Productivity in the pump and compressor industry

During 1958–80, the industry experienced long-term advances, reflecting improvements in metalworking machinery and computer aid; but since 1965, productivity has decelerated, being especially slow from 1973 forward

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Output per employee hour in pump and compressor manufacturing rose at an average annual rate of 2.1 percent between 1958 and 1980—compared with a rate of 2.6 percent for manufacturing as a whole.[1] Output increased 4.7 percent a year, employee hours 2.6 percent. Among the sources of the industry's long-term productivity advance were improvements in metalworking machinery, which lies at the core of the production processes for pumps and compressors, and computer technologies, which were increasingly applied to engineering design.

The labor productivity trend for the industry was marked by strong advances during the early part of the period (from 1958 to 1965), followed by deceleration during 1965–73, and a further slowing thereafter. As the tabulation shows, using average annual rates of change in percent, the trend pattern paralleled manufacturing:

	Pumps and compressors	*Manufacturing*
1958–80	2.1	2.6
1958–65	3.4	2.7
1965–73	2.1	2.4
1973–80	1.0	1.8

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By 1980, the level of labor productivity in the industry had risen 55 percent from 1958, as against 78 percent for all manufacturing.

The long-term productivity trend, in addition to evidencing divergent medium-term movements, was punctuated by sharp year-to-year swings. These swings were generally related to the business cycle, although they show no uniform pattern. Thus, labor productivity fell steeply in 1960 (3.2 percent), 1975 (5.6 percent), and 1980 (2.6 percent). In these years, output either grew more slowly than employee hours (1960), or fell more rapidly (1975), or fell while hours rose (1980). Yet, in 1961, 1967, and 1971, years when the economy slowed, significant increases in productivity occurred (3.9 percent, 1.7 percent, and 1.5 percent)—which, however, stemmed from drops in employee hours exceeding drops in output.

Years of recovery or boom in which productivity soared to more than twice its long-term rate, displayed a more uniform pattern of change in output and employee hours. In 1959 and 1976, gains in productivity were linked with large output increases but slight employee hour declines.

Separate data for pumps and pumping equipment, and for air and gas compressors, are available only from 1972 forward. Average annual rates of change in labor productivity for the two separate industries compare as follows for the 1972–80 span:

	Percent
Pumps and compressors	1.2
Pumps and pumping equipment	1.2
Air and gas compressors	1.1
All manufacturing	1.9

Reflecting contrasting trends in output and employee hours, labor productivity movements in the pump and pumping equipment segment were considerably less volatile than in compressor manufacturing. The former attained a productivity level in 1979 that exceeded 1973 by 7 percent (both years registered cyclical peaks); the latter failed to reattain its 1973 high.

Output increases

Pumps and compressors are used throughout manufacturing and many nonmanufacturing industries, as well as agriculture. Pumps are the second most common machine in use after the electric motor.[2] Compressors generate compressed air, which may be regarded as a form of energy ranking in breadth of use only below electricity, gas, and water, in addition to being indispensable in the transportation of gas.[3]

Between 1958 and 1980, output of pumps and compressors rose 175 percent, or at an average annual rate of 4.7 percent. Manufacturing output grew at a rate of 3.8 percent over the period. Like the long-term trend in the industry's labor productivity, the long-term trend in output rose less after 1965 than earlier, as the following tabulation indicates by showing average annual rates of change in percent:

	Pumps and compressors	*Manufacturing*
1958–80	4.7	3.8
1958–65	6.5	5.9
1965–73	2.5	3.0
1973–80	4.2	2.5

Output of pumps and compressors reached a peak index level of 115 (1977=100) in 1979, from which it receded slightly in 1980. The dip was caused by a decline in compressor manufacturing, which had climbed 51 percent between 1973 and 1979. Pump and pumping equipment output had risen 22 percent between those 2 years of cyclical highs.

Of the total output of pumps and compressors, the former accounted for about two-thirds, according to the *1977 Census of Manufactures*, the latter for the remaining one-third. Industrial pumps represented more than half of the output of pumps and pumping equipment (other than accessories). Hydraulic fluid power pumps, oil well and oilfield pumps, and other pumps and equipment installed in appliances, fire engines, and structures, made up the remaining output. Parts and attachments constituted close to one-quarter of pump manufacturing output in 1977. Given the often difficult climatic and environmental conditions in which pumps must operate, and the abrasiveness of fluids often transferred by them, speedy replacement of worn and damaged parts constitutes a vital function of the manufacturer, and is the reason for the high proportion of shipments of parts and attachments.

Air compressors accounted for well over one-quarter of the shipments of compressor manufacturers, according to the 1977 census, gas compressors for just under one-tenth. They consisted preponderantly of the stationary type. Portable compressors, which are relatively small machines, made up one-fifth of total air and gas compressor shipments. Industrial spraying equipment also added one-fifth to compressor manufacturers' shipments. Compressors, like pumps, are frequently exposed to rough operating and environmental conditions, hence a comparatively high proportion of shipments (20 percent) represented parts and attachments in 1977.

Factors underlying output growth

In general, growth in the output of pumps and compressors was related to expansion in industrial and public utility demand, particularly during the boom years of the early and mid-1960's; gains in residential and associated public works construction, such as sewage and waterworks, during the 1960's and 1970's; and intensified needs of energy-related extractive and pipeline industries, especially during the 1970's. Foreign trade, too, played an important role in sustaining output: about one-fifth of pump and compressor production was exported between 1972 and 1978.

Expansion in the productive activities of a wide array of users lay at the base of output growth of pumps and compressors. No precise statistical link can be established between the former and the latter. However, movements in the plant and equipment expenditures, adjusted for price changes, by major pump and compressor users are indicative, as are put-in-place data for construction.

Among large-scale users of pumps and compressors was the chemical industry, which accounts for about one-tenth of total pump and compressor output.[4] Chemicals nearly doubled plant and equipment outlays (adjusted for price changes) in the early 1960's, then reduced them. After 1973, however, outlays were once again raised, so that in 1979 they stood nearly twice above the 1973 level. The industry has increasingly used pumps made of fiberglas, plastics, and stainless steel to transfer salt solutions, acid, and chlorine.[5]

Steel mills and blast furnaces, whose capital spending patterns compared roughly with that of the chemical industry over the review period, purchase about 7 percent of pump and compressor output. They use a variety of industrial and hydraulic pumps as well as compressors

to move sources of energy such as liquid fuels, as well as water to absorb waste energy. Installation of multistage pumps to achieve higher pressure has, in part, been prompted by the shift from open-hearth to basic-oxygen and electric-arc steelmaking processes. The partial replacement of slabbing mills by continuous casting has required more water, hence a larger number of and more powerful centrifugal pumps.[6]

More than 18 percent of pumps and compressors are bought by energy-related extracting, processing, and distributing industries. Thus, growth in extractive activities spurred the demand for industrial as well as oil well and oilfield pumps. Between 1960 and 1970, the number of crude oil and gas wells drilled dropped sharply (by nearly two-fifths), as did footage drilled (by 27 percent). After 1970, the decline was reversed; in 1978, the two indicators ran 72 percent and 68 percent above 1971 levels. Concomitantly, output of oil well and oilfield pumps, which had risen at an average annual rate of less than 4 percent between 1958 and 1973, soared to a rate of more than 10 percent between 1973 and 1980. Oil extraction also requires reciprocal pumps for mud circulation; submersible centrifugal units to lift the crude oil; and centrifugal pumps for waterflooding (to prevent subsidence and maintain pressure).[7]

Compressors are required in oil drilling and oilfield maintenance operations, and particularly in secondary recovery efforts. The continued expansion of natural gas pipelines (whose mileage increased 9 percent between 1973 and 1978) spelled the installation of additional large compressors for gas transmission; and increases in new wells—more than twofold between 1973 and 1978—required numerous smaller compressors for gas gathering, as did the prohibition of flaring of waste gas (which now must be stored in tanks). Also, steep increases in capital expenditures of the coal mining industry—162 percent between 1958 and 1972 (after adjustment for price changes), and 169 percent between 1973 and 1977—indicate expansion in this industry's demand for compressors.

Expansion of petroleum pipeline capacity also raised the demand for pumps, particularly of the high-horsepower centrifugal kind, and for stationary compressors. While the network of petroleum pipelines operated by petroleum pipeline companies increased 16 percent between 1960 and 1970, and contracted somewhat thereafter, total oil transported rose 81 percent during the 1960's, and 48 percent in the 1970's.[8] At the same time, the average diameter of pipes was enlarged by one-third, roughly doubling capacity.[9] This required significant increases in the size and capacity of pumping equipment and compressors.

Expanding electrical generating capacity spurred the output growth especially of centrifugal pumps. These are used as boiler-feed pumps, as well as in many other operations requiring the circulation and condensation of steam and water. While the total number of electrical generating stations did not advance very much over the review period, the proportion of stations generating 500,000 kilowatts or more rose from under 3 percent in 1960 to 12 percent in 1979. Nuclear and gas-turbine driven, power-generating plants likewise increased. The rise in the number of larger electric generating plants spelled a shift to larger, more powerful pumps.[10]

Table 1. Productivity and related indexes for pump and compressor manufacturing, 1958–80

[1977 = 100]

Year	Output per employee hour	Output	Employee hours	Employees
1958	64.5	41.1	63.7	63.1
1959	68.8	43.4	63.1	62.6
1960	66.6	44.6	67.0	66.1
1961	69.2	43.9	63.4	62.6
1962	73.6	48.6	66.0	64.9
1963	78.1	51.7	66.2	64.6
1964	79.4	59.0	74.3	71.5
1965	80.9	65.2	80.6	77.9
1966	81.1	70.5	86.9	82.9
1967	82.5	70.1	85.0	82.4
1968	82.3	68.3	83.0	80.3
1969	86.3	74.0	85.7	83.3
1970	85.8	74.8	87.2	85.8
1971	87.1	69.4	79.7	79.4
1972	91.1	76.2	83.6	82.5
1973	97.8	87.7	89.7	88.6
1974	96.7	94.0	97.2	97.3
1975	91.3	87.0	95.3	96.0
1976	96.8	91.4	94.4	94.3
1977	100.0	100.0	100.0	100.0
1978	102.6	107.1	104.4	105.1
1979	102.5	114.5	111.7	112.7
1980	99.8	112.9	113.1	113.9
Average annual rates of change (in percent):				
1958–80	2.1	4.7	2.6	2.7
1975–80	1.9	6.0	4.1	4.2

Construction accounts for another 18 percent of pump and compressor output. Centrifugal and trash pumps (which accommodate up to 25 percent of small solids in the water being pumped) are used in the clearing and preparing of construction sites.[11] Portable compressors are indispensable in the many pneumatical operations at construction sites. Between 1960 and 1973, the volume of total construction put in place rose at an average annual rate of 2.9 percent; thereafter it declined at a rate of 1.5 percent. However, some construction sectors with high demand for pumps continued to expand—for example, sewage system construction (spurred by more stringent environmental regulations).

Employment and hours

Employment in the pump and compressor manufacturing industry currently numbers approximately 91,000 persons. It rose 81 percent between 1958 and 1980, or at an average annual rate of 2.7 percent (compared with 1.1 percent for all manufacturing).

The long-term trend in employee hours in the industry did not differ significantly from the long-term trend in employment. They rose at a rate of 2.6 percent a year over the period, compared with 1.1 percent for manufacturing as a whole.

Production worker employment rose somewhat faster over the 1958–80 period than production workers' hours (2.7 percent a year versus 2.4 percent). Year-to-year changes ranged from an increase of 12 percent in 1974 to a decline of 10 percent for production worker employment; the range was wider still for hours. Overtime exceeded the manufacturing durables average in 17 of the 22 years examined here.[12] Comparatively high overtime hours were probably related to hiring and separation policies which, judging by the pertinent labor turnover data, have been such as to ensure retention of a relatively skilled work force. Labor turnover in the industry ran less than three-fifths of the manufacturing average for the period.[13] High overtime and low turnover rates were probably also related to the skill composition of the industry's work force.

Data on the skill composition of employees in pump and compressor manufacturing are not directly available. Such data have been compiled by the BLS only for the general industrial machinery group (SIC 356), of which pumps and compressors represent 29 percent by employment. Craft and related workers accounted for 30 percent of the production workers employed by establishments in this group in 1980, compared with 26 percent for total manufacturing. Metalworking craftworkers represented 12 percent of all production workers in the group, compared with 5 percent for manufacturing; and machinists 3 percent, compared with 1 percent. Operatives accounted for slightly more than three-fifths of all production workers in the general industrial machinery group, the same as in manufacturing as a whole. But metalworking operatives in industrial machinery, constituting one-third of production workers, had three times the share of their counterparts in all manufacturing. Laborers, with 6 percent of production workers in the group, had little more than half their share for all manufacturing.

Wage differentials also suggest a somewhat higher skill composition for production workers in pump and compressor establishments than in all manufacturing. In 1980, hourly earnings of the former ran 10 percent above the manufacturing average, and 3 percent above the manufacturing durables average. These ratios remained substantially unchanged during 1958–80. (Hourly earnings were about the same for production workers in the industry and in the general industrial machinery group of which the industry is part.)

Employment of nonproduction workers by pump and compressor manufacturing establishments rose at a slightly faster rate than that of production workers—2.9 percent a year (versus 2.7 percent). Nonproduction workers account for a comparatively high proportion of the industry's employment—41 percent in 1980, as against 30 percent for all manufacturing. The proportion did not change significantly over the review period. One of the reasons for the high proportion of nonproduction workers resides in the larger share accounted for by mechanical engineers in the industry groups' occupational makeup (the data are, again, for the general industrial machinery group). Such engineers represented 6 percent of all white-collar workers in the group in 1980—three times the comparable manufacturing ratio. Engineering and science technicians, among them drafters, made up 11 percent of white-collar workers in the group, as against 8 percent for manufacturing. The group also employed a somewhat higher proportion of clerical and secretarial workers (42 versus 40 percent). The share of blue-collar nonproduction workers, such as truckdrivers and service employees, was generally lower than for manufacturing.

Technological changes

Small lot production is the rule in pump and compressor establishments. Pumps and compressors are often large machines, manufactured to customer specification. While many of these machines are composed of standard parts, the economies associated with mass production are generally not available in producing pumps and compressors. The production process must constantly be adapted so as to cope with the many design, casting, and machining requirements that arise. Such adaptation was facilitated by the advent of numerically controlled machine tools in the 1960's, and the introduction of computer-aided design into engineering practice.[14] Numerical controls and computer-aided design have been important sources of labor productivity advances in the industry. The impact of these technological changes will be outlined, following a brief survey of the kinds and age of the metalworking machinery used in manufacturing pumps and compressors.

According to the *12th American Machinist Inventory of Metalworking Equipment* for 1976–78 (latest available), about one-third of all metal cutting and metal forming machine tools in the pump and compressor manufacturing industry were less than 10 years old; 70 percent were less than 20 years old. Comparable data for earlier years are available only for the general industrial machinery group (SIC 356). For general industrial machinery, no distinct trend in the age composition of metalworking machinery is observable. Thus, in 1958, 34 percent of such machinery installed in the plants of this group was less than 10 years old, 74 percent was less than 20 years. In 1968, as well as in 1978, the comparable figures read 33 and 72 percent.[15]

Despite the absence of a trend toward a more mod-

ern stock of metalworking equipment in terms of age, output capability per machine tool unit improved considerably. According to the *American Machinist's 10th Inventory of Metalworking Equipment* (1968), "For the last 5 years, the number of machine tools has increased by 4.5 percent, while the value of production, as measured in constant dollars by the *American Machinist* production index, has gone up by 39 percent." In the text accompanying its 12th Inventory (1976–78), the *American Machinist* again confirmed this trend. It noted that while the total machine tool "population" had declined by about one-tenth between 1968 and 1978, the production index had risen 40 percent.[16]

Table 2. Productivity and related indexes for pumps and pumping equipment manufacturing, 1972–80

[1977 = 100]

Year	Output per employee hour	Output	Employee hours	Employees
1972	90.8	81.0	89.2	88.1
1973	94.1	91.7	97.4	94.8
1974	93.6	91.9	98.2	98.3
1975	89.9	90.4	100.6	101.4
1976	92.7	92.9	100.2	99.7
1977	100.0	100.0	100.0	100.0
1978	101.1	106.1	104.9	106.2
1979	100.7	111.6	110.8	113.0
1980	97.2	112.5	115.8	117.6
Average annual rates of change (in percent):				
1972–80	1.2	3.9	2.6	3.1

Machining time cut

The increase in the output capacity of machine tools has undoubtedly contributed to gains in the labor productivity of pump and compressor manufacturing. For example, machining time for pump casings, which often are of great weight and size, has in the leading plants been drastically reduced by specially designed milling machines. These milling machines also require less setup time, and a smaller number of setups than formerly. In one case, machining time for large centrifugal pump casings, weighing up to 18,000 pounds, was reduced from 48 to 17 employee hours; in other words, where three 16-hour shifts, involving two operators, were required earlier, only one operator working 17 hours is needed now.[17] However, electric energy requirements are considerably greater.[18]

Reductions in machining time are frequently achieved by combining in one large metalworking operation several previously separate ones. An example is the simultaneous milling, radial drilling, and facing (smoothing) of different parts of the same workpiece. Sequential operations on a given workpiece are speeded up by means of automatic tool changers, commanded by taped instructions, causing different kinds of tools (or different configurations of the same kind of tool) to be advanced, retracted, and changed, as programmed. (Such apparatus may be bypassed by manual controls, when necessary in the operator's judgment.)[19]

Reductions in setup time have also been made possible for many single-purpose machines, for example, grinders. Pump shafts must in some cases be tapered, and this has usually required several setups depending upon the length and desired fit of the shaft. In some of the industry's plants, separate setups for this purpose have been eliminated by grinders that adapt automatically and will grind several fits simultaneously.[20]

Advances in the foundry operations of pump and compressor manufacturers have also contributed to labor productivity gains. In the technically more advanced plants, molding and coremaking have been speeded up by rapid-cycle machinery, and by discarding the time-consuming sand baking process. The no-bake process uses a resin binder and a catalyst to produce the sand mold, saving energy as well as unit labor requirements.[21] Several of the same core patterns (from which pump casings and other pump and compressor parts are cast) can be cut simultaneously by means of synchronous fabricating machinery, operating on the principle of key-making apparatus.

Engineering plays a key role in pump and compressor manufacturing. As noted, much of the industry's output is manufactured to customer specifications, which of necessity involves engineering staff. Additionally, the advent of numerically controlled machine tools, and of computer numerical controls, has centered more production responsibilities in engineering departments, away from the shop floor. The growth of engineering staff has intensified concern with promoting its efficiency. Engineering efficiency has been raised in the more advanced establishments of the industry by applying certain computer technologies; designing production processes which economize on engineering time; and standardizing common parts. Efforts have also been made to bypass engineering where feasible.[22]

Computer graphics have simplified drafting by allowing corrections to be made to the draft without manually redrawing it. Detailed drawings can be made within minutes, where before it took hours. Computerized data banks permit access to all drawings on file. Computer graphics has permitted the elimination of 7 to 8 drafter jobs in one of the establishments visited by BLS staff. The computer-aided design can be programmed directly upon tape, and fed to the machine tool. This represents a considerable advance for numerical controls, inasmuch as programs previously had to be punched, or prepunched programs had to be purchased.

With design and production closely linked, owing to the computer and numerical controls, engineers conceive of computer-aided design and computer-assisted manufacturing as integral operations. Calculation of formulae, design of the product, and production are

viewed and operated as a single process. Uniformity of product dimension and quality are ensured. Changes in the detail of design are quickly and inexpensively incorporated. Engineering time saved by computer-aided design and computer-assisted manufacturing has been estimated at two-thirds of conventional engineering procedures.[23]

As noted, replacement of parts and attachments accounts for a sizable proportion of the output of pump and compressor manufacturing. Computer-aided design and computer-assisted manufacturing helps ensure that replacement parts are dimensionally accurate, while economizing on engineering time. Dimensional conformance is further ensured by certain process innovations. Thus, cores or molds for impellers and other pump and compressor components are now frequently ceramic instead of wood.

Capital expenditures

Plant and equipment outlays by pump and compressor manufacturers rose at an average annual rate of 8.1 percent between 1958 and 1980—compared with 4.9 percent per year for all manufacturing. (The expenditure data underlying these rates have been adjusted for price changes.[24]) The industry's capital spending rose at a particularly high rate during the 1960's, nearly tripling between 1958 and 1969. For a few years thereafter, such spending receded from the 1969 level, but it resumed its rise in 1972, and doubled between 1972 and 1980. Comparable figures for all manufacturing are considerably more modest, as the tabulation shows (average annual rates in percent):

	Pumps and compressors	*Manufacturing*
1958–80	8.1	4.9
1958–69	12.2	8.2
1969–80	6.9	4.6
1969–72	-10.2	-3.0
1972–80	7.6	5.4

Structure of the industry

In 1977, pumps and pumping equipment were manufactured in 613 establishments, air and gas compressors in 175. The former had increased 10 percent since 1972, the latter had more than doubled. In the preceding 9 years, no change in the number of establishments making pumps and compressors had occurred. The number of *companies* in the industry owning these establishments barely changed during the 1970's.[25]

Pumps and compressors are manufactured mostly in larger plants. Five percent of all establishments in the industry employed 45 percent of its workers in 1977, and accounted for about the same proportion of the total value of shipments. More generally, establishments with 100 workers or more represented less than one-quarter of the total number of establishments in the industry but well over four-fifths of total employment and value of shipments.

Table 3. Productivity and related indexes for air and gas compressor manufacturing, 1972–80

[1977 = 100]

Year	Output per employee hour	Output	Employee hours	Employees
1972	92.1	66.7	72.4	71.6
1973	106.8	79.8	74.7	76.6
1974	103.0	98.2	95.3	95.3
1975	96.7	80.5	85.0	85.3
1976	106.4	88.4	83.1	83.8
1977	100.0	100.0	100.0	100.0
1978	105.5	109.1	103.4	102.8
1979	106.0	120.3	113.5	112.2
1980	105.7	113.7	107.6	106.6
Average annual rates of change (in percent):				
1972–80	1.1	6.5	5.4	5.2

Concentration was high. The industry's four largest companies employed more than half of its workers in 1977, and accounted for half of its value of shipments. For manufacturing as a whole, the comparable ratios were 6 and 7 percent.

Even so, the establishments are mostly small, employing fewer than 100 persons. The smaller plants accounted for 79 percent (pumps) and 70 percent (compressors) of all industry establishments in 1977. At the same time, however, they recorded only 14 and 9 percent of total industry employment. These relationships had not changed much from earlier phases of the review period.

Outlook

Continued advances in the labor productivity of pump and compressor manufacturing are likely over the longer term. The diffusion of numerically controlled machine tools and computer-aided design within the industry's establishments, as well as among them, has still some way to go. The age distribution of metalworking machinery should continue to favor higher-capacity, modernized equipment. Organizational changes resulting from a widening scope of computer applications—for example, more centralized decisionmaking in reference to machining processes—will probably also improve productivity.[26]

So far, robots appear not to have been introduced widely. Even in the more advanced shops, they are used chiefly for paint spraying and other marginal operations. Industry observers, however, expect that robots, as their costs decline, will handle workpieces more and more during the noncutting portion of the work cycle.[27] Such a development is also bound to raise labor productivity.

The nearer-term outlook is somewhat clouded, however. The industry's output is likely to suffer from weakened demand from major users of pumps and compressors. When output slackens, a slowed rate of productivity advance, even declines in the rate, are more probable. A source of weakened demand is the stagnation in housing starts, which tends to diminish the need for pumps and compressors used in construction, as well as for such public works as water and sewage, which often require pumps and related equipment on a large scale. Another source of declining needs for (hence output of) pumps and compressors are reductions in projected increases in oilfield exploration and development. (These reductions have been linked to smaller-than-expected energy demand increases, and lessened price pressures.)[28]

At the same time, the widespread concern with cutting energy costs may bolster the demand (and output) of more energy-efficient pumps and compressors. For example, variable displacement pumps may to some extent replace fixed displacement pumps. The latter rejects excess flows by means of a relief valve, dumping them back into a reservoir. This wastes pump energy, which a variable displacement pump can avert.[29] Piston pumps, furthermore, are thought by industry observers to be also favored over fixed displacement pumps, as high-pressure hydraulics is more widely adopted in industry and transportation (especially in aircraft and mobile equipment). High-pressure hydraulics permits the use of lighter pipes, pumps, and actuators.[30]

Industry observers believe that pumps and equipment of larger size will continue to be installed in such uses as steampower generation, pipelines, and petroleum refining. The shift from gasoline to heavy fuel refining[31] requires heavier rotary rather than lighter centrifugal pumps. Slurry pipelines—which move water-suspended solids such as coal and wood chips—are believed to gain wider acceptance, because they offer important economies in transportation.

The BLS has projected a somewhat faster rise in the number of nonproduction workers than production workers for the general industrial machinery group.[32] In 1990, professional and technical workers will make up 12.4 percent of all of the group's employees, according to the projections, compared with 11.4 percent in 1980; and the share of clerical and related workers will rise slightly. The proportion of craftworkers will remain unchanged, and that of operatives will edge downward. It seems reasonable to assume that changes in occupational pattern projected for the general industrial machinery group will, by and large, be repeated by pump and compressor manufacturing. □

FOOTNOTES

[1] The pump and compressor manufacturing industry consists of two segments, pumps and pumping equipment, designated as SIC 3561 of the *Standard Industrial Classification Manual 1972* of the Office of Management and Budget; and air and gas compressors, SIC 3563. SIC 3561 consists of establishments primarily engaged in manufacturing pumps and pumping equipment for general industrial use. Measuring and dispensing pumps for gasoline stations are not included, nor are pumps installed in automobiles. SIC 3563 consists of establishments primarily engaged in manufacturing air and gas compressors for general industrial use. Refrigeration compressor units are not included. Prior to 1972, pumps and compressors were classified together in SIC 3561.

Average annual rates of change 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] William C. Krutzsch, "Introduction and Classification of Pumps," in Igor J. Karassik and others, *Pump Handbook* (New York, McGraw-Hill, 1973), p. 1 ff.

[3] John P. Rollins, ed., *Compressed Air and Gas Handbook* (New York, Compressed Air and Gas Institute, 1973), p. 1. The range of compressed air uses are discussed on pp. 1–44.

[4] U. S. Department of Commerce, Bureau of Economic Analysis, *The Detailed Input-Output Structure of the U. S. Economy: 1972* (Washington, D.C., Government Printing Office, 1979).

[5] John R. Birk and James H. Peacock, "Chemical Industry," *Pump Handbook,* p. 10–74 ff. Also, conversation with industry observer.

[6] E. R. Pritchett, "Steel Mills," *Pump Handbook,* p. 10–159; and telephone conversation with author.

[7] Elvitsky, *Pump Handbook.*

[8] U. S. Department of Labor, Bureau of Labor Statistics, *Productivity Measures for Selected Industries, 1954–80* (Washington, D.C., Government Printing Office, 1982), table 179.

[9] Mary Vickery, "Petroleum Pipeline Transportation," U.S. Department of Labor, Bureau of Labor Statistics, *Technological Change and its Labor Impact in Five Energy Industries,* BLS Bulletin 2005 (Washington, D.C., Government Printing Office, 1979), pp. 39 and 42.

[10] Telephone conversation with Krutzsch, an author of *Pump Handbook.*

[11] Benjes, H.H., "Sewage," *Pump Handbook,* p. 10–2. Also, telephone conversation with author.

[12] Overtime in pump and compressor manufacturing compared with overtime for all of manufacturing durables (all manufacturing = 100) as follows:

	Pumps and compressors		*Pumps*	*Compressors*
1958	63	1974	126	112
1959	111	1975	119	115
1960	104	1976	131	103
1961	83	1977	114	116
1962	96	1978	100	113
1963	90	1979	103	114
1964	103	1980	100	161
1965	113			
1966	123			
1967	114			
1968	103			
1969	103			
1970	110			
1971	93			
1972	103			
1973	105			

[13] Labor turnover in pump and compressor manufacturing compared with manufacturing (all manufacturing = 100) as follows (data from 1972 forward for pumps and pumping equipment only; data for air and gas compressors are not available):

	Accessions	*Separations*
1958	52	66
1959	69	56
1960	55	65
1961	54	58
1962	56	51
1963	56	56
1964	63	46
1965	60	58
1966	68	63
1967	57	59
1968	57	57
1969	68	65
1970	60	76
1971	54	56
1972	60	49
1973	67	55
1974	71	67
1975	51	68
1976	59	53
1977	63	55
1978	51	49
1979	53	54
1980	54	58

[14] See Comptroller General of the United States, *Manufacturing Technology—A Changing Challenge to Improved Productivity*, Report to the Congress, Washington, June 3, 1976, especially p. 37 ff.

[15] *The Eighth American Machinist Inventory of Metalworking Equipment—1958*, New York, McGraw-Hill. Reprinted from the *American Machinist*, Nov. 17, 1958; *The Tenth American Machinist Inventory of Metalworking Equipment—1968*, New York, McGraw-Hill, 1968. The data cited for pump and compressor manufacturing from the 12th *Inventory* are based on unpublished printouts.

[16] *American Machinist*, December 1978, p. 135. The reduction in machining time is confirmed in Donald N. Smith and Larry Evans, *Management Standards for Computers and Numerical Controls* (University of Michigan, 1977). See also John Duke and Horst Brand, "Cyclical Behavior of Productivity in the Machine Tool Industry," *Monthly Labor Review*, November 1981, pp. 27–34.

[17] William H. Parker, "Cutting time out of pump machining," *American Machinist*, January 1979, pp. 112–13.

[18] "The Machine Tools that are Building America," *Iron Age*, Aug. 30, 1976, p. 163. According to the report, electric horsepower requirements for lathes rose from 150 in the 1950's to 400 to 600 in the 1970's. Many other examples are also cited in the article.

[19] Observation of industry operations. See also *Iron Age*, cited above.

[20] Observation of industry operations.

[21] Observation of industry operations. See also Richard W. Lyon, "Foundries," in U.S. Department of Labor, Bureau of Labor Statistics, *Technology and Labor in Four Industries*, Bulletin 2104 (Washington, D.C., Government Printing Office, January 1982), p. 12.

[22] Industry sources, and observation of industry operations. See also A. Harvey Belitsky, "Major technology changes in metalworking machinery," *Technology and Labor in Four Industries*, pp. 20–33.

[23] Industry source.

[24] Adjustment for price changes was made by using the implicit deflator for nonresidential investment in structures and producers' durable equipment. See *Economic Report of the President*, February 1982, p. 236.

[25] U.S. Department of Commerce, Bureau of the Census, *General Report on Industrial Organization, 1977 Enterprise Statistics* (Washington, D.C., Government Printing Office, 1981).

[26] A. Harvey Belitsky, "Major technology changes," especially pp. 24–25.

[27] See *American Machinist*, June 1980, p. 147 ff.

[28] "Biggest U.S. Oil Concerns Likely to React to Glut by Cutting 1982 Capital Budgets," *The Wall Street Journal*, Apr. 7, 1982, p. 7.

[29] "Curbing the Energy Appetite of Hydraulic Systems," *Machine Design*, June 26, 1980, p. 95.

[30] "Modern Hydraulic Systems: the Pressure Mounts," *Machine Design*, Jan. 24, 1980, p. 81 ff.

[31] Rose Zeisel and Michael D. Dymmel, "Petroleum refining," *Technological Change and Its Impact in Five Energy Industries*, p. 26.

[32] See the articles on the Bureau's projections in *Monthly Labor Review*, August 1981, pp. 9–42.