BY MURRAY F. FOSS

The Utilization of Capital Equipment:

Postwar Compared With Prewar

INCREASES in output per unit of input over the long run have been attributed to many factors, such as the increased skill and education of labor, the increase in management knowledge, and the greater efficiency of new and existing machines resulting from technological and scientific advances. One element of importance which is related in part to some of the above factors has been the more intensive utilization of capital equipment in the postwar period as compared with prewar. This article is concerned with the measurement and significance of changes in hours worked by machinery and equipment in some major sectors of the American economy over this period.

This particular problem has received relatively little attention as a subject for serious investigation.[1] The topic is of particular interest at present in view of the recent appearance of major theoretical and statistical studies in this general area. The analysis and results in this article should be viewed as exploratory in character since at this time the basic data required for a definitive study are rather limited.

Most of this study deals with hours worked per annum by equipment in manufacturing, in particular, with changes from 1929 to the mid-1950's. It finds that for the bulk of equipment in this important industry division there has been an increase on the order of one-third to one-half in the utilization rate over this period. No attempt has been made to present similar estimates for the entire stock of fixed capital although the manufacturing experience is by no means unique: the upward shift in equipment utilization has appeared in other industries which have been examined, whether or not their capital stock is growing or declining.

An average unit of generating equipment in electric utilities in the mid-1950's worked about 60 percent more hours per year than in the decade of the 1920's. In mining, exclusive of petroleum, an average unit of machinery driven by electric motors worked about one-fifth more hours in 1955–57 than in 1929. While there has been no change in relative freight car use over this period, each locomotive in freight service is working about 20 percent more hours, and locomotives in passenger service, which have undergone a drastic decline in numbers, are working about two-thirds more hours per unit per year than they did in the 1920's. In general, the shift away from railroads toward trucking and pipelines has been one in which capital is used with greater intensity.

A comparison of the 1920's, particularly 1929, with the mid-1950's is considered to be a valid one in analyzing long-run changes; both were periods of high output and high relative resource utilization. To the extent that 1929 may differ from 1955 for cyclical reasons, however, some of the long-run change in equipment hours presented here may be overstated.

It has not been possible to demonstrate why these increases in relative equipment use have come about or to quantify the factors underlying the apparent changes, but a few reasons can at least be suggested. For one thing, there has been a definite tendency toward multiple-shift operations[2]—a development that may have been stimulated to some extent by the premium-pay-for-overtime provisions instituted by the Fair Labor Standards Act of 1938 and even by the NRA. The World War II experience must have constituted a powerful stimulus to multiple shifting and it is reasonable to assume that the experience acquired by many firms during the war with two- and three-shift operations was carried over into the postwar years of high-level demand. In fact, some of the illustrations used in this article suggest that the major change in relative equipment utilization took place during and immediately after World War II, and that changes since then (aside from cyclical movements) have been relatively small.

Also of importance over the long-run has been the advance in knowledge acquired by management in making more efficient use of machines. One example of this has been the efforts by many firms to smooth out within the year the production peaks which come from seasonal or other short-lived peak loads and which frequently entail the use of standby equipment with relatively low annual utilization. The success of the electric utilities in making more intensive use of capacity needed for peak loads—referred to further on—has been outstanding. Moreover, it is probably safe to say that over the long run, there has been a relative reduction in "downtime" for equipment repairs. The diesel locomotive is an excellent example of an innovation that has been successful in no small measure because

1. See Robert M. Solow, "Technical Change and the Aggregate Production Function," *Review of Economics and Statistics*, August 1957; Edward F. Denison, "The Sources of Economic Growth in the United States" (Committee for Economic Development 1962) p. 97. Charles L. Schultze in "Some Effects of Changes in Working Hours on Investment, Output and Real Wages," a paper presented in September 1956 at the American Statistical Association meetings in Detroit, dealt with this problem mainly in terms of changes in multiple-shifting since the turn of the century.

2. As suggested, for example, by William Fellner in *Trends and Cycles in Economic Activity*, New York, 1956, page 92.

it has required relatively less time-out for repairs and has thus increased the available working time for locomotives.

Within particular industries there have undoubtedly been efforts to introduce continuous, automatic operations in which machines tend to be used with a high degree of intensity. Moreover, there has probably been a change in product mix toward industries in which continuous operations are important—aluminum, refined petroleum, chemicals, and electric power are important examples that may be cited.

Significance of findings

What significance can be attached to the increase in hours worked by equipment? First of all, it is important to keep in mind a few of the major findings that have emerged from recent studies of productivity and economic growth. Total output, it has been found, has risen at a faster rate than has the weighted total of factor inputs.[3] Although measured in various ways, in all cases this residual portion of growth—in "total factor productivity" or output per unit of input—has been very substantial and a quantitative explanation of the many and varied sources which may account for it is difficult.[4] Furthermore, as it has been measured in the framework of such studies, the contribution of the growth of fixed capital to the increase in total output has been found to be of relatively small magnitude.

Against this background, a rise in equipment hours per year from prewar to postwar may be viewed in two ways. On the one hand, it might signify that the contribution of fixed capital to long-run output growth is greater (and productivity correspondingly less) than has been calculated in previous investigations. This is because characteristically the changes in the input of fixed capital have been measured by the real volume of capital in place, without adjustment for changes in intensity of use.

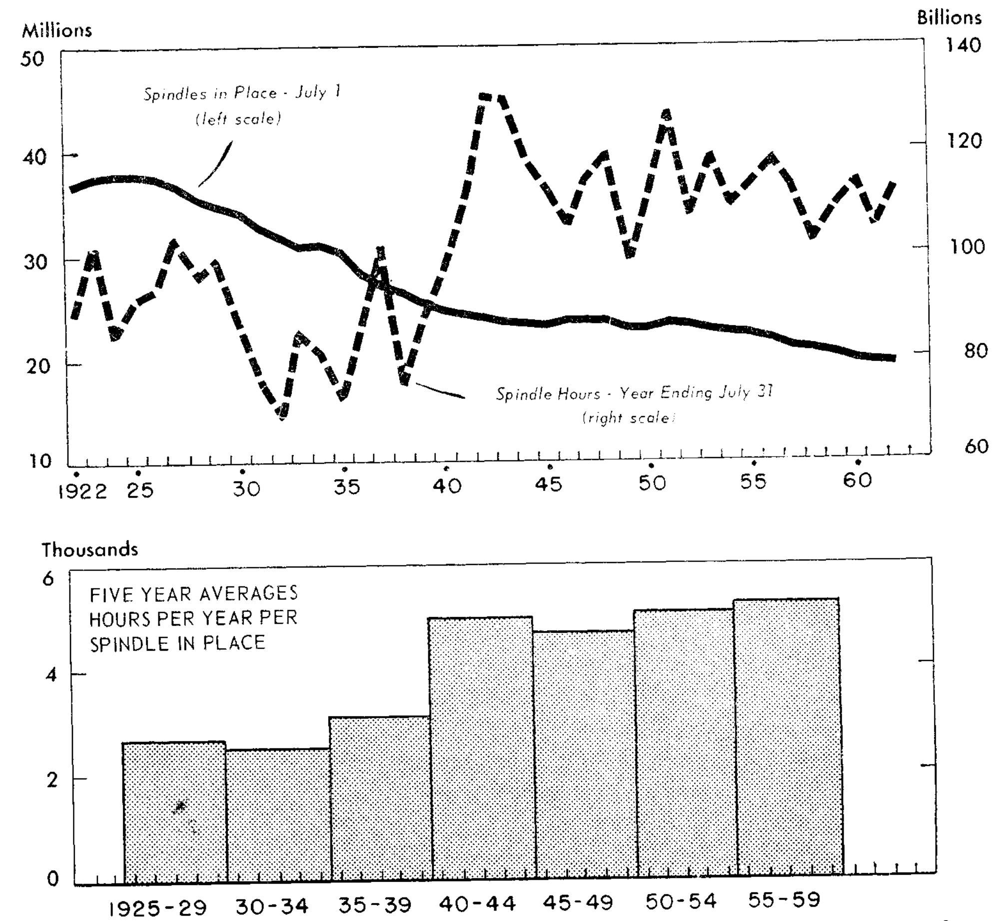
An adjustment for capital's contribution, due to increased equipment-hours worked per year, would be analogous to the adjustment of the labor input—number of persons employed—for changes in labor-hours per year. Possibly not all of the increased equipment-hours should be so handled but that part attributable to the advance in multiple-shift operations would seem to warrant such treatment.

According to the second view, the advance in hours worked by equipment should not be considered as an increase in the input of capital, which is better measured by capital in place. Instead, it should be looked at as the result (measurable in part) of certain forces that have contributed to a rise in total factor productivity over time: the advances in management efficiency, for example, that have grown out of the experience gained from working with machinery, and from engineering studies within the plant; and the gains from science and research as "embodied" in new machines of advanced technology. It may be that the first of these elements—the "advance in management knowledge"—bulks large as an explanatory factor in the increase in equipment hours since one of the focal points of management has been the reduction of idle equipment time. But increased management knowledge provides only part of the answer since it is likely that many of the new technologies incorporated in modern machinery go hand in hand with longer hours for equipment; this seems to be a distinguishing characteristic of many new processes that are labeled "continuous."

With capital input measured by stock of capital in place, a lengthening of

COTTON SPINDLES

Long Run Decline in Spindles in Place
Rise in Total Spindle Hours Since the 1920's Reflects Step-Up in Annual Hours Per Spindle



Basic data: Census

U.S. Department of Commerce, Office of Business Economics 63-6-4

3. See, for example, John W. Kendrick, "Productivity Trends in the United States," National Bureau of Economic Research, Princeton, 1961.

4. See Denison's study for a comprehensive analysis of the sources of U.S. growth.

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equipment hours per year is clearly a development of a capital-saving nature. In this connection, this shift may be a partial explanation for the observed decline in capital-output ratios from 1929 to 1955.

The pages that follow discuss in detail the basic data used to demonstrate changes in equipment hours per year in manufacturing and mining, and in a few other industries for which statistics pertaining to some important types of equipment were readily available.

Manufacturing

Labor hours of work per year have shown a fairly steady decline since the latter part of the 19th century; from 1909 to 1957 they declined from about 2,700 hours per annum to less than 2,100 hours. In manufacturing they fell from 44 to 40 per week from the 1920's to date. But hours of labor do not necessarily provide a reliable indication of machinery-hours. In principle, a 40-hour week for labor can be consistent with 40, 80, or 120 hours a week for a machine, depending on whether 1, 2, or 3, 40-hour shifts are employed.

To illustrate the use of machine-hours data, we can look at the cotton textile industry, from which the Bureau of the Census has been collecting monthly statistics on the number of cotton spinning spindles in place and the number of spindle-hours operated for approximately the past 40 years. For this type of equipment there was a 37 percent decline in the number of spindles in place from 1929 to 1956, but an 88 percent increase in hours worked per spindle in place and thus an 18 percent increase in the total number of spindle-hours worked. The basic trends are illustrated in the chart on page 9.

As a practical matter, a long-term series on capacity utilization, in which shift operations, down-time and product-mix changes were treated on a consistent basis, might serve as an index of equipment hours over time, but such figures are lacking though recently several capacity-use series for the postwar period have been published for manufacturing. It should be kept in mind that statistical measures of capacity utilization and of equipment utilization are not necessarily identical. An equipment utilization measure should merely reflect changes in hours per machine and should be independent of the complications which may possibly be introduced by changes over time in output per machine-hour.

Electric motors and electric power consumption

Although comprehensive data on machine hours for overall manufacturing are lacking, there is a body of statistics for manufacturing and mining which may yield what is needed, namely, the statistics on power equipment and on electricity consumption from the Census of Manufactures and the Census of Mineral Industries. Very briefly, the statistics provide the basis for estimates of hours worked by electric motors and thus hours worked by machinery driven by such motors, which have been the dominant source of power in American industry for many years.

For the years 1939 and 1954 Census statistics are available for each industry on the number and aggregate horsepower of electric motors in place at the end of each year; also given is aggregate electric power consumption—for all purposes—within the year, measured in kilowatt-hours. Statistics on horsepower of electric motors in place have also been published for 1929 but the electric power consumption on a detailed industry basis is confined to purchased power, as distinct from power generated in the manufacturing plant. Overall estimates of total power consumption in manufacturing, with a breakdown by broad industrial groups are obtainable, however, from other sources.

Attention is focused on electric motors because of the dominant position of such equipment as a source of work in American manufacturing industry. By 1929, according to the Census Bureau, electric motors accounted for some 80 percent of all mechanical work done in factories. The remaining 20 percent was accounted for by "prime movers" such as steam engines and turbines, gasoline engines and water wheels—which were directly connected to machines. By 1954 the electric motor ratio had risen to approximately 88 percent. If we can find out how intensively the motors were worked we should have an approximation of the intensity with which the machinery driven by the motors has been operated.

Electricity is consumed in factories for four major purposes: (1) for lighting, (2) for driving motors, (3) as a raw material in electro-chemical processes such as primary aluminum manufacturing, (4) for heating, as in heat-treatment furnaces. There are other miscellaneous uses such as welding, hand tools, measuring instruments, etc., which in aggregate are much less important than any of those shown above.

While a breakdown of power consumption in these uses for the years 1929, 1939, and 1954 is lacking, the

Table 1.—Industrial Electric Power: Distribution of Electric Energy by Major Uses, by Industry, 1945

Industry	Lighting	Motors	Electrolytic cells	Electric furnace	Other
	Manufacturing				
Food	10.6	87.3	1.6	(*)	0.5
Tobacco	14.8	84.3	.3	--------	.6
Textiles	9.8	89.4	(*)	0.2	.6
Apparel	34.3	64.6	--------	--------	1.1
Lumber	12.3	85.4	(*)	--------	2.2
Furniture	12.2	85.8	(*)	.3	1.8
Paper	3.9	93.1	2.2	.2	.6
Printing and publishing	20.2	75.0	.5	2.1	2.3
Chemicals	4.5	44.7	21.9	27.9	1.0
Petroleum and coal	5.6	93.7	(*)	(*)	.7
Rubber	12.1	87.5	(*)	.2	.2
Leather	15.2	84.1	(*)	.1	.6
Stone, clay, and glass	6.2	88.0	.1	4.4	1.3
Iron and steel	7.2	72.0	.4	18.7	1.7
Nonferrous metals	2.5	20.2	61.3	14.6	1.3
Electrical machinery	19.0	42.6	1.9	30.1	6.4
Machinery	19.8	59.2	.5	14.3	6.2
Automobiles	19.4	68.0	.2	7.3	5.1
Transportation equipment	27.0	46.6	.2	9.4	16.7
Miscellaneous products	18.4	73.0	.2	5.1	3.2
	Extracting				
Metal mining	2.8	96.6	(*)	(*)	0.5
Coal mining	4.2	92.1	0.2	(*)	3.5
Nonmetallic mining	4.7	95.0	--------	(*)	.3
Petroleum and natural gas	8.1	90.1	.1	--------	1.6

*Negligible amount, less than 0.05%.

Source: Taken from Federal Power Commission, "Industrial Electric Power in the United States, 1939-46" (F.P.C. S-46, Table II, p. X1).

Federal Power Commission conducted a fairly comprehensive survey covering the year 1945, which provides such a breakdown on a 2-digit industry basis. This study, combined with the Census data on motors in place and aggregate power consumed in each industry, provides the basic information for manufacturing. The statistics from the FPC study are shown in table 1.

The figures for a single year—1954—are considered first by way of background, although the main emphasis of this article is on change rather than on level. These calculations indicate that an average unit of electric-motor-driven machinery, measured by horsepower, was operated about 35 hours a week in that year. The computations used to derive this result are shown in the right-hand column of table 2.

Given the horsepower of electric motors in place at the end of 1954 (line 1), the first step was to assume that each electric motor could work continuously throughout the year—that is, 8,760 hours; this number times horsepower of motors in place gives total horsepower-hours of motors available in a year (line 2). The fact that such a theoretical maximum could never be attained in practice is irrelevant for the purpose at hand. Horsepower-hours were then converted to kilowatt-hours; in work measurement, 1 horsepower-hour =0.746 kilowatt-hours. The results of these calculations were adjusted upward by dividing through by 0.9, since modern electric motors have an efficiency of approximately 90 percent, that is, about 10 percent of power input into the motor is dissipated in the form of heat.[5] These calculations (line 3) give a theoretical maximum per year, measured in kilowatt-hours, against which actual kilowatt-hours of electricity consumed can be measured.

The proportion of power used for electric motors in all manufacturing (line 5) was then derived by applying the 1945 proportions of power for electric motor use, as given in table 1, to total power consumed in 1954 in each 2-digit industry, as shown in the Census of Manufactures. From this procedure, it was found that electric motors accounted for 64.6 percent of total power consumption in manufacturing in 1954, or 142.7 billion kilowatt-hours. Dividing this total by kilowatt-hours of motors in place in 1954—assuming year-round operation—indicates a utilization rate of 20.9 percent. This is the equivalent of 0.88 forty-hour shifts—since there are 4.2 forty-hour shifts in a full week of 168 hours.

5. The adjustment could also have been made by reducing the power consumption (see below) by 10 percent.

Table 2.—Horsepower of Electric Motors, Power Consumption by Electric Motors, and Relative Utilization of Motors, Manufacturing, 1929, 1939, and 1954

	Unit	1929	1939	1954
(1) Horsepower of electric motors, total	Thousand horsepower	33,844	44,827	94,116
(2) Horsepower hours assuming year-round operation (line (1)×8,760).	Millions	296,473	392,685	824,456
(3) Kilowatt-hours of motors (line 2×0.746)÷0.9 [1]	Billions of kilowatt-hours	245.8	325.4	683.3
(4) Electric power actually consumed, all purposes	Billions of kilowatt-hours	55.1	70.5	221.1
(5) Percent of power used for electric motors		71.1	70.1	64.6
(6) Power consumed by motors (line 4×line 5)	Billions of kilowatt-hours	39.2	49.4	142.7
(7) Percent utilization (line 6÷line 3) × 100		15.9	15.2	20.9
(8) Number of equivalent 40-hour weeks (line 7×4.2)÷100		.668	.638	.878

1. The 0.9 adjustment was made to take account of the efficiency of electric motors and thus provide comparability with the power consumption data.

Sources: (1) Table 1. Horsepower of Power Equipment Used in Manufacturing Industries: 1954 and Earlier Years, Bureau of the Census, *1954 Census of Manufactures*, Volume I, Summary Statistics, p. 207-2.

The 1954 horsepower figure includes an upward adjustment of 2½ percent to allow for fractional horsepower motors, which had been included in the earlier years but omitted from the 1954 Census. The Census had characterized this omission as "insignificant" for the overall totals. The 2½ percent figure was based on a British Census of Manufactures for 1951 which showed fractional horsepower motors to represent 2.4 percent of all electric motors, measured in horsepower.

(4) 1939 and 1954—Table IA. Fuels and Electric Energy Used in the Manufacturing Industries: 1954 and Earlier Years. *1954 Census of Manufactures*, Vol. I, p. 208-3. The 1954 Census total (247.7) was reduced by consumption of electric power for nuclear energy (=26.6 billion) as shown in Series S81-93 of Bureau of the Census, *Historical Statistics of the United States, Colonial Times to 1957*, p. 511. The 1929 total for manufacturing is taken from this latter table.

Stock of capital is characteristically measured in constant dollars and in combining the utilization rates for industries, or for different machines within a plant, or plants within an industry, constant dollar weights should be used rather than horsepower. Horsepower may be justified as a basis for weighting, however, on the ground that there is probably a fairly good positive correlation between the horsepower of a machine and its dollar cost. In this paper no attempt was made to combine industries conceptually more appropriate through the constant dollar weights.

Cross-sectional results

Similar calculations were also run for each of the 4-digit industries shown in the 1954 Census of Manufactures. In doing this, we were limited by the data shown in table 1, so that it was necessary to use 2-digit industry factors on power consumed by motors for all 4-digit industries within a given 2-digit group. While this procedure introduced an element of error, the broad cross-sectional results are nonetheless of interest. If the figures have any significance at all, they should yield percentages well under 100—or 4.2 40-hour shifts—and should not exceed these maximum limits. Out of almost 400 industries for which calculations could be made for the year 1954, there were almost no industries in which completely impossible results were obtained from this simple calculation. The exceptional cases included primary aluminum, for example, where electricity is used as a raw material in an electrochemical process, and where a small error in the motor ratio could seriously bias the results. There was only one small industry which could not be explained in this fashion.

In the mild recession year of 1954, the unweighted average number of 40-hour shifts for 397 industries turned out to be 0.90, or 36 hours per week. For durables, the ratio was 0.74 (30 hours), while for nondurable goods industries the ratio was 1.12 (45 hours). Partly this difference reflects the fact that durable goods were relatively depressed in 1954, and partly the fact that in nondurables continuous operations are more common than in durables. Relatively higher ratios were obtained for industries like petroleum, paper, cement, glass, cotton and rayon textiles, and hosiery, and relatively low ratios for the metal fabricating and machinery industries generally, which characteristically work far below full operations, and for seasonal industries such as fruit and vegetable canning.

Changes over time

The measurement of the change in the utilization rate over time poses many difficulties. The earliest manufacturing figures refer to the year 1929. In that year the Census of Manufactures collected figures on horsepower of electric motors by detailed industry and type of motor (using purchased as against plant produced power). The information on power consumption, as noted earlier, was limited to purchased power only, that is, statistics were not collected on electric power produced and consumed in each industry. However, for many years the Federal Power Commission has obtained from industrial concerns reports on power produced by the plants themselves. These reports, plus the Census data, provided the basis for an estimate by FPC of power consumed for all manufacturing plants, together with a breakdown into three broad groups consuming large amounts of power: chemicals and paper; primary metals; and all other manufacturing.[6]

Within each of these groups a weighted percentage of power used for motors was obtained. For this calculation the percentages used were those for 2-digit industries shown in table 1. The weights used to combine industries were estimated total power consumption by 2-digit industry. To obtain estimates of total power consumed in each 2-digit industry the assumption was made that power consumed by motors run by plant-produced power stood in the same ratio to the horsepower of such motors as purchased power was relative to motors run by purchased power. It is not likely that a serious error has been introduced into the 1929 figures by the weighting procedure.

The summary figures for manufacturing for 1929, 1939 and 1954 are shown in table 2. It may be noted on line 5 that the proportion of total power devoted to motors was less in 1954 than in either 1929 or 1939. This is because the motor ratio is smaller in durable goods manufacturing than in nondurables, and because durables were higher relative to nondurables in 1954 than in either 1929 or 1939.

6. The estimates are shown in *Historical Statistics of the United States, Colonial Times to 1957* (p. 511).

The utilization figure (either line 7 or 8) is markedly higher in 1954 than in either of the other 2 years: the 1954 ratio is 31 percent above 1929 and 38 percent above 1939. However, since 1954 was a recession year it is appropriate in any comparison with 1929 to extend the calculations to the year 1955, which was one of relatively full employment. The year 1929 was clearly one of very high output for manufacturing even though output started

Table 3.—Electric Motors, Power Consumption and Utilization Rate, All Manufacturing Industries Excluding Primary Metals, Chemicals, and Paper

	Unit	1929	1954
(1) Horsepower of electric motors.	Millions of horsepower.	20.9	52.1
(2) Kw.-hr. of motors available.[1]	Billions of kilowatt-hours.	151.7	378.2
(3) Total electric power consumed.	----do----	26.6	97.1
(4) Percent of total power consumed by motors.	Percent	80.6	76.8
(5) Power consumed by motors.	Billions of kilowatt-hours.	21.4	74.6
(6) Percent utilization (5)÷(2).	Percent	14.1	19.7
(7) Equivalent 40-hour weeks.		.59	.83

1. Includes constant adjustment for motor efficiency. See footnote (1) of table 2.

Source: U.S. Department of Commerce, Office of Business Economics.

to move down in the second half of the year. Some reduction in capacity utilization was beginning to develop in 1929 although, according to The Brookings Institution, output for the year as a whole was estimated to be approximately 83 percent of "practical capacity"—a figure considered to be relatively high.[7]

Through the use of power consumption data for 1955 by 2-digit industries from the *Annual Survey of Manufactures* and the motor percentages shown in table 1, the overall change in power consumed by motors from 1954 to 1955 was estimated to be 12 percent. For a rough approximation of the change in motors in place from 1954 to 1955 the change in real net stocks of equipment in manufacturing was used—2.2 percent. This yielded a 9½ percent rise in the utilization rate—a figure that compares with a rise of 8½ percent as shown in the FRB capacity utilization index from 1954 to 1955. Thus the equipment utilization ratio from 1929 to an approximately comparable high employment year in the 1950's shows an increase of almost 45 percent.

7. The Brookings Institution, "America's Capacity to Produce," pp. 307–9.

Some partial checks of the overall results

In considering the overall changes shown in table 2, the 1939–1954 change is not unexpected insofar as 1939 was still a depression year while 1954 was a year of high output, despite the minor recession. On the other hand, the small difference between 1939 and 1929 comes as something of a surprise because 1929 was a year of generally high activity.

A limited check of the 1929–39 change, by individual industries, was conducted, in which attention was confined to those industries in which motors driven by purchased power in 1929 accounted for two-thirds or more of the total horsepower of all motors. By considering only motors run mainly by purchased power (and the corresponding consumption of purchased power) much of the error that might have crept into the 1929 estimates due to the possibly faulty estimation of power generated by plants for their own use should be eliminated.

There were 131 industries which had not changed in definition and which could thus be directly compared; for these there was a very slight increase in

Table 4.—Capacity utilization ratios, selected industries, 1929, 1939 and 1954

	1929	1939	1954
Steel ingots and castings	89	65	71
Refined copper, electrolytic	95	66	79
Cement	67	47	94
Paper	81	82	91
Flour milling, wheat	57	59	67
Cotton textiles	33	40	59
Woolen and worsted	19	24	32
Petroleum refining	78	82	88

Note: Because capacity in this table has been figured on differing bases, comparisons should be made only within industries over time and not among industries at a given point in time.

Steel, cement, paper, flour milling, and petroleum are from published trade sources. The flour milling reflects an adjustment to a 6-day basis for 1954, to provide comparability with 1929 and 1939. The paper figure reflects a 310 day year, which is the so-called "historical" basis for calculating capacity. The cotton and wool figures were derived by the author and are based on spindle and loom hours respectively, related to around-the-clock operations throughout the year.

the 1939 utilization ratio over 1929, measured by the median change. Over the 10-year period the durable goods ratio was a little lower while the nondurables ratio was somewhat higher, and a proper weighting system would probably yield a small overall decrease, approximately in line with the aggregate change shown in table 2.

For a second check primary metals, paper and chemicals were excluded from the calculations since these industries are very large power consumers and errors in any of the 1929 estimates could bias the 1929 results. The total after these exclusions, however, yielded a change of 40 percent from 1929 to 1954, or more than the change shown by the overall manufacturing totals. Results of these calculations appear in table 3, which is partly condensed.

As another crude kind of check of the calculations presented in tables 2 and 3, the few direct measures available on capacity utilization can be examined. They show rather large declines from 1929 to 1939 in steel, cement, and refined copper but are about unchanged or somewhat higher in nondurables. About all that can be said is that they do not point to uniformly higher capacity utilization rates in 1929 as against 1939. (table 4).

The changes from 1929 to 1954 yield a clearer picture. With the exception of copper and steel, all the capacity utilization rates are higher in 1954; if the comparison were shifted from 1954 to a high-level demand period, such as 1955, the steel industry also would show a higher utilization ratio than in 1929. It is of interest to note that in the case of cotton textiles the utilization ratio derived from spindles and spindle-hours increased 41 percent from 1939 to 1954, whereas the corresponding utilization ratio derived from the electric power and motor calculations increased 34 percent.

In considering the 1929–39 comparison, it should be kept in mind that capital formation in the decade of the 1930's was extremely low; OBE estimates of the net stock of equipment in manufacturing were actually a bit lower in 1939 than in 1929, and the ratio of stocks to output was essentially unchanged over the period.

Some qualifications

In using the change in electric motor utilization as outlined in this article to measure changes in equipment utilization, the assumption has been made that there has been no change in the technical efficiency of motors over the period under consideration. According to electrical engineers, the electric motor has not changed much in this respect, mainly because its efficiency—in the neighborhood of 90 percent—was already very high even as long as a generation ago. Obviously the results would be biased if more power were required to run a motor of a given horsepower rating a given length of time today as against the 1920's. If anything, there may be a bias in the opposite direction because there has been some increase in the efficiency of very large motors.

It has also been assumed that in a given 2-digit industry the proportion of total power consumed by motors has not changed from 1929 to 1954. Aside from the few industries that are very large consumers of power—aluminum, steel and certain chemicals—the main use of electric power other than motors in manufacturing industry has traditionally been for lighting. The little evidence that bears on this point would not invalidate the above assumption. In a study made for Westinghouse Electric Corporation in 1954, the authors estimated that the lighting share of power sales made to industrial users rose moderately from 1937 to the war years and very early postwar years,

Table 5.—Electric Motors, Electric Power Consumption and Utilization Ratios, Mineral Industries [1], 1929, 1939, and 1954

	Electric motors	Available kilowatt-hours of motors [2]	Total electric power consumed	Percent used for motors	Electric power consumed by motors	Utilization ratio (5)÷(2)	Equivalent 40-hour weeks (6)×4.2
	(1) Millions of horsepower	(2) Billions	(3) Billions of kilowatt-hours	(4)	(5) Billions of kilowatt-hours	(6)	(7)
Total [1]							
1929	6.16	44.75	7.46	----------	7.04	0.157	0.66
1939	7.07	51.33	7.56	----------	7.13	.139	.58
1954	10.14	73.68	12.79	----------	12.09	.164	.69
Bituminous coal and lignite							
1929	2.83	20.57	2.51	92.1	2.31	0.112	0.47
1939	3.07	22.28	2.57	92.1	2.37	.106	.45
1954	3.78	27.49	3.76	92.1	3.46	.126	.53
Pennsylvania anthracite							
1929	0.89	6.45	0.95	92.1	0.87	0.136	0.57
1939	.91	6.64	.95	92.1	.88	.132	.55
1954	.91	6.58	.84	92.1	.77	.118	.50
Iron ore							
1929	0.32	2.31	0.48	96.6	0.46	0.199	0.84
1939	.39	2.82	.37	96.6	.36	.127	.53
1954	1.02	7.44	1.17	96.6	1.13	.152	.64
Major nonferrous ores [3]							
1929	0.88	6.39	2.47	96.6	2.39	0.373	1.57
1939	1.21	8.79	2.46	96.6	2.38	.271	1.14
1954	1.68	12.22	3.06	96.6	2.96	.242	1.02
All other [4]							
1929	1.24	9.03	1.06	95.0	1.01	0.111	0.47
1939	1.49	10.80	1.23	95.0	1.15	.106	.45
1954	2.75	19.95	3.96	95.0	3.77	.189	.79

1. Excludes crude petroleum and natural gas extraction industries.
2. Includes constant adjustment for motor efficiency. See footnote (1) of table 2.
3. Gold, silver, copper, lead, and zinc.
4. Chiefly nonmetallic minerals.

Source: U.S. Department of Commerce, Office of Business Economics.

moved back to the 1937 proportion by 1950–51 and was projected to move moderately lower over the next decade.[8] While lighting standards underwent a very marked improvement as a result of the war, it should be kept in mind that the substitution of the fluorescent lamp for the incandescent lamp, starting in the early 1940's, meant a decline of 60 percent in power consumption for a given amount of light. There are no statistics available on electricity used for lighting in manufacturing going back to 1929.

Another factor that has been ignored has been the increased use of measuring, metering and control instruments, which have grown more rapidly than machinery generally. There was no way of taking account of this development in the present calculations. Some of the larger pieces of measuring and control equipment, no doubt, have motors attached to them and to this extent would not bias the results shown here.

As noted earlier, the figures presented here take no account of machinery directly powered by internal combustion engines, steam engines and turbines, etc. In 1929 prime movers not attached to generators—that is, directly tied to factory equipment—accounted for about 20 percent of horsepower in place and by 1954 the proportion had fallen to 12 percent. The problem here is to determine the change in the utilization rate of machinery powered by sources other than electric motors. In 1954 about two-thirds of the prime movers not driving generators were in chemicals, petroleum refining and blast furnaces, steel works and rolling mills. It would probably be fair to say that the relative use of such equipment increased somewhat less than the overall rise of 31 percent from 1929 to 1954 shown for all manufacturing. In petroleum refining, where the steam turbine is predominant, the industry's operating rate, according to published data, rose from 78 percent in 1929 to 88 percent in 1954, or by 13 percent. On the other hand, in an industry like steel, equipment directly driven by steam engines in 1954 was probably of rather ancient vintage, and probably represented high-cost, stand-by equipment that saw relatively little use as compared with the modern continuous rolling mills powered by electric motors.

Finally, the calculations have ignored completely equipment such as furnaces, ovens, storage bins, furniture, hand tools, as well as transport equipment of all types.[9] To the extent that furnaces and ovens are used continuously, their relative use over time has changed only to the extent that the proportion of idle to active equipment has changed. In the case of transport equipment, hand tools, etc., it would probably be reasonable to assume that the same factors leading to more intensive use of electric motor-driven equipment—the trend to multiple shift work, the rationalization of equipment use—have been operating here. As for office furniture and related items, a rather unimportant category for manufacturing as a whole, its use has probably declined to the extent that the workweek for office workers has declined.

Other Industries

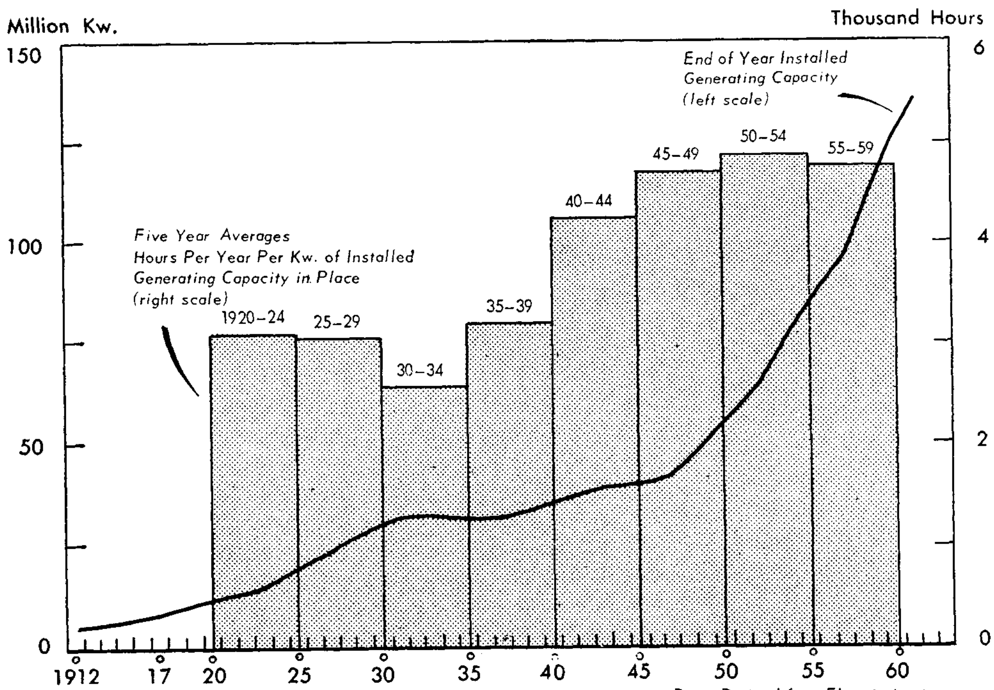
Mining

The data for mining are less comprehensive than for manufacturing. Although horsepower and electric power consumption statistics have been collected in each Census of Mineral Industries, statistics pertaining to the extraction of crude petroleum and natural gas were omitted from the 1929 Census. In addition, electric motors account for only two-thirds of the horsepower in place in mining, exclusive of petroleum and natural gas, and in the latter they are quite unimportant as a power source.

Table 5 presents the basic statistics on horsepower of electric motors and electricity consumption for all industries combined, excluding crude petroleum and natural gas, and for a few of the major industry groups for the years 1929, 1939 and 1954. According to the FPC study (table 1), about 95 percent

INSTALLED GENERATING CAPACITY OF PRIVATELY OWNED ELECTRIC UTILITIES

Annual Hours Per Unit of Installed Capacity Have Increased Since the 1920's



Data: Derived from Electric Institute

U.S. Department of Commerce, Office of Business Economics 63-6-6

8. *The Lighting Market, a Report for Westinghouse Electric Corporation, Ebasco Services, Inc.*, April 1954, p. 6.

9. In 1947 purchases of new "production machinery and equipment" represented 87 percent of all purchases of new machinery and equipment by manufacturing plants, according to the Census of Manufactures. The remaining 13 percent covered office furniture, machines and fixtures, motor vehicles, cafeteria furnishings, etc. Of course, not all "production machinery and equipment" is run by electricity.

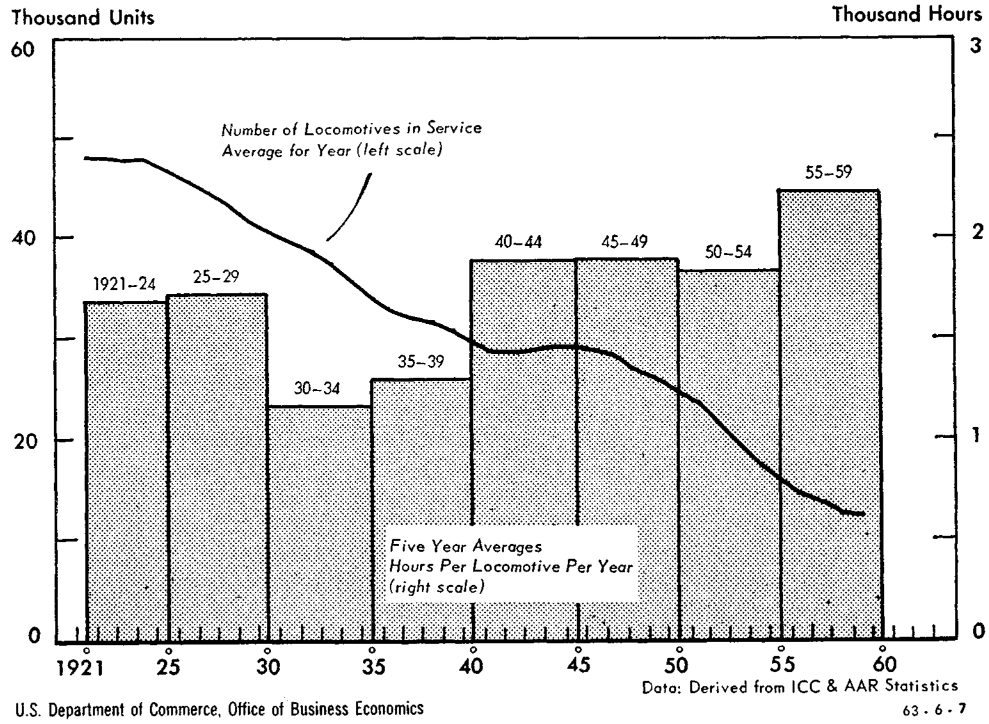
of all electricity consumed in mining is used to run motors.

For the group as a whole there was a rise in the utilization rate of only 4 percent from 1929 to 1954. Mining output, however, while comparatively high in 1929, was quite depressed in 1954 because of the recession, so that it seems quite appropriate to make some adjustment on this account. Mining output, exclusive of crude petroleum and natural gas, rose 22½ percent from 1954 to 1955–57, according to Federal Reserve data. If two-thirds of this rise were taken as a rough approximation of the increase in the relative operating rate, this would yield a 19 percent rise from 1929 to the mid-1950's. One explanation for the apparently smaller rise as compared with manufacturing is that multiple-shift operations have historically been common in many mining industries.

Electric utilities

Since electric utilities are required to furnish power to satisfy customer peak loads, generating capacity in place, which accounts for about 40 percent of gross depreciable assets of electric utilities, has characteristically been considerably in excess of average use. While the ratio of output to capacity for privately-owned utilities increased up to World War I, little progress was made during the 1920's when average usage was in the neighborhood of 3,000 hours per kilowatt of installed capacity, or about 35 percent of the 8,760 hour annual maximum. The ratio began to increase in the late 1930's until about 1948 and for the next decade fluctuated in the neighborhood of 55–58 percent.

Locomotives in Service and Average Hours Per Year, Freight and Passenger Service Combined, Class I Railroads



U.S. Department of Commerce, Office of Business Economics

An important factor in the 60 percent rise in the utilization factor from the 1920's to the 1950's has been the movement toward interconnection, by means of which plants within the same system and systems over wide geographical areas have been interconnected, so that the need for standby generating capacity in individual systems has been considerably reduced.

Railroads

Changes in the intensity of utilization of railroad equipment show a mixed picture. The relative utilization of freight cars has undergone little change from the 1920's to date and has remained at a comparatively low level. Measured in terms of traveling time—both empty and loaded—the average freight car was used 1,000 hours in 1926 and 995 hours in 1956. It may well be that if time spent waiting for unloading and loading were taken into account, average usage might in fact show some decrease over this period, though firm data on this point are lacking.

Locomotive use is another matter. The shift from steam to diesel locomotives over the past generation has been accompanied by a clear-cut increase in relative utilization. Indeed, this change has come about mainly because of the superior operating performance of the diesel as compared with the steam engine, and, among other things, has taken the form of reduced time-out for maintenance and repairs. Hours per locomotive assigned to freight service in 1926, for example, averaged 1,896 in 1926 as against 2,288 in 1956, an increase of approximately 20 percent.

With passenger service falling to exceptionally low levels, locomotives assigned to passenger service have fallen by 80 percent from the mid-1920's to the mid-1950's. Hours per locomotive have risen, however, from about 1,500 to approximately 2,500 over this period.

Locomotives in yard switching service find their most intensive use. Data are not available back to the 1920's but the available statistics suggest a considerable increase over time, given the prevalence and relative inefficiency of the steam locomotive in the earlier period. (Table 6.)

Table 6.—Hours per Year per Freight Car and Locomotive in Service, Class I Railroads

	Freight cars [1]	Locomotives		
		Freight	Passenger	Switching
1921–24	874	1,765	1,537	(2)
1925–29	969	1,811	1,524	(2)
1930–34	635	1,186	1,111	(2)
1934–39	754	1,320	1,239	(2)
1940–44	1,152	2,036	1,664	(2)
1945–49	1,102	1,937	1,743	4,779
1950–54	981	1,816	1,905	5,036
1955–59	928	2,174	2,498	5,576
1960	871	2,195	2,484	5,345
1961	852	2,115	2,42[illegible]	5,018
1962	895	2,233	2,600	5,139

1. Time traveling, empty and loaded. Excludes time in terminals.
2. Not available.

Source: U.S. Department of Commerce, Office of Business Economics. Estimated from data in *Railroad Transportation*, Association of American Railroads.

Appendix

The availability of some limited information on employment by shift suggested the possibility of an alternative approach to the estimation of equipment hours of work in mining and manufacturing.

The 1939 Census of Mineral Industries published, by detailed industry, employment by shifts, average number of hours per shift, and the average number of equivalent full-days that operations were active in the year 1939. Table 7 presents a comparison of the equivalent number of 40-hour shifts worked by equipment as derived from the two approaches, for all mining industries (excluding crude petroleum and natural gas) and for a few of the larger industries in which shift work is important (coal, iron ore, certain nonferrous ores).

The calculations making use of the shift data are shown below for all mining industries. Employment is expressed in terms of man-shifts (one man working one shift per day). Average hours per shift in 1939 were 7.3.

	Man-shifts (millions)	Average daily hours	Total daily hours (millions)
First Shift	107.0	7.3	781.1
Second Shift	22.7	7.3	165.7
Third Shift	4.5	7.3	32.8
Total	134.2		979.6

On the assumption that machines used per shift vary directly with employment and that first shift machines represent the maximum available, we get an average utilization of machines of 9.16 hours per day. (979.6÷107.0). However, the Census also reported that mines and related plants were active 203 equivalent full-time days in 1939, that is, 55.6 percent of 365 days. Multiplying 9.16 by .556 gives 5.09 hours per day, which is 64 percent of one 8-hour day. This compares with a ratio of 58 percent as derived from the horsepower and electric power consumption data.

For manufacturing, production worker employment data by shifts are available on overall basis for the year ending June 30, 1960.[10] According to this study of the Bureau of Labor Statistics, which was confined to employment in metropolitan areas, 77.2 percent of all production workers were employed on the first shift, 16.4 on the second, and 6.4 on the third and other shifts. On the same assumption used for mining, we get from this calculation 51.8 hours per week for machinery $(0.772 \times 40 + 0.164 \times 40 + 0.064 \times 40) \div 0.772$. This figure was moved back from 1959–60 to 1954 through the use of some recently published data on manufacturing capacity utilization, making some allowance for the strike in the summer and fall of 1959. This rough adjustment of 5 percent yielded a figure of 49.1 hours.[11]

Since the motor calculations were made with respect to a theoretical 365 day capacity, a similar adjustment must be made for the employment calculations, though there is little information for such an adjustment. The fact that Saturday and Sunday are typically not workdays and the fact of part-time employment are already reflected in the average weekly hours figure. One downward adjustment of 5 percent was made to allow for hours paid for but not worked because of vacations, holidays, sick leave, etc. A second adjustment was necessary to allow for the fact that even on the first shift not all work stations could be considered occupied. Since 1954 followed a year of near-capacity operations, it was decided to measure this slack by the change in employment from May 1953, the cyclical peak in manufacturing employment, to the average level in 1954. This yielded a 10 percent decline. On this very crude basis we get an average of 41.7 hours per week as against 35 hours, the figure obtained from the aggregate calculations derived from the motor and power consumption computations shown in table 2.

There are at least two major shortcomings with these calculations for manufacturing. First of all it is probably not appropriate to assume that machine hours by shift would be proportional to employment by shift. For some industries, such as metal fabricating, employment on late-shifts tends to be overweighted with maintenance workers rather than machinery-operatives. In the case of continuous industries like petroleum and industrial chemicals, however, the reverse is true. In a 1952 study it was found that only one-third of "production" workers in refineries were employed on late shifts, even though refineries are run on a 24-hour basis through the year (aside from maintenance shut-downs). On balance, the employment shift data in manufacturing probably understate late-shift operations of equipment.[12]

Table 7.—Number of Equivalent 40-Hour Shifts Worked by Equipment in Selected Mining Industries as Estimated from Employment Data by Shifts and from Motor Utilization Data, 1939

	From employment by shifts	From motor utilization
All mining industries [1]	0.64	0.58
Bituminous coal and lignite	.54	.45
Pennsylvania anthracite	.59	.55
Iron ore	.84	.53
Copper ore	1.30	1.10
Lead and zinc ores	.93	.95
Gold ore	1.18	1.31

1. Includes industries not shown but excludes petroleum and natural gas.

Source: U.S. Department of Commerce, Office of Business Economics.

The second major difficulty concerns the assumption that all machines on the first shift represent total machines available and can be appropriately adjusted downward by the 10 percent figure based on the change in employment from the 1953 peak to 1954. Only fragmentary evidence is available on this point for scattered time periods. In some unpublished BLS studies made in early 1951 covering metalworking industries, it was found that actual employment on the first shift was approximately three-fourths of the maximum that could be employed on the first shift with the available equipment. In textiles, where 3-shift work is common, Census figures indicate that first shift looms active at the end of 1962 as a percent of looms in place were 97 percent for cotton mills, 87 percent for man-made fiber and silk mills, and 76 percent for woolen mills. The rough 10 percent adjustment used above for all manufacturing is probably too low, but the resultant of the two major data biases discussed in this Appendix cannot be determined.

10. "Supplementary Wage Benefits in Metropolitan Areas, 1959–60," *Monthly Labor Review*, April 1961, Table 2, page 382.

11. Estimates were prepared by Frank DeLeeuw of the Federal Reserve and appear on page 129 of "Measures of Productive Capacity" in *Hearings before the Subcommittee on Economic Statistics of the Joint Economic Committee*, 1962.

12. This is brought out by Alan Strout in an unpublished paper prepared for the Harvard Economic Research Project and Resources for the Future, Inc. (1961).