The number of workers engaged in industry increased steadily from 1899 through 1919. There was a decided drop in 1921 which gave rise to the industrial unemployment of that year. The years 1922 and 1923 showed recovery, but the number engaged in the latter year was substantially lower than in 1919 and 1920. From 1923 to 1924 there was a drop with practically no change from that time through 1927. The percentage increase from 1899 to 1919, taken from Table 2, is 103 per cent; the decrease from 1919 to 1927 is 2.9 per cent. Thus, during the period of greatly increasing productivity, there has been a decrease in the number of workers employed.

Wages Paid.—The total cost of labor employed in manufacturing, that is, amount paid in wages, fluctuated widely up to 1919, with but comparatively little change thereafter. The total increase in percentage from 1899 to 1919 is 878 per cent. The total increase from 1919 to 1925 is 11.4 per cent.

Cost of Materials.—The total cost of materials of manufacture, that is, the amount paid for them in dollars, has shown a great increase from 1899 to 1919, with the sharpest rise in the last five years of that period, and a slight increase from 1919 to 1925, the last year for which data are available. The total increase in percentage from 1899 to 1919 is 1135 per cent.

Prime Cost.—Prime cost, the sum of labor and material costs, has fluctuated like the two factors upon which it depends. The changes are an increase from 1899 to 1919 of 1050 per cent and a slight upward trend from 1919 to 1925.

Primary Power.—The change in utilization of primary power is undoubtedly one of the most significant. There has been a steady increase in this production factor since 1899 to date. When plotted, the curve is nearly a straight line, indicating an approximately uniform rate of increase. The percentage increase from 1899 to 1919 is 205 per cent; from 1919 to 1925, 22 per cent.

Value of Manufacturing Buildings.—The value of manufacturing buildings on the 1899 base has increased at a more rapid rate than the increase in production up to the year 1922, the last one for which statistics are available for this factor. The percentage increase from 1899 to 1919 is 123 per cent, followed by a 26.7 per cent increase from 1919 to 1922. The growth has been somewhat uniform with, however, a point of flexure in 1919, corresponding in time to the beginning of the increase in productivity.

As an indication of the changes that have taken place since 1922, a statement has been prepared which gives the number of square feet of floor area of industrial buildings contracted for year by year, beginning with 1915.[2] The statement, expressed in square feet, is as follows:

1915	64,000,000	1921	36,000,000
1916	97,000,000	1922	66,000,000
1917	109,000,000	1923	62,000,000
1918	181,000,000	1924	41,000,000
1919	153,000,000	1925	59,000,000
1920	128,000,000	1926	68,000,000

[2] The figures are not for the entire United States, but include the 27 most important industrial states, and are estimated to include 75 per cent of all the construction of manufacturing buildings. The states surveyed are: Maine, New Hampshire, Massachusetts, Rhode Island, Vermont, Connecticut, New York, New Jersey, Pennsylvania, Delaware, Maryland, Virginia, West Virginia, Illinois, Indiana, Ohio, Minnesota, Michigan, Wisconsin, Iowa, Kansas, North Carolina, South Carolina, North Dakota, South Dakota, Missouri, Nebraska.

The peak year for contracting for this additional manufacturing floor area was 1918, with 1919 and 1920 also high. For these three years the total, from the foregoing tabulation, is 462,000,000 square feet, an area which was undoubtedly in use and productive when the increase in productivity turned sharply upward in 1921. The corresponding area estimated for the entire United States is 616,000,000 square feet.

Value of Manufacturing Machinery.—The changes in the value of machinery employed in manufacturing on the 1899 base is similar to that for the value of buildings. There is a decided increase from 1899 to 1922, the last year for which figures are available. The percentage change from 1899 to 1919 is 129 per cent, with a further increase of 28.7 per cent for 1919 to 1922.

Average Hours Worked per Week.[3]—The reduction during the present century in the average number of hours worked per week in American manufacturing establishments had been pretty well realized by 1919. The reduction from 1914 has been at a uniform rate. The number of hours for the year 1914 is 51.5, while the corresponding figures for the years 1925 and 1926 are 48.2. There was a drop in the depression year of 1921, recovery in 1922 and 1923, and another slight drop in 1924. The average actual hours worked per week from 1914 to 1926, inclusive, are shown in the following statement:

1914	51.5	1923	49.2
1920	48.7	1924	46.8
1921	45.5	1925	48.2
1922	49.2	1926	48.2

Weekly Wage Rate.—The weekly wage rate has increased sharply from 1914 to 1919, with a slight tendency upward after 1920 to date. In this respect it continues the age-old relationship—when productivity increases, wages increase also. The increase from 1914 to 1920 has reached a point, indeed, which the increase from 1920 to 1926 has not yet attained. Average weekly wage rates from 1914 to 1926, inclusive, are shown in the following statement:

1914	12.54	1923	26.54
1920	29.37	1924	26.28
1921	23.60	1925	26.93
1922	24.04	1926	27.16

Productivity per Wage Earner.[4]—The factor, output or productivity per worker, is the quotient of the physical volume of production divided

[3] A most useful figure which might advantageously be reported in future censuses of manufactures is the "man-hours worked per year." It would be far more significant and valuable than the figures of "average hours worked per week."

[4] See discussion of productivity per wage earner, pp. 96 and 104; also Chap. III, Construction, pp. 243 and 248; Chap. IV, Transportation, Part 1, p. 285; Chap. VI, Labor, p. 447.

by the number of persons engaged. It is, therefore, a derived figure and is dependent upon the utilization of the production factors which have a direct bearing upon production, as this is the numerator of a fraction of which the number of persons engaged is the denominator. The percentage increase from 1899 to 1919 for this factor is 4.7; that is, it had changed but little during the first 20 years of the twentieth century. The change from 1919 to 1927 is 53.5 per cent, emphasizing once more the fact that significant changes must have taken place in a number of production factors at or just preceding the critical time, 1919–20.

Unit Prime Cost.—The unit prime cost of manufactured goods, which is the quotient of total prime cost divided by production, is directly influenced by those production factors that increase the efficiency of production, the more economical use of materials and labor, as well as fluctuations in prime commodity prices and wage rates due to market changes. Therefore, changes in unit prime cost reflect technical changes. The outstanding example of this fact since 1919 is the reduction in price of automobiles, which has steadily moved downward, largely because of changes in technical processes and manufacturing methods.

From another point of view, this factor is important as indicating the effect of the cost-reduction program of American manufacturers initiated at the close of the World War.

The changes are not unlike, but reversed to those that have taken place in the productivity of the wage earner. From 1899 to 1919 the percentage increase was 182 per cent. From 1919 to 1925 the decrease has been 24.5 per cent.

Primary Power per Wage Earner.—The changes in this factor have attracted as much general attention as those that have taken place in regard to productivity. Nearly as great an over-all increase has occurred since 1919 to 1925 as from 1899 to 1919. The latter figure is 47 per cent, while the former is 30.9 per cent.

To assist in determining which factors have undergone the greatest change since 1919, they have been divided into three groups. The first includes those which have had a sharp increase in annual total or rate; the second, the single one which has had a sharp decrease; the third, those whose changes in annual total or rate have been comparatively slight.

In the first group, the over-all percentage changes, from 1919 to the last date for which statistics are available, range upward from 22 per cent. In the third group, the corresponding percentages range downward from 11.4 per cent.

The following statement shows the nature and per cent of change in these factors following 1919 (see Table 2). The figures, computed by the method of least squares, express the general trend rather than the exact changes which have taken place.

Sharp increase following 1919:	
Production	46.5
Productivity per wage earner	53.5
Total primary power	22.0
Primary power per wage earner	30.9
Machinery and equipment	28.7
Industrial buildings	26.7
Sharp decrease following 1919:	
Unit prime cost	−24.5
Slight changes following 1919:	
Total wages paid	11.4
Total cost of materials	9.7
Total prime cost	7.2
Weekly wage rate	1.04
Hours worked per week	0.9
Number of wage earners	−2.9

The first factor group, the one with which we are principally concerned, includes three physical (or, for the purpose of this study, technical) factors: primary power, industrial buildings, and machinery and equipment. These deserve further investigation. A fourth, which should also be included, is materials and processes of manufacture. Owing to the absence of data on the physical volume of materials consumed in industry, the change in the effectiveness of material utilization cannot be studied quantitatively. It is known, however, that the postwar period has produced many new materials and has seen the development of many improved processes. All these factors are further studied in Section II.

II. SPECIFIC CHANGES IN CERTAIN TECHNICAL PRODUCTION FACTORS

The information and data upon which this part of the report is based have been secured from many sources and by a variety of means.[5] The report based upon this information is arranged in eleven subdivisions of the general topics outlined at the close of Section I. These are as follows:

1. Industrial research.
2. Products and materials.
3. Industrial processes.
4. Manufacturing waste.
5. Industrial power.
6. Power machinery.
7. Industrial buildings.
8. Manufacturing machinery.
9. Material-handling equipment.
10. Mechanical safeguards for plant and machinery.
11. Artificial illumination.

[5] Operating data have come from manufacturing concerns, brought out either by correspondence or through personal contact in field work. The statistics are principally from the reports of the Bureau of the Census. Library research has secured technical data, more particularly in regard to industrial power, while a survey of current engineering literature, supplemented by correspondence, produced information of materials of manufacture, industrial processes, and material-handling equipment.

The number of items that might have been presented on each of the subtopics 2, 3, 4, and 9, was larger than reasonable space would allow. Therefore, 50 cases were arbitrarily determined upon as the maximum, those that seemed to be most typical being selected.

The extent of the case information on manufacturing operation, sought out, selected and analyzed in this part of the report as a whole, is shown by the list of subdivisions and the number of cases included in each, that follows. The total is nearly 1,100 items.

1. Industrial research	599
2. Products and materials	50
3. Industrial processes	50
4. Manufacturing waste	101
8. Manufacturing machinery	200
9. Material-handling equipment	50
11. Artificial illumination	38
Total	1,088

1. Industrial Research.—Fortunately for the purpose of this report, the National Research Council early in 1928 sent out a carefully prepared questionnaire to 5,000 manufacturing concerns in the United States, each having a commercial rating of $1,000,000 or over.[6] Inasmuch as 599 replies brought definite information, the tabulated results can be considered as an extensive assay of the industrial research situation as it exists to-day in American manufacturing. The questions asked sought to bring forth information as to whether or not a research laboratory existed, the nature of the program, amount of annual expenditures, nature of special facilities afforded to the industry, and whether or not the activities had been profitable.

The information furnished by the replies is compiled in Table 3. The control column at the left lists 40 industrial or manufacturing product groups. Then follow five columns indicating how far organized research work is done and the nature of the laboratory which is maintained, if any. The next six columns are concerned with the research program and show what objective or objectives are being sought through research. The balance of the table deals with expenditures and profit.

Classification.—The classification of industries adopted in Table 3 does not actually follow that of the Bureau of the Census but is in as close agreement with it as possible. In some instances, too few replies were received to form an individual industrial group, five having been arbitrarily fixed as the minimum. Therefore, combinations of certain groups were set up in a classification slightly different from that used by the Bureau of the Census. Various terms were used in the replies to charac-

[6] The replies to this request for information were offered for our use through the kindness of Maurice Holland, director, Division of Engineering and Industrial Research, National Research Council.

terize laboratories, including research, development, testing, and control. In the tabulation, development laboratories have been considered as belonging to the research group, and control laboratories as being devoted to testing.

One classification, that of machinery (light), needs explanation. It includes such mechanical equipment as typewriters, carpet sweepers, radio sets, firearms, and the like.

Activities.—Of the 599 manufacturing concerns supplying information, 52 per cent reported that they carried on research as a company activity. Testing laboratories are conducted by 7 per cent, leaving 41 per cent reporting that no research work is being done.

In regard to co-operative research conducted through trade associations, engineering societies, universities, or endowed fellowships, 29 per cent reported that they were supporting such activities. An additional 15 per cent stated that they were considering extension of their research activities, and 11 per cent of those doing no research work at the present time reported that they are considering taking it up in the future.

While it cannot be claimed that these percentages apply to American manufacturing as a whole, for in any such assay the more approachable and progressive concerns reply with the greater readiness, these figures indicate something of the extent of industrial research and the attitude toward it on the part of industrial managers and executives.

Co-operative Research.—Certain industries lend themselves to co-operative research. Among them are those engaged in cement manufacture, leather tanning, and gas and electric utilities. These industries, in particular, depend to a large extent upon research conducted by various national associations. On the other hand, there are certain industries which prefer to carry on research in the individual concerns largely because of the highly competitive nature of the products. Examples of such industries are the manufacture of machinery, machine tools, drugs, cosmetics, and pharmaceuticals.

Research Programs.—It was possible to divide the programs submitted into five classes, the arrangement being in the order of importance:

1. Improved product or service, 67 per cent.
2. Reduction of production costs, 59 per cent.
3. Development of new fields of application, 40 per cent.
4. By-products and new materials, 30 per cent.
5. New products, 8 per cent.

Only a few, 12 in all, specifically mentioned the elimination and utilization of waste. However, from the nature of the replies the conclusion is justifiable that many concerns interested in this subject included this element in their program under the heading of "by-products and new materials."

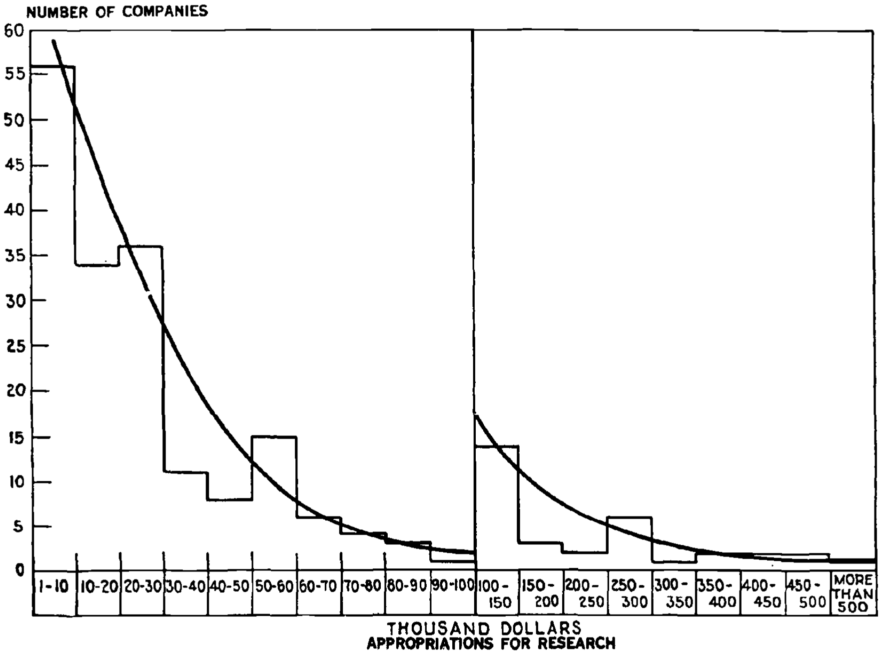
TABLE 3.—DATA ON INDUSTRIAL RESEARCH ACTIVITIES OF 40 MANUFACTURING PRODUCT GROUPS

Number of firms reporting	Industry	Extent of research being conducted					Research programs						Research expenditures and profit					
		Research laboratory or staff	Testing laboratory	No research work	Support co-operative research	Consider future activities	Improved quality of product or service	Reduced production cost	Development new fields of application	By-products or new materials	New products	Waste elimination and utilization	Number firms reporting	Annual research expenditure	Average expenditure reported	Number firms reporting amount increasing	Number reporting profit from research	Number reporting no profit from research
599	All industries	314	41	244	176	91	328	290	200	146	39	12	208	$11,991,637	$57,652	177	193	17
5	Agricultural machinery	1	...	4	1	1	3	3	3	2	1	...	...	...	...	1	...	...
19	Automobiles and accessories	10	4	5	4	3	12	8	4	1	1	...	7	230,000	32,857	4	7	...
8	Candy and confectionery	5	...	3	1	...	5	4	2	3	1	...	4	39,000	9,750	1	...	...
5	Carpets and rugs	2	...	3	1	2	3	4	...	...	...	...	3	12,000	4,000	2	2	1
7	Cement manufacture	3	..	4	3	1	4	4	1	1	...	...	2	30,000	15,000	3	4	...
16	Ceramics, brick and clay products	8	1	7	7	5	8	8	5	3	1	...	9	358,089	38,787	8	7	...
34	Chemicals	28	...	6	9	8	24	23	18	17	4	5	20	1,707,500	85,375	20	15	1
7	Clothing	1	1	5	4	1	1	1	1	1	...	...	3	52,800	17,600	1	2	...
7	Dairy products	5	...	2	2	...	3	2	1	1	...	...	2	262,000	131,000	3	2	...
17	Drugs, medicinal products and cosmetics	13	2	2	4	6	12	11	9	8	4	...	9	586,000	65,111	9	7	...
14	Electrical machinery and apparatus	12	1	1	2	3	12	8	7	2	1	...	8	1,127,000	140,877	8	4	1
24	Food products	13	1	10	7	4	14	10	8	7	4	...	7	505,000	72,143	4	8	1
6	Furniture	2	1	3	...	2	3	3	1	...	...	...	2	28,000	14,000	...	3	...
19	Hardware	12	1	6	4	1	13	9	5	6	1	1	4	88,500	22,125	6	5	...
12	Instruments—measuring	8	...	4	...	2	7	5	1	2	1	...	4	286,000	71,500	5	3	1
21	Iron and steel	12	...	9	9	3	9	10	8	4	2	1	5	81,400	16,280	6	5	...
8	Knitting	3	...	5	5	2	4	2	2	1	...	...	2	37,000	18,500	4	2	1
14	Leather and allied products	6	...	8	7	4	6	4	4	3	1	...	3	70,000	23,333	5	4	1
29	Lumber and allied products	4	...	25	13	4	9	6	5	8	1	...	3	53,500	17,633	2	4	2
13	Machine tools	6	1	6	3	1	6	5	5	2	...	...	2	75,000	37,500	1	3	1
45	Machinery	25	5	15	8	5	26	19	24	9	4	...	20	891,788	49,539	12	11	1
12	Machinery (light)	11	...	1	4	1	10	9	2	2	3	1	4	890,000	22,250	5	5	...

6	Meat packers	1	...	5	5	...	2	3	1	1	...	...	3	16,500	5,500	...	1	...
27	Metal products	11	1	15	5	4	14	13	7	5	...	...	6	274,500	45,750	3	7	1
7	Milling—flour	2	2	3	1	1	2	1	2	1	...	...	1	7,500	7,500	...	2	1
12	Nonferrous metals	10	...	2	7	5	9	9	7	5	1	1	9	269,000	29,888	7	8	...
10	Oil works and petroleum refining	6	1	3	7	3	6	7	3	2	1	...	5	911,000	182,200	3	4	1
6	Paints and varnishes	6	...	...	3	3	5	4	5	4	1	...	4	112,000	28,000	4	5	...
41	Paper	26	4	11	10	4	27	28	13	12	...	3	16	565,500	35,343	15	21	...
6	Pianos	3	1	2	...	...	4	3	...	1	1	...	2	20,000	10,000	2	...	...
34	Public utilities (gas and electric)	9	5	20	17	...	10	12	11	4	1	...	10	841,500	84,150	6	11	...
6	Railway equipment	2	...	4	...	1	2	2	1	1	...	...	1	7,500	7,500	...	1	...
9	Rubber	5	1	3	...	...	5	5	1	1	1	...	2	125,000	62,500	3	3	...
10	Shoes	2	...	8	2	1	4	4	...	3	1	...	2	4,000	2,000	2	3	...
5	Silversmiths	3	...	2	1	...	3	3	1	...	...	...	1	12,500	12,500	1	1	...
9	Steam specialties	5	2	2	4	4	5	4	3	2	...	...	2	565,000	282,500	3	3	...
6	Stone and marble works	2	...	4	2	2	4	2	4	3	...	...	1	6,000	6,000	1	2	1
31	Textiles	11	4	16	7	1	12	14	11	9	...	...	7	511,500	73,071	10	6	...
8	Wire and wire specialties	3	2	3	5	2	7	6	5	2	1	...	3	61,700	20,566	1	5	...
24	Miscellaneous	17	...	7	2	1	13	12	9	7	1	...	10	270,360	27,036	6	7	2

Expenditures.—The request for information as to annual expenditures was not generally replied to. A number of firms said that they kept no special accounts to cover industrial research activities and so were unable to furnish the information requested. However, 208 establishments reported annual expenditures to the total of $11,991,637. Expressed in averages, this total is $57,652 per year for each firm which reported its expenditures. Chart 8 shows the frequency of the various appropriations for research within this group of 208 concerns; $10,000 per year is the sum most frequently spent.

CHART 8.—FREQUENCY CURVE OF ANNUAL APPROPRIATIONS FOR INDUSTRIAL RESEARCH MADE BY 208 MANUFACTURING ESTABLISHMENTS



As to whether expenditures were decreasing or increasing, 58 per cent of those that reported stated that they were increasing year by year; 8 per cent stated that annual expenditures were remaining stationary, while only five establishments out of the total of 208 reported that their research budgets were decreasing.

Results from Research.—Of the 490 firms that conduct individual research work and support co-operative research, 39 per cent reported that their research activities had shown a profit. Seventeen firms reported that research had shown no profit. Twelve of these explained the situation by saying that they had not conducted research long enough to realize a profit from its results. And nearly all of this group believe that definite results will be attributable to their industrial research within the next year or two.

Mention has been made of the fact that many firms do not keep records of research expenditures. In this group are 73 firms that are conducting individual research or are supporting co-operative activities. In some cases the statement is made that research costs are allocated directly to products or are absorbed by general expenses.

As to the ratio of profit to the amount expended, numerous estimates range from 100 to 300 per cent. One firm reported profit as "1,000 to 1."

2. Products and Materials.—*Fifty Typical Developments.*—Replies to a questionnaire brought a considerable amount of information in regard to both materials and manufactured products which had been developed and put on the market since 1918. Obviously such data do not lend themselves to a statistical or quantitative presentation. The only practicable course is to present a sufficient number of cases as an assay to indicate the nature of the discoveries and, so far as possible, give an evaluation of their economic importance.

A selection was made of 50 items which, taken together, give a fair idea of the spread of research work that has been done to develop new materials and new products for commercial use. Where possible, the quantity of the commodity produced and the accompanying reduction in cost or the technical advantages secured are given.

For convenience they are classified into the following 11 groups:

Cellulose products.
Chemicals.
Drugs and pharmaceuticals.
Electrical apparatus.
Food products.
Metals.
Paints and varnishes.
Refractory materials.
Resinous products.
Rubber products.
Miscellaneous products.

Credit is given for each item, either to the manufacturing company that supplied the information, the United States Bureau of the Census, or the United States Bureau of Standards.

Table 4 summarizes the data which are given in some detail in the following pages.

3. Industrial Processes.—*Fifty Typical Developments.*—In the cost-reduction program of American manufacturers the development of new processes to lower costs or to bring other savings has been a prominent part of research activities. This phase of industrial research was explored for this survey through a questionnaire sent to representative manufacturing companies and to laboratories engaged in such investigations.

The information received in reply has been compiled in the same manner as that on products and materials. That is, 50 typical developments have been selected, which, taken together, give an idea of the nature of the new processes that have been discovered and put to use since 1918, with an evaluation of their economic results.

TABLE 4.—PRODUCTS AND MATERIALS FOR MANUFACTURE

Product	Use and savings	Company
CELLULOSE PRODUCTS		
Moisture-proof cellophane	Wrap for material for protection against water, gas, dust, germs, and fumes.	DuPont Cellophane Co.
Celluloid for safety glass	Nonshatterable glass—strong, clean, transparent, stable to light and heat.	
Fish-scale substitute for making pearl celluloid.	Possesses characteristics of fish scale at about 1/25 of cost.	
CHEMICALS		
Maleic acid	May replace citric acid in many uses at materially lower cost.	National Aniline & Chemical Co.
Zinc metal-arsenite	Wood preservative used as water solution.	Western Union Telegraph Co.
Phthalic anhydride	Now produced in this country at about 1/8 price of prewar importations.	
Ethylene glycol	Used in explosives manufacture and as anti-freeze material for automotive engines.	Mellon Institute of Industria Research.
DRUGS AND PHARMACEUTICALS		
Ipral	Gives equivalent results when taken in smaller doses than required by other hypnotics.	E. R. Squibb & Sons.
Novargentum	Powerful nontoxic, nonirritating, and nonstaining germicide.	E. R. Squibb & Sons.
ELECTRICAL APPARATUS		
B-battery eliminators	Radio sets. Saving to public about $15,000,000 per year.	Westinghouse Electric & Manufacturing Co.
Trickle charger	For radio sets and railway signals. Saving to public on radio sets about $2,500,000 annually.	Westinghouse Electric & Manufacturing Co.
Autovalve lightning arrester	Has displaced old electrolytic type. Annual saving about $1,000,000.	Westinghouse Electric & Manufacturing Co.
FOOD PRODUCTS		
Arkady yeast	Baking	Mellon Institute of Industrial Research.
Dry milk	Baking and export shipment	
Cellulose sausage casing	Replaces animal casings; is finer and edible.	Mellon Institute of Industrial Research.
Cane syrup	Supplements cane sugar	United States Census of Manufactures.
Oleomargarin	Butter substitute	United States Census of Manufactures.
Dried fruits and vegetables	Substitute for fresh products	United States Census of Manufactures.
METALS		
Copper oxide rectifier	Supplants electrolytic rectifiers	Union Switch & Signal Co.
Types of steel	Silico-vanadium steel for coil springs; carbon-vanadium steel for high temperature and high pressure work.	Vanadium Corporation of America.
Aluminum-silicon alloy	Supplants metallic aluminum as deoxidizer in manufacture of steel.	Vanadium Corporation of America.
Metallic tantalum	Electrolytic rectifiers, and for B-eliminators and trickle chargers.	Fansteel Products Co.
Sheet steel	For cores for electrical apparatus.	Westinghouse Electric & Manufacturing Co.

TABLE 4.—(*Continued*)

Product	Use and savings	Company
Nitralloy	Claimed to be hardest material so far produced in steel.	Ludlum Steel Co.
Alloy steel	Substitutes for common iron and steel.	United States Census of Manufactures.
Silicrome valve steels	Chiefly for exhaust valves in internal combustion engines.	Ludlum Steel Co.
Permalloy	An alloy of nickel and iron—can be cast into ingots, drawn, and rolled.	
Stainless steel	For all machine parts where ordinary steel can be used.	
PAINTS AND VARNISHES		
Lacquer (cellulose acetate, plastics, film, and lacquers).	Supplements ordinary paint	United States Census of Manufactures.
Tricresyl phosphate (lindol)	Oily liquid, noninflammable, nonvolatile, nonfreezing, odorless, colorless. Used in lacquer industry.	
REFRACTORY PRODUCTS		
Diaspore clay refractories	Substitutes for bauxite	Laclede-Christy Clay Products Co.
Artificial periclase	Used in electric furnaces for preparation of nonferrous alloys, high purity ferrochrome, ferromanganese, ferrotungsten.	Sierra Mangansite Co.
RESINOUS PRODUCTS		
Laminated bakelite	Developed as veneer for wood finishes, Pullman car windowsills, etc.	Bakelite Corporation.
Bakelite	Bond for grinding wheels	Bakelite Corporation.
Laminated bakelite	Used to replace rawhide in silent gears.	Bakelite Corporation.
RUBBER PRODUCTS		
Latex shoe cement	Used in shoe manufacture	Dewey & Almy Chemical Co.
Latex haircloth cement	Used as fiber binder in clothing industry.	Dewey & Almy Chemical Co.
Latex compound	Can sealing compound	Dewey & Almy Chemical Co.
Cord type automobile tire	Supplanted fabric type of tire	United States Census of Manufactures.
MISCELLANEOUS PRODUCTS		
Panchromatic motion picture film	Makes possible successful photography under incandescent lighting.	Du Pont-Pathé Film Manufacturing Co.
High-early-strength cement	Portland cement product of great fineness and strength.	International Cement Corporation
Thermatomic carbon	Used in compounding rubber stocks for pneumatic tires.	Thermatomic Carbon Co.
Glass and glass substitutes	Pyrex glass for cooking utensils. Quartz substituted for glass for certain purposes. Safety glass windows for automobiles. Ultra-violet windows substituted for glass in hospitals, etc.	United States Census of Manufactures.
Leather substitutes	Fabrikoid substituted for leather for binding books, etc.	United States Census of Manufatures.
Paper products	Paper to replace cloth products, such as towels and napkins, bags for cement, etc.	United States Census of Manufactures.
Rayon	Substitute for silk	United States Census of Manufactures.
Carbon dioxide ice	Substitute for water ice	United States Census of Manufactures.

TABLE 5.—INDUSTRIAL PROCESSES

Process	Process supplanted	Savings	Company
CHEMICAL			
Refining edible oils	Old processing tanks	¼ cost of old process	American Linseed Co.
Eliminating corrosion in water circulating systems by use of sodium chromate.		$25,000 per yr. in repair bills; $75,000 due to elimination of lost time in plant.	Midwest Refining Co.
Nitrocellulose lacquer			Hercules Power Co.
Indurating wood with sulphur			Texas Guld & Sulphur Co.
Recovering borax		Present production costs are less than 10 per cent of those of 1919.	American Potash & Chemical Corporation.
Refining sugar	Suchar used instead of bone char	Requires less suchar than process using bone char.	Suchar Process Co.
Mothproofing fabrics and furs			American Cyanamid Co.
Cooking straw with sodium carbonate and sodium sulphite	Supplants use of lime mixture		Paper Mill Laboratories.
ELECTRICAL			
Filament material for radio tubes	Using base metals in place of platinum for oxide coated filaments.	Annual saving of about $3,000,000	Westinghouse Electric & Manufacturing Co.
Automatic arc welding	Hand welding	Annual saving about $60,000	Cadillac Motor Car Co.
Inert gas for electric transformers		Annual average saving about $5,000	Westinghouse Electric & Manufacturing Co.
Oxide coated filaments		Saving to date about $900,000	Westinghouse Electric & Manufacturing Co.
FUEL			
Tar distillation		Saving about $1,500,000	The Barrett Co.
Low temperature carbonization of coal		Reduction of carbonizing time to two hours.	International Coal Carbonization Co.
Pulverized coal carbonization		Reduction of cost of boiler fuel burned by Central Stations.	International Coal Carbonization Co.
MECHANICAL			
Pressing linseed	Eliminates press cloths and about two thirds labor.	Four cents per bushel of linseed crushed.	American Linseed Co.
Beating paper pulp with rods		Claims savings in power from 30 to 50 per cent.	Paper Mill Laboratories (Inc.).
Dry quenching	Cooling of hot substances by liquids.	In a water gas plant, fuel saving of 2.3 pounds per 1,000 cubic feet gas made.	Dry Quenching Equipment Corporation.
Artificial periclase	Periclase produced in electric furnaces.	About half of price of electric furnace product.	Sierra Magnesite Co.
Utilization of powdered coal	Stoker firing	Operating efficiency 6 to 8 per cent higher than for stoker firing.	Combustion Engineering Corporation.
Air preheating in boiler operation		6 to 8 per cent reduction in fuel burned.	Combustion Engineering Corporation.
Emmet mercury process		Accomplishes large fuel savings	General Electric Co.

Metallurgical			
Leaching process		Recovery of approximately 20,000,000 pounds copper per year, previously wasted.	Calumet & Hecla Consolidated Copper Co.
Centrifugal cast pipe manufacture	Sand-cast process	Reduction of equipment and labor. Great savings in time.	United States Cast Iron Pipe & Foundry Co.
Hump method for hardening steel	Substitute for oil and gas fired furnaces.	Increased operating efficiency	Leeds & Northrup Co.
Homo method for tempering steel and heat treating aluminum.	Supplants process of tempering by radiation type furnace.		Leeds & Northrup Co.
Electric-thermic smelting		Reduced selling price of ferro-vanadium about 25 per cent.	Vanadium Corporation of America.
Electrolytic white lead process		Reduction of processing time	Anaconda Lead Products Co.
Petroleum Refining			
Cracking of heavy petroleum hydrocarbons.	Old pressure distillation type of apparatus.	Reduction of fuel consumption about 80 per cent.	Kansas City Testing Laboratory.
De-waxing paraffin base lubricating oil stock.		Permits all-year-round use of same oil in high compression motors.	Texas Pacific Coal & Oil Co..
Metal Working			
Chromizing steel			General Electric Co.
Drilling long oil holes	Replaces method using two spindle horizontal machines.	\$6,000 per year	Cadillac Motor Car Co.
Utilizing diamond tools	Old method of boring and reaming holes with steel tools.	Annual saving about \$15,000	Cadillac Motor Car Co.
Roughing outforging billets	Old swaging or fullering method	Annual saving about \$20,000	Cadillac Motor Car Co.
Tapping nuts		Annual saving \$5,000 in addition to improved quality of product.	Cadillac Motor Car Co.
Arc welding	Riveting	Economies effected in time and labor	Newport News Shipbuilding & Dry Dock Co.
Rubber			
Automatic tube molding		Manufacturing costs reduced about 40 per cent and quality improved.	Fisk Rubber Co.
Fillerless cord tire production	Woven fabric tire	Improved product and reduction of waste by 33 per cent.	Fisk Rubber Co.
High pressure tube method	Eliminates "wet-wrapped" method	Reduced labor cost; improved quality of product.	Fisk Rubber Co.
Semiflat tire building	Core-built and flat-band methods	Reduced production costs; improved product.	Fisk Rubber Co.
Thermoprene process			B. F. Goodrich Co.
Development of age resisters		Estimated savings to consumers about \$50,000,000 per annum.	B. F. Goodrich Co.
Miscellaneous Processes			
Filling gelatin capsules	Old process of using stamping presses and hand labor.		American Linseed Co.
Elimination of crazing	Replaces process of drying pottery	Fuel savings from 75 to 85 per cent	Homer Laughlin China Co.

For convenience they are classified into nine groups:

Chemical processes.	Petroleum refining.
Electrical processes.	Metal working.
Fuel processes.	Rubber processes.
Mechanical processes.	Miscellaneous processes.
Metallurgical processes.	

Credit is given for each item to the company or laboratory that supplied the information.

Table 5 summarizes the data that are given in some detail in the following pages.

4. Manufacturing Waste.—A widespread, unified effort at manufacturing cost reduction and improvement in operating effectiveness has been extended, since 1921, through the waste elimination movement. Initiated by the report on Waste in Industry, of the American Engineering Council, it has been based on a definite and practical point of view.

> . . . Industrial waste has been thought of as that part of the material, time and human effort expended in production represented by the difference between the average attainments on one hand and performance actually attained on the other . . .

Minimizing or eliminating waste is a continuous process, for each new attainment opens the way for another on a higher level of effectiveness.

Development has been along three principal lines: simplification of product, standardization of product, and reduction of wastage.

The first of these, simplification, has been fostered by the United States Government through the Department of Commerce, acting with manufacturing organizations, distributors, and consumers. The second, standardization, has been an activity of manufacturers' associations and technical societies. The third, reduction of wastage, has become a function of plant operation.

No comprehensive data are available to indicate the economic value and savings of these lines of effort. But the nature of the work attempted and certain detailed results achieved can be presented.

Simplification seeks to reduce the types, sizes, and varieties of a line of manufactured product to the fewest possible number. If a group of manufacturers agree to produce and market this fewest number of varieties, simplification has been carried to the establishing of "Simplified Practice."

The extent of simplification is indicated by the fact that 84 commodity classifications have been reduced to Simplified Practice. They group into the following eight general subdivisions:

Building materials.	Mill supplies and equipment.
Business documents.	Packages and containers.
Construction materials.	Plumbing supplies.
Housekeeping supplies and furnishings.	Miscellaneous commodities.

The degree of reduction in varieties, ranging upward to as high as 98 per cent, is shown by the tabulation for the various subdivisions which follows:

Simplified practice recommendation number	Item	Reduction in varieties		Per cent reduction
		From	To	
	Building Materials—Equipment, Fittings, Etc.			
7	Face brick, rough and smooth	75	2	97
	Common brick	44	1	98
12	Hollow building tile (first revision)	36	20	44
15	Blackboard slates	251	52	79
16	Lumber, softwood (second revision).[a]			
18	Builders' hardware (first revision):[b]			
	Items	6,948	5,130	26
	Finishes	100	29	71
30	Terne plate (weights)	9	7	22
43	Paint and varnish brushes	480	143	70
47	Tacks and nails:			
	Sizes	421	182	57
	Packing weights	423	121	71
48	Shovels, spades, and scoops (first revision)	5,136	2,178	57
49	Sidewalk lights:			
	Sizes	120	6	95
	Styles	80	5	94
	Shapes	10	2	80
52	Staple vitreous china plumbing fixtures	441	58	87
61	White glazed tile and unglazed ceramic mosaic.[c]			
72	Solid section steel windows	42,877	2,244	95
75	Composition blackboard:			
	Colors	3	1	66
	Widths	18	8	55
	Lengths	90	13	86
82	Hollow metal doors	[d]	45	
83	Kalamein doors	[d]	36	
	Business Documents			
34	Warehouse forms	Thousands.	15	
37	Commercial forms	Thousands.	3	
50	Checks, notes, etc	Thousands.	[e]	
	Construction Materials			
1	Vitrified paving brick (sixth revision)	66	5	92
3	Metal lath	125	24	81
4	Asphalt (first revision)	102	10	90
9	Woven wire fencing	552	69	87
	Woven wire fence packages	2,072	138	93
14	Roofing slates:			
	Descriptive terms.			
	Thicknesses and sizes	98	48	51
19	Asbestos mill board (first revision), sizes, thicknesses	21	4	81
	Asbestos paper (first revision), sizes, widths, and weight of rolls	72	17	78
26	Steel reinforcing bars, cross-sectional areas	32	11	66
29	Eaves trough and conductor pipe	21	16	24
32	Concrete building units (length, width, and height of blocks, tile, and brick)	115	14	88
38	Sand lime brick (length, width, and height)	14	3	79
53	Reinforcing spirals	7	4	43
	Homes, Hotels, Hospitals, Clubs, Etc., General Supplies and Furnishings			
2	Beds, springs and mattresses	78	4	95
5	Hotel chinaware	700	214	69
10	Milk bottles and caps (first revision):			
	Bottles	49	4	92
	Caps	10	1	90
11	Bed blankets (sizes)	78	12	85
24	Hospital beds			
	Lengths	33	1	97
	Widths {Standard / Special}	34	{1 / 2}	91
	Height	44	1	98
33	Cafeteria and restaurant chinaware	700	243	65
35	Steel lockers	65	17	74
39	Dining car chinaware	700	276	61
40	Hospital chinaware	700	279	60
54	Sterling silver flatware	190	61	68
55	Tinware, galvanized, and japanned ware	1,154	873	24
74	Hospital and institutional cotton textiles	575	26	95
80	Folding and portable wooden chairs.[f]			
85	Adhesive plaster:			
	Rolls	3	2	33
	Spools.			
	Widths	8	5	38
	Lengths	23	13	43

Simplified practice recommendation number	Item	Reduction in varieties		Per cent reduction
		From	To	
86	Surgical gauze (construction)	15	7	53
91	Clinical thermometers	[d]		
	MILL SUPPLIES, SHOP EQUIPMENT, ETC.			
6	Files and rasps	1,351	475	65
17	Forged tools (first revision):			
	Tool heads	665	361	46
	Eye sizes	120	10	91
23	Plow bolts	1,500	840	44
28	Sheet steel (first revision)	1,819	261	85
36	Milling cutters	944	570	40
45	Grinding wheels (first revision)	715,200	254,400	64
51	Die head chasers (for self-opening and adjustable die heads)	[d]		75
56	Carbon brushes, and brush shunts.[g]			
63	Metal spools (for annealing, handling, and shipping wire)	[d]	6	
71	Turnbuckles	248	115	54
79	Malleable foundry refractories	188	15	92
	PACKAGES, CONTAINERS, ETC.			
41	Insecticides and fungicides (packages)	38	22	42
42	Grocers' paper bags	6,280	4,700	25
60	Packing of carriage, machine, and lag bolts	[d]	18	
68	Flashlight cases (metal and fiber)	25	14	44
69	Packing of razor blades (systems of packing)	2	1	50
70	Salt packages	35	19	46
	PLUMBING			
8	Range boilers	130	13	90
13	Structural slates for plumbing and sanitary purposes	827	138	83
21	Brass lavatory and sink traps	1,114	76	93
25	Hot water storage tanks	120	14	88
57	Wrought iron and wrought steel pipe, valves, and pipe fittings:			
	Sizes of valves and fittings	20,000	19,238	4
	Sizes of pipe	62	49	21
	MISCELLANEOUS EXAMPLES OF SIMPLIFIED PRACTICE			
20	Steel barrels and drums	66	24	64
22	Paper	[d]		
27	Cotton duck (first revision)	460	86	81
31	Loaded shells (second revision)	4,076	768	81
44	Box board thickness	244	60	75
46	Tissue paper:			
	Roll tissue	13	3	77
	Shoe tissue	21	6	71
58	Classification of iron and steel scrap.[h]			
59	Rotary cut lumber stock for wirebound boxes:			
	Length	102	6	94
	Width	65	6	91
	Thickness	9	6	33
62	Metallic cartridges	348	256	26
66	Brake lining (automobile)	[d]	[i] 37	
67	Roller bearings	[d]	[i] 172	
73	One-piece porcelain insulators	272	210	23
76	Ash handles (grades)	[d]	3	
77	Hickory handles (grades)	[d]	11	
81	Binders' board	718	10	98
84	Composition books	86	41	52

[a] Standard nomenclature grades for sizes of softwood.
[b] These figures are average reduction in catalogue items in 1922 of four leading manufacturers of builders' hardware, as result of simplification.
[c] Shapes, patterns, dimensions, grade nomenclature, grade marks, grade specifications, and certifications of grades, for white glazed tile and unglazed ceramic mosaic.
[d] Original total not known.
[e] One size for each instrument.
[f] Elimination estimated by industry as 20 per cent in portable chairs and 19 per cent in folding chairs.
[g] Increments of increase in dimensions, and dimensional tolerances for carbon brushes, sizes of holes or slots in terminals for flexible shunts, and size and specifications for cable for brush shunts.
[h] Specification for scrap.
[i] Society of Automotive Engineers' Standards.

Herbert Hoover, when Secretary of Commerce, estimated the savings to American manufacturers from simplified practice and the application of the recommendation of the Report on Waste in Industry as upward of $600,000,000 annually. This part of the movement to eliminate waste in manufacturing may be credited with a total saving to-day of some five billions of dollars, on the basis of Mr. Hoover's estimate.

The extent of the adoption of standardization, the engineering determination of sizes, dimensions, and proportions of manufactured products, cannot be determined. A mere list of the standards adopted conveys little significant information. Neither is it possible to give an economic valuation of the benefits and savings that have come from their use. The American Engineering Standards Committee is the authority for the following statement:

> Standardization is to-day the most important approach to greater industrial efficiency. Actual savings that are now being made in the automobile industry through organized standardization activities are estimated by the industry itself at 750 million dollars a year.

Elimination of waste in the plant has dealt with many kinds of losses. During the month of October, 1927, the Newport News Shipbuilding and Dry Dock Co. secured from its supervisory and working forces some 2,770 suggestions for the elimination of waste in the plant. A classification of these, presented by William B. Ferguson, production manager, and A. A. Giese, secretary of the Waste Committee, is given in the accompanying tabular form. The 39 items and 23 actions are indicative of the kind and nature of the activities being carried on throughout American industry to lessen, avoid, and eliminate wastage. The total number of classes of intraplant waste is 148. Mr. Ferguson estimates that $250,000 will be saved annually when all these suggestions have been made effective. That amount is at the rate of about $50 per employee per year.

Another aspect of waste elimination contributed to largely by industrial research is the reclamation and reuse of materials and the development of commercially valuable by-products. Table 6 gives 50 examples of each of these kinds of saving. Here also it is impossible to make any decided estimates of the value to industry and to the nation of the savings thus effected. In one case alone, that of reclaimed rubber, the figures ran to over twenty millions in 1925.

5. Industrial Power.—In a preceding part of this report it has been shown that the increase in the primary power available to each worker in manufacturing establishments is one of the most important and significant changes which have taken place since 1919. This is not the only significant change in industrial power utilization. There have been increases in the installation of electric motors to supply mechanical power in manufacturing, in the amount of power purchased instead of generated by

Classification of Approved Waste Week Suggestions

(Figures indicate number of suggestions in that class)

Items	Products	Machinery	Equipment	Building and structures	Tools and patterns	Materials	Soliciting	Accidents and treatment	Restaurant	Smoking	Working hours & attendance	Stationery forms	Drafting forms	Direct labor	Indirect labor	Stores	Lights	Drinking water and ice	Drafting	Office depts.	Power, heat, light, air & water	Indirect depts.	Reports and records	Supervision	Apprentices and new men	Welfare	Waste elimination	Plant orders	Wage incentives	Organization	Fire protection	Stationery	Inventory and investments	Communications	Expense	Wage scales	Personnel	Budgets	Costing and accounting	Total	Classes
Addition to	1	9	41	7	2	1										1		1					3			3			1					2			1	2		75	14
Design of	24	4	20		14	9						5	3				6				1							1			1									88	11
Methods	48	1			7	9			1		7			9					23		4		2	2		4	6	2	3	4				4		2	3		4	145	20
Organization								1						7	1				2	2		2					1										1			17	8
Quality			1		3	2																		8					1								1			16	6
Purchasing					1	6																																		7	2
Maintenance			2		4															1																				7	3
By-products and salvage	1	1	4		3	27																																		36	5
Routing	6	1				1													1									2												11	5
Quantity			1											2									1																	4	3
Miscellaneous																			1																					1	1
Rules							1			1										1																				3	3
Planning	19		4			9							3	5					3			3	1					3												50	9
Control	4		3		2	18		5			1		6	5			2				5		2									8	2		2		4			69	15
Storage			1		3	3																																		7	3
Follow-up and tracing						2																																		2	1
Investigation and inspection	12	3	1		2	6														1	1																			26	7
Repair		4	2	6	1																																			13	4
Standardization	10	2	11		6	15							3							1			4																	52	8
Care or preservation	5		1			3						2							5																	1				17	6
Instructions													1	3					2					1	3												4			14	6
Selling	2																																							2	1
Move or rearrange		3	3	2		2					1						3														1									15	7
Total	132	28	95	15	48	113	1	6	1	1	9	7	16	31	1	1	11	1	37	6	11	5	13	11	3	7	7	8	5	4	2	8	2	6	2	3	14	2	4	677	148

TABLE 6.—EXAMPLES OF REDUCTION OF MANUFACTURING WASTE

PART 1.—FIFTY CASES OF RECLAMATION AND REUSE

Waste	Process	Use
Aluminum borings	Separated from scrap heap and cleaned.	Sold separately at higher price.
Babbitt and lead, from worn-out bearings.	Removed and remelted	Reused.
Battery lead	Melted	Reused.
Belting, worn and greasy	Cleaned, reconditioned	Lighter use.
Bolt head dies	Reground	Reused.
Bolts and nuts with worn threads	Cleaned and recut	Reused (in one plant over one ton of these are reclaimed daily).
Broaches	Reground and reworked to smaller sizes.	Reused.
Brooms and brushes	Trimmed	Rough work.
Burlap from incoming shipments		Outside of bales of scrap cloth.
Burlap sacks containing raw materials	Resold to shipper	Reused.
Bushings	Removed from machinery	Reused.
Cardboard boxes and cartons enclosing raw materials	Recut to desired sizes	Used for packing products.
Carpet and upholstering material scrap.		Used in packing automobiles, especially for export.
Cement mill dust	Electrical precipitation	Returned to process.
Copper wire	Reworked	Cables or wire screens.
Cutting oils	Removed from finished materials and scrap by centrifugal separators.	Reused.
Dies, discarded due to faulty design, or worn out.	Annealed, threads recut, hardened.	Reused.
Drills	Reground to smaller sizes	Reused.
Excelsior, clean, received in incoming shipments.		Used in shipping room with clean and new excelsior.
Files, worn out	Cleaned and refiled by sand blast method.	Reused.
Flashlight batteries, worn out	Zinc removed	Reused.
Gages	Reground	Other uses.
Grinding wheels	Edges trued and reconditioned	Reused (2,319 wheels repaired in one month at saving of $7,475 in one plant; savings in another plant $1,500 per month).
Hammers	Reconditioned	Reused.
Iron filings	Reclaimed	Certain manufacturing processes.
Iron pipe	Cleaned and painted	Replaced in stock.
Liquor, waste sulphate process	Soda reclaimed	Returned to sulphate process.
Lumber used for car braces and packing in incoming shipments	Cleaned and cut	Reused for export shipment.
Lumber, short length		Reused.
Metal borings and turnings	Remelted after cutting oil has been removed.	Reused.
Metal punchings, cheap	Refining	Reused, washers and gaskets.
Nails in board ends	Removed by magnets	Sold as metal scrap.
Oil used in testing motors	Separated from turnings and cleaned.	Reused.
Paper from incoming shipments	Baled	Sold.

TABLE 6.—(*Continued*)

Waste	Process	Use
Paraffin from coating of clippings obtained in manufacture of drinking cups	Recovered	Reused.
Rags for cleaning automobiles	Washed	Reused.
Reamers	Reground and reconditioned	Reused.
Rivet shears	Old blades cut off, new ones rewelded.	
Rubber and leather scrap	Sterilized	Soling and patching shoes worn by men around plant—in wet places and where hot metal is handled.
Rubber[a]	Reclaimed	Mechanical rubber goods.
Sal-ammoniac skimmings	Reclaimed	For ammonia and zinc contents
	Refined	Used as soldering acid.
Saw blades	Reconditioned	Reused.
Sheet material, metal and nonmetal.	Co-ordination of design so that parts which would be scrapped for one product become raw material for another.	Reused.
Sheet steel scraps	Recovered	Reused (savings in some cases amount to 50 per cent of new material purchased).
Solvent	Recovered at rate of 100 gallons per day in one factory (would otherwise contaminate atmosphere).	
Stock clippings obtained in manufacture of drinking cups	Reworked	Cheaper furnishes.
Sugar bags	Reclaimed	Used in place of cheesecloth for wiping and dusting purposes, or can be torn open and sold to furniture dealers.
Syrup	Reclaimed from syruping machines, cleaned.	Reused.
Tin cans	Tin and steel reclaimed	Reused in new cans (one ton of "empties" yields about 18 pounds of tin).
Wooden boxes and cases containing material for manufacture.	Cleaned, markings removed	Reused or taken apart and made into boxes for shipping finished products.

[a] Production of reclaimed rubber during the past ten years, in long tons, is as follows: 1919, 81,366; 1920, 86,395; 1921, 36,725; 1922, 57,834; 1923, 74,766; 1924, 80,079; 1925, 132,930; 1926, 180,582; 1927, 189,144.

The United States Census of Manufactures quotes the following figures on the value of reclaimed rubber for sale as such: 1919, $20,173,040; 1921, $7,424,453; 1923, $11,714,438; 1925, $23,020,517.

TABLE 6.—(*Continued*)

PART 2.—FIFTY CASES OF UTILIZATION THROUGH BY-PRODUCTS

Waste	Process	Product	Use
Acid waste from tin plate...	Chemical............	Copperas............	Red paint. Ink.
Bagasse.................	Mechanical and chemical.	Paper...............	Field cover to control weeds. Insulating board.
Beet pulp................	Drying.............	Stock feeds..........	Hydraulic cements.
Blast furnace slag..........	Mechanical and chemical.	Cements............	
Blood....................	Mechanical..........	Fertilizers...........	
Bones....................	Mechanical..........	Buttons............. Fertilizer............ Ornaments..........	
Calcium chloride...........	Drying and crystallization.	....	On highways.
Cans, tin.................	Electrochemical.......	Tin tetrachloride......	Silk weighing.
Cement mill fumes.........	Electrical precipitation	Potash salts..........	Fertilizers. Glass and soap.
Chlorine..................	Chemical............	Bleaching powder.....	
Chlorine from caustic soda industry...............	Chemical............	Chloroform.......... Carbon disulphide.....	In anaesthesia. Manufacture of carbon tetrachloride.
Copper refinery sludge......	Chemical............	Silver............... Gold................	
Corncobs................	Chemical............	Furfurol (aldehyde)....	Synthetic resins. Paint remover. Solvent for gelatinizing agent for nitrocellulose and cellulose acetate. Motor fuel. Fungicide, germicide, and preservative. Dyes. Anaesthetic. Plastic.
	Chemical............	Adhesive "A"........	Substitute for silicate of soda used in fiber container and wallboard manufacture. Substitute for dextrine and other organic gums and glues. Sizing of walls previous to applying paper.
	Chemical............	Adhesive "B"........	Used in manufacture of briquettes and as a core binder.
	Chemical............	Cellulose............	Has high absorption power excellent for blotting papers. Substitute for wood flour in manufacture of dynamite and plastics.
	Chemical............	Oxalic acid..........	

TABLE 6.—(*Continued*)

Waste	Process	Product	Use
Cottonseed	Mechanical and chemical.	Oil Stock feed Linters	 Paper and nitrocellulose products.
Cull, citrus fruits	Chemical	Pectin Citric acid	Jelly-making. Soft drinks.
Fabric	Mechanical and chemical.	Felt	Prepared roofing.
Ferric oxide from aniline oil manufacture.	Mechanical and chemical.		Red paint for iron
Fish scrap	Mechanical	Fertilizer ingredient	
Flax straw	Mechanical and chemical.	Paper pulp	
Flaxseed	Mechanical	Floor coverings	
Fluorine	Chemical	Fluorides	Metal enamels.
Garbage	Chemical and mechanical.	Glycerin Greases and oils Fertilizer	
Gases from beehive coke ovens.	Chemical and mechanical.	Coal-tar by-products	In synthetic organic chemicals.
Gasoline in natural gas	Chemical and mechanical.	Casing head gasoline.	Motor fuel.
Helium in natural gas	Mechanical and chemical.	Helium	In dirigibles.
Hoofs and horns	Chemical	Glue	
Hydrogen	Chemical		Hydrogenating oils or nitrogen fixation.
Iodine from nitric acid manufacture	Chemical	Iodine	In medicines.
Kernels	Chemical	Oils, pastes	Food.
Linseed oil, press cake from	Mechanical		Cattle feed.
Lye liquors from soap manufacture	Chemical	Glycerin	
Molasses	Fermentation	Alcohol	Industrial and scientific uses.
Molasses fermentation waste	Calcination	Potash	Agriculture.
Oat hulls	Chemical	Furfurol	Synthetic resins.
Paper	Mechanical and chemical.	Cardboard Low-grade paper	Wrapping paper. Cartons, boxes, etc.
Paper waste	Mechanical and chemical.	Papier-maché Wall board	
Photographic fixing solutions	Chemical	Silver	
Powder, smokeless, low-grade.	Chemical	Pyraline	Handles, ornaments, etc.
Pyroligenous acid from charcoal production.	Chemical	Acetic acid Methanol Wood tar	
Rubber industry, cuttings from.	Mechanical and chemical.	Roofing	
Sawdust	Chemical and germentation.	Alcohol	
Selenium from copper refining	Chemical	Selinum	Glass manufacture. Electrolytic cells.
Shells (of fruit pits and nuts)	Charring	Charcoal	For fuel. In gas masks.

TABLE 6.—(*Continued*)

Waste	Process	Product	Use
Smelter fumes	Electrical precipitation.	Arsenic	Insecticides. Fungicides.
Steffens' waste from beet sugar manufacture.	Evaporation and calcination.	Potash salts	Fertilizers.
Sulphate pulp mill waste	Chemical	Turpentine	
Sulphur dioxide fumes from metals	Chemical	Sulphuric acid	
Wood, waste	Mechanical and retorting.	Charcoal acetates	Manufacture of acetic acid.
		Methanol wood flour	Dynamite and linoleum.
Wool-scouring waste liquors.	Acid cracking centrifugal.	Fertilizer	
		Neutral grease	
		Potash	
		Nitrogen	
		Filler (sand and dirt)	
	Typical savings made in one plant[b]		
Department refuse and sweepings	Chemical	Precious metals	Reused.
Junk cable	Mechanical	Paper	To paper mill.
Junk cable	Mechanical	Copper	To copper mill.
Junk cable	Mechanical	Lead	Reused.

[b] Savings on these four items represent: .05 of total savings for 1919 to 1923; .08 of total savings for 1924; .09 of total savings for 1925; .13 of total savings for 1926; .21 of total savings for 1927.

manufacturing establishments, and in the efficiency of prime movers. The first two of these trends account, in part, for the rapid development of electric public utility companies. The increase in the capacity of prime movers which supply power to manufacturing establishments is a rough measure of the increased use of machinery by those establishments.

The change whereby the total amount of owned power in manufacturing has decreased slightly since 1919, and the purchased power supplied through electric motors has increased considerably in the same period, indicates a shift which is often referred to as from a "machine civilization created by steam power to a machine civilization created by electric power." Dr. Glenn Frank, president of the University of Wisconsin, has drawn this contrast:

> In a machine civilization created by steam power, the worker must go to the power, but in a machine civilization created by electric power, the power can be taken to the worker; and that is a revolutionary fact which means that when we say "machine civilization" in terms of 1950, we may be dealing with a machine civilization that is as different as imagination can conceive from the machine civilization which began when James Watt first harnessed the expansive power of steam to the processes of production.[7]

Increase in Electric Motor Power.—The electric motor first appeared as a factor in industrial power in 1899, the amount of power purchased

[7] Address delivered at the Midwest Power Conference, Chicago, February 14 to 17, 1928.

at that time and applied through electric motors being but 1.8 per cent. So rapid has been the increase, however, that in 1927, the last year for which we have statistics, nearly 50 per cent of the power applied in manufacture was by means of electric motors operating on purchased power.

The statistics which show this growth are given in Tables 7, 8, and 9.

TABLE 7.—INDUSTRIAL POWER MACHINERY IN THE UNITED STATES

(Horse power)

Year ending Dec. 31	Steam engines and turbines	Internal combustion engines	Water wheels and turbines	Total, own power	Electric motors operating on purchased power	Total prime movers in industry[a]	Elec. motors on purchased power is per cent of total
1899....	8,189,564	134,742	1,454,112	9,778,418	182,562	10,097,893	1.8
1904....	10,917,502	289,423	1,647,880	12,854,805	441,589	13,487,707	3.3
1909....	14,228,632	751,186	1,822,888	16,802,706	1,749,031	18,675,376	9.4
1914....	15,591,171	988,591	1,826,413	18,409,941	3,884,724	22,290,899	17.4
1919....	17,036,210	1,241,829	1,765,131	20,043,170	9,284,499	29,327,669	31.7
1923....	16,700,993	1,224,262	1,803,310	19,728,565	13,365,663	33,094,228	40.4
1925....	16,916,856	1,186,116	1,800,828	19,903,800	15,868,828	35,772,628	44.4
1927[b]...	16,941,088	1,170,759	1,784,962	19,896,819	19,143,744	39,040,563	49.0

[a] Includes in earlier years a small amount of "other rented power," chiefly through belts or shafting from other establishments.

[b] Figures for 1927 are preliminary.

Source: *United States Census of Manufactures.*

TABLE 8.—AMOUNT OF TOTAL PRIMARY FACTORY POWER APPLIED THROUGH ELECTRIC MOTORS

(Horse power)

Year ending Dec. 31	Total primary power[a]	Total horse power in electric motors	Operated by energy generated in plant	Operated by energy from central stations	Per cent electrified[b]
1899................	10,097,893	492,936	310,374	182,562	5
1904................	13,487,707	1,592,475	1,150,886	441,589	12
1909................	18,675,376	4,817,140	3,068,109	1,749,031	25
1914................	22,290,899	8,823,254	4,938,530	3,884,724	39
1919................	29,327,669	16,253,702	6,969,203	9,284,499	55
1923................	33,094,228	22,151,997	8,819,217	13,332,780	66
1925................	35,772,628	26,123,573	10,254,745	15,868,828	73
1927[d]...............	39,040,563	30,360,026	11,216,282	[c]19,143,744	78

[a] From 1914 onward. this table eliminates all establishments reporting products under $5,000 in value. In addition, items covering establishments engaged in automobile repairing have been omitted.

[b] Primary horse power embraces prime movers driving industrial motors; these prime movers are about 89.5 per cent of the capacity of the motors connected to them, not all of which are ever in operation at any one time. For this last column the horse power of motors operated by energy generated in the plant itself has been scaled down accordingly.

[c] Operated by energy from purchased current.

[d] Figures for 1927 are preliminary.

TABLE 9.—EXTENT OF ELECTRIFICATION OF 16 MAJOR INDUSTRIAL GROUPS

Industrial group	Electrically operated machinery; per cent of total prime movers		
	Operating on purchased electricity	On electricity made locally	Per cent of total power
Machinery manufacture	69.8	25.9	95.7
Transportation equipment[a]	68.4	26.7	95.1
Rubber products	67.4	27.0	91.7
Nonferrous metals, etc	60.4	29.2	89.6
Tobacco products	39.6	47.5	87.1
Leather products	46.5	36.8	83.3
Railroad repair shops	62.0	20.2	82.2
Stone, clay, glass, etc.[b]	54.1	26.3	80.4
Musical instruments	39.7	39.1	78.8
Textiles and their products	41.4	33.2	74.6
Food and kindred products[c]	49.8	15.9	65.7
Chemical and allied products[d]	37.6	27.2	64.8
Paper and printing, etc	33.3	29.6	62.9
Iron, steel, etc	32.4	25.7	58.1
Lumber and allied products	25.1	22.1	47.2
Miscellaneous industries	70.3	13.0	83.3
Total: All industries	[e]44.4	[e]25.6	[e]70.0

[a] Automobiles, motorcycles, bicycles, carriages, locomotives, cars, ships, etc.
[b] Including the cement industry which is said to be 100 per cent electrified.
[c] Including refrigeration.
[d] Including manufactured gas, coke, fertilizers, distilleries, petroleum refining, etc.
[e] Weighted average.
Source: *United States Census of Manufactures*, 1925.

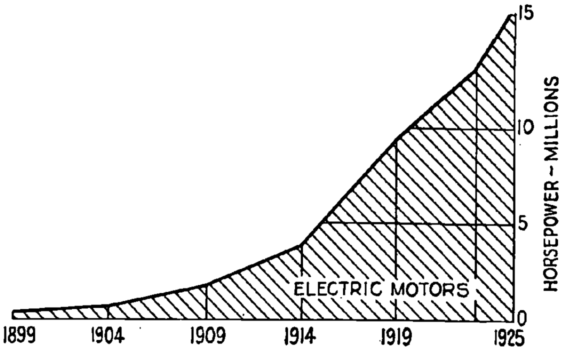
The first of these tables, Table 7, shows that from 1919 to 1927 there has been a growth of electrical horse power, and a decrease in all classes of mechanical power.

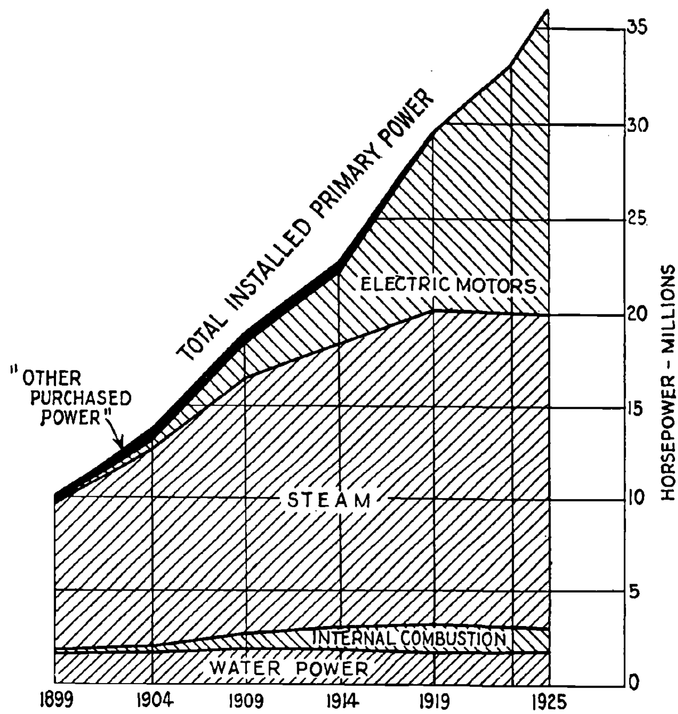
Table 8 shows the amount of total primary power in factories which is supplied through electric motors, the current being both self-generated and purchased. The growth has been from 5 per cent in 1899 to 55 per cent in 1919 and to 73 per cent in 1925. That is, the growth from 1919 to 1925 has been 17 per cent. Table 9 shows the extent to which manufacturing machinery is electrically operated in 16 industrial groups, the range being from 95.7 per cent in the manufacture of machinery to 47.2 per cent in the production of lumber and allied products.

Chart 9 shows graphically the relationships of the power supplied by water power, internal combustion engines, steam, and electric motors, while Chart 10 shows the relationship between mechanical and electric power in the factories of the United States.

Purchased Power.—Chart 10 also shows graphically the increase in the amount of purchased power which to-day is about one-half that used in the industry. So rapid has been this shift that it has frequently been said that the isolated power plant is doomed. A statement of this

CHART 9.—POWER SUPPLIED BY FOUR KINDS OF PRIME MOVERS

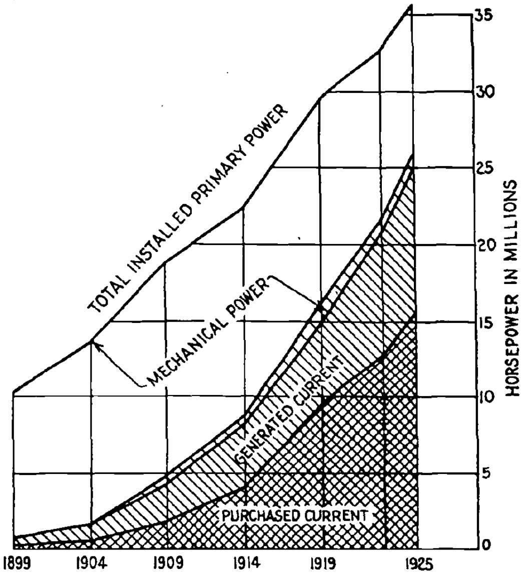




kind, however, overlooks the fact that much steam is required for processing, and this service cannot, in general, be supplied by the central station.

However, the increase in purchased power from 9,284,499 horse power in 1919 to 15,868,828 horse power in 1925 is not only impressive but is indicative of the rate of growth. The effect of this change upon production and productivity cannot be determined. However, electric power is making industry more mobile as regards location and is probably contributing to a reduction in prime cost.

CHART 10.—RELATIONSHIP BETWEEN MECHANICAL AND ELECTRIC POWER IN MANUFACTURING INDUSTRIES



6. Power Machinery.—Unfortunately, not much can be said in regard to changes in efficiency as regards the prime movers in use in manufacturing plants. Where new power plants are installed they make use of the most efficient equipment available. But many plants are old and are operating under disadvantageous conditions with generally low efficiencies.

As to industrial power plants generating energy for the use of the owners only and not selling to the public, the reciprocating steam engine, once used almost exclusively, is rapidly becoming obsolete. It is still found in use in old concerns where such machines have been in service for years, and in plants and factories where large quantities of process steam are needed, such as paper mills, chemical manufacturing plants, and laundries. The same reasoning also applies to large buildings that have to be heated in winter and at the same time use power, and which are so located that, all things considered, purchased power proves to be too expensive; in such circumstances there must be independent generation of process or heating steam, or both. In other words, it is still good economy to "use an engine as a reducing valve," especially when the engine is already there and in good mechanical condition. Such new reciprocating engines as are in use are generally of the uniflow type; as this engine gives the economy of the compound engine, yet has only one cylinder and set of reciprocating parts. As to the economy of steam power in the average industrial field, figures mean little or nothing, on account of the huge demand for industrial or processing steam.

For certain large industrial establishments where considerable pr steam and power are needed, the tendency is toward higher boiler pressu with steam turbines as reducing valves, even with steam mains at more than one pressure intermediate of the boiler, as a maximum, and the lowest process pressure, which is the back pressure of the last turbine, as a minimum. One large plant recently installed 400-pound pressure boilers with turbines exhausting against 125 pounds process pressure, and another new plant is being built using 1,200 pounds boiler pressure and process steam at 200 pounds.

Where process steam is not the determining factor, and the demand is merely for mechanical power, the choice usually lies between either purchasing from a steam or hydroelectric central station distributing system, or using oil engines. And when considerations other than that of available power determine the location of a manufacturing plant, so that it is completely out of reach of the power lines of a central station, the oil engine is in high favor. These, of course, are normally the smaller plants. The oil engine has also a practical monopoly on the smaller central stations, supplying light and power to towns and villages located far from the transmission lines of large steam or hydroelectric central stations.

It is worth noting, in this connection, that the so-called "semi-Diesel" engine has been about driven from the field by the true Diesel. The solid injection type is used up to a certain output capacity, and the compressed-air atomizing type for larger capacities. Even comparatively small Diesel units now operate steadily on 0.5 pound of oil per horsepower-hour, and are remarkably dependable and fool-proof. Diesel engines are also being installed as stand-bys in many hydroelectric central stations, and even in a number of manufacturing plants using purchased electric power, where certain processes are carried on that would involve the company in serious financial loss if there were any interruption in the power supply.

Central Station Efficiencies.—The record of central station power is quite different, for facts are available to show the steady progress which has been made in decreasing the consumption of fuel per kilowatt-hour generated. Table 10 shows this change from 1919 to date, during which period the remarkable improvement has occurred of reducing the consumption of fuel to 55 per cent of what it was in 1919 per unit of electrical energy generated. During this same period the output of energy has more than doubled, the figures, in millions of kilowatt-hours, being as shown in the following statement:

1919	24,315	1924	39,044
1920	27,405	1925	43,514
1921	26,005	1926	47,602
1922	30,453	1927	50,330
1923	36,327	1928	51,103

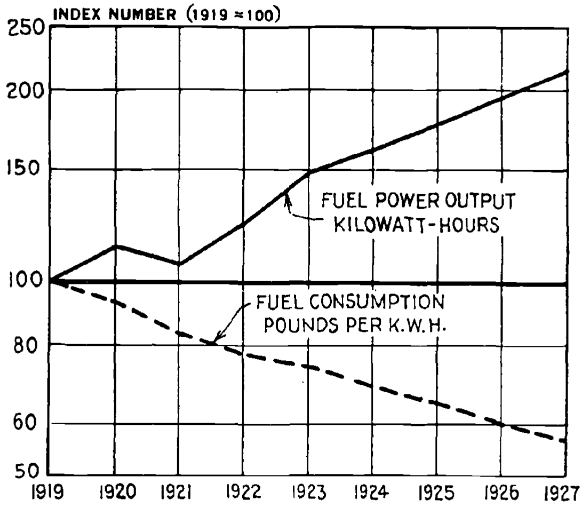
TABLE 10.—CONSUMPTION OF FUEL BY ELECTRIC POWER PLANTS

Year	Coal (short tons)	Fuel oil (barrels)	Gas (thousand cubic feet)	Total coal equivalent (short tons)	Pounds of coal per kilowatt-hour generated	Per cent of 1919
1919	35,100,000	11,050,000	21,406,000	38,880,000	3.20	100
1920	37,124,000	13,123,000	24,706,000	41,420,000	3.02	94
1921	31,585,000	12,045,000	23,722,000	35,240,000	2.70	84
1922	34,179,000	13,197,000	27,172,000	38,000,000	2.49	78
1923	38,954,000	14,679,000	31,433,000	43,522,000	2.40	75
1924	37,556,000	16,630,000	48,443,000	43,130,000	2.21	69
1925	40,222,000	10,246,000	46,621,000	44,780,000	2.06	66
1926[a]	41,311,000	9,399,000	53,207,000	45,856,000	1.93	61
1927	41,888,000	6,782,000	62,919,000	45,910,000	1.84	57
1928	41,336,000	7,126,000	77,174,000	46,434,000	1.76	55

[a] Table includes, besides all electric light and power plants, the electric railways and certain manufacturing establishments which contribute all or a portion of their output to the public supply.
Source: United States Geological Survey.

Chart 11 shows the relationship between this decrease in fuel consumption and the increase in power generated.

CHART 11.—RELATIONSHIP BETWEEN FUEL CONSUMPTION PER KILOWATT-HOUR AND TOTAL OUTPUT OF ELECTRICAL ENERGY



The advance in the design, construction, and operation of large steam central stations has been principally along three lines: (1) larger generating units using steam turbines exclusively as prime movers and larger boilers; (2) higher steam pressures and superheat temperatures; and (3) greater use of waste-heat recovery apparatus. To these might be added improvements in all auxiliary machinery, to the advantage of the over-all efficiency of operation. A rough idea of the advance in efficiency may be had from the fact that for one station, generating from 20,000 to 100,000 kilowatts, the present rate of coal consumption is about 2 pounds per kilowatt-hour as against about 3.5 pounds per kilowatt-hour 10 years ago. Heat economies have also been introduced all the way from the furnaces to the last expansion stage of the turbine.

Higher efficiencies than now obtained by the best, about 13,000 B. t. u. per kilowatt-hour, are expected and can be produced; but not a great deal higher for the best all-around results. The trend at present is rather to raise the general average of power generation all over the country than to construct occasional units of exceptional efficiency, leaving the majority of power-generating plants in their present condition.

To-day central station pressures are to be found in three ranges for modern installations: (1) a range around 400 pounds per square inch; (2) a range from 550 to 750 pounds; (3) a range from 1,000 to 1,400 pounds. The greatest activity at present is in the first and third ranges, the intermediate one being proportionately neglected. The choice between these two, the basis of selection, is partly a matter of load, but more a matter of coal prices. For a cheap coal with a small average load, the 400-pound range is preferred; with a higher priced coal and a high average load, the 1,000-pound range is preferred; both may be found in the same station. Thus, in modern existing stations, with units already in use operating at 400 pounds or less, 1,000-pound boilers can be added and high-pressure turbines can use this steam, exhausting it into the lower-pressure steam mains, after reheating for the lower-pressure turbines.

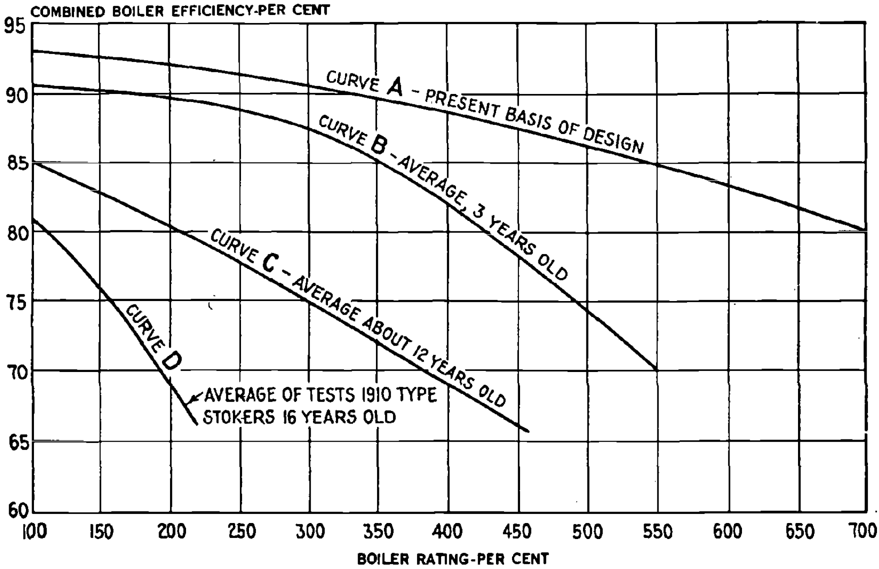
Temperatures are now limited to about 750° F. because as yet the metallurgists have not been able to provide a steel at a usable price that is perfectly reliable for higher temperature. The tendency, however, is upward, and 800° and 850° F. are already in use to a limited extent.

There is also a tendency toward larger boiler units; some in operation to-day are good for over 400,000 pounds of steam per boiler per hour. Others now under erection have a specified capacity of 1,000,000 pounds of steam per boiler per hour. It seems probable that the practice will soon be to provide each turbine with its own boiler, no matter how large the turbine.

Interconnection of stations is also extending, making it unnecessary to have both peak-load and base-load units in one and the same station, by substituting base-load stations and peak-load stations. Interconnection also improves the average load through the "diversity factor," peak loads on one part of a chain not occurring at the same time as on another part. This is noticeable in one district, for instance, where a mine and colliery load is just going off at the same time that the electric traction load of a near-by city is just rising to its peak in the early evening.

Boiler Efficiencies.—The improvement in boiler efficiencies has been toward the attainable maximum, a fair statement of the change in well-operated plants being indicated by Chart 12. This shows in curve A what may be expected of boiler and stoker performance on the basis of design, age, and from 100 to 700 per cent rating; curve B is on the basis of boilers three years old; curve C shows an average for those about 12 years old; and curve D was developed from a group of tests on stokers and boilers 16 years old.

CHART 12.—IMPROVEMENT OF BOILER EFFICIENCY IN RECENT YEARS



In fuel, the outstanding change of the past few years has been the growth of pulverized coal installations. The extent of the use of fuel in this form is indicated by the fact that at the present time 40 public utilities in the United States are either partially or fully operated with pulverized coal, the aggregate generator capacity so fired being 2,200,000 kilowatts. In addition, there are now under construction five new plants and extensions to two old plants having together a total capacity of 440,000 kilowatts, all of which will be operated with pulverized coal. The significance of these figures can better be appreciated from the following tabulation:

	Number	Capacity, kilowatts
Installations in operation	40	2,200,000
Installations under construction	7	440,000
Total	47	2,640,000
Installations in operation and under construction entirely operated with pulverized coal	27	1,700,000
Plants with 40,000 kilowatts capacity or more operated with pulverized coal	27	2,250,000

Steam Turbines.—The increase in size of steam turbine units has been mentioned. What this increase has meant in recent years in improvement in the water rate and in a few other significant factors is indicated

TABLE 11.—STEAM TURBINE DEVELOPMENT, 1918–1928

(Westinghouse Electric & Manufacturing Co.)

	1918–1920	1921–1924	1925–1926	1927–1928
Largest single-cylinder turbine built	25,000 kilowatts	30,000 kilowatts	40,000 kilowatts	60,000 kilowatts.
Best point water rate (straight condensing).	12.46 lbs./kilo-watt-hours	10.24 lbs./kilo-watt-hours	10.22 lbs./kilo-watt-hours	9.16 lbs./kilo-watt-hours.
Steam conditions	185 lbs.–125° S–28½″	265 lbs.–214° S–29″	260 lbs.–214° S–29″	290 lbs.–700° TT–29¼″
Normal speed	1,500 R.P.M.	1,800 R.P.M.	1,800 R.P.M.	1,800 R.P.M.
Largest compound turbine built	60,000 kilowatts	62,000 kilowatts	104,000 kilo-watts	165,000 kilo-watts.
Number of cylinders	3	3	3	2.
Best point water rate (straight condensing).	10.58 lbs./kilo-watt-hours	7.56 lbs./kilo-watt-hours	7.97 lbs./kilo-watt-hours	9.12 lbs./kilo-watt-hours.
Steam conditions	265 lbs.–175° S–29″	550 lbs.–725° TT–29″ Reheated between HP and IP to 700°F.	550 lbs.–725° TT–29″ Reheated between HP and IP to 500°F.	265 lbs.–290° S–29″
Normal speed	H.P.–1,800 R.P.M. Ea. LP–1,200 R.P.M.	1,800 R.P.M.	1,800 R.P.M.	1,800 R.P.M.
Other compound turbines built.		50,000 kilowatts	80,000 kilowatts	110,000 kilo-watts.
Number of cylinders		2	2	2.
Best point water rate (straight condensing).		10.10 lbs./kilo-watt-hours	9.05 lbs./kilo-watt-hours	8.74 lbs./kilo-watt-hours.
Steam conditions		265 lbs.–200° S–29″	375 lbs.–258° S–27½″	400 lbs.–258° S–29″
Normal speed		1,200 R.P.M.	1,800 R.P.M.	1,800 R.P.M.
Approximate weight per kilowatt rating	42.5 lbs	34.3 lbs	23.2 lbs	14.9 lbs.
Approximate floor space per 1,000 kilowatt of rating	59 sq. ft	39.6 sq. ft	34 sq. ft	16 sq. ft.

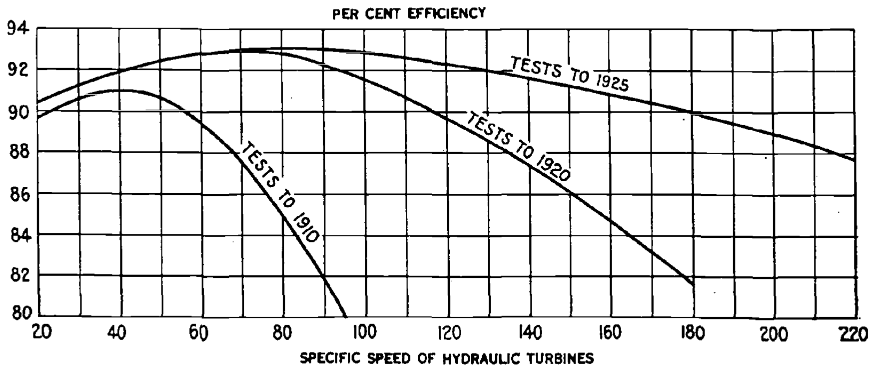
by Table 11, which is from the practice of the Westinghouse Electric & Manufacturing Co.

Diesel Engine Efficiencies.—The Diesel engine is the only mechanical prime mover which has increased in number of horse power applied in manufacturing plants since 1919. The reason for this is undoubtedly because it is the most efficient converter of heat energy and fuel into mechanical power. Its thermal efficiency is approximately 33 per cent, and this is true even in units as small as 50 horse power. The ratio of useful energy can be considerably increased in certain cases by the utilization of the waste heat in exhaust heaters, boilers, and exhaust turbines.

Recent changes in Diesel engine construction have substantially reduced the weight per horse power, have slightly reduced the first cost per horse power, and have slightly reduced the fuel consumption.

Hydraulic Turbines.—Recent improvements in the design and construction of hydraulic turbines have increased the efficiencies, particularly at higher specific speeds. Chart 13, from a paper presented by George

CHART 13.—INFLUENCE OF IMPROVEMENTS IN HYDRAULIC TURBINES ON THEIR EFFICIENCIES AT VARIOUS SPEEDS



A. Jessop, chief engineer, S. Morgan Smith Co., to the American Society of Civil Engineers in 1925, gives the relation of efficiency to specific speed based on test models of Holyoke size for three years, 1910, 1920, and 1925. He has extended this information to date as given by the following comparison:

Year	Specific speed	Percentage efficiency
1910	40	91.0
1920	70	93.0
1925	80	93.1
1926	45	94.0
1928	78	93.7

7. Industrial Buildings.—It has seemed advisable to extend the figures for industrial buildings through 1927.[8]

A study by Professors Charles W. Cobb and Paul H. Douglas gives values of manufacturing buildings for census years, from 1899 to 1919, and for the subsequent year 1922. These economists also give a cost index for this same period based upon those commodities which are most important in construction work, namely, pig iron, rolled and forged steel, lumber, coke, cement, bricks, and copper.[9] The United States Department of Commerce gives industrial buildings contracted for in square feet of floor space, year by year, from 1915 to 1926, inclusive. The statistics are for the 27 most important industrial states and are estimated to be 75 per cent of the construction for the United States as a whole. Increasing these figures to give a total estimate, yields the figures given in the following statement:

1915	85,300,000	1921	48,000,000
1916	129,300,000	1922	88,000,000
1917	145,300,000	1923	82,600,000
1918	241,300,000	1924	54,600,000
1919	204,000,000	1925	78,600,000
1920	170,600,000	1926	90,600,000

The unit value per square foot in dollars, added in the Cobb-Douglas statement for the period 1919 to 1922, was computed by dividing the total increase in dollars by the number of square feet contracted for in the years 1918, 1919, 1920, and 1921. This factor was then multiplied by the number of square feet in the preceding table, and the resulting sum in dollars was added as the increment for the succeeding year. That is, to the total estimated dollar value of industrial buildings for 1922 was added the sum obtained by multiplying the number of square feet contracted for 1921 by the average square foot value. This process yielded the estimated value of industrial buildings, 1899 to 1927 (1899 base year), as shown in the following statement:

Year	Value	Index number	Year	Value	Index number
1899	$1,450,000,000	100	1923	$4,481,000,000	309
1904	2,036,000,000	140	1924	4,566,800,000	316
1909	2,704,000,000	187	1925	4,689,600,000	323
1914	3,238,000,000	223	1926	4,864,000,000	336
1919	3,285,000,000	226	1927	5,066,000,000	350
1922	4,283,000,000	295			

It should be explained that the total values from 1899 through 1922 had been corrected for the change in dollar value during that period, that

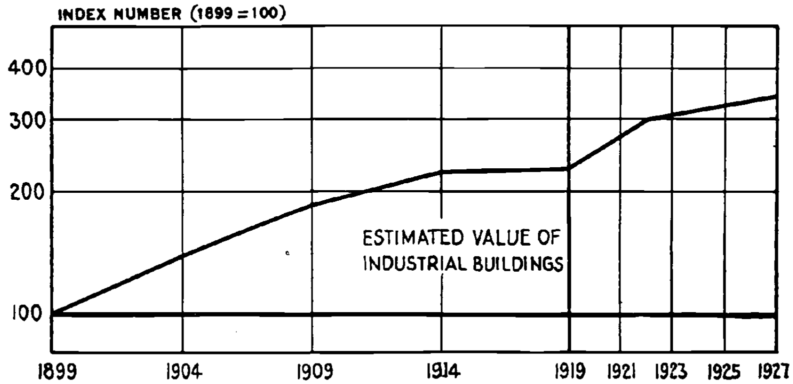
[8] This can be done provided one assumption is accepted, namely that the square footage of industrial buildings contracted for in any one year does not, on the average, go into use and become productive until a year later.

[9] *American Economic Review*, Supplement, March, 1928.

they may reflect the physical changes in industrial buildings. No correction is possible, however, for industrial buildings that may have been abandoned and destroyed for various reasons, or for construction work carried on without the letting of contracts. Inasmuch as the purpose of this investigation is to indicate a trend rather than actual values, it may be assumed that these two factors substantially offset one another.

The values given in the immediately preceding tabulation, reduced to index numbers with 1899 as the base, are plotted in Chart 14. The construction of this curve shows that, following a sharp rise in the addition of industrial buildings between 1919 and 1922, the rate of addition has become much less, in fact the curve is flat. The construction of industrial buildings is thus seen to have been less active, and the increase in this production factor has had less influence on manufacturing operations since 1922 than immediately before that date.

CHART 14.—INDEX OF VALUE OF INDUSTRIAL BUILDINGS, 1899–1927

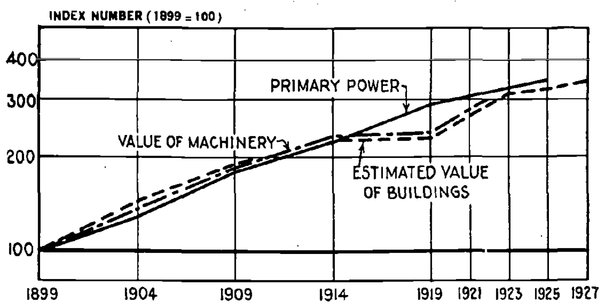


8. Manufacturing Machinery.—Manufacturing machinery is one of the production factors that were shown in the first section of this chapter to have had a marked change in amount following 1919, and presumably as having had a major influence upon the increase of productivity per man-hour which exhibited itself following 1921. All of the available data on such machinery are there presented. However, certain other relationships are worthy of presentation here.

Examination of trend curves shows that from 1899 to 1919 the curve of machinery, in so far as it can be plotted, lies coincident with the curves for primary power and industrial buildings. From 1914 to 1922 it lies between these two curves, but somewhat closer to the one for industrial buildings. In the immediately preceding pages, the curve for industrial buildings has been extended through 1927. Chart 15 places in comparison three curves: primary power, 1899–1925; industrial buildings, 1899–1927; manufacturing machinery, 1899–1922.

If it can be assumed that the curve for machinery continues to lie between the one for primary power and the one for industrial buildings, its position is approximately located on the chart.

CHART 15.—THE INCREASE IN VALUE OF MANUFACTURING MACHINERY AS COMPARED WITH PRIMARY POWER AND INDUSTRIAL BUILDINGS



There are several reasons which lead to the belief that the increase in manufacturing machinery approximates, though perhaps at slightly higher levels, the increase in industrial power. The demand for higher speeds, greater output, and lower-cost production, has tended to increase the size and weight of manufacturing machinery and horse power required to drive it per machine. While this tendency has exhibited itself in regard to machinery, the pressure for lower costs has tended to increase the effectiveness with which the floor area of industrial buildings is used. Thus, machines are being concentrated with only sufficient surrounding space to store material in process and only sufficient aisle width to care properly for the various services that must be rendered in any producing department. The trend of technical discussion to-day in regard to industrial buildings is how to increase effectiveness of manufacturing floor areas; that is, how, per thousand square feet, to install more machines, and increase employees and production. The influence of these elements of improvement would tend to increase the amount of machinery installed per unit of floor area and, turning back to Chart 15, would tend to lift the curve for machinery somewhat above that for buildings.

Another indication of this change is found in the horse-power curve which tends to rise more rapidly than the curve for industrial buildings, indicating that primary power per unit of floor area is tending to increase.

During the postwar period a change has come in the basis upon which new manufacturing machinery is installed, either as additional to plant or as replacement for old and less efficient equipment. The attitude toward all new manufacturing equipment is expressed by these questions:

> Will it improve the quality of our product?
> Will it improve our service in the filling of customers' orders?
> Will it reduce cost?

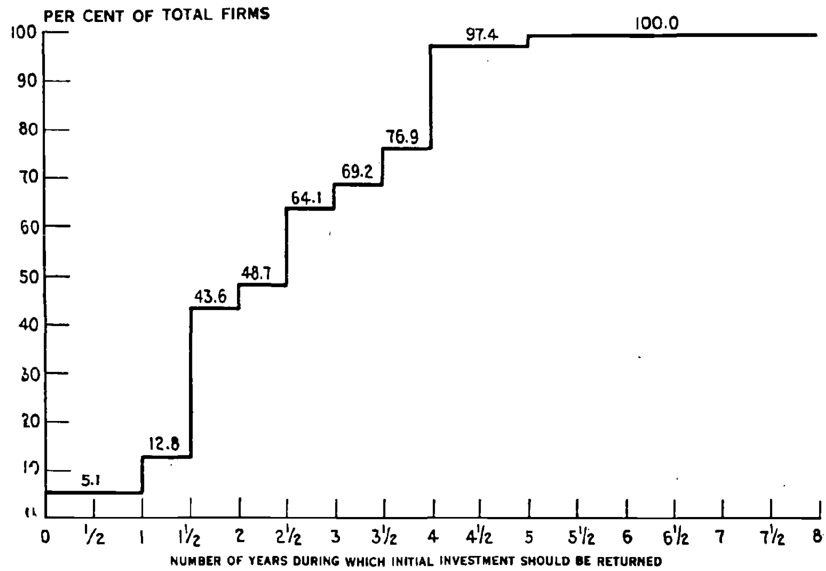
A questionnaire sent to 800 of the larger and more representative manufacturing concerns of the United States sought to disclose the policy pursued when purchasing new equipment. The question bearing upon this point read:

Has your company a policy against the purchase of new equipment unless the production savings will return the initial investment within a definite period? If so, what is this period?

Nearly 200 replies were received to this questionnaire, disclosing that 43.6 per cent of the companies required that new equipment should return its cost through savings in a period of two years or less, and that 64.1 per cent required that it should pay for itself in three years or less.

Chart 16 shows the relationship between the number of years during which the initial investment must be returned and the percentage of firms requiring the return in that period or in a shorter time.

CHART 16.—POLICY OF MANUFACTURING FIRMS IN REGARD TO THE PURCHASE OF NEW EQUIPMENT



The existence of a policy of this kind indicates the nature of the technical efforts being put forth not only to improve the capacity of manufacturing machinery, but also to increase its economy. Without doubt this is a most important element in the cost-reduction program of 1919 to date.

9. Material-handling Equipment.—*Fifty Typical Installations.*—The lessening of the supply of crude laborers owing to the restriction of immigration, reduction of working hours in certain industries, and the greatly increased cost of unskilled labor, have compelled the installation of machinery and equipment to do work formerly performed by muscular effort.

TABLE 12.—FIFTY TYPICAL INSTALLATIONS OF MATERIAL-HANDLING EQUIPMENT

Material or product handled	Equipment used	Plant	Savings and improvements
AUTOMOBILES AND ACCESSORIES			
Cylinder blocks	Standard conveyors	Nash Motor Co	$8,600 per year.
Annealing pots	Tier-lift trucks	New Departure Mfg. Co	$10,800 per year.
BUILDING MATERIAL			
Materials	Overhead carrying system	Architectural Tile Co	$5,000 per year.
Cement materials	2 hoists	Crex Patent Column Co	$6,000 per year.
Sand and gravel	Portable conveyor and loader	Crume Brick Co	$3,900 per year.
Lumber on trailers and switching cars	Tructractor	M. B. Farrin Lumber Co	$4,650 per year, congestion eliminated; 15 horses eliminated; 70 per cent return on investment.
Building material	Locomotive crane	Dwight P. Robinson Co	$18,000 in six weeks.
Lumber	Locomotive crane	St. Helena Dock & Terminal Co	$41,000 per year.
Crushed stone	Belt conveyor	Leathem D. Smith Stone Co	Doubled capacity.
FOOD			
Sugar	Automatic packing and handling equipment.	American Sugar Refining Co	One-half of labor.
Coal and ashes	Bucket conveyor	George Ehret Brewery Co	Equipment handles 20,000 tons of coal per year at 9 cents per ton including maintenance and repair charges.
Coal	Conveyor	Freeman Dairy Co	$0.98 per ton; $2,500 per year.
Sugar packed in cartons	Conveyors	National Sugar Refining Co	$8,800 per year.
Candy in boxes and cartons	Gravity conveyors and spiral chutes.	Samoset Chocolate Co	$3,370 per year.
Materials	Overhead trackway connecting all departments.	Swift & Co	$125,000 per year; $0.60 per ton material handled.
FOUNDRY			
Cupola charges	Hoist	Davis & Thomas Co	$5,850.
Castings	Belt conveyors	Kelsey Wheel Co	$10,000 per year.
Materials	3 tructractors	Southside Malleable Castings Co	$22,500 per year.
Castings	Tructractors	Standard Sanitary Mfg. Co	Annual savings 17 times cost of equipment.
IRON AND STEEL			
Iron and steel	2 tructractors	American Radiator Co	$22,000 per year; $1.345 per ton.
Steel, machinery, forgings	2 locomotive cranes	E. W. Bliss Co	Equipment pays for itself each year.
Iron and steel	15-ton locomotive crane	Delaware River Steel Co	$10,300 per year.
Rails	Locomotive crane	McKenna Process Co	Doubles production.
Steel (on buggies)	Tructractor	Riter-Conley Mfg. Co	$2,960 per year; saves $8,000 in increased production; labor turnover reduced; pays for itself in about 54 days.
Iron and steel scrap	Locomotive crane	Sonken-Galamba Iron and Metal Co.	$30,000 to $40,000 per year; big saving in time.
LEATHER			
Fleshings	Tractor	Joseph Eisendrath Co	$3,400 per year.
Patent leather in frames	Overhead carrying system	Greiss-Pfleger Tanning Co	$5,000 per year.
MACHINERY			
Shipping cases	Gravity chute	General Electric Bloomfield Plant	$6,000 per year; rapid loading of cars.
Castings and foundry supplies	4 tructractors and trailers	Holt Mfg. Co	$13,300 per year.
Materials	3 cranes	Reliance Electric & Engineering Co	$9,350 per year.

METAL WORKING			
Materials	Complete conveyor system	Belden Mfg. Co.	Yearly profit $12,450 on investment of $19,611.
Materials	2 tructractors	Bullard Machine & Tool Co	$10,500 per year.
Assembling stoves	Conveyor	Detroit Vapor Stove Co	Increases production; saves 50 per cent of space.
Materials	Roller and belt conveyor	Hobart Bros. Co	Cut production cost 25 per cent.
Dies	Tier-lift truck	Ireland & Matthews Drop Forging Co.	$32,000 per year.
Materials and product	3 elevating conveyors	Tin Decorating Co	$47,400 per year.
Materials	Overhead carrying system	United Metal Co	$7,500 per year.
Coal, coke, ores, and slag	Locomotive crane	United States Metals Refining Co	Increased production 100 per cent.
Materials	Stationary roller conveyors and containers.	Walworth Co	$60,000 per year.
PAPER			
Paper	Skids for loading box cars	Champion Coated Paper Co	Reduction in labor 93 per cent.
Paper	Electric hoist	Paper Manufacturers Co., Inc	Increased production on one process 66 per cent.
Paper in rolls to cutting machines	5 hoists	Paterson Parchment Paper Co	$4,100 per year.
Paper and paper stock	Nailed wooden skids for shipping	West Virginia Paper and Pulp Co	Reduction in shipping material cost 77 per cent; reduction in labor in handling shipments, 80 per cent.
TEXTILES			
Materials	Complete conveyor system for mill	Jackson Mills	$16,250 per year; successful material control and improvement in machine operations.
Raw cotton	Pneumatic conveyor	Milstead Mfg. Co	$1,600 per year.
MISCELLANEOUS			
Lumber and materials	Miscellaneous handling equipment	American Seating Co	Reduced handling cost per man-hour from 17 to 9 cents; annual saving, $95,000; additional saving over handling improvement about $25,000 per year.
Materials	Conveyor system for entire plant	B. T. Babbitt Co	Unloading costs $0.02 per box for metal cans; $0.02 per drum for caustic soda; $0.04 per drum for line; $0.50 per thousand for fiber boxes; $1.50 per thousand for wooden boxes; shipping cost $0.0075 per package.
Flaxseed from ship to storage to mill	Conveyor and elevating system	Bisbee Linseed Co	$15,000 per year.
Clay	Tructractor	Champion Porcelain Co	$8,400 per year.
Materials and products	Complete system of conveyors, elevators, lift trucks, spiral chutes, and gravity devices.	E. R. Squibb Co	Elimination of unnecessary travel of material in process and finished product.

Two beneficial results have been secured: (1) a reduction in the cost of moving and transporting materials and product; (2) an increase in production, for the new machinery in many cases has set the pace of the production process.

Table 12 gives information on 50 typical installations of material-handling equipment. For each item the material or product handled is indicated, the kind of machinery installed is designated, the plant where the installation was made is named, and the savings or improvements are given. For 37 of these installations the savings aggregate over $850,000 per annum. For many of these and for most of the other 13, the statement is made that production has increased.

Large as the money saving is, it is probable that the improvement in production, reflected in increased productivity of the worker and lower manufacturing costs, is of even greater significance. In fact, the control of production which is being secured through the aid of modern material-handling machinery is probably the greatest single improvement which has come in the technical operation of manufacturing establishments since 1919.[10]

10. Mechanical Safeguards for Plant and Machinery.—Changes which affect health, comfort, and well-being in working are known to have an influence upon production and productivity. The degree of their influence is difficult to measure and the improvement represented by the best practice to-day has been recognized for a number of years. In fact, it is doubtful if any plant constructed during the later war period and since has not been reasonably up-to-date in regard to all such features.

Included in the facilities which contribute to working conditions are safeguards, artificial illumination, heating, ventilation, provisions for removing fumes and dust, provisions for medical and dental attention, and facilities for serving food. Of these, only two are subject to quantitative determination in regard to the position they occupy in American industry to-day. Most of them are subject to some regulation under state factory laws, and are inspected to assure at least minimum compliance. Two of these, safety and illumination, are capable of study to show the nature of recent changes.

Within a year the American Engineering Council has completed an extensive investigation to determine the relationships that exist between safety and production. The investigation comprised some 14,000 plants, about 2,500,000 workers, and over 54,000,000,000 man-hours.

It was shown that the coefficient of correlation between safety and production, that is, of those cases where productivity had increased at

[10] The information in Table 12 is from two sources: the replies to the questionnaire sent out on behalf of the Survey, and library research in current engineering and technical publications. All of the installations have been reported upon since 1924, and have been in operation since 1920.

the same time that accidents had been reduced, was 0.835. That is, the manufacturing plant with high productivity may be expected to have a low accident rate and vice versa.

W. H. Heinrich, assistant superintendent of inspection, Travelers, Insurance Co., has recently made a determination of the percentage of industrial accidents due to physical causes. His study comprised 73,000 cases where the records were available either in the files of his own company or in those of manufacturing concerns. His conclusion is that the lack of mechanical safeguards is to-day a comparatively minor cause factor in industrial accidents, for he attributes to all physical causes only 10 per cent of all the accidents which occur. Two per cent are unavoidable, and the other 88 per cent are due to managerial and supervisory fault. This may be taken as an indication that the safeguarding of machinery in the plants which yielded the 73,000 cases studied had been carried to a reasonable degree of excellence.

11. Artificial Illumination.—The changes which have taken place in provisions for industrial lighting during the past decade have been particularly noteworthy. Intensities have increased, for it has been shown that such improvements have a direct beneficial effect upon production.

Table 13 shows the progressive increase in intensities which have taken place from 1915 to date, as represented by adopted lighting codes and by good practice. Table 14 shows, for a group of representative manufacturing operations, actual increases which have taken place in intensities and the resulting improvement in production. An interesting fact displayed by this table is that the intensities actually used range somewhat higher than the maximum recommended in the codes of Table 13.

TABLE 13.—ARTIFICIAL ILLUMINATION CODES FOR FACTORIES, 1915 TO 1928, INCLUSIVE

(In foot-candles)

Operation or industry	Illuminating Engineering Society, 1915[a]	Illuminating Engineering Society, 1917[a]	Natl. Elec. Light Association, 1921[b]	Illuminating Engineering Society, 1923[a]	Edison Lamp Works, 1926[c]	Westinghouse Lamp Co., 1928[d]
Assembling:						
Rough	1.25–2.50	2–4	3–6	2–5	3–6	5–8
Medium	....	....	4–8	5–10	5–10	8–12
Fine	....	....	6–12	5–10	8–16	12–20
Chemical works:						
Hand furnaces, boiling tanks, stationary driers, stationary or gravity crystallizing	....	....	2–4	2–5	2–4	3–5
Mechanical furnaces, generators and stills, mechanical driers, evaporators, filtration, mechanical crystallizing, bleaching	....	....	3–6	2–5	3–6	4–6
Tanks for cooling, extractors, percolators, nitrators, electrolytic cells	....	....	4–8	5–10	4–8	6–10
Engraving	10–15	10–15	8–16	10–20	10–50	25–50–100
Foundries:						
Charging floor, tumbling, cleaning, pouring, and shaking out	1.25–2.50	2–4	2–4	2–5	3–6	5–8
Rough molding and core-making	....	....	3–6	....	4–8	6–10
Fine molding and core-making	....	....	5–10	5–10	6–12	10–15
Glass works:						
Mix and furnace rooms, casting and Lehr	....	....	3–6	2–5	4–8	6–10
Grinding, glass blowing machines, cutting glass to size, silvering	....	....	4–8	5–10	5–10	8–12
Fine grinding, polishing, beveling, inspecting, etching and decorating	....	....	6–12	5–10	6–12	10–15
Glass cutting (cut glass), fine inspection	....	....	....	10–20	10–50	15–25–50
Inspecting:						
Rough	....	....	3–6	5–10	4–8	6–10
Medium	....	....	5–10	5–10	6–12	10–15
Fine	....	....	8–16	10–20	10–20	15–25
Jewelry and watch manufacturing	10–15	10–15	8–16	10–20	10–50	25–50–100
Leather manufacturing:						
Vats	....	....	2–4	2–5	2–4	3–5
Cleaning, tanning and stretching	....	....	3–6	2–5	3–6	4–6
Cutting, fleshing, stuffing	....	....	4–8	5–10	4–8	6–10
Finishing and scarfing	....	....	6–12	5–10	6–12	10–15
Machine shops:						
Rough machining and rough bench work	1.25–2.50	2–4	3–6	2–5	4–8	6–10
Medium bench and machine work, ordinary automatic machinery, rough grinding, medium buffing and polishing	....	3–6	5–10	5–10	6–12	10–15
Fine bench and machine work, fine automatic machinery, medium grinding, fine buffing and polishing	3.50–6.00	4–8	8–16	10–20	8–16	12–20
Paint shops:						
Dipping, spraying, firing	....	....	3–6	2–5	3–6	5–8
Rubbing, ordinary hand painting and finishing	....	....	4–8	5–10	5–10	8–12
Fine hand painting and finishing	....	....	6–12	5–10	8–16	10–15

Extra fine hand painting and finishing (automobile bodies, pianos, etc.)	....	....	8–16	10–20	10–50	25–50–100
Paper manufacturing:						
Beaters, machine grinding	....	....	3–6	2–5	3–6	4–6
Calendering	....	....	4–8	5–10	4–8	6–10
Finishing, cutting and trimming	....	....	6–12	5–10	6–12	8–12
Roadways and yard thoroughfares	....	0.05–0.25	0.05–0.25	0.05–0.25	0.25–1.00	
Rubber manufacturing and products:						
Calenders, compounding mills, fabric preparation, stock cutting, tubing machines, solid tire operations, mechanical goods building, vulcanizing	....	....	4–8	5–10	5–10	8–12
Bead building, pneumatic tire building and finishing, inner tube operations, mechanical goods trimming, treading	....	....	5–10	5–10	6–12	10–15
Stairways, passages and aisles (except exits and passages leading thereto)	0.25–0.50	0.75–2.00	1–2	1–2	1–2	2–3
Steel and iron mills—bar, sheet and wire products:						
Soaking pits and reheating furnaces	....	....	1–2	2–5	1–3	2–3
Charging and casting floors	....	....	2–4	2–5	3–6	4–6
Muck and heavy rolling, shearing (rough by gauge), pickling and cleaning	....	....	3–6	2–5	3–6	5–8
Automatic machines, rod light and cold rolling, wire drawing, shearing, fine by line	....	....	4–8	5–10	5–10	8–12
Textile mills:						
Light goods	3.5–6	4–8	4–12	5–10	4–10	6–15
Dark goods	10–15	10–15	6–16	10–20	8–20	10–20
Woodworking:						
Rough sawing and bench work	....	....	3–6	2–5	3–6	5–8
Sizing, planing, rough sanding, medium machine and bench work, gluing, veneering, cooperage	....	....	4–8	5–10	5–10	8–12
Fine bench and machine work, fine sanding and finishing	....	....	6–12	5–10	6–12	10–15

[a] *Lighting Codes*, Illuminating Engineering Society, 1915, 1917, and 1923.
[b] *Industrial Lighting*, published by Commercial National Section, National Electric Light Association, 1921.
[c] *Bulletin* LD-117C, "Calculation of the Lighting Installation," Edison Lamp Works of General Electric Co., August, 1926.
[d] *Bulletin* E-108, "Design of Lighting Installations," Westinghouse Lamp Co., March, 1928.

TABLE 14.—INSTALLATIONS OF ARTIFICIAL LIGHTING EQUIPMENT AND CORRESPONDING INCREASE IN PRODUCTION

Operation	Average intensity old system	Average intensity new system	Per cent increase in production	Name	Address	Business
	Foot-candles	*Foot-candles*				
Carburetor assembly	2.1	12.3	12.0	....	....	....
Dispatching division	3.3	7.6	12.5	Post Office	....	Letter separating.
Final sorting	3.3	5.9	20.0	Post Office	....	Letter separating.
Grinding and machine work	1.2	6.5	13.0	Detroit Piston Ring Co.	Detroit, Mich.	Piston ring manufacturing.
Grinding and machine work	....	9.0	17.9	Detroit Piston Ring Co.	Detroit, Mich.	Piston ring manufacturing.
Grinding and machine work	....	14.0	25.8	Detroit Piston Ring Co.	Detroit, Mich.	Piston ring manufacturing.
Heavy steel machine shop	3.0	11.5	10.0	....	....	
Inspecting	43.0	55.0	42.0	American Pile Fabric Co.	Philadelphia, Pa.	Plush manufacturing.
Inspecting	5.0	6.0	4.0	Timken Roller Bearing Co.	Canton, Ohio	Roller bearing manufacturing.
Inspecting	....	13.0	8.0	Timken Roller Bearing Co.	Canton, Ohio	Roller bearing manufacturing.
Inspecting	....	20.0	12.5	Timken Roller Bearing Co.	Canton, Ohio	Roller bearing manufacturing.
Knitting	6.2	17.0	6.3	Reid Hosiery	Philadelphia, Pa.	Hosiery manufacturing.
Knitting	4.5	17.2	10.8	Philadelphia Sweater Mills	Philadelphia, Pa.	Necktie manufacturing.
Knitting (day)	....	17.3	3.9	Realart Silk Hosiery	Philadelphia, Pa.	Hosiery manufacturing.
Knitting (night)	7.2	17.3	5.75	Realart Silk Hosiery	Philadelphia, Pa.	Hosiery manufacturing.
Loom	10.0	13.0	15.0	American Pile Fabric Co.	Philadelphia, Pa.	Plush manufacturing.
Loom	3.3	10.0	16.0	Shenn Manufacturing Co.	Philadelphia, Pa.	Towel and wash rag manufacturing.
Loom	6.8	7.9	7.7	John Sidebotham	Philadelphia, Pa.	Tape manufacturing.
Loom	....	15.5	11.1	John Sidebotham	Philadelphia, Pa.	Tape manufacturing.
Loom (day)	1.9	3.7	1.85	M. J. Smith Belting Co.	Philadelphia, Pa.	Belting manufacturing.
Loom (day)	....	4.74	2.18	M. J. Smith Belting Co.	Philadelphia, Pa.	Belting manufacturing.
Loom (day)	....	9.66	3.22	M. J. Smith Belting Co.	Philadelphia, Pa.	Belting manufacturing.
Loom (night)	....	3.7	13.95	M. J. Smith Belting Co.	Philadelphia, Pa.	Belting manufacturing.
Loom (night)	....	4.74	16.75	M. J. Smith Belting Co.	Philadelphia, Pa.	Belting manufacturing.
Loom (night)	....	9.60	19.8	M. J. Smith Belting Co.	Philadelphia, Pa.	Belting manufacturing.
Loom	1.8	8.8	25.0	Taylor Brothers	Philadelphia, Pa.	Cotton dress goods.
Machine shop	3.4	8.7	3.0	D. B. Flower	Philadelphia, Pa.	Brass machine shop.
Metal shop	3.3	15.0	18.1	Decorative Lamp & Shade Co.	Philadelphia, Pa.	Lamp and shade manufacturing.
Pulley finishing	0.2	4.8	35.0	....	....	Pulley shop.
Soft metal bearing	4.6	12.7	15.0	....	....	Metal bearing.
Splicing	4.7	27.5	7.8	Matell Mills	Philadelphia, Pa.	Cotton spinning.
Turret lathes	11.6	20.0	12.35	American Metal Works	Philadelphia, Pa.	Radio and electrical goods.
Turret lathes	....	14.0	6.73	American Metal Works	Philadelphia, Pa.	Radio and electrical goods.
Turret lathes	....	7.4	2.35	American Metal Works	Philadelphia, Pa.	Radio and electrical goods.
Wire drawing	2.9	9.2	16.5	B. Wilmsen	Philadelphia, Pa.	Christmas tree ornaments.
Woodworking shop	4.5	25.0	20.9	Decorative Lamp & Shade Co.	Philadelphia, Pa.	Lamp and shade manufacturing.
	1.5	9.0	17.0	....	....	Jute spinning.
	0.7	13.5	12.2	Dover Mfg. Co.	Dover, Ohio	Manufacturing gas and sad irons.

III. CHANGES IN TECHNICAL PRODUCTION FACTORS FOR 12 INDUSTRIES

Not all manufacturing product groups have progressed in keeping with the productivity and cost trends of manufacturing industry as a whole. On the other hand, there are some whose records far exceed the averages. This part of the report presents the changes in certain production factors for 12 product groups.[11]

The information for each group is presented in two ways. First, by a table of index numbers of statistical data, and, second, by a chart which plots these data. They are mainly on the 1914 base. For convenience, these product groups are divided into two classes. In the first, the increase in productivity per man-hour, over the period for which figures are available, has been more than 50 per cent. In the second, the increase in productivity has been less than 50 per cent.

This arbitrary division gives six groups in each class and brings together those industries which in general have the same operating characteristics and the same established trends. The significance of these analyses lies in their indication of those factors which, on the one hand, have changed favorably in those industries which have made the greater gain in productivity, and, on the other hand, have changed unfavorably for those that have made less satisfactory progress.

The industries of product groups showing the percentage increase in productivity are shown in the following statement:

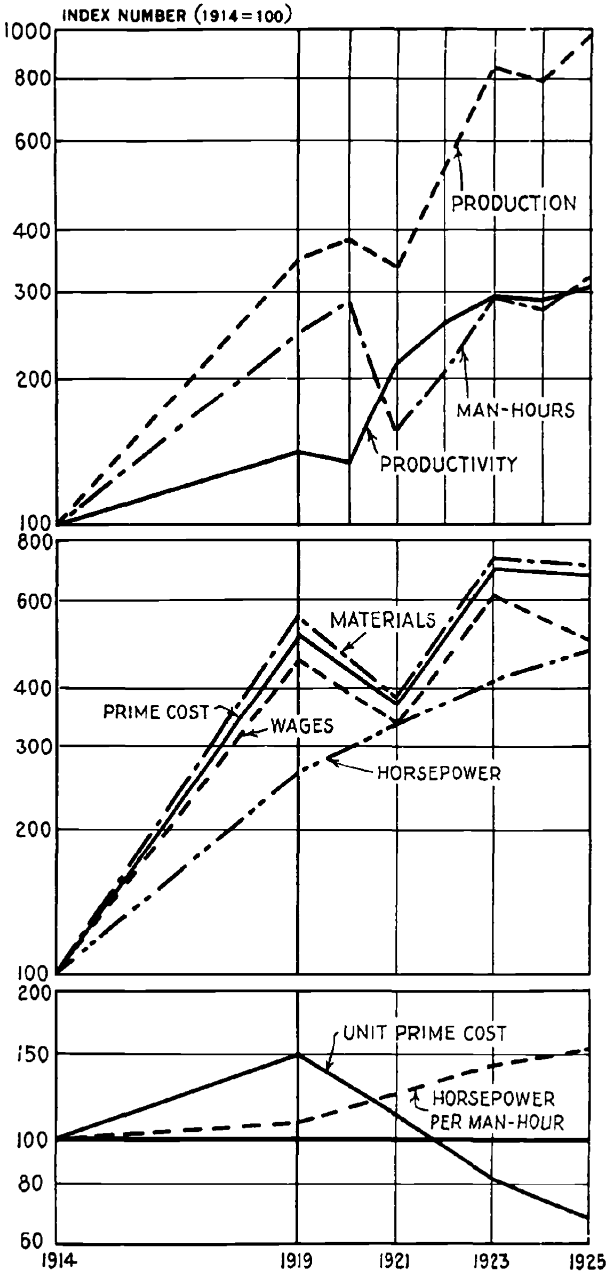
Industries in first class:	
Automobiles	210
Rubber tires	211
Petroleum refining	77
Cement manufacture	58
Blast furnaces	54
Steel works and rolling mills	60
Industries in second class:	
Flour milling	39
Slaughtering and meat packing	27
Leather tanning	28
Cane sugar refining	27
Paper and wood pulp	26
Boots and shoes	17

Each of these product groups will be taken up separately to show significant features in the trends of the production factors. A glance

[11] Data covering these changes were secured from the following sources: *United States Census of Manufactures*, 1925, and *Monthly Labor Review*, issues for July, October, November, and December, 1926. Revised figures for three factors, production, man-hours, and productivity per man-hour, have been compiled by the United States Bureau of Labor Statistics for these 12 product groups since December, 1926, but could not be obtained in time for inclusion in this report. The index numbers used, however, show the general trend of these factors.

at the chart for the automobile industry, Chart 17, and the one for boots and shoes, Chart 28, will make evident the great differences between a very prosperous industry and one not well-favored.

CHART 17.—FLUCTUATIONS OF THE PRODUCTION FACTORS OF THE AUTOMOBILE INDUSTRY



Unfortunately, two important factors, industrial buildings and manufacturing machinery, could not be included owing to the absence of data. The most that can be said in regard to them is that they have probably varied substantially in accordance with the changes in primary power.

Automobile Manufacturing.—Automobile manufacturing and the associated industry of rubber-tire building have had similar experiences since 1914. Although the increase in productivity of tire building is slightly greater than that of automobile manufacturing, the statistics for the latter are more complete and are, therefore, presented first.

The striking changes which this industry has experienced are increases in production, primary power available, and productivity per man-hour, with a decrease in unit prime cost. The index numbers for 1925 from 1914 as a base are as shown in the following statement:

Production	988
Primary power	485
Productivity	310
Unit prime cost	69

The increase in primary power, as given in Table 15, is consistent, plotting into nearly a straight line, as shown in Chart 17. All of the other principal factors change their direction markedly with the year 1919.

TABLE 15.—INDEX NUMBERS OF PRODUCTION FACTORS OF THE AUTOMOBILE INDUSTRY, 1914–1925

Year	Physical production	Man-hours	Productivity per man-hour	Wages paid	Cost of materials	Prime cost	Primary power	Primary power per man-hour	Unit prime cost
1914	100	100	100	100	100	100	100	100	100
1919	353	250	141	468	540	526	270	108	149
1920	384	289	133	...	...	...	...	...	...
1921	333	155	215	331	378	370	...	...	112
1922	554	210	264	...	...	...	...	...	...
1923	870	295	295	610	735	710	416	141	82
1924	804	278	289	...	...	...	...	...	...
1925	988	319	310	510	720	681	485	152	69

Rubber Tire Building.—The changes in production factors for the industry building rubber tires and inner tubes in general show the same characteristics as those which have been presented above for automobile manufacturing. The industry has greatly increased its use of power from 1921 on, worked more man-hours, steadily improved its productivity to the equal of the automobile industry, and has reduced unit prime cost. (See Table 16 and Chart 18).

CHART 18.—FLUCTUATION OF PRODUCTION FACTORS OF THE RUBBER TIRE INDUSTRY

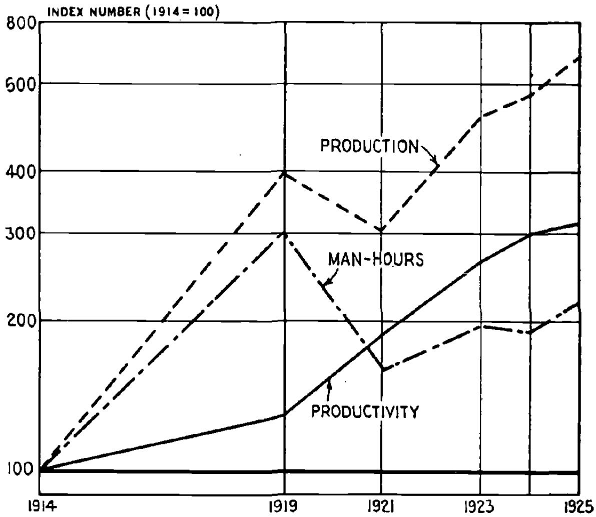


TABLE 16.—INDEX NUMBERS OF PRODUCTION FACTORS OF THE RUBBER TIRE INDUSTRY, 1914–1925

Year	Physical production	Man-hours	Productivity per man-hour
1914	100	100	100
1919	394	303	130
1921	309	163	190
1923	527	198	266
1924	580	193	301
1925	680	219	311

Petroleum Refining.—Although the over-all percentage changes in production factors in the petroleum industry are smaller than those of the automobile and tire industries (see Table 17), they present the same characteristics. Production has consistently increased since 1914. Productivity per man-hour, which decreased slightly between 1914 and 1919, consistently increased thereafter. There is no flattening of the curve, shown by Chart 19, up to 1925. Primary power utilized increased at nearly a uniform rate up to 1923 and held that level with only a slight increase up to 1925. The man-hours worked increased from 1914 to 1919, and have fluctuated but little since. The year 1919 also shows a change in direction of the curve of unit prime cost, which dropped sharply down to 1923 and then continued at a nearly uniform level.

CHART 19.—FLUCTUATIONS OF PRODUCTION FACTORS OF THE PETROLEUM REFINING INDUSTRY

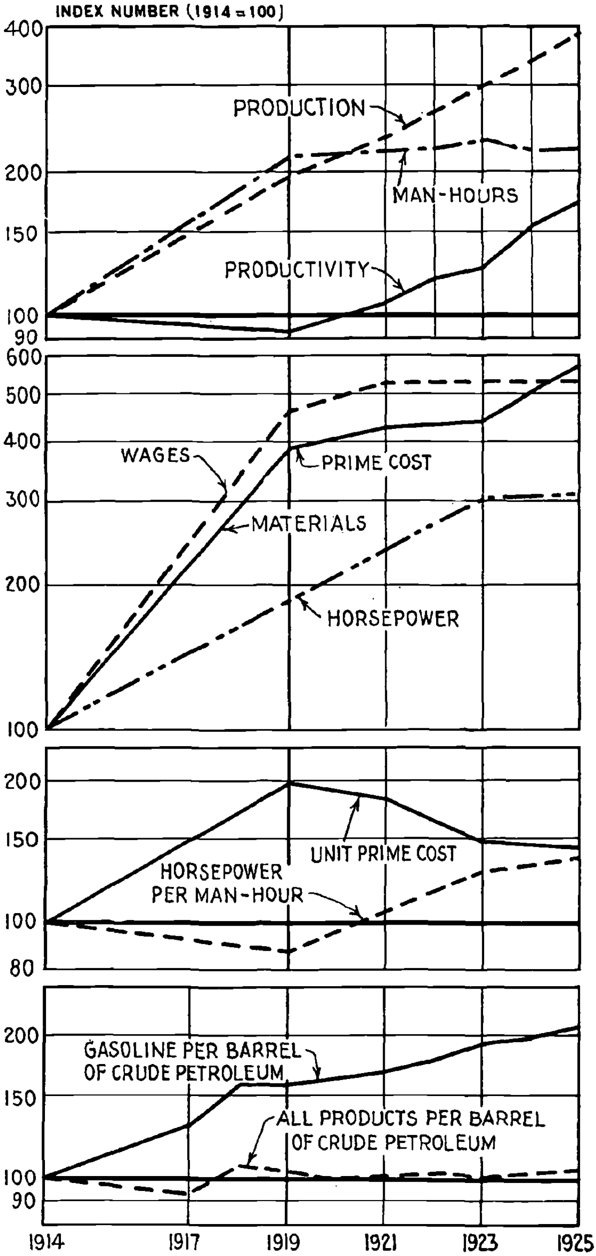


TABLE 17.—INDEX NUMBERS OF PRODUCTION FACTORS OF THE PETROLEUM REFINING INDUSTRY, 1914–1925

Year	Physical production	Man-hours	Productivity per man-hour	Wages paid	Cost of materials	Prime cost
1914	100	100	100	100	100	100
1917	...	...	...	...	...	...
1918	...	...	...	...	...	...
1919	197	214	92	462	384	388
1920	...	...	...	...	...	...
1921	235	217	108	530	425	430
1922	269	220	122	...	...	...
1923	302	237	129	535	440	445
1924	347	220	158	...	...	...
1925	399	225	177	540	580	580

Year	Primary power	Primary power per man-hour	Unit prime cost	Number of gallons of products per barrel of crude petroleum	Number of gallons gasoline per barrel of crude petroleum
1914	100	100	100	100	100
1917	...	...	...	93	129
1918	...	...	...	106	157
1919	187	88	197	104	157
1920	...	...	...	100	162
1921	...	...	183	101	166
1922	...	...	...	102	177
1923	305	129	148	101	186
1924	...	...	...	102	199
1925	307	137	145	103	210

The two other curves of Chart 19 show the increases in yield of refined products per barrel of crude petroleum. While the total recovery has changed but little, the amount of gasoline has more than doubled since 1914. This record is an indication of the improvement in technical processes.

Cement Manufacture.—The changes in the production factors of the cement manufacturing industry show the characteristics exhibited by the industries discussed above, but they are at a level lower than those that prevail for petroleum refining. The index numbers are given in Table 18. Production has consistently increased from 1919, accompanied by similar increases in productivity and primary power utilized. Their curves, as plotted in Chart 20, indicate no tendency to flatten. Unit prime cost began to drop in 1919 and by 1923 had reached a level which has since been substantially maintained.

CHART 20.—FLUCTUATIONS OF PRODUCTION FACTORS OF THE CEMEN MANUFACTURING INDUSTRY

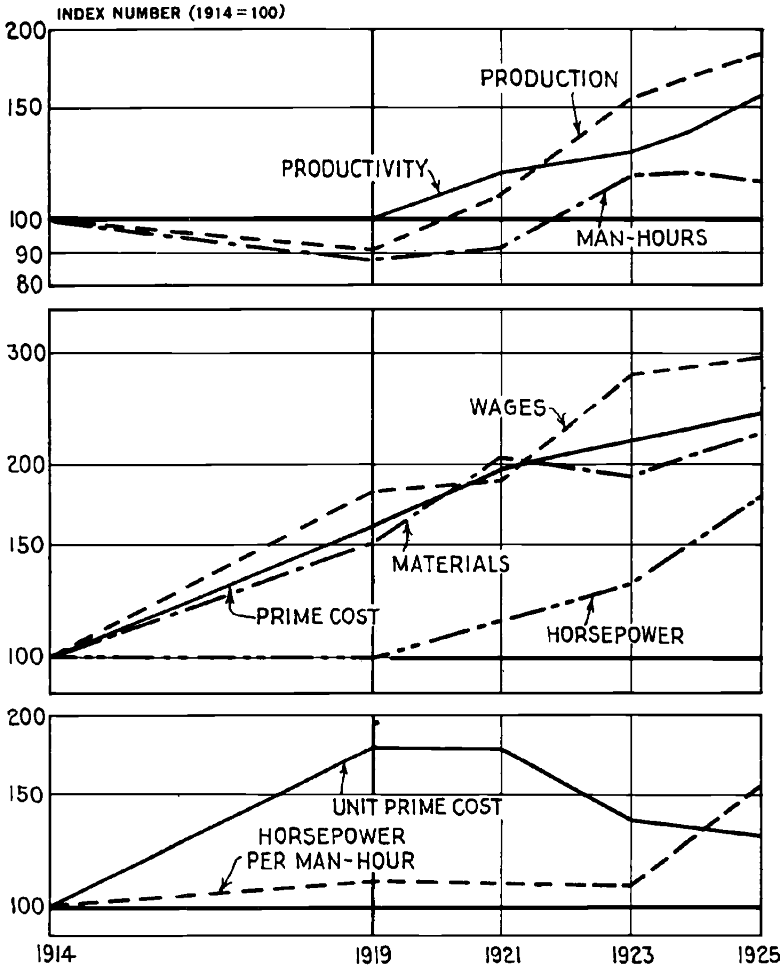
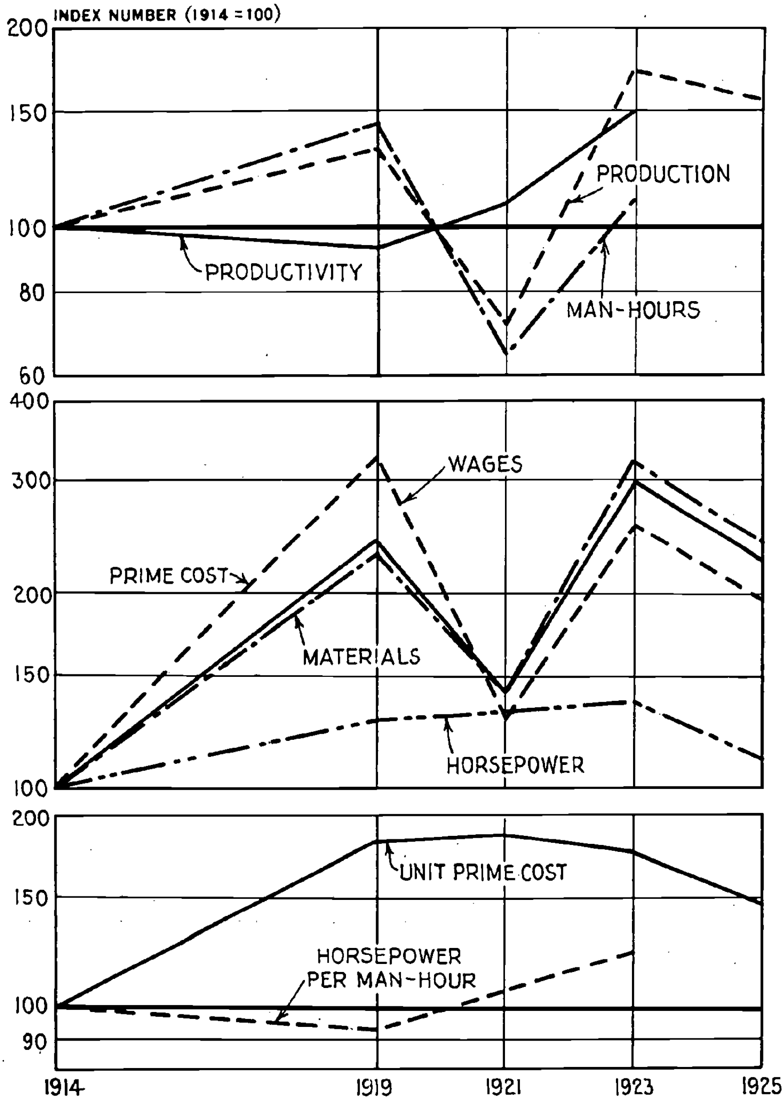


TABLE 18.—INDEX NUMBERS OF PRODUCTION FACTORS OF THE CEMENT MANUFACTURING INDUSTRY, 1914–1925

Year	Physical production	Man-hours	Productivity per man-hour	Wages paid	Cost of materials	Prime cost	Primary power	Primary power per man-hour	Unit prime cost
1914	100	100	100	100	100	100	100	100	100
1919	91	90	102	182	153	161	100	111	177
1921	111	92	121	190	198	195	...	...	176
1923	156	120	130	274	193	215	131	109	138
1924	169	120	141	...	...	...	...	...	...
1925	183	116	158	296	220	240	178	154	131

CHART 21.—FLUCTUATIONS IN THE RECORD OF BLAST FURNACE OPERATIONS



Blast Furnaces.—The productivity increase of the pig iron industry, as shown by the record of blast furnace operations, is the lowest of the first class presented here. (See Table 19). The trends of production and primary power utilized are downward after 1923. The drop in unit prime cost, which began to show in 1921, does not become pronounced until after 1923. (See Chart 21).

TABLE 19.—INDEX NUMBERS OF PRODUCTION FACTORS OF THE BLAST FURNACE INDUSTRY, 1914–1925

Year	Physical production	Man-hours	Productivity per man-hour	Wages paid	Cost of materials	Prime cost	Primary power	Primary power per man-hour	Unit prime cost
1914	100	100	100	100	100	100	100	100	100
1919	133	139	95	324	234	242	129	93	182
1921	72	65	110	129	136	136	...	...	189
1923	174	112	154	258	312	308	138	123	177
1925	157	[a]	[a]	199	233	230	113	...	147

[a] Figures included by Bureau of Labor Statistics in those for steel works and rolling mills.

Steel Works and Rolling Mills.—The characteristics of the principal production factors of steel works and rolling mills are similar to those presented for the pig iron industry. (See Table 20.) Productivity did not turn definitely upward until 1921. Primary power utilized has increased steadily since the base year 1914. Unit prime cost did not begin to drop until 1923. Production increased only slightly from 1923 to 1925. The factors are plotted in Chart 22.

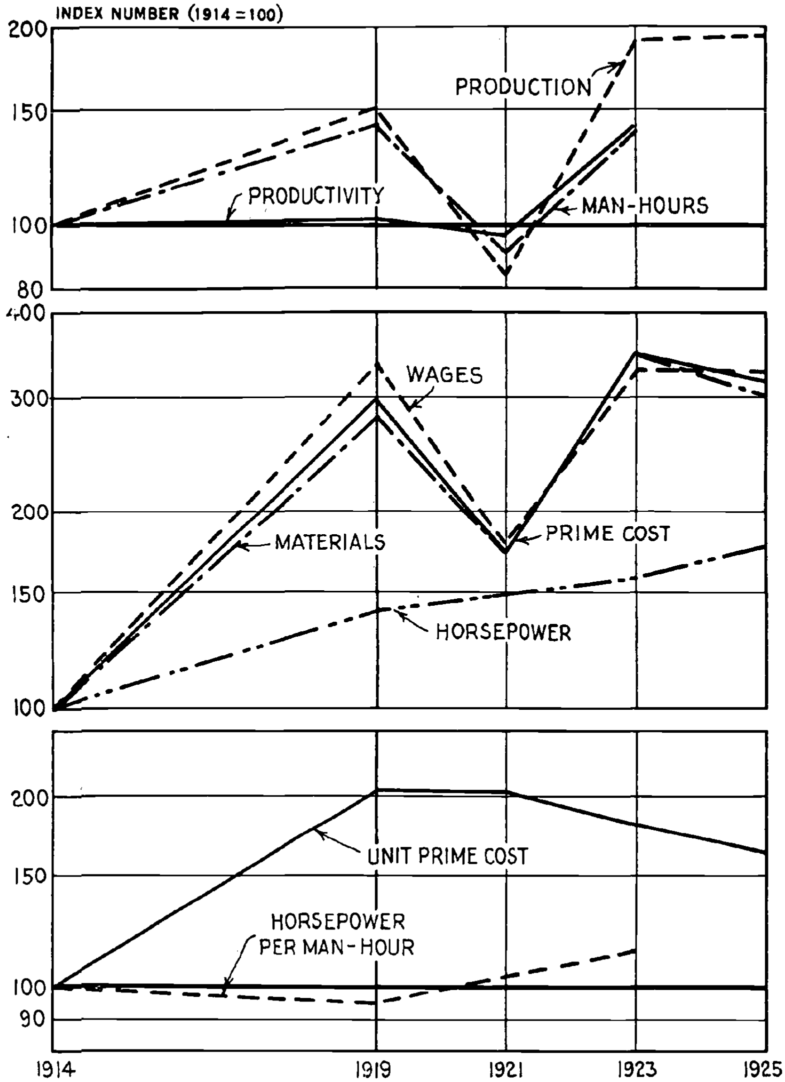
TABLE 20.—INDEX NUMBERS OF PRODUCTION FACTORS OF STEEL WORKS AND ROLLING MILLS, 1914–1925

Year	Physical production	Man-hours	Productivity per man-hour	Wages paid	Cost of materials	Prime power	Primary cost	Primary power per man-hour	Unit prime cost
1914	100	100	100	100	100	100	100	100	100
1919	148	147	101	339	284	298	141	96	201
1921	85	91	93	173	170	171	...	...	201
1923	192	139	138	340	346	346	160	115	180
1925	194	[a]121	[a]160	327	307	312	176	146	161

[a] Include figures for blast furnace industry.

Considering this group as a whole, these trends prevail: Production has increased from 1914 to 1925, but at a higher rate in the industries exhibiting the greatest increases in productivity. Productivity has consistently increased from 1919 through 1925. The utilization of primary power has increased at a nearly consistent rate in all cases and for only one industry has there been a drop from a high level previously attained. Unit prime cost has dropped consistently from 1919 on, except in two industries, namely, blast furnaces, and steel works and rolling mills, where the drop did not manifest itself until 1923.

CHART 22.—FLUCTUATIONS OF PRODUCTION FACTORS IN STEEL WORKS AND ROLLING MILLS



Second Classification of Product Groups.—The six industries which fall into the second class of industrial product groups do not show equally consistent trends, nor the same characteristics for the various factors, as are exhibited by the first group. The basis of classification is productivity, and while those in the first class had an increase greater than 50 per cent, those in this class are in the range from 39 to 17 per cent. As before, each one of the product groups in this class will be discussed separately.

CHART 23.—FLUCTUATIONS OF PRODUCTION FACTORS OF THE FLOUR MILLING INDUSTRY

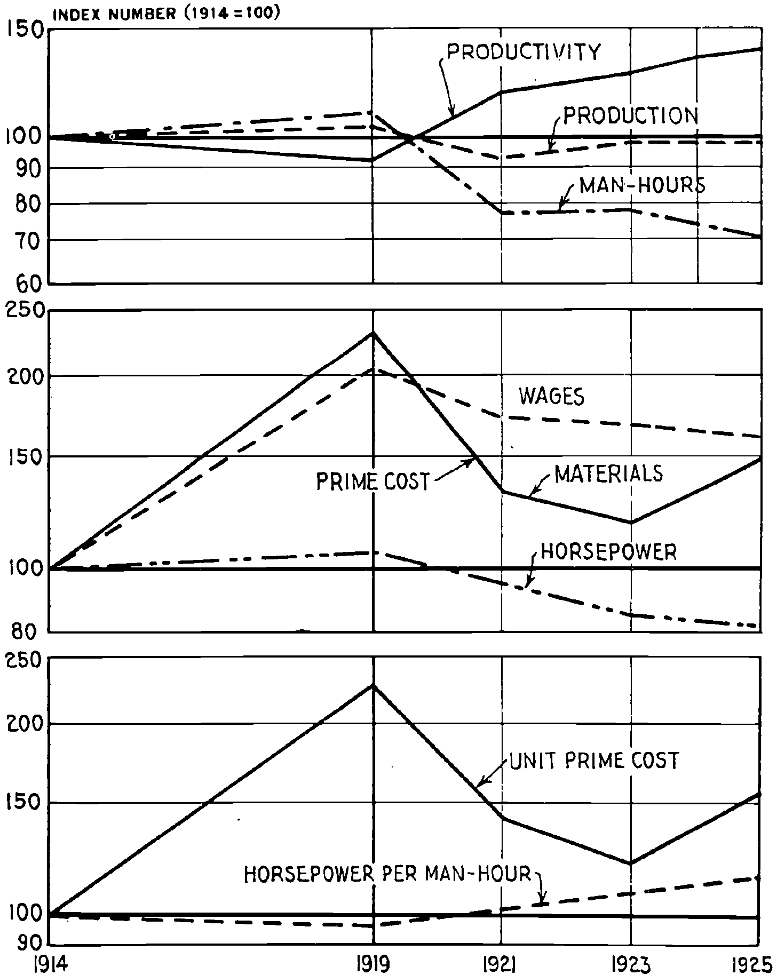


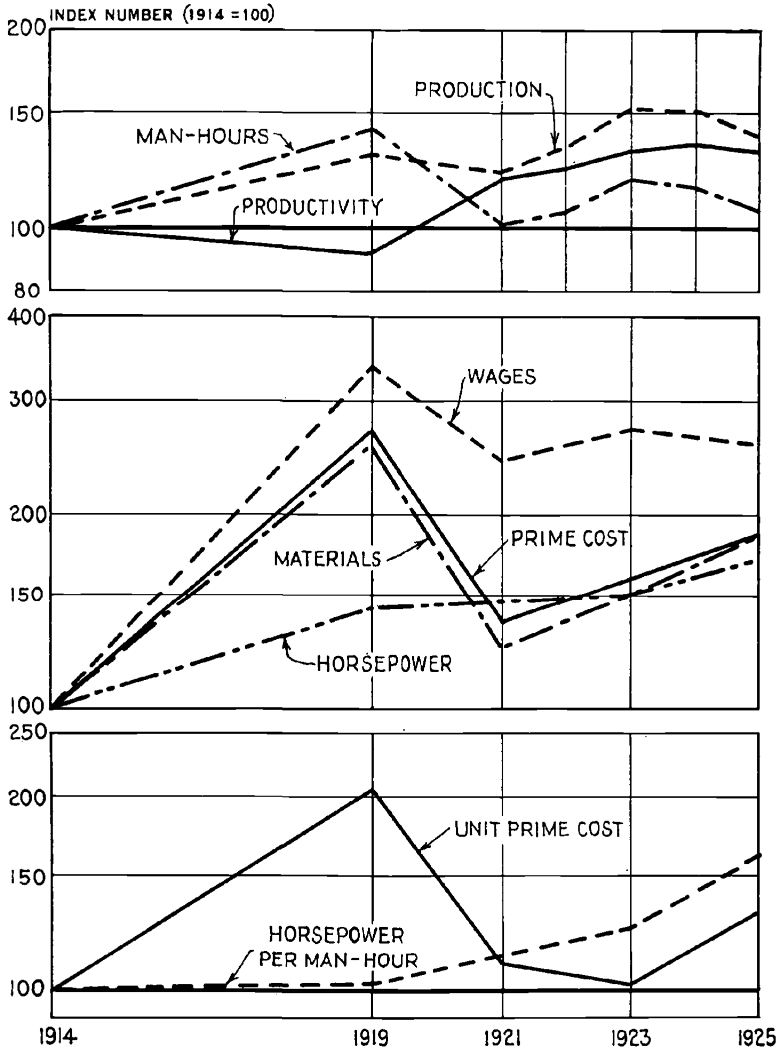
TABLE 21.—INDEX NUMBERS OF PRODUCTION FACTORS OF FLOUR MILLING INDUSTRY, 1914–1925

Year	Physical production	Man-hours	Productivity per man-hour	Wages paid	Cost of materials	Prime cost	Primary power	Primary power per man-hour	Unit prime cost
1914	100	100	100	100	100	100	100	100	100
1919	104	110	95	206	239	238	107	97	229
1921	93	77	120	175	132	134	...	...	144
1923	98	78	126	170	118	119	86	110	122
1924	98	74	133	...	...	...	...	...	...
1925	98	71	139	162	150	150	82	116	153

Flour Milling.—For the flour milling industry all of the factors show a decrease from 1919 to 1925 with the exception of productivity and primary power per man-hour, which have increased. (See Table 21 and Chart 23).

Slaughtering and Meat Packing.—For slaughtering and meat packing the factors lie at a higher level than the other industries

CHART 24.—FLUCTUATIONS OF PRODUCTION FACTORS OF THE SLAUGHTERING AND MEAT PACKING INDUSTRY



in this class with the exception of productivity, which is exceeded by flour milling and leather tanning. (See Table 22). The curve, Chart 24, for production is irregular; that for primary power shows a continuous and steady increase; the curve for man-hours is irregular, with a downward turn beginning in 1923; unit prime cost dropped sharply from 1919 to 1923 but turned upward again from 1923 to 1925.

TABLE 22.—INDEX NUMBERS OF PRODUCTION FACTORS OF SLAUGHTERING AND MEAT PACKING INDUSTRY, 1914–1925

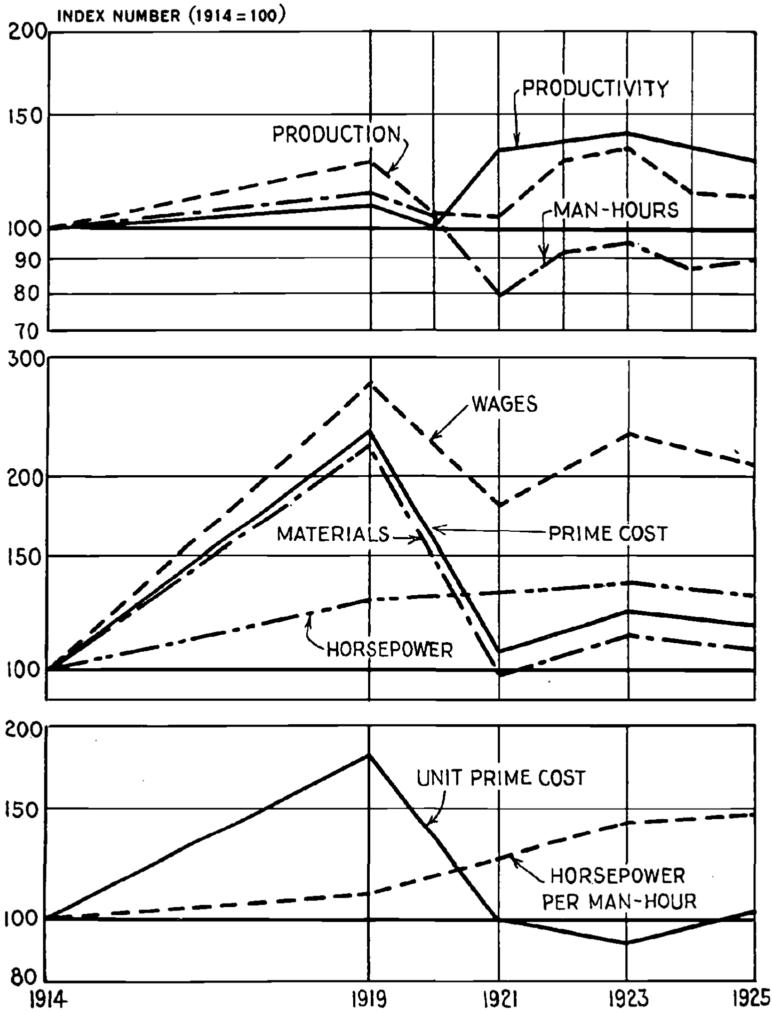
Year	Physical production	Man-hours	Productivity per man-hour	Wages paid	Cost of materials	Prime cost	Primary power	Primary power per man-hour	Unit prime cost
1914	100	100	100	100	100	100	100	100	100
1919	131	141	92	337	262	266	142	101	203
1921	122	102	119	246	129	135	...	...	111
1922	133	107	125	...	...	...	...	...	...
1923	153	120	128	270	151	157	151	126	103
1924	152	117	130	...	...	...	...	...	...
1925	139	109	127	257	182	186	175	161	134

Leather Tanning.—The record of the leather tanning industry is quite similar to that for flour milling, as shown by the data of Table 23. Production which increased up to 1923 decreased from that date through 1925. (See Chart 25). Primary power which had increased continuously up to 1923 decreased through 1925. The change in the number of man-hours worked has been irregular, with the 1925 figure lower than in 1914. Productivity reached its highest level in 1923 and decreased slightly after that date. Unit prime cost began to decrease in 1919 with little change after 1921.

TABLE 23.—INDEX NUMBERS OF PRODUCTION FACTORS OF LEATHER TANNING INDUSTRY, 1914–1925

Year	Physical production	Man-hours	Productivity per man-hour	Wages paid	Cost of materials	Prime cost	Primary power	Primary power per man-hour	Unit prime cost
1914	100	100	100	100	100	100	100	100	100
1919	127	115	110	276	227	232	127	110	183
1920	106	104	101	...	...	...	...	...	...
1921	105	79	133	181	98	106	...	...	101
1922	127	93	136	...	...	...	...	...	...
1923	134	96	140	231	113	125	135	141	93
1924	115	86	134	...	...	...	...	...	...
1925	114	89	128	209	108	118	130	146	104

CHART 25.—FLUCTUATIONS OF PRODUCTION FACTORS OF THE LEATHER TANNING INDUSTRY



Cane Sugar Refining.—Of the major factors, production, primary power utilized, and productivity, have increased. The number of man-hours worked has decreased steadily from 1919 on, and unit prime cost has also decreased, a decided drop occurring between 1919 and 1925. (See Table 24 and Chart 26).

CHART 26.—FLUCTUATIONS OF PRODUCTION FACTORS OF THE CANE SUGAR REFINING INDUSTRY

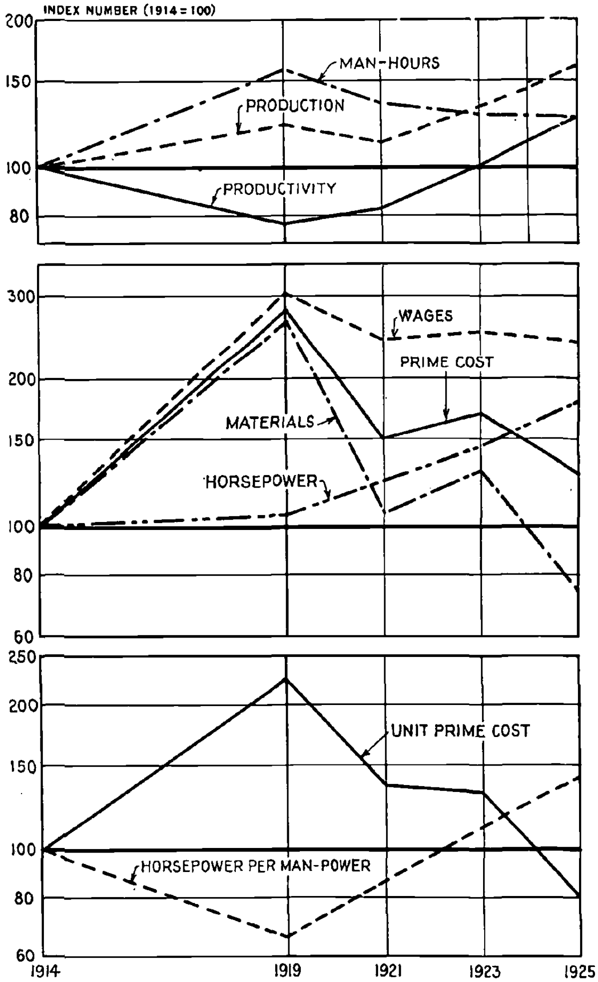
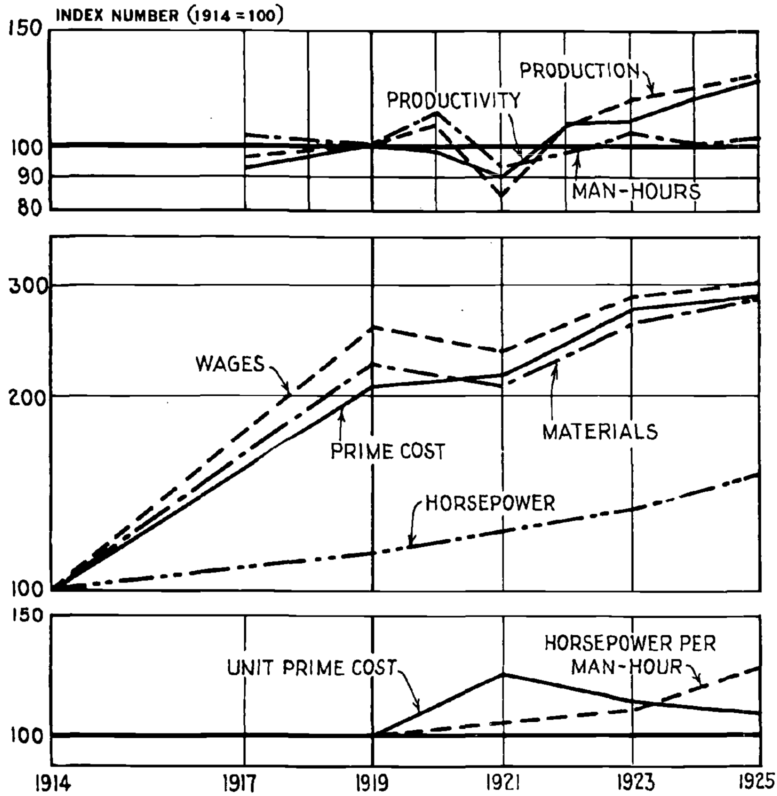


TABLE 24.—INDEX NUMBERS OF PRODUCTION FACTORS OF CANE SUGAR REFINING INDUSTRY, 1914–1925

Year	Physical production	Man-hours	Productivity per man-hour	Wages paid	Cost of materials	Prime cost	Primary power	Primary power per man-hour	Unit prime cost
1914	100	100	100	100	100	100	100	100	100
1919	123	158	78	290	277	281	106	67	228
1921	112	137	82	248	106	153	...	...	137
1923	131	129	101	256	131	173	146	113	132
1924	143	127	113	...	...	...	...	...	...
1925	161	126	127	242	73	128	179	142	79

Paper and Wood Pulp.—The data for production, man-hours, and productivity for this industry do not extend back beyond 1917, and are so shown in Table 25. Data for the other factors are given from 1914 to date. Production has had an irregular record since 1919, with 1921 as the low point, from which time there has been a steady increase. Man-

CHART 27.—FLUCTUATIONS OF PRODUCTION FACTORS OF THE PAPER AND WOOD PULP INDUSTRY



hours have also been irregular, with a tendency to decrease since 1923. The resulting factor, productivity per man-hour, decreased from 1919 to 1921 and then has irregularly increased to 1925. Primary power has steadily increased in amount and utilization, the plotted curve in Chart 27 being nearly a straight line. Unit prime cost increased sharply from 1919 to 1921 and decreased thereafter, the 1925 point, however, being higher than the corresponding value for 1919.

TABLE 25.—INDEX NUMBERS OF PRODUCTION FACTORS OF PAPER AND WOOD PULP INDUSTRY, 1914–1925

Year	Physical Production	Man-hours	Productivity per man-hour	Wages paid	Cost of materials	Prime cost	Primary power	Primary power per man-hour	Unit prime cost
1914	...	...	...	[a]100	[a]100	[a]100	87	...	...
1917	96	103	94	...	...	...	...	...	...
1918	98	101	98	...	...	...	...	...	...
1919	[a]100	[a]100	[a]100	254	220	206	[a]100	[a]100	[a]100
1920	118	119	99	...	...	...	...	...	...
1921	84	93	90	238	209	215	...	...	125
1922	106	97	109	...	...	...	...	...	...
1923	117	106	110	284	259	272	117	110	114
1924	122	102	120	...	...	...	...	...	...
1925	129	103	126	301	284	288	131	128	108

[a] Base year.

Boots and Shoes.—The boot and shoe industry has the smallest increase in productivity of the product groups studied in this report. From 1914 to 1925 production has been irregular, with an over-all increase of only 10 per cent. (See Table 26). Primary power has increased at a

CHART 28.—FLUCTUATIONS OF PRODUCTION FACTORS OF THE BOOT AND SHOE INDUSTRY

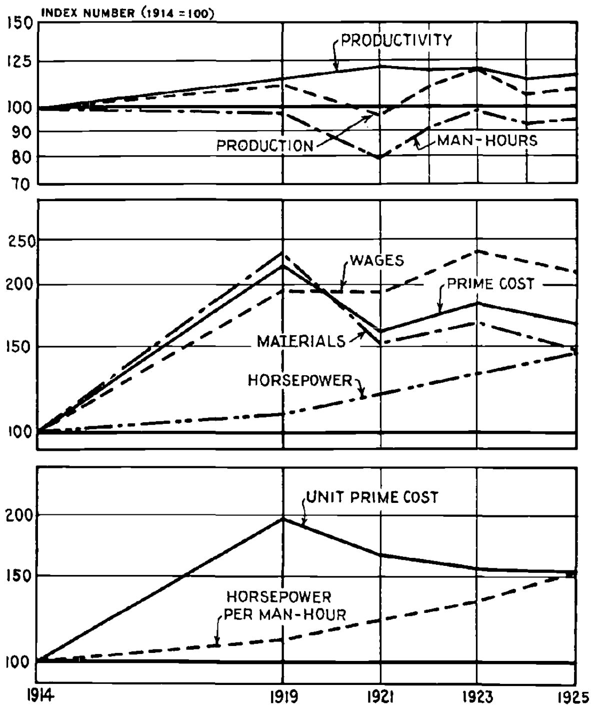


TABLE 26.—INDEX NUMBERS OF PRODUCTION FACTORS OF BOOT AND SHOE INDUSTRY, 1914–1925

Year	Physical production	Man-hours	Productivity per man-hour	Wages paid	Cost of materials	Primary cost	Prime power	Primary power per man-hour	Unit prime cost
1914	100	100	100	100	100	100	100	100	100
1919	113	99	115	198	230	222	110	112	196
1921	98	80	123	194	154	164	...	...	167
1922	111	91	121	...	...	...	...	...	...
1923	120	99	121	237	173	187	134	135	156
1924	107	93	115	...	...	...	...	...	...
1925	110	95	117	213	150	170	146	154	154

TABLE 27.—INDEX NUMBERS OF PRODUCTIVITY PER MAN-HOUR FOR 12 PRODUCT GROUPS

(1914 = base year)

Year	Automobiles	Rubber tires	Petroleum refining	Cement manufacture	Blast furnaces	Steel wks. and rolling mills
1914	100	100	100	100	100	100
1917	...	...	...	...	...	...
1918	...	...	...	...	...	...
1919	141	130	92	102	95	101
1920	133	...	...	...	...	...
1921	215	190	108	121	110	93
1922	264	...	122	...	...	...
1923	295	266	129	130	154	138
1924	289	301	158	141	...	...
1925	310	311	177	158	[a]	[b]160

Year	Flour milling	Slaughtering and meat packing	Leather tanning	Cane sugar refining	Paper and wood pulp	Boots and shoes
1914	100	100	100	100	...	100
1917	...	...	...	...	94	...
1918	...	...	...	...	98	...
1919	95	92	110	78	[c]100	115
1920	...	...	101	...	99	...
1921	120	119	133	82	90	123
1922	...	125	136	...	109	121
1923	126	128	140	101	110	121
1924	133	130	134	113	120	115
1925	139	127	128	127	126	117

[a] Figure included in 1925 figure for steel works and rolling mills.
[b] Includes figure for 1925 for blast furnaces.
[c] Base year for paper and wood pulp industries.

nearly uniform rate. The number of man-hours worked has been irregular with the largest number in recent years in 1923, and a decrease from that date to 1925. Productivity has been irregular, with the highest value in 1921, and has progressively decreased through 1924. The curve of unit prime cost in Chart 28, from 1919 on, has been irregular, with a tendency downward.

The industries in this second class show, in respect to the changes in major production factors, a record very different from those included in the first class. Not only are the levels of attainment lower but the changes are irregular and advantageous trends are not so pronounced.

In general, there has been some increase in production and each has shown a slight increase in productivity. Table 27 gives a comparison of productivity per man-hour for the 12 industries in the two classes discussed in the preceding pages. Not all have shown an increase in the utilization of primary power; in fact, several show actual decreases. There has been a decrease in the number of man-hours worked from 1919 on. As regards unit prime cost, all but one show a decrease from 1919, although few of the decreases are large in percentage, and several of them do not become evident until 1923.

To place the operating records of these product groups more sharply in comparison, Table 28 has been prepared. It gives the over-all percentage change, computed by the method of least squares, for the three unit factors—productivity per man-hour, primary power per man-hour, and unit prime cost—for each of the 12 product groups.

TABLE 28.—COMPARISONS OF OVER-ALL PERCENTAGE CHANGES IN THREE UNIT PRODUCTION FACTORS FOR 12 PRODUCT GROUPS

(Computed by method of least squares)

Industry	Over-all percentage changes, 1919–1925		
	Productivity per man-hour (per cent increase)	Primary power per man-hour[a] (per cent increase)	Unit prime cost (per cent decrease)
Automobiles	139	41	56.5
Rubber tires	142	...	...
Petroleum refining	[a]93	57	29
Cement manufacture	52	39	29
Blast furnaces	[b]66	[b]32	18
Steel works and rolling mills	[b]40	[b]20	20
Flour milling	42	20	38
Slaughtering and meat packing	34	59	38
Leather tanning	24	33	47
Cane sugar refining	69	112	64
Paper and wood pulp	32	28	[c]3.6
Boots and shoes	1	38	22

[a] Percentages calculated from terminal values.
[b] Percentage change from 1919 to 1923.
[c] Increase.

IV. SUMMARY

This report presents the results of a study into certain technical changes that have occurred in the operation of manufacturing industries during the past decade.

The recent turning point in the more economical utilization of production factors seems to have taken place about 1919–20. For many of them, and for a number of product groups, this favorable change has continued through the year 1925, the last for which national statistics are available. Among these trends are:

An increase in physical volume of product.

An increase in productivity of the individual worker or of the man-hour worked.

An increase in primary power utilized both in total volume and in amount per employee.

An increase in the total amount, and also in the proportion, of horse power for industrial purposes which is purchased instead of being self-produced.

A decrease in the number of workers employed.

An increase in fixed capital assets, that is, in manufacturing buildings, equipment, and machinery.

A decrease in unit prime cost.

An increase in the attention given, resources available, and funds spent for industrial research.

Increase in the development of new manufacturing materials.

Increase in the development of new manufacturing processes.

Increase in the efficiency of power-generating machinery.

Increase in material-handling machinery utilized, both to reduce the cost of transporting materials and product and to act as a pace-maker for the speed of production.

Reduction in wastage of manufacturing materials and the reclaiming of former waste products through the development of by-products.

Increase in safety of industrial establishments, with safeguarding carried to such a degree that the greater number of industrial accidents are now attributable to supervisory failure, not to a physical cause.

Increase in the extent, degree, and quality of artificial illumination.

Improvement in working surroundings and in those physical conditions that can be modified by technological means.

However, the degree of improvement in the utilization of production factors differs in various industries. Only a limited number of product groups have been studied but these fall into two classes—the first commonly looked upon as prosperous, and many of the second as notoriously in trouble and beset with economic and business difficulties.

A comparison of the records of these two groups shows that the second has not made the same increases in the utilization of production factors as the first. This fact seems to point to the place where improvement may be initiated.