Instruments to measure electricity: industry's productivity growth rises

Growth in labor productivity has been spurred by the spread of automated production machinery and increased use of integrated circuits in instruments; nonproduction workers—professional and technical—are a growing proportion of industry employment

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Output per employee hour in the manufacture of instruments for measuring electricity—such as oscilloscopes, and voltage and watt-hour meters—rose at an average annual rate of 2.4 percent between 1972 and 1981, compared with a 1.9-percent annual rate for all manufacturing. Both output and hours increased substantially over the period—output at 8.6 percent a year, employee hours at 6.0 percent.[1]

The advance in labor productivity was partially associated with the diffusion of automated production machinery, particularly in wiring and for installing integrated circuitry in measuring instruments. The growing use of small- and large-scale integrated circuits in electronic instruments was also a factor that spurred productivity improvement.

Year-to-year movements in output per hour deviated considerably from the long-term rate, ranging from a gain of 7.4 percent (in 1980) to a drop of 1.3 percent (in 1979). In general, the year-to-year fluctuations were linked with large increases in output that in turn were accompanied by large increases in employment and hours. (See table 1.) This linkage caused productivity to dip or to rise only slightly in a number of years when growth in output was quite strong. For example, in 1978, output rose 15.5 percent, but employee hours rose 15.2 percent, resulting in virtually no change in labor productivity. Again, in 1979, an output rise of nearly 11 percent was accompanied by an employee-hour rise of 12 percent, so productivity decreased slightly.

The exception to this pattern occurred in 1975, a recession year. Productivity rose by more than 4 percent, chiefly because of a steep drop in hours which was associated with a somewhat lesser drop in output.

Strong output growth

With the exception of 1974–75, output increased every year from 1972 to 1981. Six of the years studied showed double-digit percentage increases. The rate of output growth was especially strong from 1975 to 1980. The modest increase of 2.4 percent in 1981 reflects the 1980 economic slowdown. (Recessionary effects tend to be delayed in this industry.)

The four major industrial markets served by this industry are aerospace, communications, electric utilities, and computer and other electronics manufacturers—the last being the strongest growth market. (Telecommunications and data communications demand are also sizable.) The communications, aircraft, and aerospace industries together use the widest variety of instruments to measure electricity, followed closely by research laboratories and electric utilities. (See table 2.)

Foreign demand has helped fuel the increase in output. Exports now account for a significant proportion of instruments for measuring electricity—32.5 percent in 1981, up

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Table 1. Productivity and related indexes for the industry which produces instruments to measure electricity, 1972–81
[1977 = 100]

Year	Output per employee hour	Output	Employee hours	Employees
1972	84.7	71.7	84.7	82.3
1973	90.8	84.2	92.7	90.5
1974	92.0	94.0	102.2	102.1
1975	95.9	85.9	89.6	91.6
1976	95.5	87.3	91.5	91.9
1977	100.0	100.0	100.0	100.0
1978	100.3	115.5	115.2	115.2
1979	99.0	128.0	129.3	127.2
1980	106.3	151.0	142.0	142.7
1981	109.1	154.6	141.7	142.6
	Average annual rates of change (in percent)			
1972–81	2.4	8.6	6.0	6.3
1976–81	2.4	12.7	10,1	10.1

from 19.5 percent in 1972.[2]

The strong increase in output was largely a response to the rapidly expanding application of electronic components. The electronics industry uses instruments that measure electricity in testing semiconductor components, in research and development laboratories, and in engineering.[3]

Other functional applications in many industries include monitoring energy usage for conservation purposes; troubleshooting automatic process operations; recording and analyzing shutdown and startup sequences; operating test and inspection stations; classifying and diagnosing power-line or voltage disturbances; and servicing electrical field equipment.

The industry makes general-purpose as well as customized instruments which can be either electrical or electronic. General-purpose (or broad-spectrum) instruments are produced in relatively large quantities. They include oscilloscopes, signal generators, and demand meters, which are sold mostly in industrial markets. Simpler, less expensive instruments, such as multitesters, are frequently big sellers in the nonindustrial market.

Customized products are often technologically more sophisticated instruments, designed to solve specific measurement problems. However, they also include less complex equipment such as panel meters, which are made to order for utility companies.

Complex, electronic instruments such as combination and group test sets or some voltage, current, and resistance measuring equipment have become very important to this industry's growth.[4] Because of advances in electronics technology, these instruments are able to perform many different functions, thereby replacing several simpler instruments. The demand for new electronic instruments has been a major factor behind the industry's output growth.

Thus, changes in electronics technology have not only indirectly fueled demand through the explosive growth in semiconductor components (which in turn generated the need for more measuring instruments), but, by influencing the form and function of products, have brought new instruments and growth directly into their markets.

Product improvements have also contributed to the growth in demand by widening markets. For instance, many instruments now have direct digital readouts and automatic calibration for ease of operation, and are designed so that minimal training is required to use them.[5] These instruments are designed to be "user-friendly" and to perform some data analysis prior to printout, thereby allowing companies without engineers or other technical personnel to make use of them.

Growing employment

The number of persons employed in the industry expanded greatly over the period studied (73 percent), with especially large increases from 1977 to 1980. Employment rose at an average annual rate of 2.4 percent between 1972 and 1976, and of 9.7 percent from 1977 to 1981:

Years	*Average annual rates of change* — *All employees*	*Production workers*	*Nonproduction workers*
1972–81	6.3	4.1	9.5
1972–76	2.4	1.4	4.0
1977–81	9.7	5.9	14.9

The proportion of nonproduction workers rose from 37 percent in 1972 to 47 percent in 1981. (Such workers accounted for 30 percent of all manufacturing employees in 1981.)

Total employment dropped only twice over the 9-year period studied—and one decline (1980–81) was very small, 0.1 percent. As the following table shows, average layoffs per 100 employees were less than one quarter the average for all manufacturing industries. Average recalls, separations, quits, and layoffs from 1972 to 1980 all ran well below the average for all manufacturing, reflecting industry efforts to minimize turnover and retain skilled workers:

	Average per 100 employees (1972 to 1980) — *Instruments to measure electricity*	*All manufacturing*
Recalls (1976–80)	0.14	0.88
Separations	2.39	4.17
Quits	1.46	2.00
Layoffs	0.29	1.30

Production workers. These employees, mainly assemblers and testers, declined in number twice—in 1975 and in 1981. The number of production workers increased 45 percent from 1972 to 1981, to 50,200. Until recently, average weekly and hourly earnings generally ran below the manufacturing average.[6]

Women account for an unusually high proportion of production workers. (The average percentage of women in this industry's total work force from 1972 to 1981 was well above the average for all manufacturing—46 percent versus 31 percent.) At many companies the assemblers are almost all women. Reasons given for women's dominance of assembly jobs vary from "tradition" to "manual dexterity."[7]

Many assembly jobs require little prior job training, thus attracting women with no previous employment experience. Some industry sources also claim women are able to cope better with the exacting but tedious assembly work.

In addition to the training all production workers receive on the job, testers often have trade school education in electronics. Because of the significant investment in training, companies prefer not to lay workers off during a downturn. Instead, many businesses reduce payroll costs through shortened workweeks and temporary plant shutdowns. Many companies, particularly the smaller ones, seek to avoid layoffs because of strong employee-company loyalty.[8]

There are two types of testers found in most plants: incoming parts or quality control testers and technicians (as defined by the industry). Testers for incoming parts need less training and are usually lower-paid than technicians. Technicians test complex assemblies and final assemblies, and usually are required to have trade school experience. Women do not appear to dominate in these work groups.

Nonproduction workers. The rising percentage of nonproduction workers in the industry is largely related to trends in product design. A significant proportion of the companies in this industry manufacture increasingly complex, sophisticated instruments at low production rates. Thus, large support groups of engineers and technicians are needed for research and design. An expenditure of 6 to 7 percent of sales for research and development is common in this industry. Considerable investment in research and development is needed to keep up with both the changing technology in the products whose "electricity is to be measured" and the advances in electronics that can improve the measuring instruments' capabilities.[9]

Professional and technical workers, especially engineers, represent a significantly larger proportion of the industry's work force than of all manufacturing employees.[10] Managers and clericals account for a slightly larger proportion when compared with all manufacturing. These general trends in white-collar occupations reflect the importance of engi-

Table 2. Significant users of specific product groups from SIC 3825, Instruments to Measure Electricity[1]

Product groups and 1977 value of shipments (in million of dollars)	Semiconductor and computer manufacturers	Computer users (all industries)	Computer installers/servicers	Refiners and chemical plants	Communications, aircraft, radio, TV, aerospace industries	Utilities/private power companies	Automobile manufacturers	Appliance, TV, and radio repairers	Auto garages	Hospitals and other specialized power users	Labs (all industries)
AC watt-hour and demand meters ($151.7)	—	—	yes	—	yes	yes	—	—	—	—	—
Voltage, current, and resistance measuring equipment and multimeters ($171.4)	yes	yes	yes	yes	yes	yes	—	yes	—	yes	yes
Power and energy measuring equipment ($9.1)	—	—	yes	yes	—	yes	—	—	—	—	—
Frequency and time measuring equipment ($86.4)	yes	—	—	—	yes	yes	—	yes	—	—	yes
Oscilloscopes and signal generating equipment ($380.4)	yes	yes	yes	—	yes	—	—	yes	yes	—	yes
Field strength and intensity measuring equipment ($59.0)	yes	—	yes	—	yes	—	—	—	—	—	yes
Impedance and standing wave ratio measuring equipment ($17.3)	—	—	—	—	yes	yes	—	—	—	—	yes
Electronic x-y plotters ($69.3)	—	—	—	yes	yes	—	—	—	—	—	yes
Multifunction test and measuring equipment[2] ($349.6)	yes	yes	—	—	yes	—	—	yes	—	—	yes
Standards and calibration equipment ($40.1)	—	—	—	—	yes	—	—	—	—	—	yes
Microwave test equipment ($48.5)	—	—	—	—	yes	yes	—	—	—	yes	yes
Internal combustion engine analyzers ($151.7)	—	—	—	—	—	—	yes	—	yes	—	—
Panel meters ($138.8)	—	—	—	yes	yes	yes	—	—	—	—	—
Switchboard instruments ($14.1)	—	—	—	yes	—	yes	—	—	—	—	—
Elapsed time meters ($15.3)	—	—	—	—	yes	yes	yes	—	—	—	—
Electrical recording instruments ($184.9)	—	—	—	yes	—	yes	—	—	—	yes	yes
Parts and accessories, including transducers ($30.8)	yes	—	—	—	yes	—	yes	yes	yes	yes	—

[1] "Users" include both civilian and military purchasers.
[2] Including semiconductor test equipment.

NOTE: Information provided by industry sources.

neers and related workers to the establishments in the industry.

Changes in technology

There are several basic steps in the production of a typical electronic instrument designed to measure electricity: The needed parts are purchased, or made in-house. These parts are checked and then prepared (wired, preformed, and so forth) for production. The components are inserted in printed circuit boards which are then soldered. Assemblies are tested, interconnected, and installed in cases. Additional testing and calibration of the finished instruments follow.

Parts needed for production in this industry range from complex printed circuit boards made in-house to semiconductor devices ordered from catalogs. Many of the incoming parts and components are performance tested (usually through sampling). Some firms make their own custom electronic parts, thereby ensuring complete quality control of critical components. Most firms purchase a large proportion of their components from vendors. Thus, they must adapt their product designs to accommodate standardized parts, sacrificing some quality control. (The failure rate during quality control of incoming parts is often higher than that accepted for inhouse production.)

There has been an increased effort, particularly by medium to large-sized firms, to design products so that they comprise several subassemblies (modules) which are interconnected electrically and mechanically at the end of the manufacturing process. This subassembly design concept has many advantages which can lead to lower unit costs, increased productivity, and more reliable products. One advantage is that subassemblies can be better adapted to automated assembly and testing. Also, several different instruments can be designed so that they include nearly identical subassemblies, thus increasing subassembly production quantities. In addition, varied customer preferences (options) can be more efficiently added or deleted from the basic instruments.

The use of integrated circuits and microprocessors in the more technologically advanced instruments has also enabled producers to reduce the number of components, thus reducing assembly time.

When purchased parts are received, they must be counted and checked. Equipment is now available that weighs parts in lieu of manually counting them. Inventoried components like resistors and capacitors must then be preformed and harnesses wired. (Harnesses are grouped bundles of wires.) Wiring of harnesses can be done manually or by mass termination machines, which can do in 5 minutes what takes 1-½ to 2 hours to do by hand. These machines attach ribbon wire to connectors, which are then attached to printed circuit boards. Even in companies that have mass termination machines, however, hand wiring may still be done for older products because of the extensive time and large outlays required to redesign products in order to make use of these machines. (Hand wiring is also used for connecting high voltage wires, or where small numbers of wires are going to many points.)

Next, components (both integrated circuits and discrete parts like diodes) must be stuffed (inserted) into printed circuit boards using assembly drawings as guides. This is done either manually or automatically by insertion machines (which require a substantial investment). (The first insertion machines purchased by a company are generally used for handling integrated circuits.) The machines are preprogrammed (usually by production engineering staff) and then loaded with the necessary preformed components. (It is the expense of programming, in addition to the relatively high capital outlay, that prohibits the use of insertion machines in small batch production runs.) The machine then inserts components into printed circuit boards automatically. At higher volumes of production, insertion machines save about 80 percent of labor compared with manual insertion of integrated circuits, and 15 to 20 percent over manual stuffing of discrete parts.

Another advantage of these machines is an increase in production consistency, which is especially important as boards become packed more tightly. (Five years ago, there were about 50 components on a typical board; now there may be 350.) Thus, it is more and more difficult and time-consuming to ensure that boards are assembled correctly. The first newly-designed board stuffed by machine is thoroughly checked and approved. Once that is done, all subsequent boards stuffed by the insertion machines will be of higher quality and greater reliability than if they had been assembled manually. Actual postproduction testing time is not reduced, however.

Manual insertion methods may range from bench assembly, where one person inserts all components into the printed circuit board, to progressive subassembly, where several individuals each insert a number of components.

Stuffed boards are then routed to solder flow machines, which have been in use for about 15 years. These are probably the most widely diffused machines in the industry, and represent a major technological improvement over hand soldering. After soldering, cables are manually connected to the boards and the boards are tested for solder shorts and opens, incorrectly inserted components, and malfunctioning components. Subassemblies then go through final assembly and are put in cases. The product is then tested and calibrated. Completed instruments are often run for extended periods under controlled conditions to test them for accuracy and reliability (the burn-in process).

Test equipment. Testing is a critical process in this industry because of the nature of the products. Testing is usually done at several steps in the manufacturing process—when purchased components are received, after subassemblies are completed, and after final instrument assembly. Improvements in test equipment for incoming parts have enabled quality control personnel to make more extensive tests and to check a larger percentage of parts. In most tests, there is some degree of automation involved in that measurement instruments are used. However, *fully* Automatic Test Equipment (ATE) is now available—although it is costly. This computer-based equipment can test bare printed circuit boards or assembled (inserted) printed circuit boards. It is used mostly for the latter purpose. Automatic Test Equipment (parts of which are measuring instruments) is state-of-the-art electronic equipment, capable of performing multiple, complex tests. Some labor savings are realized when it is used. It also allows testers to perform more tests on each product, thus keeping up with the growing complexity of the instruments. More consistent, higher quality products result.

Computers. There are four general areas of computer use: Management control systems, computer-aided engineering, warehouse automation systems, and computer-aided manufacturing (CAM).[11] Computer usage is usually limited to research and design and to simple business functions such as maintaining payroll and sales records. In most companies that have computers, several computer systems are employed, but the databases are rarely integrated. Some increase in nonproduction worker productivity has resulted from engineers' extensive use of computers in product design and development, and from drafters' utilization of computer-aided-design (CAD) systems to draw circuit layouts and schematics for printed circuit boards. Improved software tools for engineers and better CAD systems for drafters have allowed them to further reduce the time spent in designing products and making design changes, in writing customized programs, in communicating with other parts of their organization, and in finding errors.[12]

Advanced business computers can be used to reduce costs through better purchasing practices and inventory control. Some systems are also capable of scheduling work, keeping track of employee hours, or controlling material levels, but these are employed less frequently. For the companies that use them, advanced, integrated CAD/CAM systems are capable of increasing labor productivity, in addition to permitting more efficient use of materials, greater reliability, faster turnaround (from design to finished product), and smaller inventories.[13] Automatic testing systems, used to check assemblies during production, are also computerized. They are used as quality control tools and as a means to improve productivity.

Implementation of most of the technological advances in the production process mentioned requires significant capital outlays. New capital expenditures by this industry increased over 600 percent (in current dollars) between 1972 and 1981. In dollars per production worker, the increase was also very large, 389 percent, compared with a 226-percent increase for all manufacturing. These percentage increases ran substantially above the increase in value of shipments over the same period. The spending surge is an indication of the move to more automated production systems. The spread of automated equipment is also reflected in the 176-percent increase in value added per production worker over the study period. In 1972, value added per production worker in this industry was 13 percent higher than for all manufacturing; in 1981, it was 31 percent higher.

Industry structure

When firms are grouped by number of employees or sales volume, there are identifiable differences in both the technology employed in production and the type of products produced. The smaller companies often produce nonelectronic instruments, many of which are broad-spectrum or general use types (for example, some signal generators and multimeters), as well as customized electronic and mechanical equipment in low volume operations. The advent of prepackaged and pretested electronic components has allowed small companies with limited skills to produce more sophisticated instruments.

Medium-sized companies employ varying amounts of automatic equipment and are often at the forefront of the new technology in instruments that measure electricity.[14] Production usually takes place in limited runs. These firms face some direct competition, but often try to find market niches in which only their products will fit. (Sales are frequently made through sales representatives who sell instruments from several companies.)

The larger companies account for most of the low-cost, high-volume products as well as some of the more costly and complex instruments. It is in high-volume operations that the most automated production processes are found. Along with the additional capital required to automate, these firms face extensive development costs. Thus, only firms with high-volume production facilities can take advantage of reduced unit labor and materials costs, and cover large capital and developmental expenditures. (In a few cases, automatic equipment may also be installed if there is a very high error rate or if repair and troubleshooting costs are exorbitant.)[15] The following tabulation presents the 1977 percent distribution of establishments, employment, and new capital expenditures in the industry, by establishment size:[16]

	Establishments	*Employment*	*New capital expenditures*
Total	100.0	100.0	100.0
Establishments with average employment of:			
1–19	58.4	3.5	2.3
20–99	23.7	11.3	7.5
100–499	13.4	28.4	23.7
500–999	2.7	18.3	20.4
1000 or more	1.8	38.6	46.1

The number of establishments in this industry rose from 632 in 1972, to 671 in 1977. (The estimate for 1981 is

653.)[17] From 1972 to 1977, the corresponding percentage increase in number of *companies* (2 percent) was lower than that for *establishments* (6 percent). The number of employees per establishment also increased—from 87 in 1972 to 99 in 1977.

Outlook

The capabilities of measuring instruments will grow as their manufacturers incorporate advances in electronics technology, especially microprocessors and related devices, into their products.[18] The instruments themselves will become smaller. More components will be produced and tested automatically. Testing of assemblies and final products will continue to be a major concern as product complexity increases and improvements in instruments' accuracy and reliability remain important competitive tools.

Smaller companies will be able to install more automatic equipment as lower prices for such equipment permit a favorable return on investment even with low-volume production. The large white-collar work force should become more efficient as business computers are utilized more fully and improvements in software aid both engineers and drafters in their product development work.

The electronics industry, the largest market for measuring instruments, should continue to expand as the economy recovers and capital spending picks up. In addition, electronics firms (which include companies that produce instruments to measure electricity) are expected to install more automatic controls and to concentrate on producing high-quality products—both of which goals will necessitate more accurate and precise measuring capabilities. The increase in sales of instruments that are a part of ATE should be especially strong as electronics firms strive to reduce labor costs, improve product quality, and keep up with the growing complexity of electronic components.[19] Logic analyzers, used to test microprocessor-based systems, should also be big sellers. The data and telecommunications industries are also expected to experience strong output growth—thereby stimulating purchases of measuring equipment.[20] Exports should continue to increase because of growing worldwide use of electronic components, and the unique products offered by some U.S. companies.

Rapidly changing electronics technology will be both a pushing and a pulling force as it continues to fuel demand and improve both the products and productivity in this industry.

Workers will become more dependent on computers as automated production processes, business computers, and ATE spread throughout the industry. The demand for computer-trained production workers, and for programmers and engineers who maintain the machines, will thus increase. There will continue to be a strong need for design and development engineers as research and development levels stay high. □

———*FOOTNOTES*———

[1] The 1972 Standard Industrial Classification manual classifies Instruments for Measuring and Testing of Electricity and Electrical Signals as Industry 3825. The major products included are: AC watt-hour meters; demand meters; voltage, current, and resistance measuring equipment; multimeters; power and energy measuring equipment; frequency measuring equipment; waveform measuring and/or analyzing equipment (oscilloscopes); signal generating equipment; field strength and intensity measuring equipment; impedance and standing wave ratio measuring equipment; electronic time measuring and counting equipment; electronic x-y plotters; combination and/or group test sets; component part test sets (semiconductor test equipment); standards and calibration equipment; analyzers for testing characteristics of internal combustion engines; panel meters; switchboard instruments; elapsed time meters; portable instruments; and electrical recording instruments.

Average annual rates of change presented in this article are based on the linear least squares of the logarithm of the index numbers. Extensions of the indexes will appear in the annual BLS Bulletin, *"Productivity Measures for Selected Industries."*

[2] U.S. Department of Commerce, Industry and Trade Administration, *1982 U.S. Industrial Outlook* (Washington, Government Printing Office, 1982), p. 274.

[3] Al Esser, "Modular ATE satisfies gamut of testing needs," *Electronic Design*, Oct. 28, 1982, pp. 127–28.

[4] The increase in value of product shipments for all of SIC 3825 was 93 percent between 1972 and 1977. For combination and group test sets, the increase was 250 percent; for multimeters, 195 percent; and for electronic analog voltage, current, and resistance measuring equipment, the increase was 320 percent.

[5] Roger Allen, "DVMS, DMMS advance on several fronts: Low costs systems performance," *Electronic Design*, Oct. 15, 1981, pp. 129–46.

[6] Earnings data for SIC 3825, as a percent of all manufacturing:

	Average weekly earnings	*Average hourly earnings*
1972	88.5	87.4
1973	86.3	84.8
1974	86.0	83.9
1975	89.6	89.9
1976	99.4	100.2
1977	99.0	98.8
1978	98.8	96.9
1979	101.3	97.5
1980	105.5	101.7
1981	96.7	95.7
1982	101.0	98.7

[7] Industry sources.

[8] Industry sources and U.S. Department of Commerce, *1982 U.S. Industrial Outlook*, p. 274.

[9] Industry sources and "Semiconductor orders to lead recovery for electonics in 2nd half, industry says," *Wall Street Journal*, June 16, 1982, p. 12.

[10] Discussion is based on unpublished BLS occupational data for SIC 382. SIC 3825 makes up about 38 percent of SIC 382.

[11] "CAD/CAM systems shape up for total automation," *Electronic Design*, Oct. 14, 1982, p. 226.

[12] Industry sources.

[13] *Electronic Design*, Oct. 14, 1982, p. 228.

[14] Observation of industry operations, and industry sources.

[15] Observation of industry operations, and industry sources.

[16] Data are from *1977 Census of Manufactures, Part 3* (Bureau of the Census), p. 38A–17, table 4.

[17] U.S. Department of Commerce, *1982 U.S. Industrial Outlook*, p. 274.

[18] "Test/Measurement," *Electronic Engineering Times*, Jan. 1, 1981, p. 18.

[19] "Electronics-electrical/basic analysis," *Standard and Poors' Industry Survey*, Jan. 14, 1982, p. E18.

[20] U.S. Department of Commerce, *1982 U.S. Industrial Outlook*, pp. 274–75.

APPENDIX: Measurement techniques and limitations

Indexes of output per employee hour measure changes in the relation between the output of an industry and employee hours expended on that output. An index of output per employee hour is derived by dividing an index of output by an index of industry employee hours.

The preferred output index for manufacturing industries would be obtained from data on quantities of the various goods produced by the industry, each weighted (multiplied) by the employee hours required to produce one unit of each good in some specified base period. Thus, those goods which require more labor time to produce are given more importance in the index.

In the absence of physical quantity data, the output index for the industry which produces instruments to measure electricity was constructed using a deflated value technique. Value of shipments of the various product classes was adjusted for price changes by appropriate Producer Price Indexes to derive real output measures. These, in turn, were combined with employee hour weights to derive the overall output measure. These procedures result in a final output index that is conceptually close to the preferred output measure.

The indexes of output per employee hour relate total output to one input—labor time. The indexes do not measure the specific contribution of labor, capital, or any other single factor. Rather, they reflect the joint effect of factors such as changes in technology, capital investment, capacity utilization, plant design and layout, skill and effort of the work force, managerial ability, and labor-management relations.