Technology and Labor in Four Industries

Meat products/Foundries
Metalworking machinery
Electrical and electronic equipment

U.S. Department of Labor
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Raymond J. Donovan, Secretary
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Preface

This bulletin appraises some of the major technological changes emerging among selected American industries and discusses the impact of these changes on productivity and occupations over the next 5 to 10 years. It contains separate reports on the following four industries: Meat products (SIC 201), foundries (SIC 332,336), metalworking machinery (SIC 354), and electrical and electronic equipment (SIC 36).

This publication is one of a series which presents the results of the Bureau's continuing research on productivity and technological developments in major industries. Preceding bulletins in this series are included in the list of BLS publications on technological change at the end of this bulletin.

The bulletin was prepared in the Office of Productivity and Technology under the direction of John J. Macut, Chief, Division of Technological Studies. Individual industry reports were written by staff members of the Division under the supervision of Rose N. Zeisel and Richard W. Riche. The authors were: Meat products, Gary E. Falwell; foundries, Richard W. Lyon; metalworking machinery, A. Harvey Belitsky; and electrical and electronic equipment, Robert V. Critchlow.

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Contents

Chapter 1. Meat Products

Summary

Technological change will probably be limited in the meat products industry in the 1980's, with the possible exception of more sophisticated equipment for processing retail cuts of beef. Improvements to existing machinery are being made, but design concepts or functions are not expected to change. In meatpacking and poultry processing plants, new technologies were introduced in the 1960's that mechanized processing to some extent and reduced unit labor requirements. However, most cutting tasks must still be performed manually, and the industry remains relatively labor intensive.

Because advances in equipment have not occurred, the outlook is for little change in job content or skill requirements. Currently the major impact on production and labor utilization in meatpacking comes from growth in the marketing and distribution of "boxed beef." In contrast to the labor intensity of meatpacking and poultry processing, mechanized batch processing is typical for the making of sausages and other prepared meats. The use of highly mechanized equipment in this sector is already widespread, and new techniques are not expected.

Output of all meat products rose sharply from 1960 to 1980; however, the growth rate in the 1960's was much greater than in the 1970's. The data do not measure increased processing in the plant, e.g. production of "boxed beef", packaged subprimal cuts of beef. Boxed beef has increased rapidly to about half of federally inspected steer and heifer slaughter in 1979. It is expected to become increasingly important in the industry.

For the separate industry sectors, the best available data on output (deflated value of shipments) and employee hours appear to indicate strong productivity growth in meatpacking and moderate growth in prepared meats since 1960. Official BLS productivity measures are not currently available because increased processing in the plants has made accurate measurement of output and hours difficult to achieve.

Capital expenditures increased substantially from 1960 to 1978, to a peak of over $500 million. Real outlays (expenditures deflated to account for price changes) were significantly larger in the 1970's than in the 1960's. Despite these increases, capital spending per production worker in meat products is considerably below the average for all manufacturing.

About 361,800 people were employed in the industry in 1980, 12 percent more than in 1960. While employment has risen overall, some industry sectors have experienced declines. Because of the labor-intensive character of the manufacturing processes, the proportion of production workers is relatively high: 83 percent compared to an average of 71 percent for all nondurable goods manufacturing. Women constitute almost one-third of all employees, comparable to manufacturing as a whole, but their proportion varies greatly in the different sectors of meat production.

The outlook for employment in the 1980's is not clear. According to BLS projections based on three versions of economic growth, employment in the meat products industry could show almost no increase or could increase as much as 1.0 percent annually from 1980 to 1990—compared with the average of 0.7 percent from 1960 to 1980.

Technology in the 1980's

Little technological change is expected in the meat products industry in the 1980's, although improvements to existing machinery will continue. With the possible exception of more sophisticated equipment for processing retail cuts of beef, design concepts or functions are not expected to change.

In meatpacking plants (SIC 2011), new technologies introduced in the 1960's automated processing and reduced unit labor requirements. In beef processing, rail systems for moving carcasses between cutting stations eliminated the constant repositioning required in the older "bed" system. Also, for carcass splitting, workers were equipped with power knives and saws and were stationed on horizontally moving platforms. Mechanical hide pullers were introduced that eliminated many of the highly skilled hand cutting operations necessary in hide removal. Rendering operations were mechanized to the extent that one worker operating a central control panel became responsible for the entire process. In pork processing, rail systems were also adopted. Currently, these methods are widespread.

A large proportion of the cutting operations—particularly fabricating the carcass into primal cuts—is still done manually, without the aid of powered equipment. Further automation is hindered by the difficulty of developing economical and reliable cutting machinery capable of adapting to the physical differences in animal carcasses.

Boxed beef

The beefpacking industry is undergoing significant structural changes due to the growing acceptance by retailers and wholesalers of boxed beef instead of whole carcasses. Boxed beef is beef processed to primal or subprimal cuts, vacuum packed, and placed in cartons by the packers. In contrast to carcass beef, boxed beef allows mass production techniques and has lower unit freight costs. While not new, boxed beef has grown from a relatively minor product to a significant component of the industry.

Boxed beef represents a shift in processing from retail establishments to the packinghouse. Although packinghouses have been cutting and boxing beef for many years, their market, primarily institutions, was very small. Traditionally, cutting the carcass into parts was done by butchers in retail establishments or, to some extent, by wholesalers selling to larger customers. In recent years, however, boxed beef has become much more acceptable to retailers as quality control has increased. Also, according to claims by boxed beef producers, boxed beef sales result in savings for retailers from lower transportation costs, less product shrinkage, lower construction costs for retail meat areas, greater ability to tailor products to specific markets, and lower unit labor costs.

As a result of aggressive marketing, the boxed beef market has greatly expanded, from only 9 percent of federally inspected slaughter of steers and heifers in 1971 to about 46 percent in 1979, according to estimates of the U.S. Department of Agriculture. As yet, only relatively few packers—the large companies—are providing boxed beef, but it is generally expected that demand for boxed beef will become increasingly important in the industry.

The processing of carcasses into boxed beef does not require new technology. Conventional conveyors move chilled carcasses between stations where operators work in an assembly-line fashion, performing most cutting, packaging, and boxing tasks manually. In larger plants, however, computerized warehouse systems are used to place boxes in storage, keep inventory records, and retrieve and assemble boxes for shipment.

The growth of boxed beef has had no significant impact on skill requirements in the industry. Because the carcass is processed on an assembly line, a high level of skill is not required. Each worker on the line must master only a single cut; this minimizes training, skill, and unit labor requirements. However, boxing beef has meant the addition of packaging workers at the end of the processing line. Semiskilled workers manually bag each cut of meat, then operate machinery that vacuum seals the meat in a protective film. Other workers manually sort the packaged cuts into boxes for shipping.

It is likely that the shift in processing from retail establishments to the packinghouses will continue in the next decade, to include consumer-size retail cuts. This could be associated with more sophisticated cutting and packaging equipment.

Processed meats and poultry

Operations in the processed meats sector of the industry (SIC 2013) lend themselves to batch processing, and automated production techniques are well established. Bulk handling of materials, mechanized processing, and automated packaging have been commonplace in the industry for many years. In frankfurter production, for example, workers oversee continuous processing machinery which mixes, stuffs, cooks, chills, and packages weiners automatically. Also, an in-line cleaning arrangement reduces labor requirements for maintenance and holds downtime to a minimum.

In general, the amount of labor and skill now necessary to operate processed meat production lines has been minimized. Job assignments require the monitoring of machinery rather than manual processing. Because this industry sector is already highly mechanized, the outlook is for improvement to existing machinery rather than changes in production methods. The effect on labor is consequently expected to be minimal.

Similarly, technology in poultry processing (SIC 2016, 2017) is not expected to change significantly in the 1980's. Currently, some steps are highly mechanized. Slaughtering and feather removal are generally accomplished by machine. Also, conveyors and rail systems which move poultry carcasses through the plant, as well as automated packaging equipment, are widespread. However, manual cutting is still extensive. Most of the tasks in evisceration and carcass breakdown are done with knives or shears. In only a few steps—such as lung or neck removal—are workers assisted by power tools. As in meatpacking plants, machinery has not been developed to accommodate the physical differences in poultry carcasses. Also, the comparatively low wages paid poultry workers reduce the incentive for more mechanization.

Output and Productivity Outlook

Output

Output of all meat products (SIC 201) rose at an average annual rate of 1.9 percent between 1960 and 1980, according to Federal Reserve Board data.[1] However, the rate of growth in the 1970's contrasted sharply with the trend in the 1960's. From 1960 to 1970, output increased an average of 2.9 percent annually, with only 1 year of decline. In contrast, declines in 4 of the 10 years from 1970

[1] Board of Governors of the Federal Reserve System index of production for meat products, SIC 201, based on weighted production data of the U.S. Department of Agriculture.

Butchers cutting carcasses for boxed beef

to 1980 reduced the average growth to 1.2 percent for that period.

For the major sector of the industry, meatpacking plants, data on commercial meat production are provided by the U.S. Department of Agriculture. These data present certain problems because they are only a measure of the weight of animal carcasses. They do not, for example, include sausages and prepared meats or plant output of hides and other byproducts. Nor do they take account of additional processing, e.g., boxed beef, the major output change. Nevertheless, these data, which are the best available for this analysis, show that total commercial production of beef, pork, veal, and lamb and mutton increased more than 40 percent from 1960 to 1980, to over 38 billion pounds. Output growth was strong in the 1960's, averaging 3.0 percent annually over the decade, but slowed to only 0.7 percent from 1970 to 1980.

Beef is the major product in the meatpacking industry. It currently accounts for about 55 percent of total meat production; pork makes up about 43 percent. Beef has experienced a relative decline, from a peak of 66 percent of total meat in 1976 to slightly more than half in 1980. Per capita consumption of beef increased from 85 pounds annually in 1960 to 129 pounds in 1976 but has since declined to about 106 pounds in 1980. The other components of meat output, veal and lamb and mutton, have historically been only a small proportion of production—about 2 percent in recent years.

As mentioned earlier, boxed beef is replacing carcass beef as the predominant method of marketing beef. However, data on output of boxed beef are limited. One survey by the U.S. Department of Agriculture of the major boxed beef producers shows that production more than tripled in volume from 1.3 billion pounds in 1971 to over 4.1 billion pounds in 1976.[2] A more recent Department of Agriculture survey[3] indicates that, in 1979, boxed beef production totalled 4.8 billion pounds, or about half of federally inspected steer and heifer slaughter.

Concentration in the beefpacking industry is becoming an area of concern, according to testimony in Congressional hearings.[4] In 1977, 5 percent of the total number of packers were responsibile for 70 percent of steer and heifer slaughter; 10 percent accounted for 80 percent of the slaughter. Concern focuses not only on the share of the wholesale market which larger firms maintain, but also on their capability to control sources of supply.

Data on output of poultry processing plants compiled by the U.S. Department of Agriculture also have certain limitations, but can be used to approximate total output of this sector.[5] These data show that commercial broiler production more than doubled from 1960 to 1980, to over 11 billion pounds. Very substantial growth occurred in the 1960 decade when the annual rate averaged 5.5 percent; from 1970 to 1980, the rate was 4.2 percent.

Like production of commercial broilers, turkey production has also shown substantial growth since 1960—output more than doubled to about 2.5 billion pounds in 1980. Higher prices for red meat and greater marketing efforts have increased demand for turkeys and have made purchases less seasonal. The growing preference for turkey is evident in increased per capita consumption, from about 6 pounds in 1960 to about 10 pounds by 1980.

Output of sausage and prepared meat establishments (SIC 2013) appears to have increased substantially, but no official data are available.[6] One measure, Census value of shipments data deflated by BLS price indexes, indicates that 1978 output was almost double that of 1960.

Productivity

Currently, no official productivity data are published due to the problems of measurement. Because output data based on carcass weight do not accurately account for the growth in processing, their use in productivity measurement has become an issue.[7] In the case of boxed beef, for example, output data must be adjusted to reflect the processes of cutting and boxing as well as the traditional labor in slaughtering operations. Because the proportion of boxed beef in the industry has increased, productivity data based on carcass weight output would be understated.

Nevertheless, approximate overall trends can be identified. For this purpose, the best approximate measures are the Census value of shipments data adjusted for changes in inventory and prices. The use of these output measures with data on employee hours as indicators of productivity suggests markedly different patterns of growth among the major sectors (chart 1).

In meatpacking plants, employee hours declined almost every year from 1960 to 1978 (1½ percent annually), while output is estimated to have increased moderately (about 2 percent annually), indicating substantial productivity growth over this period. In the 1960 decade, estimated productivity growth was especially strong. Output is estimated to have increased 2½ percent annually as employee hours declined almost 2 percent per year. In the years 1970–78, productivity gains

[2]Agricultural Marketing Service, U.S. Department of Agriculture, unpublished data.

[3]Unpublished data.

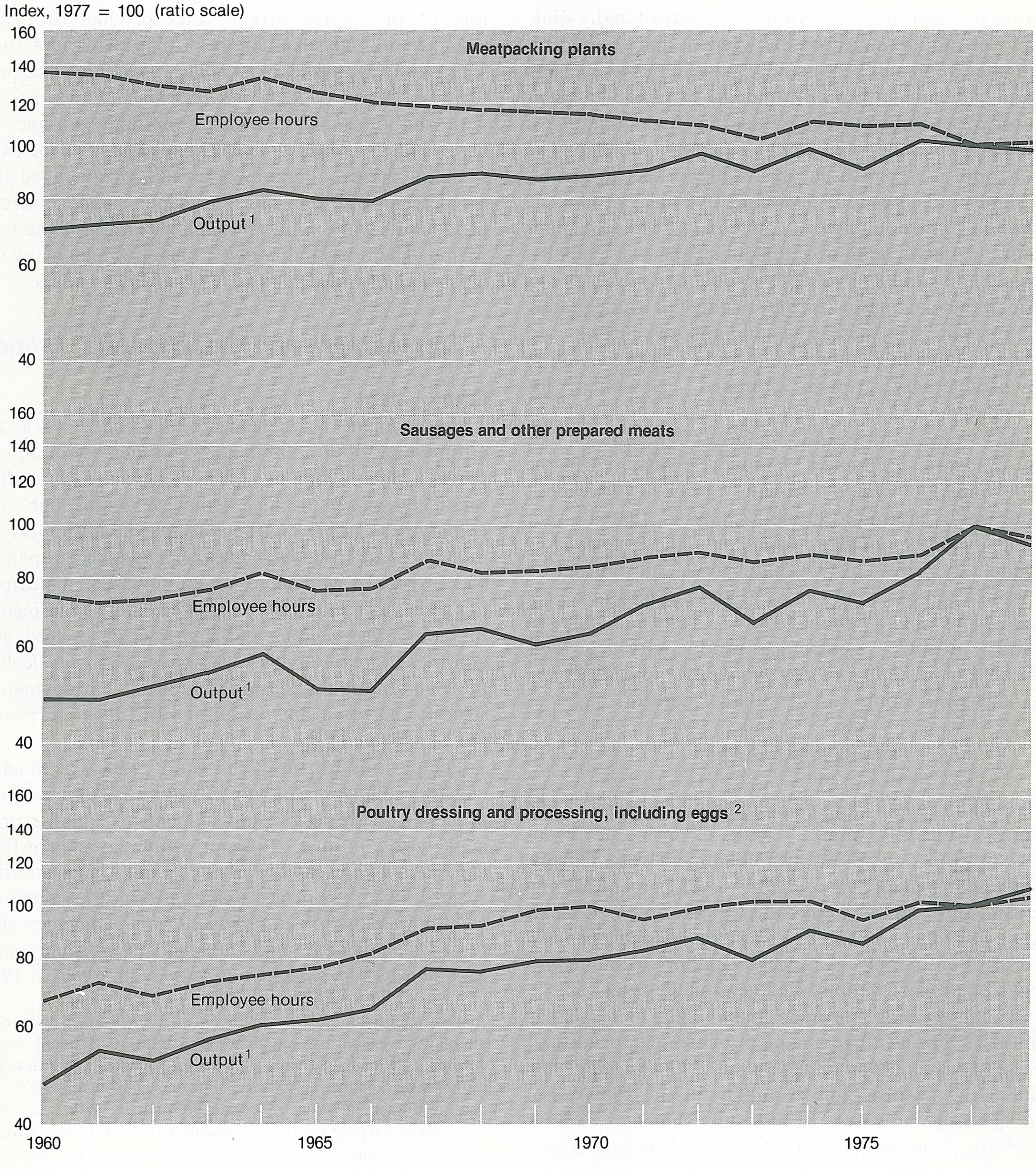
[4]U.S. Congress, House of Representatives, Committee on Small Business. *Small Business Problems in the Marketing of Meat and Other Commodities*, 1979.

[5]Although Department of Agriculture data for pounds of broiler and turkey production reflect overall trends, they do not measure industry output of processed poultry and eggs, specialized poultry products, and small game, nor do they reflect the trend in recent years toward more in-plant processing and packaging.

[6]Unpublished BLS data.

[7]See, for example, Amalgamated Meat Cutters and Butcher Workmen of North America (AFL-CIO), *1979 Fact Book*, table 1.

Chart 1. Output and employee hours for industry sectors, meat products, 1960-78



[1] Deflated value of shipments, unpublished data.

[2] Includes SIC's 2016 and 2017.

Sources: Bureau of Labor Statistics and Bureau of the Census.

may have slowed somewhat as estimates of output increased only about 1½ percent annually while the decline in hours slowed down to a rate of slightly over 1 percent.

In contrast, it is likely that the sausage and prepared meats sector experienced only moderate productivity growth in the years 1960–78, and growth in the 1970's was stronger than in the 1960's. From 1960 to 1970, output growth probably averaged about 3 percent annually while employee hours increased between 1 and 2 percent. Estimates of greater productivity gains in the 1970's were associated with stronger output growth—estimated at almost 5 percent per year—while the rise in employee hours remained between 1 and 2 percent per year. The strong output growth in the 1970's reflected greater consumer preference for less expensive meat products.

In poultry processing (SIC 2016, 2017), as in the other sectors, deflated value of shipments is the best available measure of output. Again, a productivity measure is difficult to develop because output data fail to adequately account for the increasing amount of cutting and packaging operations being done in the plants. Therefore the productivity growth estimated below may be understated.

The best available output and hours data indicate that very moderate productivity gains were achieved in the 1960–78 period. Output growth appears to have been strong while hours rose moderately in that 18-year period. However, data for 1960–70 suggest slow productivity growth. Output grew substantially—between 5 and 6 percent per year—but hours almost kept pace—rising slightly more than 4 percent annually. In contrast, in 1970–78, stronger productivity growth is indicated as output increased between 3 and 4 percent annually while hours rose less than 1 percent.

Investment

Expenditures for new plant and equipment reached a peak of over $550 million in 1978, according to Census data, as prices for plant and equipment rose sharply. Meatpacking plants spent the most (42 percent of total industry outlays), while the sausage and prepared meats sector and the poultry dressing sector each spent 27 percent. Poultry and egg processing plants accounted for only a small part—about 4 percent of the total.

Capital spending was much greater in the 1970's than in the 1960's. For meatpacking plants, current expenditures averaged $200 million annually for 1970–78, more than double the average annual outlay in the 1960's. For sausage and prepared meat establishments, average expenditures more than tripled, from $32 million to over $97 million in these periods. For the poultry industries, the average expenditure was only $34 million in the 1960's but rose dramatically to over $92 million for 1970–78.

Even when these expenditures are deflated (by the BLS food products machinery price index) to account for price changes, the data indicate a marked increase in outlays. In meatpacking, real average annual expenditures increased 30 percent in 1970–78 from the 1960 decade, while in the sausage and prepared meat sector real expenditures rose 85 percent over the earlier period. For the poultry industries, the increase was 66 percent.

Despite the increases in capital outlays in the 1970's, capital/labor ratios in meat products are relatively low compared to all manufacturing. For example, expenditures per production worker in meat products for 1972–78 averaged only 60 percent of the ratio in all manufacturing. This relatively low ratio of capital to labor is a measure of the labor intensity of the processes. The industry sector with the most automated technology—sausages and other prepared meats—had the highest level of capital spending per production worker but still averaged about 80 percent of the ratio of capital expenditures to production workers in all manufacturing for the 6-year period. The other industry sectors—in which many tasks must be performed manually—had lower ratios.

Employment and Occupational Trends

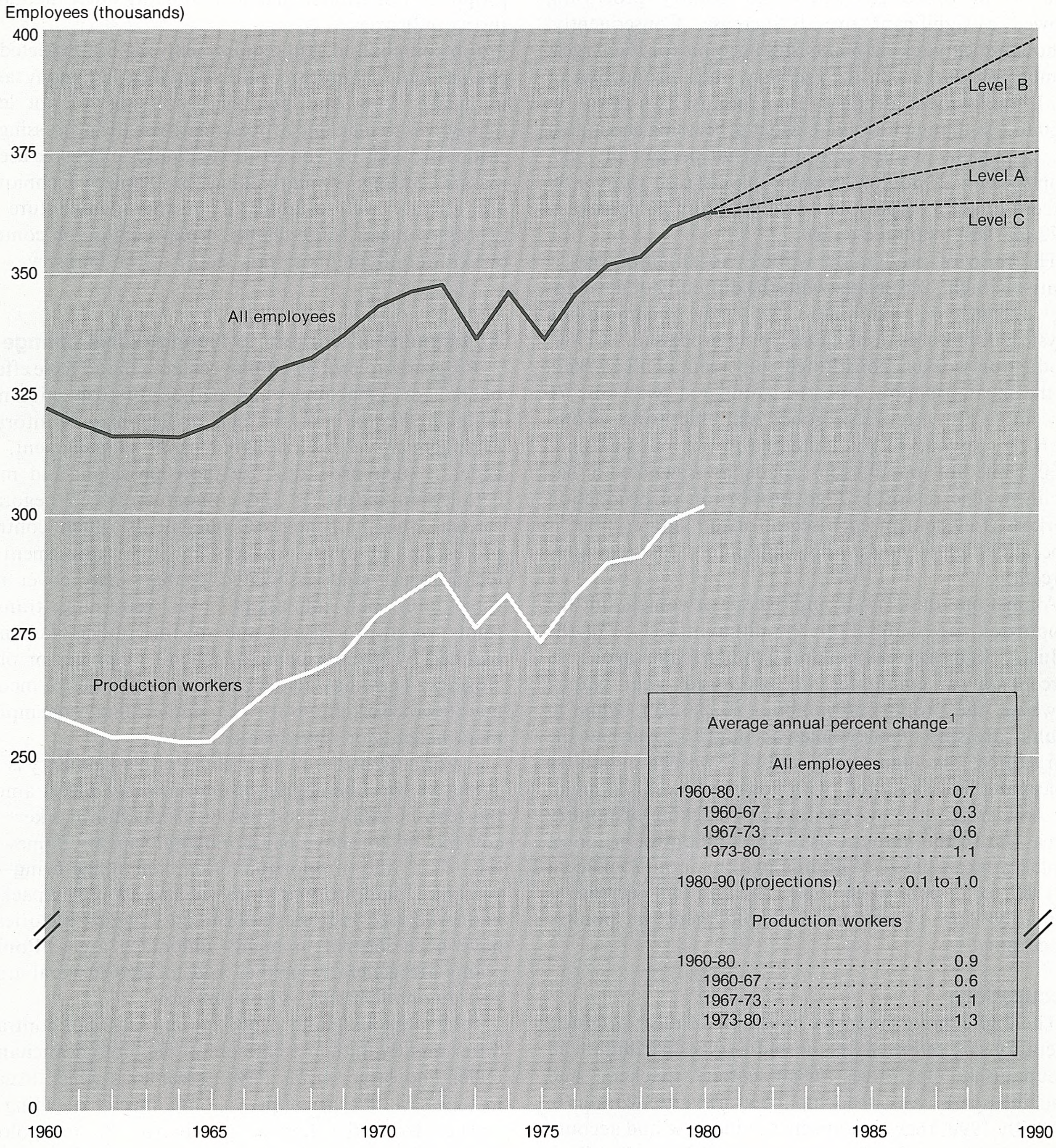
Employment

Employment in the meat products industry was at an alltime high of 361,800 in 1980, an increase of about 12 percent since 1960, or 0.7 percent annually. After a relatively sharp decline from 1958 through 1962, employment stabilized, then increased continuously at a moderate rate from 1964 until 1972. A sharp drop in 1973 was associated with decreased employment in meatpacking plants as cattle marketings were reduced in response to retail price ceilings and higher costs of feed grain. Another decrease in 1975 was associated with declining hog and poultry marketings. Since 1975, employment has steadily increased but not until 1977 did it surpass the 1972 level (chart 2).

The outlook for the 1980's is not clear. The impact of new technology is expected to be minimal and the shift in processing from retail establishments to slaughterhouses is likely to continue. However, employment growth will depend to a large extent on general economic conditions. According to BLS projections based on three versions of economic growth,[8] employment in the meat products industry could show almost no increase or could increase as much as 1.0 percent annually from 1980 to 1990—

[8]Projections for industry employment in 1990 are based on three alternative versions of economic growth for the overall economy developed by BLS. The low-trend version is based on a view of the economy marked by a decline in the rate of expansion of the labor force, continued high inflation, moderate productivity gains, and modest increases in real output and employment. In the high-trend version I, the economy is buoyed by higher labor force growth, much lower unemployment rates, higher production, and greater improvements in prices and productivity. The high-trend version II is characterized by the high GNP growth of high-trend I, but assumes the same labor force as the low trend. Productivity gains are quite substantial in this alternative. On chart 2, level A is the low trend, level B is high-trend I, and level C is high-trend II. Greater detail on assumptions is available in the August 1981 issue of the *Monthly Labor Review*.

Chart 2. Employment in meat products, 1960-80, and projections for 1980-90



[1] Least squares trend method for historical data; compound interest method for projections.

Note: See text footnote 8 for explanation of alternative projections.

Source: Bureau of Labor Statistics.

compared with the average of 0.7 percent from 1960 to 1980.

The industry's increase in employment of 12 percent from 1960 to 1980 was the result of very different employment trends in the individual sectors. Employment in meatpacking plants declined steadily from 1960 to 1973 but stabilized thereafter. In contrast, the number of workers in processed meats and poultry processing showed a significant overall increase. Consequently, although meatpacking plants still account for the largest number of workers in the industry, their proportion of total employment declined from almost two-thirds in 1960 to less than half in 1980. Meat processing accounted for 15 percent in 1960 and almost 20 percent in 1980. Employment in poultry dressing plants rose to over 30 percent of total employment by 1980 from 26 percent in 1972 (earliest available data).

The ratio of production workers to all employees is relatively high—associated with the difficulty of developing automated techniques that will accommodate physical differences in carcasses being processed. In 1980, production workers constituted 83 percent of all workers in the meat products industry, compared with only 71 percent in all nondurable goods manufacturing. Moreover, the percentage has increased in the industry since 1960 while for nondurable goods as a whole, it has declined. The relatively high proportion of production workers is evident in each sector of the industry, but is especially high in poultry dressing plants—exceeding 90 percent.

Almost one-third of all employees are women, but the proportion varies greatly in the different sectors of the industry. In meatpacking plants, women make up only 18 percent of all employees. In processed meat plants, however, the proportion is about 30 percent, while in poultry dressing plants women account for over half the work force. The higher proportion of women in poultry processing is associated with lower physical strength requirements in the evisceration and packing of poultry carcasses. In the industry as a whole, the proportion of female workers has risen gradually from about 25 percent in 1960 to 33 percent in 1980. This gradual increase is primarily due to increased employment in poultry processing.

Occupations

The highly labor-intensive character of meat products operations is reflected in the industry's distribution of occupations. Operatives—meat cutters, packers, and machine operatives—made up 3 out of every 5 workers in 1978. By 1990, they are expected to increase and account for two-thirds of the work force (chart 3). Craft workers—about 8 percent of industry employees—consist primarily of blue-collar worker supervisors and heavy-equipment mechanics. These mechanics are among the most skilled and highest paid workers in the plants. Laborers, including freight and material handlers, constituted 8 percent of industry employees—a relatively high proportion compared to only 5 percent in all manufacturing. White-collar employees—professionals, managers, and sales and clerical workers—accounted for less than 18 percent of industry employment in 1978. By 1990, they are expected to decline in number and make up only 15 percent of industry employment. This decrease is in sharp contrast to the trend toward an increase in the proportion of white-collar jobs in many other manufacturing industries.

Job content and skill requirements are not expected to change in the near future. As discussed earlier, many tasks in meatpacking and poultry processing do not lend themselves to machine processing. Even the processing of cattle carcasses into boxed beef requires extensive use of manual cutting. Similarly, since mechanized techniques are already well established in the manufacture of processed meats, little change is expected in job content or skill requirements in this sector of the industry.

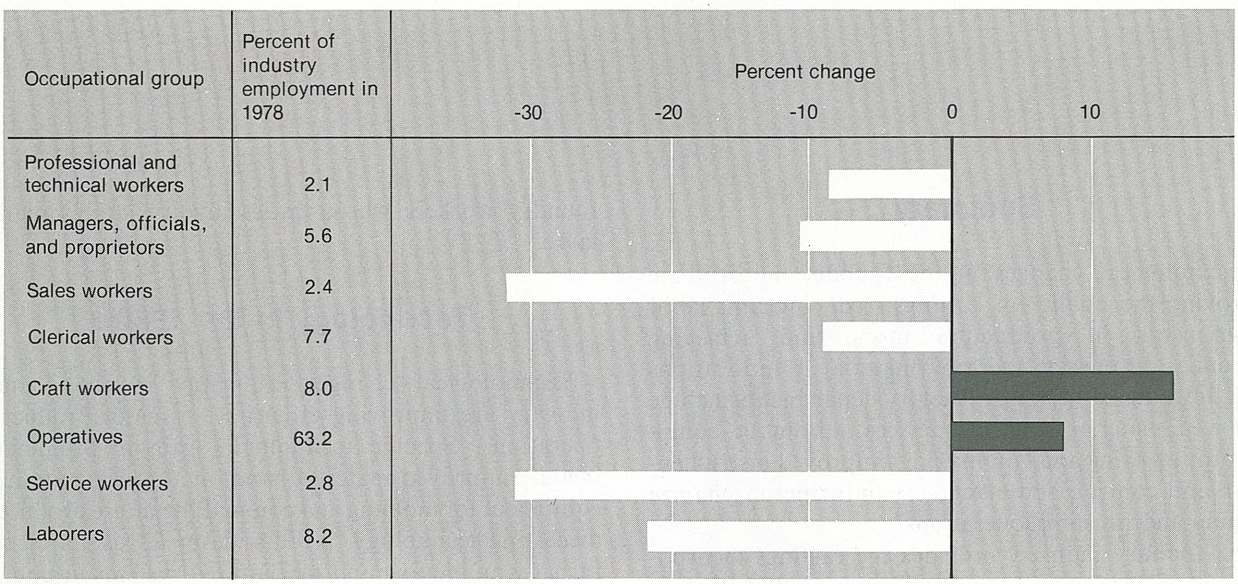
Adjustment of workers to technological change

Programs to protect employees from the adverse effects of changes in machinery and methods of production may be incorporated into contracts or they may be informal arrangements between labor and management. In general, such programs are more prevalent and more detailed in industries and companies which negotiate formal labor-management agreements. Such contract provisions to assist workers in their adjustment to technological and associated changes may cover new wage rates, new job assignments, retraining, transfer rights, layoff procedures, and advance notice of changes planned by management for machine changes or plant closings. They may also include various types of income maintenance programs such as supplementary unemployment benefits or severance pay.

Union affiliation in the meat products industry is not extensive, but the degree of unionization differs among the sectors. About one-third of production workers are covered by collective bargaining agreements, somewhat less than the proportion in all manufacturing—40 percent. Unionization is more widespread in meatpacking and processed meats establishments, which historically have been located in highly unionized areas. Poultry plants are generally smaller and located in rural areas, and union affiliation is not common.

In meatpacking and processed meats, labor contracts differ greatly in their treatment of technological change. Older and larger firms have agreements which usually include several types of provisions aimed at shielding the worker from the impact of changes in technology. Automation adjustment plans, worker retraining, interplant transfer rights, and separation payments are common. In contrast, newer firms generally have contracts with no specific provisions relating to technological change. Moreover, other provisions that could help worker adjustment are often of limited benefit. For example, although seniority generally determines the

Chart 3. Projected changes in employment in meat products by occupational group, 1978-90



Source: Bureau of Labor Statistics.

order of layoffs and recalls, priority is usually determined within production divisions rather than plant- or company-wide. Retraining or transfer rights are seldom established. Also, in these contracts management typically reserves the right to change methods of production without advance notice.

Labor-management contracts usually run 3 or 4 years. Either contracts are negotiated on a plant basis or master agreements are established for multiplant companies. However, since some of the newer and larger packers are not parties to master agreements, these types of contract arrangements are not as widespread as they once were. The predominant union is the United Food and Commercial Workers International Union (founded in 1979 by a merger of two unions, the Amalgamated Meat Cutters and Butcher Workmen and the Retail Clerks International Union).

Workers in the meat products industry suffer from a relatively high incidence of on-the-job injuries. For example, 27 cases of injury per 100 full-time workers were reported in 1979. This injury rate was the highest for any industry of the food products group and was twice the rate for all manufacturing for the same period. As a result, promoting safe working conditions is an important issue in labor-management relations. Many contracts in this industry have provisions requiring the company to furnish protective devices such as mesh guards, knife and hook pouches, helmets, and leather aprons. Also, safety committees composed of union and management representatives are common.

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Chapter 2. Foundries

Summary

Technological changes in the foundry industry are improving the quality of castings, reducing unit labor requirements in production tasks, and achieving economies in energy and raw materials.[1] Innovations being introduced in major foundry departments include improved material handling devices, automatic equipment for molding and coremaking, improved instrumentation and control, and machinery to further mechanize cleaning and finishing operations.

The foundry industry provides the castings incorporated in a wide range of consumer and industrial products. During 1960–80, output of iron and steel castings increased at an annual rate of 1.6 percent and output of nonferrous castings at a slightly higher annual rate. Productivity in gray iron and steel foundries increased moderately as output rose at a greater rate than employment. Capital spending has been increasing for modernization, expansion, and technology to meet Federal and State pollution and health and safety requirements.

The outlook is for employment to rise through 1990; growth is projected to be higher in iron and steel than in nonferrous foundries. Between 1960 and 1980, employment in iron and steel foundries increased at an average annual rate of 0.7 percent, while employment in nonferrous foundries rose at a higher annual rate—1.4 percent. The trend to more extensive mechanization is expected to result in a larger proportion of professional, technical, and maintenance workers and a further reduction in hand molders, coremakers, and other foundry workers whose duties involve largely manual tasks.

Technology in the 1980's

Technological changes underway in the foundry industry are improving efficiency in major production operations. Specific technologies gaining prominence include improved material handling devices, automatic equipment for molding and coremaking, more productive diecasting technology, more widespread use of electric furnaces in melting and mechanized systems in pouring operations, advances in cleaning and finishing equipment, and more extensive instrumentation and computerization. The foundry industry also has invested substantial funds for technology to reduce pollution and improve worker health and safety. Although new technology has resulted in a reduction in unit labor requirements in some operations, displacement of employees has not taken place in the industry as a whole. Table 1 describes innovations underway in the industry, their impact on labor, and prospects for further diffusion.

Material handling

Improving the handling of the large quantities of materials required in the manufacture of castings—from 70 to 80 tons for each ton of castings produced—remains a major means of achieving productivity gains in foundries. Conveyors, trucks, cranes, and hoists of improved design continue to replace manual handling and less efficient equipment. Modern material handling systems lower machine downtime, improve production control, reduce material waste, and enhance working conditions through a reduction in manual tasks and fewer accidents.

The use of increasingly versatile lift trucks and front-end loaders to transport materials has expanded greatly. Between 1963 and 1977, the average number of trucks and loaders in use in foundries almost doubled.[2] Their

[1] This report covers Standard Industrial Classification (SIC) 332, iron and steel foundries; and SIC 336, nonferrous foundries (castings). Under the U.S. Government's SIC classification system, establishments are assigned industry codes on the basis of principal end product(s) produced or services provided. Therefore, this report excludes analysis and data (except where indicated) pertaining to "captive" foundry departments of manufacturing plants where the castings produced are incorporated in a wide range of consumer and industrial end products. According to *Foundry Management and Technology* (see references at end of chapter), there are more than 1,100 "captive" foundry departments of all types in U.S. manufacturing plants which, combined, produce a reported 45 percent of total castings output. Although these "captive" foundries are outside the scope of this report, the new developments in technology and their implications, described in this report, would likely be applicable to them as well.

[2] Equipment inventory data included in *Foundry*, April 1964, and *Foundry Management and Technology*, April 1978. The equipment inventory data cited include U.S. and Canadian foundries as well as foundries operating as part of another establishment ("captive" foundries). Thus, these data relate to an industry broader in scope than SIC 332, iron and steel foundries and SIC 336, nonferrous foundries.

Table 1. Major technology changes in the foundry industry

Technology	Description	Labor implications	Diffusion
Material handling	New and improved trucks, cranes, and hoists are replacing less efficient equipment to transport material through foundry operations. Improved conveyor systems for mold handling, transport of molding sand, and other production tasks also are being diffused more widely.	Improved material handling technology has the capability to reduce manual tasks, improve safety, and lower unit labor requirements.	Mechanization of material handling is increasing. Between 1963 and 1977, the average number of trucks and loaders per foundry nearly doubled (from 2.5 to 4.9) and average conveyor footage per foundry rose from just under 700 feet to 1,100 feet. Further extension of conveyorization is anticipated.
Molding and coremaking	Improvements in conventional or green sand molding technology include the introduction of automatic, flexible equipment suitable for small and medium-size foundries, further adoption of no-bake molding, and specialized molding technology including the shell and investment processes. In coremaking, more energy-efficient, more automatic, and faster cycling production equipment is replacing older coremaking equipment.	Advances in molding and coremaking technology have lowered unit labor requirements for molders, reduced manual labor in shakeout and cleaning operations, and raised productivity. At one foundry which converted to no-bake molding, output per worker rose 15 percent and material and energy requirements were lowered. New coremaking technology, which bypasses the baking operation, has contributed to lower unit labor requirements.	Further advances are anticipated, with continued adoption of technologies well suited for small and medium-size foundries. No-bake molding and nonthermal coremaking will be employed more widely. Specialized processes also will be applied more widely, but increased costs will limit diffusion.
Diecasting	Major developments include the installation of larger capacity machines and more extensive use of automatic control. Robots are being used on a limited basis in casting extraction, quenching, and positioning for further processing.	Reduced unit labor requirements for machine operators.	Diecasting accounted for 60 percent of total nonferrous casting production in 1977, compared to 48 percent in 1963. Developmental work is continuing to make ferrous diecasting a practical production method.
Melting and pouring	Electric furnaces for melting and mechanized pouring systems are being introduced more widely.	Mechanized pouring systems lower unit labor requirements for metal pourers.	The number of electric furnaces in use more than doubled between 1963 and 1977. However, cupolas are expected to remain the major unit for melting iron in large quantities. Mechanized pouring systems are being used in a limited but growing number of high production foundries.
Cleaning and finishing	Although technological change has been relatively slow in finishing and cleaning, gains in efficiency have resulted from several innovations. These include improved batch and continuous blast cleaning, more productive and safer handtools, and advanced material handling equipment. New technology for dust removal, ventilation, and lighting has been introduced to comply with Federal Government regulations.	The cleaning and finishing of castings are expected to continue to be labor intensive even though productivity gains from new innovations are anticipated. One foundry which introduced a modern, multistation conveyor system reported that output of castings per grinder operator rose by 127 percent, and output of castings per welder was higher by 200 percent. In the latest technology for cleaning and finishing, the operator no longer performs certain grinding and cleaning steps, with safety and efficiency improved.	Further installation of higher capacity cleaning and finishing technology is expected. These changes are expected to facilitate the handling of higher levels of output made possible by innovations in other departments.
Instrumentation	Improved instrumentation for inspection, testing, and measurement has increased quality of castings. Electronic computers for business and production control applications and programmable controllers are being introduced more widely.	Improved instrumentation has raised quality control so that less labor is required in the cleaning and finishing department.	Expanded use of instruments is expected to continue.

diffusion in smaller foundries affords a measure of mechanization of material handling when the installation of expensive, specialized types of equipment—efficient in high-volume production work—is not feasible.

Improved conveyors being introduced in foundry production operations are reducing unit labor requirements. In mold handling, for example, improved conveyor systems have accompanied the development of high-output, automated molding systems in a growing number of foundries. In these systems, molds are transported from the machine, poured, and moved to shakeout, and bottom boards and flasks are returned to the molding machine on a continuous basis. Thus, unit labor requirements in material handling tasks are lower than in less mechanized systems. Conveyors also are improving productivity in transporting molding sand and in other material handling tasks. Average conveyor footage in use in foundries is estimated to have increased from just under 700 per foundry in 1963 to an average of 1,100 in 1977, with further extension of conveyorization anticipated over the next decade.[3]

Molding and coremaking

Advances in molding machine design continue to lower labor requirements for molders in conventional or green sand molding—the molding method used for more than 90 percent of industry output. Automatic, rapid-cycle machines are being installed in an increasing number of foundries; gains in molding productivity are a key benefit. One significant development in molding technology is the introduction of automatic equipment suitable for use in small and medium-size foundries. These machines incorporate a high-production molding capability together with features allowing quick pattern changes and noncontinuous cycling. They provide the flexibility required for short production runs which make up much of the work of these foundries. In many instances, firms introducing automatic equipment in green sand molding also are installing more efficient handling systems for flasks, molds, sand, and cores.

The use of the no-bake process in about a third of all foundries is a major development in molding operations. No-bake molding, which utilizes a chemical reaction between, typically, a resin binder and a catalyst to produce the sand mold, is increasingly replacing the traditional green sand method in many molding applications. Compared to green sand molding, which involves the compaction of sand, clay, and water, no-bake is a simpler production process which offers the advantages of lower capital, energy, and direct labor requirements as well as reduced scrap. The process is used, ideally, in conjuction with a shot-blast reclamation system in which the mold is broken down, the casting cleaned, and the sand reclaimed and reconditioned by a single piece of equipment. This procedure eliminates the need for a separate shakeout operation with its attendant heat, dust, and manual labor. No-bake sand is readily reclaimable, reducing acquisition and disposal costs. One foundry which converted to no-bake to turn out castings for large pumps anticipates a 15-percent gain in output with the same labor force in addition to savings in energy and other production costs.[4]

Specialized molding methods are employed to produce a limited but growing volume of casting production. These include the "investment" process, which has experienced the greatest recent growth. The greater costs of these specialized processes, due to more expensive binders and patterns and the additional costs necessary for special equipment, are expected to continue to restrict their use. Applications are likely to remain limited to instances where economies may be obtained in subsequent machining, where extremely close tolerances are a primary consideration, or when casting certain alloys.

Coremaking technology also is undergoing change. The growing replacement of older coremaking equipment with more automatic, faster cycling equipment, including core blowers, shooters, and shell core machines, is reducing unit labor requirements for coremakers. Features such as the production of several cores simultaneously are raising coremaking efficiency. More extensive use of the no-bake process and cold box coremaking—which also does not require the baking operation—save time, labor, and energy.

Diecasting

The installation of larger capacity machines is a major development underway in diecasting. Larger machines make possible an increase in the number of cavities per die and in the size of the cast part. Production tasks, including metal feeding, casting removal, die lubrication, and temperature control, are being regulated automatically in an increasing number of diecasting establishments. Robots also are being used increasingly for such tasks as casting extraction, quenching, and positioning for further processing.[5]

These innovations are improving casting quality and reducing unit labor requirements for diecasting machine operations. The greater efficiency made possible by advances in diecasting technology is reflected partially in the 30-percent increase in output of diecastings during 1963–77, a period when the number of diecasting machines in use declined by 12 percent.[6]

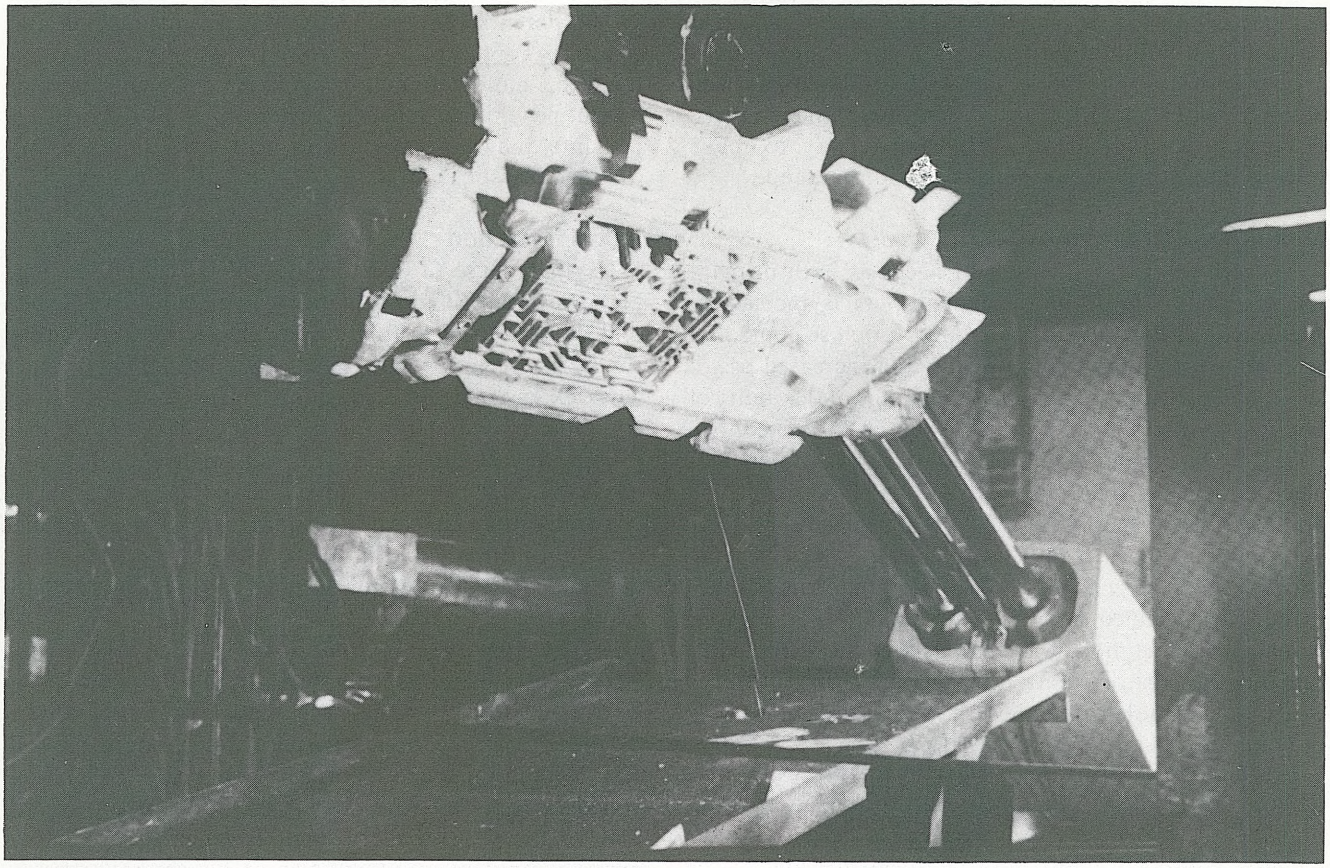
Diecasting, limited to casting of certain nonferrous metals, is growing in importance and accounted for 60 percent of total nonferrous casting production in 1977,

[3] *Foundry*, April 1964, and *Foundry Management and Technology*, April 1978.

[4] *Foundry Management and Technology*, December 1978, p. 76.

[5] Robert C. Cornell, "Automation in Diecasting—an Update," *Foundry Management and Technology*, April 1978, pp. 208–214.

[6] Output data are from *Current Industrial Reports*, Bureau of the Census, U.S. Department of Commerce, *Summaries* for 1963 and 1977. Data on diecasting machine inventory are from *Foundry*, April 1964, and *Foundry Management and Technology*, April 1978.



Robot placing diecast transmission housing on conveyor

Automatic metal-pouring machine

compared with 48 percent in 1963. The demand for weight reduction in automotive applications is contributing to growth in diecasting. Diecasting of iron and steel has been deterred by the high melting temperature of these metals. However, developmental work is underway to make ferrous diecasting a practical production method.

Melting and pouring

The use of electric melting furnaces as both primary melters and holding and refining units is increasing. Electric furnaces have the capability for close control of melt temperature and composition and increased use of scrap metal. They also have the advantage of flexibility of batch type melting and incur fewer pollution control problems compared to cupola melting. The number of electric furnaces in use more than doubled between 1963 and 1977; they account for the bulk of total steel castings production and a significantly smaller but growing proportion of iron castings output. Although the number of cupolas declined between 1963 and 1977 as electric furnaces became more widespread, they are expected to remain the major units for melting iron in large quantities. Cupolas are expected to be used increasingly in combination with electric holding furnaces.

Mechanized pouring systems, some featuring automatic control, are being employed in a limited but growing number of foundries. Advantages of these systems include improved control of temperature and other variables, a reduction in labor requirements of metal pourers, a significant cutback in the number of castings rejected, improved working conditions, and energy savings.[7]

Cleaning and finishing

The cleaning and finishing of castings are expected to remain relatively labor intensive, although equipment is increasingly available to eliminate manual work. Chippers and grinders, who work with power and hand tools, are among foundry workers whose jobs involve substantial manual tasks.

Advances in cleaning and finishing operations have not matched those in other foundry departments. Consequently, the productivity potential of mechanized molding and coremaking often cannot be fully realized because the cleaning and finishing department cannot handle increased casting production.

Some technological improvements in finishing and cleaning are raising efficiency. Among the most important are improved batch and continuous blast cleaning equipment; more productive and safer hand-held tools, which are the predominant technology for grinding, chipping, welding, and polishing; and improved conveyor lines and related handling equipment. In addition, the foundry industry has installed new technology for dust removal, ventilation, and lighting.

The potential for productivity gains in finishing and cleaning is significant. One foundry which introduced a modern, multistation conveyor system reported that output per grinder operator rose from 75 to 170 castings per shift, and output per welder increased from 100 to 300 castings per shift.[8]

Instrumentation

Expanded use of instruments for inspection, testing, and measurement is improving casting quality. New types of inspection and testing equipment introduced during the 1970's include sonic, ultrasonic, and eddy current.[9] More extensive use of conventional inspection and testing equipment for strength and hardness determination also is underway. Because of more extensive instrumentation, quality control is improving and less labor is required to repair castings in cleaning rooms prior to shipment. Control of quality is of growing importance as demand has increased for lighter weight and higher strength castings.

A growing number of foundries are utlizing computers. According to a survey by the Cast Metals Federation, iron and steel foundries are using computers for a diversity of applications ranging from standard payroll and accounting functions to process control of melting and other production tasks.[10] This survey also revealed that a number of smaller foundries which cannot justify onsite computers are utilizing computer service bureaus. The application of computers to foundry operations reportedly has brought about efficiency gains including energy savings. One foundry which installed computer control of arc melting of iron reported a 15-percent savings in electric power costs.

Industry Structure

The trend to larger and more mechanized foundries is expected to continue. Between 1963 and 1977, the number of iron and steel foundries declined slightly (by 2 percent) and the number of nonferrous casting establishments remained virtually unchanged.[11] However, employment in both major foundry industries increased over this period with the result that, by 1977, employment in iron and steel foundries averaged 157 workers per foundry, up by 18 percent, and employment in nonferrous foundries averaged 47 workers, higher by 24 percent.

Although the total number of establishments fell in the two broad industry groups covered in this report, the number increased in some industry sectors. In steel

[7] Wallace D. Huskonen, "Roundup of Mechanized Pouring Systems," *Foundry Management and Technology*, March 1976, pp. 28–40.

[8] Wallace D. Huskonen, "Conveyorization of Castings Cuts Cleaning Costs," *Foundry*, November 1973, pp. 49–51.

[9] "Foundry Equipment Inventory and Buying Plans," *Foundry Management and Technology*, April 1978, pp. 34–36.

[10] "Foundry Use of Electronic Data Processing," *Foundry Management and Technology*, March 1977, pp. 112–114.

[11] U.S. Department of Commerce, Bureau of the Census. 1977 data are the latest available.

foundries, for example, the number of establishments increased significantly between 1963 and 1977. The number of aluminum foundries was higher by 9 percent, due in part to new applications for aluminum castings, particularly in the auto industry. In contrast, the number of gray iron foundries declined by 16 percent over this period.

The general shift to a more capital-intensive industry has been a factor in the increase in the proportion of larger foundries. From 1963 to 1977, the number of iron and steel foundries employing 250 or more workers increased by 8 percent, and the number of nonferrous foundries of this size rose by 4 percent. In contrast, iron and steel foundries employing less than 50 workers declined by 4 percent over this period, and nonferrous foundries in this size group fell by 8 percent. Factors contributing to the decline in smaller foundries include their inability to obtain or justify the substantial and increasing capital investments required to modernize to be competitive with larger foundries, or to acquire the expensive technology needed to comply with Federal and State requirements on pollution and worker health and safety.

Output and Productivity Outlook

Output

The rate of growth in output in the past two decades has been uneven. Over the entire period 1960–80, output of iron and steel castings (Federal Reserve Board data) increased at an average annual rate of 1.6 percent, and output of nonferrous castings rose at a slightly higher rate—1.9 percent. For 1960–67, however, output of iron and steel foundries increased at a substantially higher annual rate of 7.7 percent, and nonferrous foundries at an even higher rate—9.9 percent. Between 1967 and 1980, in contrast, foundry output was sharply lower, with output of iron and steel foundries decreasing by an annual rate of 0.3 percent and nonferrous output declining at a rate of 0.8 percent. Output for both segments of the foundry industry peaked in 1973. Over the period 1967–73, output in iron and steel foundries increased at an average annual rate of 1.8 percent and in nonferrous foundries by 0.1 percent; in contrast to 1973–80 when output in iron and steel foundries declined at an average annual rate of 2.6 percent and in nonferrous foundries at a 1.3-percent rate annually.

Productivity

Productivity has increased in the major sectors of the foundry industry for which BLS publishes measures.[12] Output per employee hour in gray iron foundries (SIC 3321) rose at an annual rate of 2.3 percent during the longer term 1960–79, while output per employee hour in steel foundries (SIC 3324, 3325) increased at a lower annual rate of 1.0 percent over the same period.

Productivity gains varied within the period. Output per employee hour in gray iron foundries rose at an annual rate of 2.8 percent during 1960–67, and increased at a 2.4-percent rate during 1967–79. In steel foundries, output per employee hour increased at an annual rate of 2.5 percent during 1960–67, and 0.8 percent between 1967 and 1979.

The more recent period, 1973–80, was marked by a steep decline in foundry output during 1974–75 as the economy experienced a downturn. Following a recovery during 1975–79, output dropped sharply again in 1980 in both segments of the industry.

Output per employee hour in both gray iron and steel foundries declined during 1974–75 as output fell during the general downturn in the economy. A recovery followed in gray iron foundries, with output per employee hour up at an annual rate of 1.6 percent during 1975–79 and output higher by 3.4 percent annually.[13] However, in steel foundries, output per employee hour continued to decline over this period while output increased at an annual rate of 1.2 percent.

Although productivity measures for nonferrous foundries are not published by BLS because of data limitations, it appears that productivity followed a trend similar to iron and steel foundries and rose during 1960–79. Over this period, output (Federal Reserve Board data) rose by 2.3 percent annually and total employment (BLS data) increased at a lower annual rate, 1.5 percent.

While the impact of new foundry technology on industrywide productivity cannot be measured precisely, unit labor requirements frequently are lower following installation of new equipment. At one plant which installed an automated molding system featuring automatic equipment and advanced material handling, for example, direct labor per ton of castings declined while other benefits accrued from the new molding system including improved quality of castings and a reduction in plant floor space.[14] At another foundry which expanded capacity by installing new, automatic molding systems and electric furnaces, labor requirements per ton of castings declined by about 30 percent with further savings anticipated. The extent to which foundry technology with labor-saving potential will be diffused more widely depends largely on the availability of funds for capital improvement over the decade of the 1980's.

[12] BLS productivity measures are published for two of the three major components of iron and steel foundries (SIC 332). An index for malleable iron foundries is not available. However, employment in gray iron and steel foundries, combined, accounts for over 90 percent of iron and steel employment. BLS productivity measures are not published for nonferrous foundries (SIC 336).

[13] The output used in BLS productivity measures is based on value of shipments (Bureau of the Census) and therefore differs from the physical output data (FRB) discussed in the preceding section.

[14] John R. Bates, "High Production Molding Through Automation." Remarks presented at the First National Congress on Technology for Productivity, sponsored by The American Society for Metals and presented by Foundry Equipment Manufacturers Assoc., Inc., Detroit, Oct. 21, 1971.

Investment

Expenditures for new plant and equipment have been increasing as foundries modernize and expand or replace existing capacity. By 1976, expenditures by iron and steel foundries (in constant 1972 dollars) totaled $458 million and in nonferrous foundries, $81 million—well above the 1960 levels of $119 million and $54 million, respectively.[15] Capital expenditures per production worker also have risen sharply. In iron and steel foundries, expenditures per production worker (in constant 1972 dollars) totaled $2,559 in 1976, compared with $703 in 1960. In nonferrous foundries, the increase was less dramatic but nonetheless substantial—from $939 per production worker in 1960 to $1,167 in 1976. As foundries further mechanize during the 1980's, capital outlays are expected to continue to rise. Levels of spending will depend on the state of the economy, developments in technology, environmental requirements, and related factors.

Employment and Occupational Trends

Employment

Employment in foundries has been increasing relatively slowly (charts 4 and 5). Between 1960 and 1980, employment in iron and steel foundries increased at an annual rate of 0.7 percent. During 1960–67, the number of employees working in iron and steel foundries rose at a substantially higher rate, 3.2 percent, but during 1967–80 declined at a rate of 0.1 percent. The employment trend in nonferrous foundries also was up over the longer term, 1960–80, at an annual rate of 1.4 percent. For the period 1960–67, employment in nonferrous foundries increased at the relatively high annual rate of 5.4 percent. This growth rate was not maintained during 1967–80 when employment increased at an annual rate of only 0.3 percent.

Total employment in iron and steel foundries peaked at 249,700 in 1974 but by 1980 had fallen to 204,500—over 45,000 workers below 1974, with three-fourths of the decline occurring in 1980. Employment in nonferrous foundries reached a record high of 99,400 in 1979 before declining to 89,700 in 1980. In both iron and steel and nonferrous foundries, employment dropped sharply in 1974–75 (by 8 percent and 20 percent, respectively) when production of castings declined as the economy slackened. In iron and steel foundries, the proportion of production workers during the period of 1960–80 declined from 85 percent to 80 percent of the work force. In nonferrous foundries, this trend was evident to a lesser extent; the proportion of production workers declined from 83 percent in 1960 to 80 percent in 1980.

The outlook is for foundry employment to increase during 1980–90, according to BLS projections based on three versions of economic growth.[16] The number of employees in iron and steel foundries is expected to increase at an annual rate ranging between 3.9 and 4.2 percent during 1980–90, a substantial increase over the rate during 1967–80, and higher also than the rate during the longer term period 1960–80. In nonferrous foundries, the rate of change in employment during 1980–90 is projected to range between –0.1 and 0.6 percent—lower than the rate during the longer period from 1960 to 1980.

Occupations

The general trend to more extensive mechanization in foundries is expected to continue to alter the structure of occupations. Foundries are employing proportionately larger numbers of engineers, technicians, and maintenance workers in response to more extensive and complex production equipment.

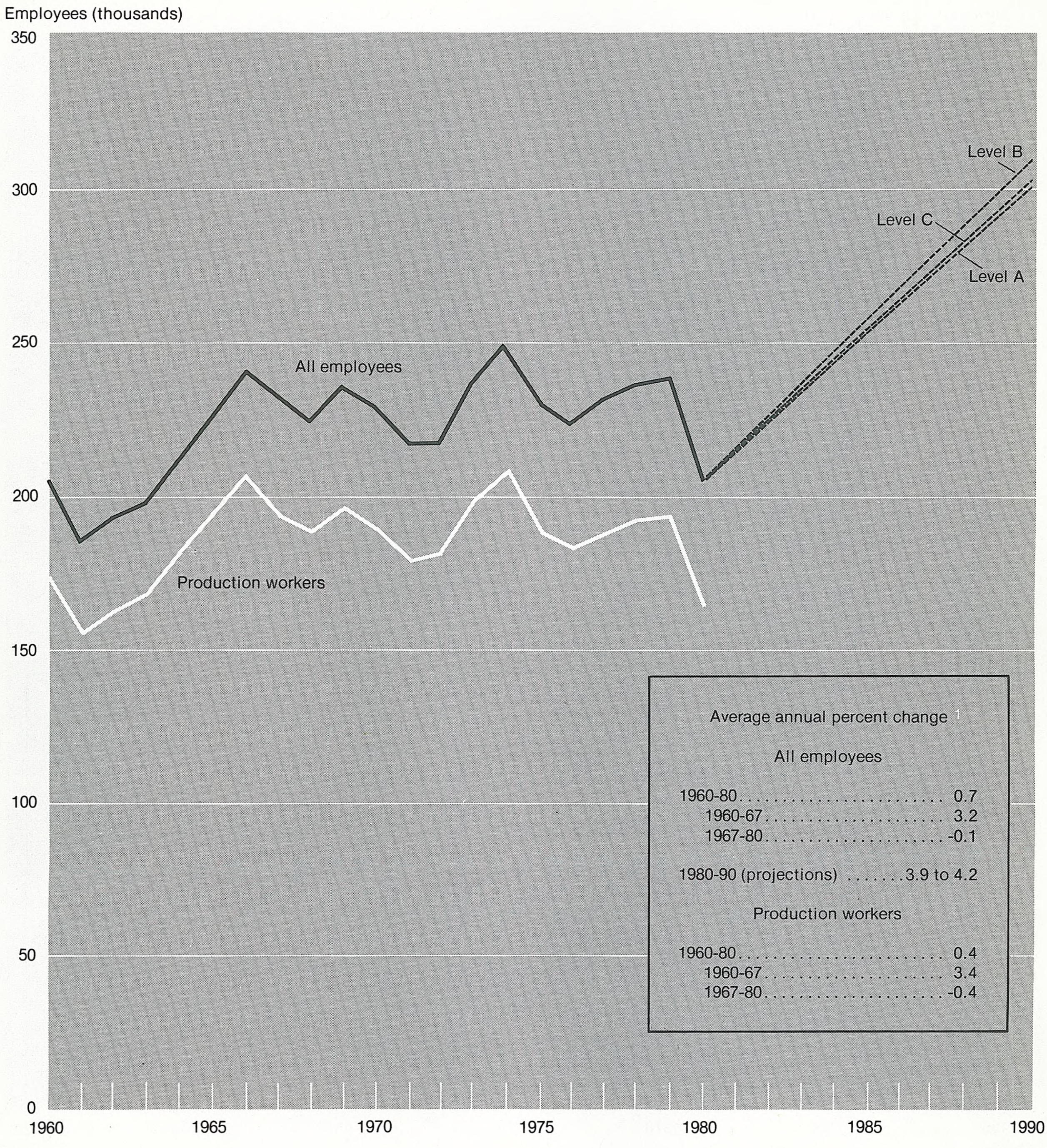
Production workers have declined relative to the total foundry work force, and the composition of occupations within this large category also is changing. In general, a further decline in the proportion of occupations which involve largely manual tasks is anticipated. Fewer hand molders and coremakers will be required, for example, as automatic machinery, no-bake processes, and other improvements are adopted more widely. The more widespread use of improved trucks, hoists, conveyors, and related equipment will require fewer hand laborers but more truck operators to move materials through production tasks. More maintenance mechanics and repairers will continue to be needed to service more complex equipment. Industrial robots are expected to assume some foundry job functions, including those in environments where heat, dust, noise, and fumes prevail.

The structure of occupations in the more highly mechanized, larger foundries differs significantly from that in plants of smaller size (about 80 percent of all foundries employ fewer than 100 workers). In general, the larger, more mechanized foundries which produce castings in high volume use proportionately less unskilled manual labor. The availability of highly mechanized production equipment in the larger foundries also affects the skilled work force in that proportionately fewer molders and coremakers are required compared to smaller foundries.

[15] The capital expenditures data are unpublished, deflated gross total annual investment series developed in the BLS, Office of Economic Growth. See *Capital Stock Estimates for Input-Output Industries: Methods and Data,* Bulletin 2034 (Bureau of Labor Statistics, 1979). Expenditures data for 1976 are the latest available.

[16] Projections for industry employment in 1990 are based on three alternative versions of economic growth for the overall economy developed by BLS. The low-trend version is based on a view of the economy marked by a decline in the rate of expansion of the labor force, continued high inflation, moderate productivity gains, and modest increases in real output and employment. In the high-trend version I, the economy is buoyed by higher labor force growth, much lower unemployment rates, higher production, and greater improvements in prices and productivity. The high-trend version II is characterized by the higher GNP growth of high trend I, but assumes the same labor force as the low trend. Productivity gains are quite substantial in this alternative. On charts 4 and 5, level A is the low trend, level B is high-trend I, and level C is high-trend II. Greater detail on assumptions is available in the August 1981 issue of the *Monthly Labor Review.*

Chart 4. Employment in iron and steel foundries, 1960-80, and projections for 1980-90

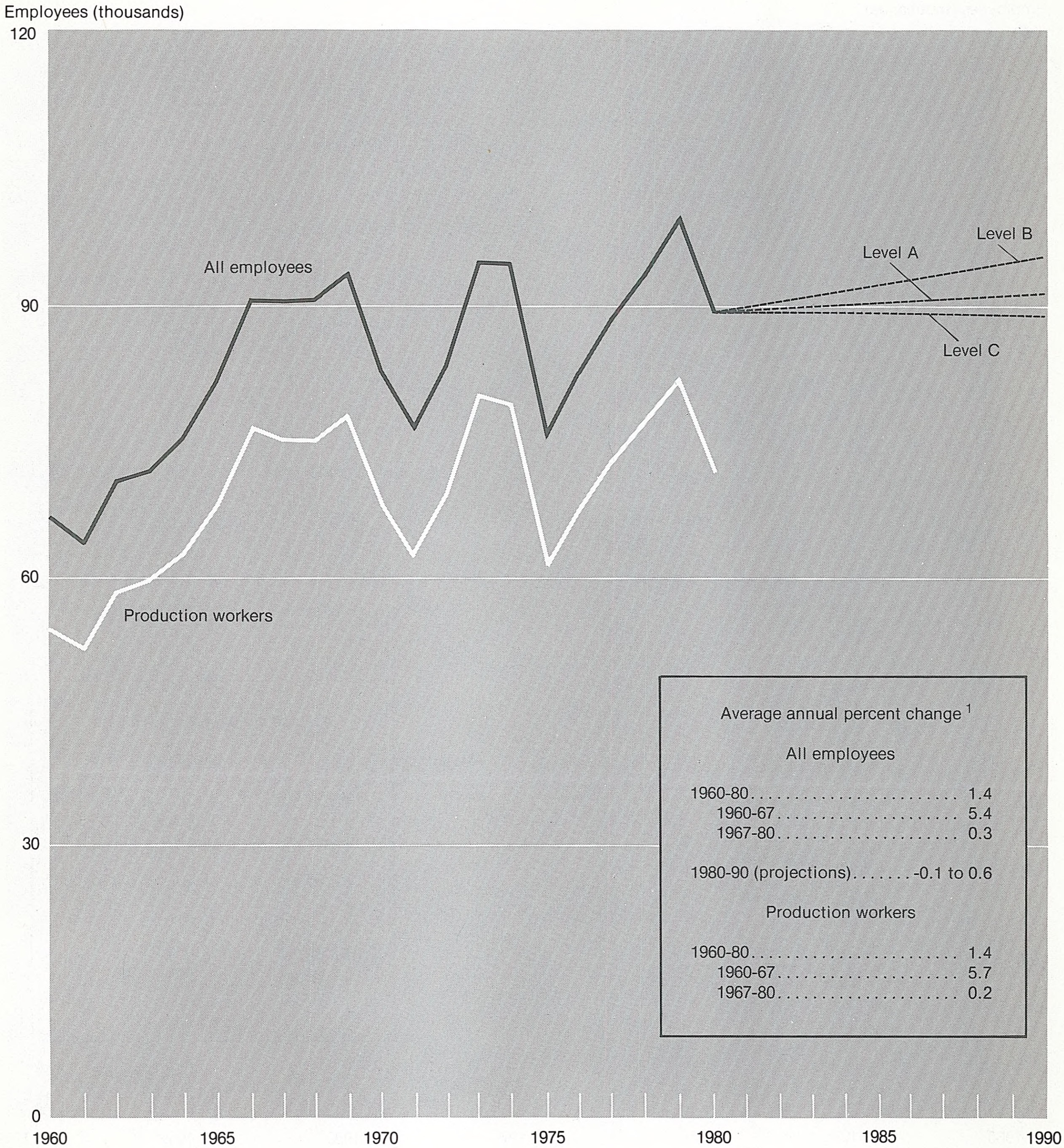


[1] Least squares trend method for historical data; compound interest method for projections.

Note: See text footnote 16 for explanation of alternative projections.

Source: Bureau of Labor Statistics.

Chart 5. Employment in nonferrous foundries, 1960-80, and projections for 1980-90



Average annual percent change[1]

All employees	
1960-80	1.4
1960-67	5.4
1967-80	0.3
1980-90 (projections)	-0.1 to 0.6
Production workers	
1960-80	1.4
1960-67	5.7
1967-80	0.2

[1] Least squares trend method for historical data; compound interest method for projections.

Note: See text footnote 16 for explanation of alternative projections.

Source: Bureau of Labor Statistics.

Adjustment of workers to technological change

Although unit labor requirements have been lowered in instances where new foundry technology has been applied, the anticipated continued demand for castings is expected to result in moderate employment gains through 1990. Widespread displacement due to new technology is not foreseen, although the structure of occupations is changing and job skills will likely be modified. Training programs initiated by foundries, industry organizations, and unions will be one major method of preparing the work force for new job requirements.

Union contracts, which cover a majority of the foundry industry work force, contain provisions which could be useful in making adjustments to technological change. A substantial majority of workers in iron and steel foundries and approximately 60 percent of workers in nonferrous foundries are employed in establishments with collective bargaining agreements covering the majority of production workers.[17] Contracts that include provisions relating to seniority, grievances, retraining, supplementary unemployment benefits, and related clauses are available to assist workers in adjustment to any displacement resulting from technological change. Additionally, production workers in iron and steel and nonferrous foundries are eligible for benefits when separated because of technological changes or plant closings. Major unions covering foundry workers are the International Molders and Allied Workers of North America (AFL-CIO), the United Steelworkers of America (AFL-CIO), and the United Automobile, Aerospace and Agricultural Implement Workers of North America (Ind.).

[17]See the following *Industry Wage Surveys* of the Bureau of Labor Statistics: *Iron and Steel Foundries, September 1979,* Bulletin 2085, and *Nonferrous Foundries, May 1975,* Bulletin 1952. The former includes establishments employing 50 workers or more; the latter encompasses establishments employing 8 workers or more. Thus, although these surveys exclude a substantial number of small foundries, they cover establishments which employ more than 90 percent of the foundry industry work force.

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Chapter 3. Metalworking Machinery

Summary

The metalworking machinery industry is rapidly increasing the application of the numerically controlled (NC) machine tool. NC machines accounted for an estimated 30 percent of the value of machine tools installed in the metal-cutting machine tool sector in 1979. Increased diffusion of NC is expected in the 1980's in response to a host of economic conditions, including the advanced age and low productivity of the machine tools in use, the need to meet increasingly precise and complex requirements for machined parts, and the shortage of skilled workers.

While utilization of NC machine tools is likely to increase steadily among the industry's large and medium-size plants, the many small shops which manufacture simple parts will still rely heavily upon manually operated machine tools. Other, more sophisticated technologies such as machining centers (multifunction NC machines), controls utilizing sensors, and NC by computer are also economically feasible, principally for the larger plants. Complex microprocessors, which have fallen sharply in price, permit firms of all sizes to use various intermediate technologies which are not as sophisticated as NC. In general, these technologies increase output per employee hour, improve quality, and reduce occupational skill requirements.

Although definitive measurements of productivity for the industry as a whole are not available, very small productivity improvement in 1960–78 is suggested by an average annual rise in output of about 2 percent and in employee hours of less than 1 percent. Wide swings in output—with associated lags in adjustment of hours—and aging equipment are major reasons for the industry's comparatively low productivity growth rate.

While the industry's dollar outlays for new plant and equipment rose by nearly two-thirds from 1966 to 1978, expenditures in real terms did not surpass the 1966 peak. Real expenditures rose to a comparatively high level in 1974, declined in 1975, and then rose in the succeeding 3 years. They have generally continued to increase, and this may enable manufacturers to compete more effectively with imports for the large tooling requirements of automobile, commercial aircraft, and defense-related manufactures.

Employment in the industry stood at the relatively high level of 371,500 persons in 1980. The average annual increase from 1960 to 1980 was 1.4 percent (about the same rate as for all durable goods manufacturing). The outlook for employment growth from 1980 to 1990 is in the range of 0.8 to 3.8 percent (average annual rates) as projected by BLS, based on alternative versions of economic growth. Increases are projected for virtually all of the industry's occupational groups, but the number of craft workers is expected to grow only half as rapidly as the number of operatives. A shortage of skilled workers could remain a principal obstacle to expansion in the metal-cutting machine sector for at least the immediate future.

Industry Structure

This study examines the metalworking machinery industry as a whole (SIC 354) and three major sectors within the industry: Metal-cutting machine tools (SIC 3541); special dies and tools, die sets, jigs and fixtures, and industrial molds (SIC 3544); and machine tool accessories and measuring devices (SIC 3545). Reference is also made to metal-forming machine tools (SIC 3542). The other metalworking sectors not covered in this study are: Power-driven handtools; rolling mill machinery and equipment; and such machinery as gas cutting and welding equipment.

Some characteristics of this industry tend to limit productivity growth. An estimated three-fourths of the industry's output is in batches of less than 50 pieces. This holds true particularly for the machine tool makers, who often produce special machines for their customers, and for the tool-and-die firms, which frequently produce one-of-a-kind parts. Moreover, establishments in metalworking are comparatively small and highly specialized. Such firms often find it economically unfeasible to invest in new equipment. For example, the tool-and-die sector of the industry (SIC 3544) is made up of 7,100 establishments, averaging only 15 employees. In comparison, the average size of all manufacturing establishments is 55 employees. Additionally, the sharp fluctuation in industry output over the course of the business cycle tends to reduce productivity growth.

Technology in the 1980's

Numerical control (NC) of machine tools is the most significant new technology introduced in the metalworking industry in the past 25 years. It has experienced substantial and frequent changes in concept and/or design. However, some metalworking firms are investing in intermediate technologies, i.e., technologies which are not as sophisticated or expensive as NC, but which nevertheless improve productivity. These include digital readouts and manual-data-input controls which are applied largely to conventional machine tools. Innovations have also taken place in management techniques and cutting-tool materials. The major technologies, their diffusion, and their labor impact are discussed in more detail below and are presented in table 2.[1]

Numerically controlled machine tools

Numerical control (NC) involves the automatic control of a machine tool's movement by an electronic controller or special computer which reads instructions in digital form. NC tools are more productive than manually operated tools. They reduce setup time; consequently a higher proportion of working time is spent on cutting. The need for costly jigs, templates, and other tooling devices is eliminated. NC tools can produce parts with greater precision and uniformity, thereby further saving machining time and minimizing scrap losses. NC may make possible the production of complex parts that could otherwise not be turned out, or only at great cost; and the process permits engineering changes on a part by merely changing portions of the input program.

NC enhances managerial control by predetermining and coding every stage of machining onto a control tape. It becomes possible for managers to plan more accurately such operations as machine loading and shop scheduling, and it is much easier to predict labor and machine requirements.

NC provides the opportunity to attain some automation in the small batch production which characterizes this industry. The innovation may be more fully appreciated by characterizing NC as a manufacturing system, and not merely a means to control a machine.

Despite the advantages of NC, only about 3 percent of all metal-cutting tools in the metalworking industry in 1976–78 were NC.[2] However, they accounted for a much larger proportion of output. Another indication of the importance of NC is the value of recently installed NC machines. In the metal-cutting machine tool sector, value of shipments was estimated to be 30 percent of all machine tools installed in 1979.

The reason for the lack of diffusion of NC throughout the metalworking machinery industry is the small size of the majority of the firms; they have limited funds for investment in this comparatively expensive technology. Although NC is intended for small batch operations, the risk of investment may be too great because of the volatility of demand for the industry's products. Moreover, firms producing simple parts are unlikely to utilize NC. In addition, NC is not feasible, technically, for some machining methods, such as broaching. It is also interesting to note that surveys disclose that only a few of the general managers in firms without NC fully understood its workings.[3]

Currently, except for a small number of comparatively large firms which use advanced sophisticated NC, most machine tool shops still rely heavily upon skilled workers working on conventional tools. Nonetheless, numerous modest-sized contract tool-and-die shops—also referred to as contract tooling and machining shops—have adopted NC because they do a significant amount of precision machining.

However, if, as expected, NC replaces a large proportion of conventional tools in the 1980's, it could have considerable impact on the metalworking industry. The application of NC should be accelerated by shortages of skilled workers and by the growing need for parts of greater precision. Adding urgency is the steadily increasing demand for variety and versatility in products.

Firms which introduce or expand their use of NC can experience pronounced savings in labor and material. A study of over 350 companies[4] disclosed direct and indirect savings of NC over manually operated tools. Reduced machining time ranged from 35 to 50 percent. Indirect savings of 25 percent or higher were found for material handling, scrap, and inspection. A majority of firms did not even have higher outlays for NC programming if "process planning" on conventional machines is taken into account.

With the introduction of NC, the occupational composition of the work force generally changes. The number of machine operators is likely to decline for a given level of production, since one person can often operate two NC machines. In many cases, skill requirements are reduced. For example, operators no longer need to interpret a blueprint in selecting machine settings. On the other hand, they must be perceptive to a malfunction. Some firms try to enhance the duties of the operator of a very expensive NC machine to make the job

[1]This study does not include the more than 20 technologies that are identified as nontraditional machining processes, although production and application of some of these processes are increasing. Two of these are electrochemical machining and electrical discharge machining. Electrical discharge machining is used widely in tool-and-die shops.

[2]"The 12th American Machinist Inventory of Metalworking Equipment 1976–78," *American Machinist*, December 1978, p. 136.

[3]Edwin Mansfield and others, *Research and Innovation in the Modern Corporation* (New York, Norton and Company, Inc., 1971), pp. 201–202; George P. Putnam, "Why More NC Isn't Being Used," *Machine and Tool Blue Book*, September 1978, pp. 100–101.

[4]Donald N. Smith and Lary Evans, *Management Standards for Computer and Numerical Controls* (Ann Arbor, University of Michigan, 1977), pp. 185, 192, 212, 214, and 222.

attractive to a skilled machinist. The new position of programmer required with NC is being filled in a growing number of firms by skilled machinists who have received supplementary training. A somewhat larger number of maintenance personnel may be required, and their skill requirements are higher, calling for special training. In general, NC machinery is operated in two or three workshifts, without comparable labor additions on the later shifts.

Numerical control by computer

According to some experts, the combination of the computer with NC in small batch production compares in impact to the introduction of the assembly line and interchangeable parts. Software advances in the late 1960's made it possible for a computer to convey numerical data directly to a machine control unit, thereby eliminating the need for a special control system to operate a machine tool by tape commands. Computer NC (CNC), first with minicomputers and later with microcomputers, made it possible to operate one or more machines and even to connect to larger computers. CNC eliminates the problem of the constant redoing of tape. Also, workpiece program data can be changed in the control system without the necessity for reading an entire program tape. A computer can also keep track of the time each machine tool is in use.

A significant proportion of the NC units in the metalworking industry are the CNC type. Costs of electronic controls have declined so sharply in recent years that some CNC units are competitive with tape-driven control units and are economically feasible for small and medium-size firms. Whereas minicomputers accounted for 50 percent of the cost of a CNC tool in the late 1960's, they now account for less than 20 percent. All the reasons for the lack of diffusion of NC apply even more to CNC. And direct numerical control (DNC), in which a central computer may control up to 100 or more machine tools, is currently used by only a few of the larger toolbuilders in the metalworking industry.

The principal new job classifications arising from the use of CNC are computer programmers, electronic maintenance personnel, and, in some firms, systems analysts. Personnel skilled in preventive maintenance assume great importance with CNC, and machine problems require a multiskill approach.

Machining centers

Machining centers are more elaborate and costly than basic, single-purpose NC. The centers may have automatic tool-changing systems for selecting among 20 to 100 tools that bore, drill, mill, and tap. With rotary heads and tables, a center can work on many surfaces of a part in a single setup. The centers substantially improve managerial flexibility. Moreover, they raise productivity because tool changing is less than on basic NC; one operator may control several machines. While NC may be most suitable for low-volume metalworking shops, a machining center can be justified whether the volume of parts is small or large.

Nevertheless, this technology has only been minimally adopted by the metalworking machinery industry. There are many reasons for this slow acceptance, including high initial cost, simple products which are unsuitable for machining centers, and lack of managerial knowhow.

Adaptive controls

Adaptive controls utilize sensors that automatically control such factors as vibration, tool wear, tool or workpiece deflection, and cutting temperatures. Such sensors can be integrated within an NC controller, or they can operate with conventional machine tools. Although the technology has been available for about 20 years, the application of these controls in metalworking machinery is limited to large shops. Utilization by small shops will depend upon development of improved sensors, their cost effectiveness relative to the availability of skilled workers, and the type of work performed.

Reported improvements in productivity in currently available controls range from 20 to 40 percent, with largest gains when a part requires diverse cutting conditions and the material is hard to machine. Besides improved machining time, scrap and cutter breakage are reduced.[5]

Sensory devices tend to reduce worker skill requirements because they assume many functions traditionally performed by the operator. These devices help to standardize unit labor time. While machining time on an identical part can vary by over 30 percent for different operators, adaptive controls virtually eliminate the differences.

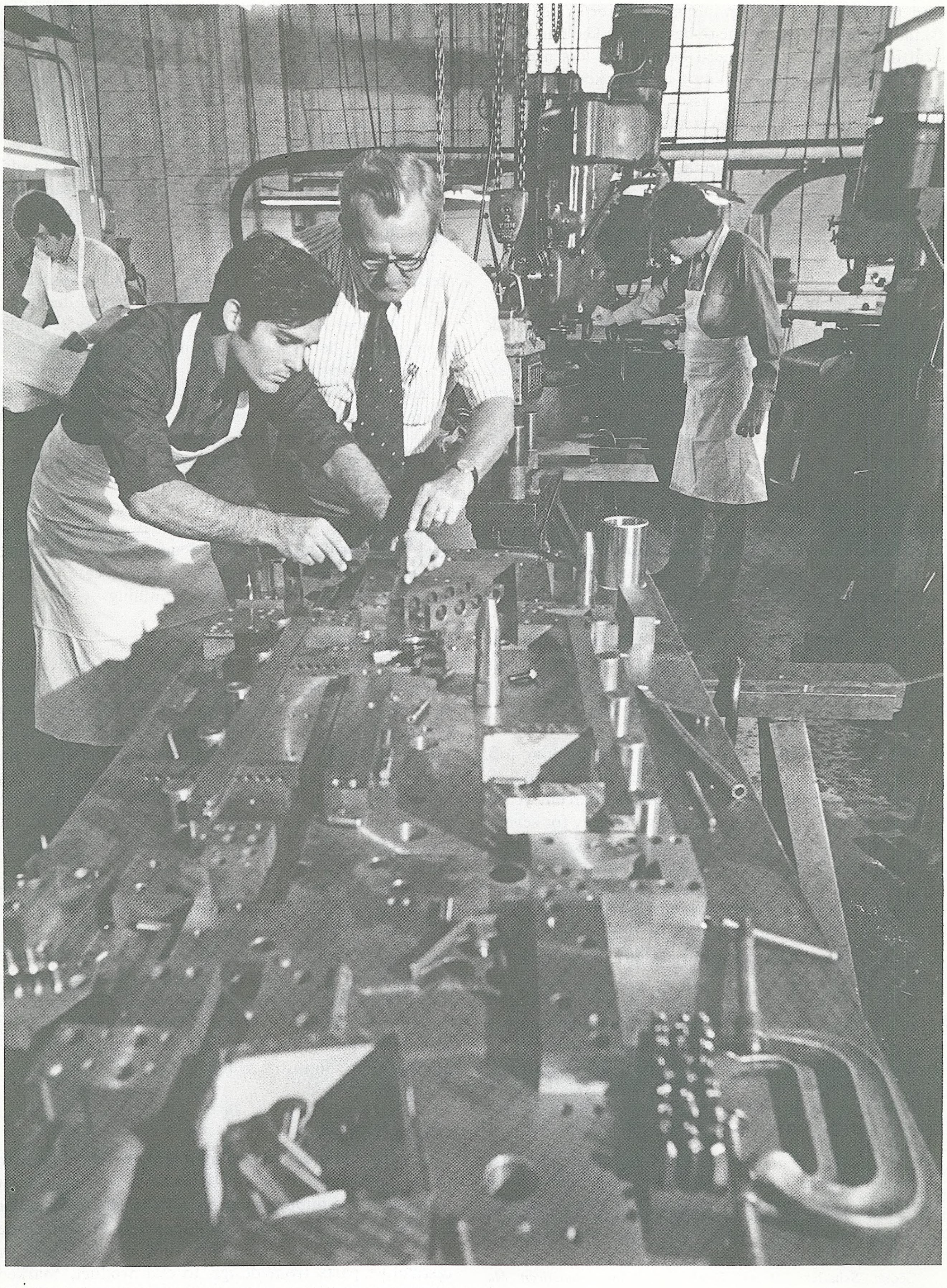
Computer-aided design and manufacture

Computer-aided design and computer-aided manufacture (CAD/CAM) constitute a system which utilizes computer-controlled methods to unite several technologies. Computers are used to assist in developing designs for products to be manufactured (CAD). CAM, among other things, directs numerically controlled machines and automatically guides workpieces among machines on computer-controlled material handling systems. CAD/CAM is influenced by continuing improvements and applications in various phases of manufacturing, including: Assembly with industrial robots; adaptive control; systems to monitor maintenance; and systems to inspect parts automatically. The total impact on productivity and the work force is substantially greater than that of any single technology.

Currently, only the largest machine tool manufacturers utilize CAD/CAM. Its diffusion to medium-size firms will continue to be severely limited by cost and lack of technical expertise.

Higher productivity resulting from adoption of CAD/CAM is associated with the shift of workers to more skilled jobs

[5] D.N. Smith and L. Evans, *op. cit.*, pp. 123, 129, 151.



Tool-and-die makers machine and assemble intricate industrial tools

and the reduction in the number of lesser skilled jobs. Skilled machinists continue to be needed. The number of drafting personnel is reduced because of less need for extensive lettering and layouts. Some workers have to be retrained for new tasks associated with computer terminals. In addition, worker involvement in decision-making will increase although it will be informal, unlike the practice in some other industries.[6]

Intermediate technologies

There are other technologies being introduced into the industry which are not as sophisticated or expensive as NC, but which improve productivity.[7]

Digital readout (DRO). This device enables a machine operator to position the moving portion of a machine tool more rapidly and accurately. A major change in the DRO followed the introduction of an electronic display panel separate from the metering component. A measure of automatic control is added to almost any manually operated machine, although readouts can be used for verification on NC tools, too. The DRO also enables an operator to change a cutting machine from inch to metric measure by flipping a switch; this is the most economical way of providing certain machines with metric capability.

Increases in efficiency result from fewer operator errors and faster machining cycles. Shop efficiency is also raised because less time is required for setups, repetitive tasks, and inspection. The devices decrease positioning times by up to 80 percent.[8] Although machine setups require highly skilled machinists, operators need less training than previously to carry out a job with the aid of a DRO. Also, operator fatigue is reduced.

The use of DRO's is expanding among machine tool builders and is already widespread among tool-and-die shops. DRO manufacturers anticipate 25-percent yearly growth in sales to the metalworking industry for several years. Major improvements on some DRO's since their introduction about 15 years ago can make programming easier for operators. DRO's can be installed on existing machines and are also relatively reasonable; the payback period is usually considered to be less than 1 year. Consequently, they are feasible for the job shop which cannot afford NC

Manual-data-input control. Manual-data-input (MDI) control of machine tools is more sophisticated than the DRO. Both types of controls inform an operator of machine position, but the MDI also enables an operator to change the machine's position automatically, reducing further the chance of error. Many MDI's can be transformed into NC systems by inserting a tape reader; most current NC systems contain editing capabilities to accept programs manually. MDI usually controls simpler machines and turns out simpler workpieces than does NC. Further, some firms do not want or may be unable to add NC machines. A major difference is that an MDI machinist (and not a programmer, as with NC) usually plans and enters the program for a part.

Increased use of MDI in recent years by the metalworking industry has been stimulated by substantial improvements in microcircuit technology and declining costs compared with other controls. A separate programming department is not needed with MDI, and it can be applied in large as well as small shops. While precise data on the utilization of MDI are unavailable, its use is spreading among machine tool builders, and even more rapidly in the contract tool-and-die shops.

Higher labor productivity and improved product quality are credited to MDI. In addition, MDI can help alleviate the shortage of skilled workers because a machine operator may be able to tend two machine tools. Also, some MDI's utilize "shop language" for programming so that a moderately skilled machinist can use the programming language after brief training.

Cutting-tool materials

Improved cutting-tool materials can play a substantial role in the application of highly productive, advanced technologies. The performance of a $250,000 NC machine tool depends on the cutting capability of a $30 end mill. Firms which can utilize the improved tool materials can more efficiently satisfy material and quality specifications of customers. The new cutting-tool materials improve productivity because, unlike older materials, they do not wear out as fast and thus do not have to be changed as often.

Such new materials as coated carbides, polycrystalline diamonds, and special ceramics are being used in place of tungsten carbide. Applications of the relatively long-lasting coated carbides will continue to increase because of sizable price increases for tungsten. According to an industry analyst, the coated carbides will increase from a current application of some 15 percent to at least 25 percent of cutting-tool materials used by the metalworking machinery industry in 1985.

Group technology

Group technology (GT), a management technique, can be as important to productivity as new machines. It involves the grouping of parts on the basis of similar shapes and/or processing requirements. GT revises the belief that small batch manufacturing consists of making distinctive parts from design to end-product. Marked savings are attributed to GT as a result of improved

[6] *Proceedings, Eighth Annual Tri-Service Manufacturing Technology Coordination Conference,* Arlington, Texas, Nov. 8–12, 1976, p. 170.

[7] Programmable controllers, normally associated with mass-production industries, and programmable hand calculators are also intermediate technologies which have had successful applications in small batch manufacturing. See National Center for Productivity and Quality of Working Life, *New Technologies and Training in Metalworking,* Summer 1978, pp. 4–7.

[8] George Schaffer, "Digital Readout Systems," *American Machinist,* May 1979, p. SR–4.

production scheduling, reduced inventory, and greater efficiency in machine loading. Design rationalization and reduced, as well as more efficient, setup and tooling are also credited to the process.

GT also could reduce skill specializations which often exist in medium-size and large machine tool shops. Unlike the usual practice in Europe and Japan, only a small proportion of the U.S. metalworking firms which have introduced GT have broadened the skill requirements of their work forces.

Small firms cannot afford the sophisticated effort needed to install GT, and it is used by less than 20 percent of all toolbuilders. Tool-and-die shops do not utilize GT as such, but elements of it are present in shop layout procedures among firms engaged in precision machining and the manufacture of machine tools.

Table 2. Major technology changes in metalworking machinery

Technology	Description	Labor implications	Diffusion
Numerically controlled machine tool (NC)	Tool is controlled by instructions received from tape, punched cards, plugs, or other media. Allows rapid change to new product designs; permits stricter tolerances for parts; and reduces setup time. Useful for small batch production, because parts can be machined by merely changing tapes and resetting tool.	Estimated reduction in machining time of 35–50 percent; typically used two or three shifts. Reduces unit requirements for machine operators; requires less skill than manually operated tools, creates new job of programmer; requires more broadly trained maintenance personnel.	Three percent of all machine tools in metalworking are NC, but they account for a much larger proportion of total output. In metalcutting sector, the value of NC machines is estimated at 30 percent of all machine tools installed in 1979. Considerable growth in the number of NC tools and their share of total output is expected in the 1980's.
Numerical control by computer (CNC)	On-board computer stores and conveys information directly to NC control unit; utilizes latest microprocessor technology.	Same labor implications as NC but, unlike NC, may require computer personnel. Saves time in reprogramming to remove errors or make design changes. Requires maintenance personnel with electronic skills.	Significant proportion of NC machines; mainly limited to larger and medium-size machine tool shops. Expected to increase substantially in the 1980's as result of cost reductions in electric controls; some smaller shops will introduce it.
Machining center	An automatic tool changer makes the center a multifunction NC machine. Each center is equivalent to several machines, each having a specific function.	Raises productivity by permitting operations on many surfaces of a part in a single setup. Operator may control several machines.	Accounts for a small but growing percentage of machine tools in larger plants, but a disproportionately large share of the industry's output.
Adaptive control	Automatically controls feed rate to reduce or eliminate such factors as vibration, tool wear, and cutting temperatures, and alerts operator. Can be used with conventional tools or with NC.	Raises productivity in machining through substitution of sensors for workers' own perceptions. Reduces skill requirements.	Used by large plants. Utilization by small shops will depend upon development of improved sensors and their cost effectiveness relative to the availability of skilled workers and also the type of work performed.
Computer-aided design/computer-aided manufacture (CAD/CAM)	Computers are used to develop designs for products to be manufactured (CAD). CAM directs numerically controlled machines and automatically guides workpieces among machines on computer-controlled handling systems.	Reduces need for low-skilled operators; increases requirements for higher skilled workers.	Used by large machine tool manufacturers only; diffusion to medium-size firms will be severely limited by the technology's cost.
Digital readout (DRO)	A device is applied to movable portion of a machine tool to measure its actual movement; can provide some automatic control; measurement appears on a display unit.	Operator efficiency and accuracy are enhanced during the positioning phase of the machine cycle. Operators are trained in less time and fatigue is reduced.	Use is limited but increasing among machine tool builders; already widespread among tool-and-die shops. Producers of DRO's expect a 25-percent annual growth in their sales to the metalworking machinery industry in the next several years.
Manual-data-input control (MDI)	Enables an operator to change the position of a machine automatically; also identified as "operator-programmed NC."	Machinist can plan and enter part programs; possible in "shop language." Training period shorter than for NC programming.	Precise data on utilization are unavailable, but its use is spreading among machine tool builders and even more rapidly in the contract tool-and-die shops.
Cutting-tool materials	Durable new materials, such as coated carbides, polycrystalline diamonds, and special ceramics more efficiently meet continued increases in machining speed.	Reduce labor requirements somewhat because tools do not have to be changed as often.	Tungsten carbide expected to remain the major material, but coated carbides may increase from current 15 percent to 25 percent of all cutting-tool materials in metalworking machinery in 1985.
Group technology (GT)	Management skills used to reduce small batch operations. Involves the grouping of parts on the basis of similar shapes and/or processing requirements. Workers may perform a wide range of tasks.	Improves efficiency and quality of output. Workers may broaden skills and replace narrow specializations.	Used by some large machine tool builders; elements of GT likely to spread slowly to smaller builders and tool-and-die shops.

Output and Productivity Outlook

Output

The metalworking industry has undergone sharp fluctuations in output in response to the business cycle, typical of the experience of other capital goods industries. Although reliable output data are not available for the total metalworking machinery industry, Census value of shipments data adjusted for price changes (used as a crude measure of output) suggest an average annual growth rate of about 2 percent in 1960–78. Output grew very rapidly (8–9 percent a year) in the period 1960–67. However, in 1967–73, average output declined by about 2 percent and, in 1973–78, the average rate of decline was still about 1 percent, reflecting the 1970 and 1975 recessions. Although later data are not available, there is evidence that some sectors of the industry are recovering in response to the large tooling requirements of the automobile, aircraft, and defense industries.

While all sectors had impressive rates of growth in 1960–67, the pattern of the sectors varied considerably in the next decade.[9] Metal-cutting tool output advanced at a double-digit rate annually (12.0 percent) in 1960–67, and then experienced a very steep decline (8.9 percent annually) in 1967–73. However, in 1973–80 a moderate rate of recovery (2.7 percent) occurred, as output grew strongly after the 1975–76 recession. A similar rise and fall, but not as pronounced, occurred in metal-forming output in 1960–67 and 1967–73. However, in the succeeding period, 1973–80, metal-forming output declined—more steeply than in 1967–73. As in the recession years of 1975 and 1976, output again fell sharply in 1980. Nevertheless, in certain sectors, e.g., metal cutting, delivery time for some orders was as much as 2 years.

One explanation for the decline in metal-cutting output over the longer period of 1967–79 is the tardiness of customer industries in buying new tools. The aging of the machines in the U.S. economy has been a long-term problem. The percentage of metal-cutting machines that are less than 10 years old has been declining steadily since the end of World War II; an estimate of 31 percent for 1976–78 approaches the rate at the end of the depression in 1940. Moreover, when all U.S. metal-cutting and metal-forming tools are combined and compared with tools in six other major industrial nations, the United States had the smallest percentage of machines less than 10 years old and the highest percentage of machines over 20 years old.[10]

[9]Output data for the metal-cutting (SIC 3541) and metal-forming sectors (SIC 3542) are weighted output measures developed by BLS for 1958 to 1980. The data for all other sectors, as well as the entire industry (SIC 354), are deflated Census value of shipments data; latest year, 1978.

[10]"The 12th American Machinist Inventory of Metalworking Equipment 1976–78," *American Machinist, op. cit.*, pp. 133, 135, and 137. The data for the six foreign industrial nations are based on the most recent studies in each country, ranging from 1973 to 1978.

Of major importance is the change in the mix of output as the proportion of numerically controlled tools has increased. It is estimated that, in 1973, about 40 percent of the value of shipments of NC milling machines and machining centers plus comparable conventional machine tools was accounted for by NC machines; the percentage rose to 66 percent by 1977, according to estimates of a consultant to the industry. In the case of NC lathes and conventional lathes, the estimated rise in NC shipments was from 32 percent of the total value in 1973 to 52 percent in 1977. Because NC is considerably more productive, fewer machines are required for a given amount of production.

To some extent, output growth in the industry has been held back by the lack of skilled workers to accommodate to periods of higher demand. While the industry has undertaken considerable worker training in strong growth periods, numerous trained skilled workers had to be laid off when slumps in production took place. Some of these workers left the industry for more stable jobs in other industries; this was especially the case for workers who experienced more than one long spell of unemployment.

Foreign trade. Traditionally, the United States has enjoyed a comfortable advantage in the export of metal-cutting machines. In 1958–65, the value of exports was at least three times as large as the value of imports. Although a trade advantage was maintained in the years 1966–76, it was no longer as large as in earlier years, and in only 2 years (1970 and 1971) was the trade advantage as high as 2 to 1.

In 1977, imports of metal-cutting machines exceeded exports for the first time. Although exports of cutting machines continued to average more in the 1970's than in the 1960's (83.5 percent higher), the rise in imports was considerably more rapid (4.2 times as high in the 1970's). In 1978, the continued deterioration in the trade position of metal-cutting machines offset the favorable trade balance of the metal-forming sector for the first time, and the trade imbalance rose even higher in 1979.

U.S. machine tool manufacturers have not been competing successfully with foreign producers in domestic markets, as is evident by the increase in the import penetration ratio, that is, imports as a percent of apparent consumption (imports plus domestic production, excluding exports). This ratio more than doubled between 1972 and 1979, rising from 9 percent to 22 percent, with the biggest jump in 1978. It rose again in 1980. U.S. manufacturers may be unable to recapture a large portion of the imports of conventional machine tools from Japan and Taiwan. As a result, U.S. firms will have to become more competitive with Japan and also West Germany in the production and sale of NC machines, machining centers, and specialized machines.

In addition to the very rapid expansion in imports, the unfavorable balance of trade in metal cutting was also affected by the way in which foreign trading relationships in these machines are established. During several prosperous years in the 1960's, machine tool builders did not have much incentive to expand their exports to new customers. Yet, machine exports depend upon the establishment of a long-term relationship. Machine buyers often rely upon the machine makers to service and ultimately even rebuild their machines after several years of usage. In the absence of more commercial ties abroad, U.S. machine tool firms could not take advantage of their excess capacity during the recessions of the 1970's to increase their exports. More recently, the sizable upswing in domestic orders has again been reducing interest in exports, as numerous firms are operating at or near capacity levels, and skilled workers are in short supply. Prospective exporters are also handicapped because their lead times for delivery of new machines are relatively longer than in some other countries.

Productivity

Although a reliable measure of productivity is unavailable for the metalworking machinery industry as a whole, trends can be estimated from available output and employee-hours data. Deflated value of shipments, used as a crude measure of output, increased by about 2 percent annually in 1960–78, while the rate of change in employee hours was less than 1 percent for the same period (chart 6). These data suggest that the productivity growth rate averaged only 1–2 percent annually in the 1960–78 period. While productivity (estimated as above) grew moderately from 1960–67, it rose more slowly in 1967–73 and then edged down in 1973–78.

In the metal-cutting sector, for which a BLS weighted measure is available, productivity growth averaged only 1.2 percent in the 1960–80 period, approximately the rate of growth for the whole industry. While productivity grew at an average of 4.1 percent annually from 1960 to 1967, it only edged up at less than 1 percent from 1967 to 1973, when output dropped about 9 percent. In the succeeding 7 years, 1973–80, productivity showed no growth. While growth was relatively strong after 1976, it just offset the recession declines.

Traditionally in capital goods manufacturing, which is highly cyclical, there is a lag in the adjustment of hours to output changes. In this industry, there is often considerable reliance on changes in the overtime component of employee hours in order to adapt to the wide shifts in output. This is especially evident in the metal-cutting sector. Metal-cutting production has characteristics that are not present to the same degree in other industries, particularly labor intensity, high skill needs, and the considerable time and cost to train workers. Moreover, there is a shortage of skilled workers. Consequently, during an upturn, overtime hours are increased; in a downturn, firms keep as many of their employees on the payroll for as long a period as they regard practicable, but reduce overtime.

In contrast, the products of the accessory sector, which include perishable tools and various attachments and accessories for machine tools and other metalworking machinery, enable these manufacturers to benefit from a production process of typically shorter time frames and larger batches than in machine tools. The accessories firms stock numerous standardized products to accommodate anticipated industry demand. Moreover, while the accessory sector needs skilled instrumentmakers to produce measuring devices, the bulk of its output requires a relatively less skilled work force than does metal cutting. Therefore a downturn in the accessory sector output is more likely to be matched by a comparable decrease in employment than in the metal-cutting sector.

The machine tool builders have less flexibility in the adjustment of employment. This can be attributed to the length of time required to complete orders for metal-cutting machinery and the limited standardization that is possible in its production. Such machinery is usually only manufactured when purchase orders are in hand and requires several months to make. The special machines that are manufactured in this sector are necessarily made in small production runs. Even many of the so-called universal machines are in some way modified to meet individual buyer specifications, thereby ruling out some of the economies associated with longer production runs.

The industry has made some attempt to overcome the obstacle of small batch production to improve productivity in the machine tool sectors. For instance, construction standards have been developed over a 20-year period by NC committees of the Electronic Industries Association to enable greater output of standard components and interchangeable subassemblies. In addition, standards have been revised to accommodate advances in technology, such as the capability of computer NC systems to handle manual data input.

Aging machinery is a factor which limits productivity growth in firms throughout the metalworking machinery industry. It has been stated that many of the rather old manually operated tools in use actually cut metal for much less than 10 percent of the time a workpiece is in a batch production shop. Considerable time is involved in setting up to make a part, or parts are being loaded or unloaded, or tools are being changed. As noted in the next section, an upswing in investment in new plant and equipment was underway in the metal-cutting sector. Future data may better reflect the installation of newer, more productive machines, because, in general, optimization of new plant and equipment can be a lengthy process.

Investment

Capital expenditures

Real capital expenditures[11] by the metalworking machinery industry in 1978 were less than 80 percent of peak levels in 1966, although in current dollars they rose by nearly two-thirds. The cyclical volatility of capital outlays

[11] Deflated by implicit price deflator for metalworking machinery.

in this industry is pronounced. Expenditures (in constant dollars) rose almost steadily to their highest level in 1966, moved down rapidly in 1970, and plummeted in 1971 to reach the lowest level since 1963. After rising to near peak levels in 1974, expenditures fell sharply again in 1975. Although they recovered in succeeding years, the peak outlays of 1966 were not surpassed.

Approximately the same pattern is reflected in the three major sectors of the metalworking machinery industry. In metal-cutting machinery, peak expenditures (real) occurred in 1967. In 1978, over a decade later, real expenditures were less than 65 percent of the peak. Machine tool accessories and measuring devices attained their summit in real capital expenditures in 1966–67; by 1978 they were only about 85 percent of the level for those 2 years.

The third major sector—special dies and tools, die sets, jigs and fixtures, and industrial molds—which typically accounts for well over one-third of capital expenditures in metalworking machinery, surpassed its 1966 peak in expenditures in 1974. More pronounced, however, than in the other sectors, was the decline in outlays in 1975, to half of those of the previous year. By 1978, real outlays were about 80 percent of the peak.

No more recent Census data are available, but, according to industry reports, outlays by the machine tool builders were rising sharply in response to increasing demand, noted earlier, by the automobile, aircraft, and defense industries. Capacity of this sector may be greatly enlarged in the early 1980's. The more productive, automated machinery being installed may improve the industry's competitive position vis-a-vis foreign imports.

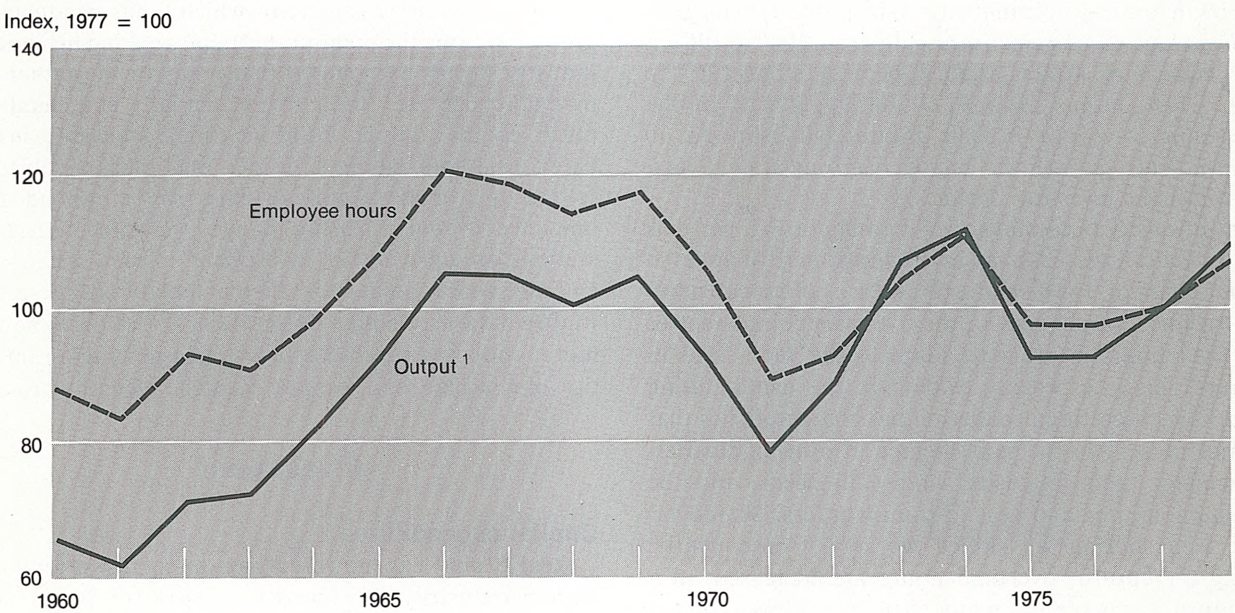
Research and development

A few of the relatively large machine tool builders have undertaken research as well as development. However, in general, most of these firms are in development only. For example, large machine tool makers are involved in the development of improved computer controls for machine tools. To some extent, large companies outside the industry have undertaken R&D at least in part to improve machining standards in their own work. For instance, a firm pioneered in the recent development of a cutting tool with polycrystalline diamond material.

Some joint interindustry development has taken place, including the pooling of development costs by several machine tool builders and an automobile manufacturer in order to increase the speed of lathes. However, there is currently relatively little in the way of joint efforts by government, industry, and labor compared with those in some countries, notably Japan.[12]

[12]Comptroller General of the United States, *Manufacturing Technology—A Changing Challenge to Improved Productivity,* June 3,1976, pp. 74, 88–89.

Chart 6. Output and employee hours, metalworking machinery, 1960-78



1 Deflated value of shipments, unpublished data.
Sources: Bureau of Labor Statistics and Bureau of the Census.

Considerable R&D effort has been directed toward standardization. Whereas once there were more than 30 adapters in use by machine tool builders, the industry is moving toward more universal use of an adapter developed by a large machinery manufacturer. The adapter makes possible substantial reduction in cutting-tool inventories and is considered particularly useful for small firms with NC machines.

The National Bureau of Standards is also advancing the pace of innovation within the industry. The Bureau has research underway to improve the ability of NC and industrial robots to work together. The Bureau is also trying to improve the adaptability of robots. According to a Bureau research analyst, the largest share of robot applications during the 1980's will be in loading and unloading machine tools.

Employment and Occupational Trends

Employment

The industry's employment increased at an average annual rate of 1.4 percent in 1960–80, about the same as for all durable goods manufacturing industries. While employment growth averaged 5.1 percent in 1960–67, it declined 3.0 percent annually during 1967–73, but rose again at 2.3 percent annually in 1973–80. For the period 1980–90, three employment projections by the Bureau of Labor Statistics, based on alternative versions of economic growth, fall in the range of 0.8 percent annually (only about half the 1960–80 rate) to 3.8 percent (2½ times the 1960–80 rate).[13] The low-trend estimate for metalworking machinery is only half the growth rate expected for all durable goods by 1990, while the high-trend estimate (Level B on chart 7) exceeds the projected growth rate for durable goods manufacturing.

At 371,500 persons, employment in 1980 was exceeded only during 2 World War II years. After dropping to a postwar trough in 1949, employment rose steadily to 314,000 in 1953, and was not surpassed until the second half of the 1960's. Over the years 1960–80, there were three periods of sharp cyclical fluctuations affecting every major sector of the metalworking industry. Employment hit a low in 1961 and then exhibited strong continuous growth through 1967 when peak levels were attained. Subsequently, the industry reflected the economy's recessions with deep employment declines in 1971 and again, but not as steeply, in 1975 and 1976. Since then, employment has moved up sharply.

As mentioned earlier, overtime hours play an important role in this industry. By expanding and contracting overtime hours of production workers in response to changes in output, employers tend to moderate short-term hirings and layoffs. While this is true for the entire metalworking machinery industry, it is more marked in the metal-cutting sector. Overtime hours in metal cutting during the sector's cyclical peaks and troughs of 1960–61, 1969–70, and 1973–75 ranged, respectively, from 5.5 to 1.9 hours, 6.5 to 1.8 hours, and 7.8 to 1.8 hours (average weekly data). The proportion of production workers to all employees in the industry has not changed significantly in the last two decades. Production workers accounted for 75 percent of all employees in 1960 and 73 percent in 1980. The comparable figures for all durable goods manufacturing industries were 74 percent and 69 percent.

The three largest industrial sectors in metalworking machinery—namely, tool and die, metal cutting, and machine tool accessories—accounted for slightly over three-fourths of the industry's total employment in the years 1960 through 1980, but the metal-cutting sector declined in relative importance. They all exhibited growth from 1960 to 1967, but the tool and die and machine tool accessory sectors grew at faster average annual rates than did metal cutting. In spite of its recent sharp rise, employment in metal cutting has not recovered fully from its low levels of 1971 and 1972, while the other two sectors recovered more rapidly and attained their peaks in 1979 and 1980 (chart 7). Tool and die and machine tool accessories firms increased their share of employment within the metalworking industry from 50 percent in 1960 to 55 percent in 1980. The share of metal-cutting employment declined from 27 percent in 1960 to 21.5 percent in 1980.

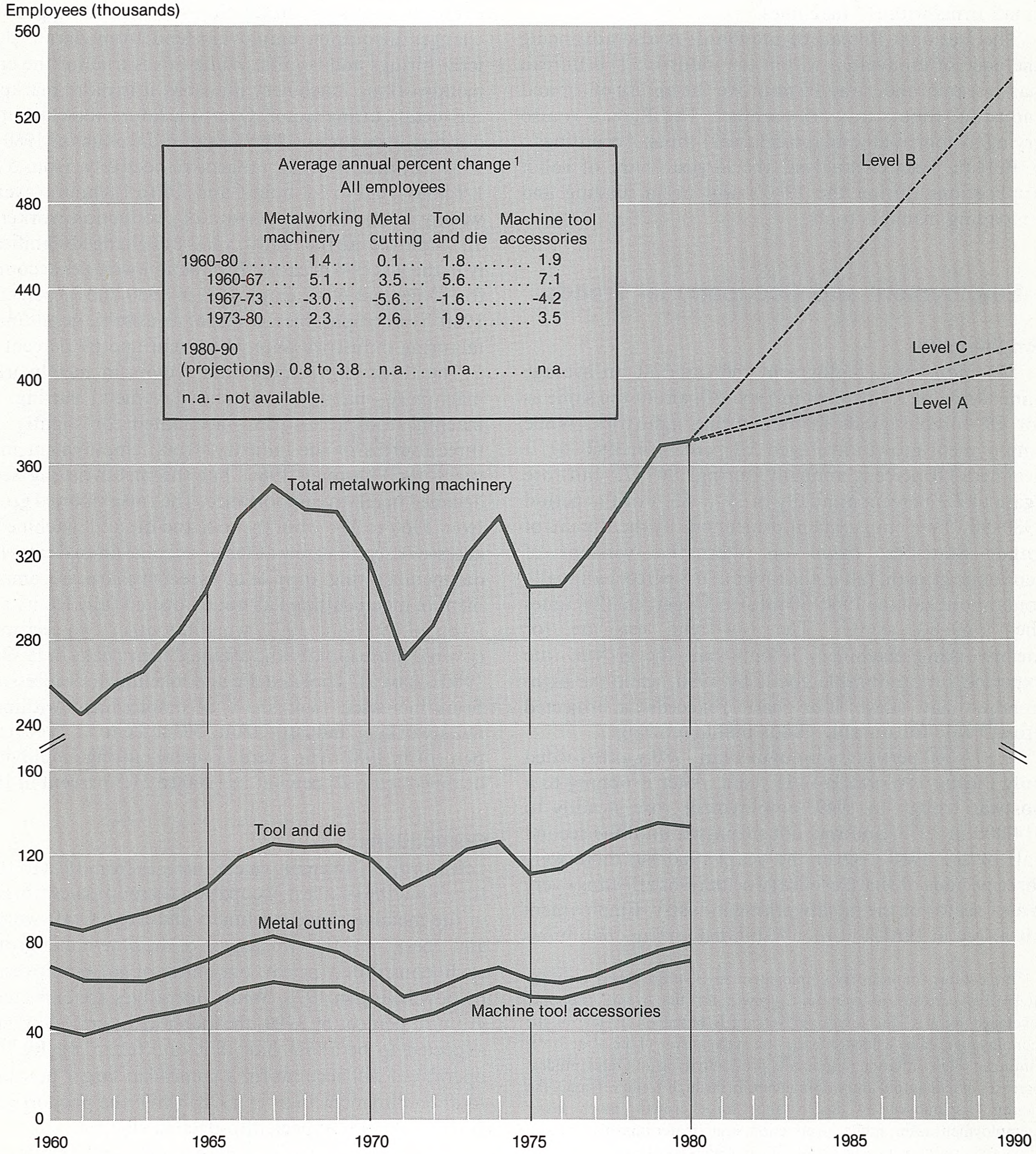
Occupations

BLS projects an employment increase from 1978 to 1990 for all but the smallest occupational group (sales workers) in the metalworking machinery industry. Craft workers and operatives, the two largest of the blue-collar groups, each constituted nearly one-third of all employees in metalworking in 1978. While operatives are expected to grow 36 percent by 1990, the increase for craft workers is expected to be about half that rate (chart 8). By 1990, operatives will account for a somewhat larger percent of total employment than in 1978, while the proportion of craft workers is expected to decline slightly.

A major influence on occupational skills and responsibilities in the past decade has been the use of numerically controlled machines. For example, the more rapid growth in employment of operatives is at least partly attributable to the recent expansion of NC

[13]Projections for industry employment in 1990 are based on three alternative versions of economic growth for the overall economy developed by BLS. The low-trend version is based on a view of the economy marked by a decline in the rate of expansion of the labor force, continued high inflation, moderate productivity gains, and modest increases in real output and employment. In the high-trend version I, the economy is buoyed by higher labor force growth, much lower unemployment rates, higher production, and greater improvements in prices and productivity. The high-trend version II is characterized by the high GNP growth of high-trend I, but assumes the same labor force as the low trend. Productivity gains are quite substantial in this alternative. On chart 7, Level A is the low-trend, Level B is high-trend I, and Level C is high-trend II. Greater detail on assumptions is available in the August 1981 issue of the *Monthly Labor Review*.

Chart 7. Employment in metalworking machinery and selected industry sectors, 1960-80, and projections for 1980-90

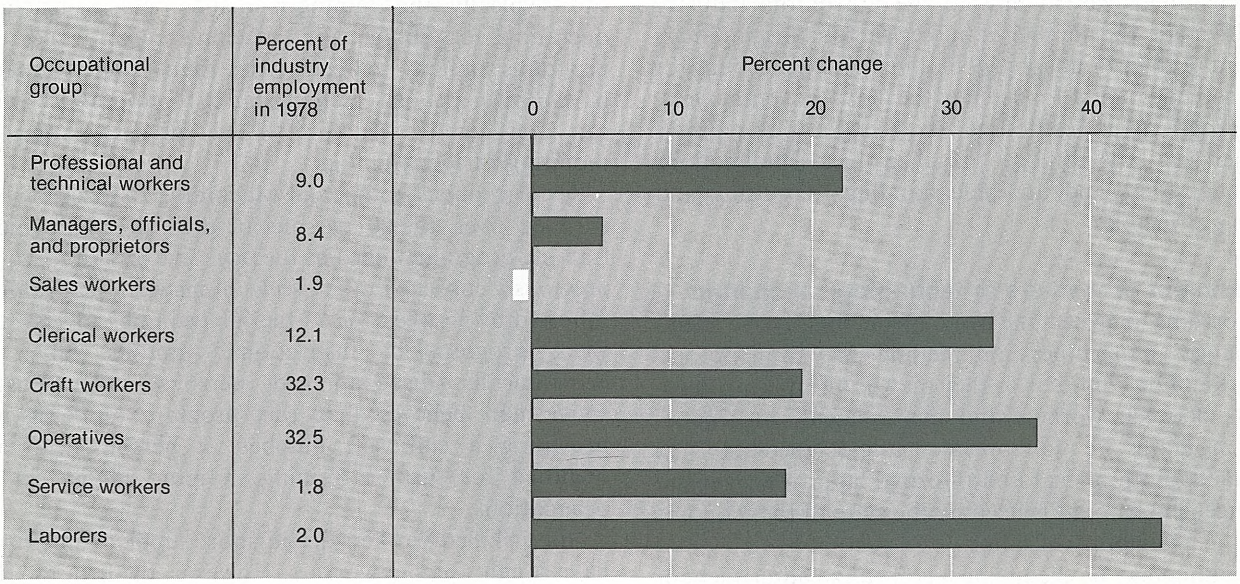


[1] Least squares trend method for historical data; compound interest method for projections.

Note: See text footnote 13 for explanation of alternative projections.

Source: Bureau of Labor Statistics.

Chart 8. Projected changes in employment in metalworking machinery by occupational group, 1978-90



Source: Bureau of Labor Statistics.

machines and various intermediate technologies. A shortage of skilled workers is a major reason certain firms have turned to NC. Over 800 member firms of the National Tooling and Machining Association indicated that they needed on average a 26-percent increase in skilled toolmakers and machinists.[14] Similarly, the great majority of nonelectrical machinery manufacturing plants responding to an *Industry Week* survey reported shortages of skilled workers; the most pressing needs were for machine operators, mechanics, electricians, and tool-and-die makers.[15]

A study which compared the skills of machinists on NC with those on manually operated machine tools revealed that NC machines are associated with a decline in demand for motor skills and decisionmaking abilities.[16] According to a BLS study, NC operators need less knowledge because tapes are programmed to control speed, feed, and width and depth of cut.[17] At the same time, the study referred to the need for greater conceptual skills on NC machines.

There will, however, be continued need for highly skilled machine operators on the most advanced NC machines. Moreover, the costliness of NC machines and the intricacy of their control systems increase the need for preventive maintenance mechanics trained in electronics with practical knowledge of hydraulics and pneumatics. BLS projects that employment of mechanics, repairers, and installers, a subdivision of the craft worker group, will expand five times as fast as all craft employment.

While employment of professional and technical workers is projected to grow by 22 percent from 1978 to 1990, the projected increase for managers, officials, and proprietors will be only at one-fourth that rate. The former's share of total industry employment will be virtually unchanged by 1990, while the latter's share will decline. Changed skills and responsibilities, also largely related to NC equipment, are occurring for these occupational groups. The competitive structure of the industry and complexity of NC equipment and other technologies require not only knowledge of the new machines but also the capability to organize a shop's production so that the machines are utilized optimally.

[14] National Tooling and Machining Association, *Record*, Vol. 2, No. 5, May 1979, p. 4.

[15] Daniel D. Cook and John S. McClenahen, "Skilled Worker Nears Extinction," *Industry Week*, Aug. 29, 1977, p. 46; also see Michael Marley, "If They Could Clone Skilled Workers," *Iron Age*, Vol. 221, No. 37, Sept. 11, 1978, pp. 36–38.

[16] R.J. Hazlehurst, R.J. Bradbury, and E.N. Corlett, "A Comparison of the Skills of Machinists on Numerically Controlled and Conventional Machines," *Occupational Psychology*, Vol. 43, Nos. 3 and 4, 1969, p. 177.

[17] *Technological Change and Manpower Trends in Five Industries*, Bulletin 1856 (Bureau of Labor Statistics, 1975), p. 42.

Engineers will remain the dominant occupation for the professional and technical worker group in 1990, with about half the engineers still in the mechanical field. Drafters will remain, by far, the largest single occupation in the technician group. While computer specialists are expected to increase at only half the rate for total industry employment, the number of numerical tool programmers will more than double by 1990, but will still account for less than one-half of 1 percent of the industry's employees. The programmer position on advanced NC tools requires mathematics, the ability to visualize objects and motions in dimensions, and an understanding of cutting and tooling principles.

Adjustment of workers to technological change

Programs to protect the worker from the adverse affects of changes in machinery and methods may be incorporated into union contracts or they may be informal arrangements between workers and management. In general, such programs are more prevalent and detailed in formal contracts. Both formal and informal labor-management arrangements are influenced by the state of the economy and the availability of labor.

Training may be the major factor in the adjustment of workers to technological change in this industry. Officers of leading machine tool manufacturing firms refer to shortages of trained machinists and other technical and skilled workers as a principal obstacle to maintaining high levels of production or increasing them.

Provision for an adequate level of training is complicated by demographic factors. An aging work force is making it steadily harder to maintain a nucleus of skilled workers as many, including tool-and-die makers, continue to retire. To cover the skill shortages, NC tool builders have provided short, intensive training programs in the fundamentals of maintenance to electricians and other skilled workers. Machinists and even experienced machine operators are being trained in programming.

The extent of training provided by employers is not precisely known. In some cases, small firms have taken a multiemployer approach to apprenticeship and other qualifying training. While some form of training is provided by most employers, local union bargaining agreements typically do not refer specifically to training. A BLS survey of structured training in the nonelectrical machinery industries disclosed that only 18 percent of the surveyed establishments provided training in one or more skilled occupations; and only about one-third of the training was for skill improvement, while two-thirds was training to qualify for the job. The survey excluded the most common forms of training, namely, learning through experience and informal training. The survey included metalworking machinery establishments but data for them were not available separately.

Since 1966, the U.S. Department of Labor (DOL) has provided training funds which have been distributed by the National Machine Tool Builders Association. As of fiscal year 1979, trainees hired by the machine tool manufacturers for the DOL program have to be economically disadvantaged persons. The training (including classroom instruction) is conducted on the job site. Typically, the training is in such fields as machine operation, assembly, and machine repair, and the programs run 13 to 16 weeks. More than 14,000 graduates have proven a good screening source for apprentices who can later qualify for more skilled, higher paying jobs requiring further training.

The National Tooling and Machining Association has enrolled over 15,000 persons in their preemployment training program funded by the DOL. The program, which previously consisted of 16 weeks of institutional training followed by 36 weeks of on-the-job training, now is a 12-week program of institutional training only for economically disadvantaged persons. An industry spokesman believes that this program alone is not providing a sufficient number of persons who are qualified for further training in more highly skilled occupations.

Since skilled workers are in short supply, some firms have sought foreign workers. However, the firms do this reluctantly because of the time involved in completing paperwork and securing approval for immigration. A survey in Milwaukee disclosed that the careers of machinist or machine operator ranked rather low with high school students, even though the city is a major machine tool producer.[18] However, some metalworking firms are making greater efforts to attract young people to the industry by enrolling high school students in cooperative programs (involving morning school attendance and afternoon work), much as they have done successfully with engineering personnel.

The International Association of Machinists and Aerospace Workers (IAM) is the major union in this industry. The United Automobile Workers (UAW) and the United Steelworkers of America (USA) are the other two leading unions. Overall, these unions plus several others have organized about one-third of the workers in the industry.

Contract provisions for nine metalworking firms studied by BLS which each employ at least 1,000 workers appear to be representative of the bargaining agreements negotiated by the three leading unions. In general, the prevalence of seniority provisions acts as a measure of job security when technological change takes place. Agreements provide for seniority rights in the event of layoff and for purposes of rehiring. Interplant transfers are quite uncommon. A provision requiring advance notice of layoff is present in a majority of the agreements studied,

[18] J.G. Udell and others, *Skilled Labor in the Milwaukee Area: The Supply, Education, Problems and Opportunities,* Wisconsin Economy Study No. 15 (Madison, University of Wisconsin, Graduate School of Business, July 1977).

but such notices are generally unrelated to technological change. Nevertheless, some agreements specifically refer to "new equipment" and most UAW agreements deal with "new jobs." Companies in these instances are normally required to consult with the union regarding changes in job description or occupational assignment of the job, and provisions exist for resolving grievances.

Considerable effort by management to improve job security is related to the shortage of skilled workers. The problem is complicated by the cyclical nature of the industry. A Connecticut machine tool builder visited by BLS made the following arrangement: During a 9-month slack period, the firm employed its work force for 3-week periods, and unemployment insurance (UI) payments were secured for the fourth week of each month. (In Connecticut, no waiting period is required for UI payments.)

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Chapter 4. Electrical and Electronic Equipment

Summary

The pace of technological change has been uneven in the diverse group of industries that make up the electrical and electronic equipment group. The electronic components sector, for example, is a leader in technological innovation and has experienced strong growth in production, employment, and capital investment. The electrical machinery industries, however, are experiencing less rapid technological change. Production and employment growth also has been slower in these industries.

A number of occupations will be affected by technological change. Improvements in assembly procedures, primarily in the use of automatic equipment, including robots, are changing skill requirements and increasing productivity for several kinds of operatives. In the largest occupation—assemblers—work is shifting from manual assembly toward machine monitoring, loading, and maintenance tasks. The need for welders and painters may decline, while more mechanics and repairers may be needed. Engineers and technicians will make greater use of video terminals and computer techniques in designing machines and electronic circuits—which should improve their productivity and reduce the need for drafting employees. Solid-state controls, which are manufactured in this industry, will also be used in appliances and other products manufactured in this industry. They will increasingly replace mechanical controls (switches, timers, etc.) and bundles of electrical wires, which will increase the need for scientists, engineers, and technicians, while reducing the amount of manual assembly and soldering work required.

Production in the electrical and electronic equipment industry has grown steadily during the 1960–80 period. The electronic component sector has grown most rapidly, due to strong demand for integrated circuits and other semiconductors. Production has also increased in each of the other industries within this sector.

There is no BLS index of output per employee hour (productivity) for the broad industry group, but indexes are available for several individual industries. Productivity has increased, at varying rates, in each of the industries for which data are available. The household appliance industry experienced the highest rate of productivity growth. Productivity gains in these industries were most rapid during the earlier portion of the 1960–79 period.

Expenditures for plant and equipment have been increasing, with capital outlays highest for electronic components and communication equipment. Capital spending is expected to increase as those parts of the industry experiencing rapid technological development continue spending for new plant and equipment.

Employment rose at a relatively low annual rate of 1.6 percent between 1960 and 1980; the growth rate was highest in the early half of the period. Employment is projected to increase at an average annual rate of 1.7 to 2.5 percent between 1980 and 1990.

Technology in the 1980's

Technological changes are taking place in most sectors of the electrical and electronic equipment industry (SIC 36). To varying degrees, these changes will affect employment levels and occupational structures. Improvements in assembly operations include more automatic equipment to assemble printed circuit boards, and production lines with automatic stations to manufacture household appliances and television receivers. The trend toward more automated operations may lower unit labor requirements somewhat and shift job skills more toward machine monitoring and maintenance. Computer techniques are being developed to assist engineers in designing solid-state (semiconductor) electronic components and integrated circuits. Solid-state controls and switches, and printed circuits, important products of this industry, are replacing mechanical controls and electrical wires in household appliances, television and radio receivers, communication equipment, and other products made by this industry. Designing and installing solid-state controls generally require more engineers and technicians, and fewer assemblers, solderers, and machine operators than the older processes. Numerically controlled machine tools are achieving labor and other savings in turning out communication equipment and other industry products. Electrodeposition painting technology is being used in household appliances, resulting in reduced labor requirements and materials costs. Table 3 provides a brief overview of the major

Table 3. Major technology changes in electrical and electronic equipment

Technology	Description	Labor implications	Diffusion
Equipment to design and fabricate semiconductors and related devices, including microprocessors	Computers and video display terminals can be used to design and lay out complex integrated circuits in less time than is necessary for older methods. This is especially applicable to microprocessors, which are among the most complex semiconductor devices. Fabrication of semiconductors is highly automated. Packaging the semiconductors after the fabrication step can be either very labor intensive or very automated, but the latter requires substantial capital investment.	Designing and fabricating semiconductors require relatively more scientists, technicians, and engineers—and fewer assemblers and machine operators—than the manufacture of electron tubes or mechanical switches and controls which they replace. Computer-assisted design (CAD) of semiconductors could reduce the demand for drafting employees, because engineers using CAD can do more of the design and layout work themselves, instead of delegating this work to drafters. If automated packaging technology becomes more widely used, it could reduce the demand for workers involved with manual packaging operations.	Computer-assisted design and automatic packaging equipment are in limited use due to their high cost. Highly automated fabrication equipment is standard.
Increased automation in assembly-line operations	Computer controlled automatic sequencing and inserting equipment for electronic components, along with a new assembly line where operators control the line speed while inserting components manually, are being put into use to manufacture television receivers. In the production of household appliances, larger capacity presses and a range of automatic assembly processes are being introduced, including limited applications of robots; and automatic equipment for some welding, fastening, material handling, and production operations.	New assembly technology generally lowers unit labor requirements and modifies job duties. New technology for assembly of appliances, for example, requires a higher proportion of worktime for equipment monitoring, machine feeding and loading, and maintenance. Manual tasks are reduced.	This TV assembly line is the first U.S. installation of a technology expected to be used more widely in the United States and already in general use in Japan. Most of the automated assembly equipment used in appliance manufacturing has been introduced in the last 5 years. Robots are likely to increase in use.
Numerically controlled machine tools	Numerically controlled machine tools are being used to turn out a wide range of products which are produced in small volume. In advanced systems, cutting sequences, machine speed, and other operations are controlled by a computer.	Unit labor requirements in machining operations are lower in numerical control, and skill requirements for machinists are modified. Operators monitor the machine tool operation rather than directly manipulate equipment, with programmer and maintenance workers skilled in electronics required in numerical control installations.	Nearly 5,000 numerically controlled machine tools were in use in the industry in 1978, with increased diffusion anticipated. The communication equipment and electrical industrial apparatus sectors of the industry lead in application of numerical control.
Advanced production equipment	Advanced equipment is being used to turn out several key products of the industry. For example, some portions of electric motors are now produced on automatic equipment, resulting in increased productivity. In the manufacture of automobile headlights, filaments are positioned more accurately and testing time reduced by use of new equipment. Household appliances can be painted on automatic lines, with the use of electrostatic painting technology. The electrostatic spray process uses either liquid or dry powder paint. An electrocoating process, in which metal parts are dipped into paint, is also used for high-volume finishing work on household appliances.	Advanced production technology generally reduces unit labor requirements. New electrostatic painting lines, for example, feature modern conveyor lines and little or no manual painting. Labor requirements are lower with dry powder paint than with liquid paint. Labor requirements are also low for electrocoating operations.	Electrostatic and electrocoating processes are in use in a number of plants.

technological changes taking place in this industry, their labor implications, and their expected diffusion.

Production of electronic components

Manufacturing electronic components (SIC 367) has traditionally been labor intensive, involving assemblers, machine operators, inspectors, and related occupations.[1] This industry's development of semiconductors since the mid-1960's has changed its production methods and labor requirements considerably. Semiconductor devices perform most functions of electron tubes (except cathode ray tubes), but are smaller, more reliable, and generally less expensive. As a result, semiconductor devices have replaced most electron tubes. The switch from manufacturing electron tubes to semiconductor devices requires more engineers, scientists, and technicians; and fewer assemblers and operators since many manufacturing operations are automated. The impact of this technology is marked. Employment in the part of the industry manufacturing electron tubes has declined steadily, while employment in the rest of the industry—including semiconductors—has risen sharply.

The first steps in fabricating a semiconductor device—circuit design and mask making—are complex and require high-level technology. Many months are needed to

[1] Electronic components (SIC 367) consists of two major product groups. One group comprises all types of electron tubes: Television cathode ray picture tubes (SIC 3672), all other radio and television tubes (SIC 3671), and transmitting, industrial, and other special-purpose electron tubes (SIC 3673). The second group contains several products; the most important from the standpoint of technological and occupational changes are semiconductors and related devices (SIC 3674).

design a complex integrated circuit and to make photo masks from which the circuits will be produced. Design and layout involve determining which electronic components (transistors, resistors, etc.) are required to make the circuit perform as desired; then deciding how to arrange the circuit components in the circuit base material.

Conventional methods of circuit design and layout—drawing circuits by hand on graph paper and assembling "bread board" circuits for testing—are slow and require skilled scientists and technicians. Computer-assisted design (CAD) is faster, more accurate, and allows the designer flexibility in circuit design and layout. Developing a CAD system requires complex programming to store information in the computer and to display and position the simulated circuits on a cathode ray tube terminal. CAD is used by only a few manufacturers, since equipment and software costs are high and the system must be used intensively to be cost effective. But where it can be used, results can be dramatic: In some applications for thick-film integrated circuits, computer-aided design reduced costs by 300 percent.[2]

As CAD technology is diffused more widely, several occupations will be affected. Computer specialists will be needed for initial program set-up, but this could be a one-time operation for each CAD system. Drafters might be largely bypassed as engineers use video terminals for design and layout. Computer control may also be extended to photographic and mask-making operations, similar to automatic printing plate technology used in the graphic arts industry. This could reduce employment of technicians who presently do the photographic work in mask making.

Integrated circuit fabrication is a highly automated, batch-type process that can produce hundreds of separate, complete circuits in each production run. Silicon cylinders several feet long by several inches in diameter are sliced into thin wafers, loaded onto special trays, and put through production steps as a group. During production, many tiny circuits are fabricated, side by side, across the surface of each wafer.

Labor costs in integrated circuit fabrication are relatively low because of extensive automation. Most labor requirements are associated with loading and unloading the trays of wafers, and with operating fabricating and testing equipment.

After the wafer is cut into individual circuits, the tiny circuits are encased in protective packages. The packages are larger and stronger than the circuit dies, and contain the electrical connections needed for electronic appliances. In general, the packaging process involves bonding individual circuit dies onto metal stampings, then attaching very fine wires to make the electrical connections between the dies and the electrodes on the stampings. Plastic covers are then molded around the dies, sealing them inside the now-complete packages. Finally, each circuit is tested to insure proper operation.

Circuits are most commonly packaged manually, which is quite labor intensive. An alternative has been to use automated handling equipment, although high equipment costs have limited this option. However, since labor costs are rising and packaging technology is improving, use of automated equipment may increase.

Microelectronic technology

Microprocessors are a fairly recent development of semiconductor technology, and are of importance to the electronics industry both as a product sold to others and as a technology that can be applied to the industry's own design and production operations. A microprocessor contains a complete miniature processing unit on a single silicon chip. It can be combined with other chips containing memory, timer, and input-output functions to build a complete microcomputer system on a single circuit board. Designing and fabricating microprocessor chips is a very complex undertaking, but the range of applications is already substantial and is growing rapidly. The largest volume of microprocessors in use are low-powered 4-bit devices that provide relatively simple control functions. More powerful 8-bit devices, however, account for most of the revenue from sales related to microprocessors.

Microprocessor-based systems are expected to dramatically change the function and capabilities of household appliances during the 1980's. Estimates vary on the rate of diffusion of microelectronics in the appliance industry through the mid-1980's, but one industry source estimates that 50 percent of all major appliances will be controlled by microelectronic devices.[3]

One of the most popular applications of microcomputers will continue to be microwave ovens, where sophisticated controls allow a wide range of cooking sequences and temperatures (including ovens that can be programmed by the user). Microcomputers also are being used in cooking ranges, dishwashers, clothes washers and dryers, and other household appliances.

The growing application of microelectronics to industrial and household appliance controls has brought about changes in design and production operations. Mechanical engineers and industrial designers work more closely with electrical engineers to develop electronic controls as substitutes for mechanical and electromechanical controls. Assembly operations and labor requirements change when solid-state controls are used. It is no longer necessary, for instance, to route and solder large numbers of individual wires into place; thus fewer solderers are needed. Also, flat electrical cables and flexible printed circuits with plug-in connectors are replacing bundles of separate wires. There may be a secondary impact in that fewer components and less equipment are needed to produce electronic controls. This could reduce the labor

[2] "Hybrid-circuit Technology Keeps Rolling Along," *Electronics*, July 22, 1976, p. 104.

[3] Donald L. Owens, "Microelectronics: A New Horizon for Appliances," *Appliance*, July 1979, pp. 28–31.

Automated equipment to test TV picture tubes

needed for stock control, material handling, warehousing, and transportation.

Improvements in assembly technology

Many types of assembly operations take place in the diverse group of industries that make up the electrical and electronic equipment industry. Technological innovations in assembly include increased automation and improved manual assembly lines for TV receiver producers and, in appliance manufacturing plants, automated assembly operations for household appliances and in-house assembly of printed circuit boards.

A major domestic TV manufacturer has begun operating a new assembly line that has increased productivity and product quality. This is the first such TV receiver assembly line in operation in the United States, although this type of assembly line has been used for several years in Japan with considerable success. The new line features both computer-controlled automatic sequencing and component inserting equipment, as well as new technology for inserting parts manually, and is achieving productivity gains. On the new line, solid-state components come packaged in reels from vendors. Only one type of component is included in each reel, and each reel may contain several hundred components. A number of these one-of-a-kind reels are mounted on a component sequencing machine which—under computer control—automatically removes individual components and deposits them on a conveyor in the sequence required for the automatic inserting machine. The conveyor transports each component through an automatic testing station to insure that it functions properly and is in the correct sequence. Finally, the components are automatically taped onto a new reel for use in the inserting machine, which automatically inserts components onto the circuit boards and then cuts and crimps the wire leads on each component to secure them to the board. Completed circuit boards are transported through an automated wave soldering machine that solders all electrical connections in one operation.

Most operators on the new line originally held assembly jobs involving manual insertion of components into circuit boards or manual assembly of parts onto the television chassis. When the automated equipment was brought into the plant, this group was retrained to load and operate the machines. The machine operator positions involve higher skill and pay levels.

Productivity is increased with the automatic sequencing and inserting equipment in that operators can insert more components per hour than is possible with the same number of people manually inserting components into circuit boards. Additionally, quality is improved since every component in the automatic line is tested before being inserted into the boards. A major feature of the new line is the specially designed assembly equipment for manually inserting components that cannot be handled on the automatic equipment.

In the manufacture of appliances, improved technology is being installed in major production tasks. Sheet-metal components are being fabricated by larger capacity presses fed directly from coils of sheet metal. These components are produced at high speeds with a minimum of manual handling.

New technology for high-volume assembly also is being introduced. Assembly tasks are labor intensive. When assembly lines become automated, unit labor requirements are lowered and job skills frequently shift to machine monitoring, machine feeding and unloading, and machine maintenance.

One manufacturer is using automatic assembly techniques to insert a retaining pin into the spout cap of a tea kettle, in place of a manually fastened screw-and-nut assembly. The automatic equipment has increased the assembly rate by 84 percent, lowered unit labor requirements, and decreased fastener costs.

Another appliance manufacturer has installed an automatic line to assemble washing machine cabinets that has a maximum output of 350 cabinets an hour. Sheet-metal blanks pass through presses that shape them into cabinets, which then move past automatic welding stations where gussets and brackets are attached. The cabinets next are transported by conveyor through a manned inspection station and then to the finishing area.

The entire line is staffed by three operators and one inspector, who checks cabinets as they come off the line. In a less mechanized, conventional system with the same volume of output, labor requirements would be higher. A solid-state control system with a cathode ray tube (CRT) display terminal provides data on malfunctions and defects which facilitate repairs. The automatic assembly line has increased output by 40 percent, raised cabinet quality, and improved operator safety.[4]

Robots are being used in several assembly applications by one large manufacturer of appliances to cut costs and improve productivity. In one application, two robots are used to load and unload a press that trims plastic liners used in refrigerators. In another application elsewhere on the assembly line, two more robots spray the interiors of the refrigerator cabinets with an adhesive that holds a layer of foam insulation; each robot takes the place of two workers and there is a 10-percent reduction in the amount of adhesive material used.[5]

One manufacturer recently built a highly mechanized assembly line for energy-saving refrigerators that speeds production and testing procedures, and reduces labor requirements for machine operators, welders, and material handlers. The cabinets are produced on a semiautomatic line that includes an automatic destacker (which transfers metal cabinet blanks onto the production line) and an automatic electric resistance welding station. Serpentines—the metal tubes that carry freon inside refrigerators—are made in an off-line operation. Coils of metal tubing are fed into a machine that automatically straightens the tubing, then cuts and bends it into the proper dimensions for installation in refrigerators. Solid-state controls give flexibility in programming the equipment to make serpentines of varied sizes.

Foam insulation is injected into the cabinets on a 6-station automatic foaming installation that utilizes solid-state controls. Only one person is needed to operate this equipment. Cabinets are brought by conveyor belt, where a system of photo cells and magnetic tape readers routes the cabinets—via a turntable and runout conveyors—to the proper foaming station. The cabinets are automatically positioned on the foaming fixtures, filled with insulation, and lowered onto another conveyor to leave the foaming operation.[6]

Appliance manufacturers have begun to assemble their own printed circuit boards instead of purchasing them from electronic component suppliers. Thus, technology and labor are "transferred" from one sector of the electrical and electronic equipment industry to another. The assembly of printed circuit (PC) boards involves inserting resistors, capacitors, integrated circuit (IC) chips, and other components onto the boards, soldering all connections, then cleaning and inspecting the completed boards. Assembly methods range from largely manual tasks—the predominant method at this time—to semiautomatic and fully automatic processes. There are several "aided manual" systems that allow relatively unskilled operators to assemble complete PC boards. One of these systems, for example, positions the PC board in a machine which guides the operator through a sequence of production steps by illuminating the appropriate holes in the PC board into which each succeeding component is to be inserted. At the same time, a tray of parts is positioned so that only the proper component is accessible to the operator. If the more automatic processes become more prominent, the employment of assemblers will be affected.

Numerically controlled machine tools

Numerically controlled machine tools are being used increasingly in the electrical and electronic equipment industry. They are used most extensively in the communication equipment and electrical industrial apparatus sectors of the industry to turn out a wide range of products which are produced in small volume. More than 1,000 numerically controlled machine tools are being used in each of these two major sectors.[7] In advanced numerical control systems, cutting sequences,

[4]James Stevens, "A New Cabinet Line Pays off for Maytag," *Appliance*, February 1976, pp. 34–35.

[5]"Robots Join the Labor Force," *Business Week*, June 9, 1980, p. 68.

[6]Gene Morgan, "A Sophisticated System Speeds Production," *Appliance*, September 1977, pp. 50–52.

[7]"The 12th American Machinist Inventory of Metalworking Equipment 1976–78," *American Machinist*, December 1978.

machine speed, and other operations are controlled by a computer with significant savings in unit labor requirements, tooling costs, and lead time. The function of the machine operator has changed from direct manual manipulation of equipment to monitoring the operation of the machine tool and loading and unloading parts. A programmer—a new position—develops the sequence of operations, tools to be used, and feed and speeds of the machine tool. Maintenance workers with a knowledge of electronics are needed to service numerical control systems. The outlook is for further advances in numerical control technology including its use for inspection of parts.

Advanced production equipment

Other production processes where new technology is being used include the manufacture of portions of electric motors, testing of automobile headlamps, and painting of household appliances.

Automated stator production. Automated equipment is being used to manufacture stators for electric motors. Automatic presses stamp out selected parts, insulation is inserted automatically into the stator core, and coils are wound and inserted automatically. The new equipment has considerably increased line speed, increasing the output without increasing the work force.

Automobile headlamp testing. Photometric equipment that evaluates and records headlamp performance automatically is helping manufacturers test headlamps to ensure they meet specifications set by the Federal Government. The time required to test headlamps has declined from 20 minutes to less than 5 minutes, with sophisticated optical equipment available to position headlamp filaments to close tolerance, thus increasing worker output and productivity.

Advanced painting technology. New technology for the electrical depositing of paint onto household appliances is being introduced more widely. In electrostatic painting, paint particles are electrically charged and sprayed onto surfaces carrying an opposite electric charge to form a strong bond. The painted surface is then baked to a hard finish. The electrostatic process can be used with liquid or "wet" paint or the increasingly popular dry powder paint. Labor requirements in the new electrostatic systems are lowered since material handling and painting tasks are largely automatic; robots are used in some installations. At one plant manufacturing household appliances, an operator manning a control console on a newly installed wet painting electrostatic line can change paint colors in 60 seconds. Quality of painting is improved and maintenance costs are lowered.

Dry powder paint, used in the electrostatic process, is expected to be employed more widely during the 1980's. Dry powder painting systems require fewer operators than liquid or "wet" systems since paint mixing is eliminated and manual touch-up is reduced. Other factors favorable to further diffusion include easier paint handling and clean-up operations. Energy requirements also are lower. One firm which replaced a wet system with a porcelain enamel powder system reported labor costs were lower by 33 percent, rejects and materials were reduced by 50 percent, and quality was improved.[8] A disadvantage is the inability of dry painting systems to handle frequent color changes. In 1976, nearly 40 electrostatic thin-film powder spraying systems for appliances were in use. Additional installations are forecast for the 1980's.[9]

Another form of electrodeposition—electrocoating—involves immersing a metal part into a tank of coating material. The metal and the liquid in the tank carry opposite electrical charges, which form the bond, providing a continuous, evenly deposited film on the metal part. This process was introduced for high-volume finishing operations in the mid-1960's, and has since gained wide acceptance, especially for applying primer coats on appliances. The process is less labor intensive than conventional painting processes, gives a uniform coating even on intricately shaped objects that have hidden or recessed areas, minimizes material costs because there is almost no wasted paint, and causes much less air and water pollution.[10]

Output and Productivity Outlook

Output

The electrical and electronic equipment industry turns out a variety of products for government, industry, and consumer use. This product diversity is shown in table 4, which presents output growth in major industry sectors.

Output in the industry as a whole has increased at a relatively high annual rate. According to the Federal Reserve Board production index for this industry, output grew steadily from 1960 through 1980, averaging a growth rate of 5.9 percent a year. As shown in table 4, the rate of growth in output was substantially higher during 1960–67 than in 1967–80. There was a slight dip in output during 1970 and 1971, after which output climbed to a peak in 1974, dropped rather abruptly in 1975, and then rose sharply in 1976 through 1980.

Output in the electronic components industry (electron tubes, semiconductors, integrated circuits, etc.) has grown more rapidly than in any other industry in the group, increasing at an average annual rate of 12.5 percent during 1960–80, more than double the annual growth rate for total electrical and electronic equipment over the same period. Most of this expansion in output has been in integrated circuits—which include micro-

[8]"Plant Experiences with Porcelain Enamel Powders," *Appliance*, November 1978, pp. 49, 67.

[9]Gene Morgan, "Focus: Powder Coating," *Appliance*, September 1976, pp. 45–49.

[10]Gene Morgan, "Electrocoating," *Appliance*, November 1978, pp. 39–41.

Table 4. Output growth in electrical and electronic equipment, 1960-80

SIC	Industry sector	Average annual percent change[1]		
		1960-80	1960-67	1967-80
36	Total electrical and electronic equipment[2]	5.9	10.5	4.2
361,2	Electrical equipment and parts	4.2	8.1	2.8
363	Household appliances ..	4.6	8.7	2.5
365	Radio and TV receiving equipment	3.3	13.8	.6
366	Communication equipment	3.8	7.0	2.7
367	Electronic components	12.5	22.0	8.8
369	Miscellaneous electrical equipment	5.5	7.2	5.0

[1] Least squares trend method.
[2] Includes data for SIC 364, electric lighting and wiring equipment, not available separately.

SOURCE: Board of Governors of the Federal Reserve System.

processors, introduced in the mid-1970's and gaining widespread acceptance. Passive components (such as capacitors, resistors, and connectors) and discrete semiconductors have made lesser contributions.

Output of electron tubes was fairly stable during the 1970's; the decline in production of receiving tubes (as solid-state components became more widely used) was offset by slight gains in TV picture and specific-purpose tubes.

Output growth was slowest in radio and TV and communication equipment. Consumer discretionary income and imports affect the level and growth of output in the radio and TV industry—which includes a number of consumer electronic components in addition to radio and TV receivers. In communication equipment, telephone and telegraph products account for almost one-third of the value of industry shipments. The remaining two-thirds consist of electronic systems and equipment for which the U.S. Government is the major purchaser—especially the Departments of Defense and Transportation, and the National Aeronautics and Space Administration. Output growth, therefore, depends heavily upon the demand from new households, business communication needs, and Federal Government procurement policies.

The expansion of output in the major sectors of the electrical and electronic equipment industry will continue to depend on several factors. In electronic components, for example, the growing commercial diffusion of a relatively new product, microprocessors (a complex integrated circuit finding application throughout the economy in a growing number of products from games to industrial robots), will require further expansion of production facilities. In electrical equipment, demand for electric transformers and switchgear depends heavily upon residential, commercial, and industrial construction. In major household appliances, population growth, family starts, and housing construction influence final demand.

Productivity

Although a productivity measure for total electrical and electronic equipment is not published by the BLS, the measures available for several of the individual industries indicate that productivity change varies significantly by industry, and that growth rates have slowed over the past decade.[11]

The rate of increase in output per employee hour in the industries for which BLS publishes measures ranged during 1960-79 from an annual rate of 1.8 percent in electric lamps to an annual rate of 4.4 percent in major household appliances (table 5). In household appliances, output grew more rapidly than employee hours during 1960-68; output continued to grow slowly and employee hours declined during 1969-79. In all five of the industries included in table 5, the rate of increase in output per employee hour was lower from 1967 to 1979 than from 1960 to 1967. The sharpest decline in productivity was in motors and generators.

The extent to which technology affected the movement of productivity cannot be measured precisely. In all five of these industries, and in others for which BLS measures are not available, new technology has reduced unit labor requirements in selected production operations. The anticipated higher levels of spending for new plant and equipment could contribute to further productivity gains in key production tasks.

Table 5. Output per employee hour in selected electrical and electronic equipment industries, 1960-79

SIC	Industry	Output per employee hour: Average annual percent change		
		1960-79	1960-67	1967-79
3621	Motors and generators	2.1	5.6	1.2
3631,32, 33,39	Major household appliances	4.4	6.1	3.9
3641	Electric lamps	1.8	2.8	2.1
3645,46, 47,48	Lighting fixtures	[1]2.6	[2]2.9	[3]2.6
3651	Radio and TV receiving sets	3.9	6.0	3.4

[1] 1961-78.
[2] 1961-67.
[3] 1967-78.

SOURCE: Bureau of Labor Statistics.

[11] Productivity measures are published by the BLS for the following five industries: Motors and generators (SIC 3621); major household appliances (SIC 3631, 32, 33, and 39); radio and TV receiving sets (SIC 3651); electric lamps (SIC 3641); and lighting fixtures (SIC 3645, 46, 47, 48). See *Productivity Measures for Selected Industries, 1954-79*, Bulletin 2093 (1981).

Investment

Capital expenditures

The electrical and electronic equipment industry has invested substantial funds for capital improvements, including the latest production technologies discussed in this report. In 1976, expenditures for new plant and equipment totaled $1.7 billion (constant 1972 dollars), more than twice the $800 million invested in 1960.[12] Capital expenditures per production worker averaged $1,385 in 1976, well above the average of $803 in 1960.

The pace of capital spending has been uneven. Over the longer term 1960–76 period, expenditures for plant and equipment rose at an annual rate of 5.3 percent. Capital spending during 1960–67 increased at a substantially higher annual rate of 14.0 percent. In the 1967–76 period, however, during which expenditures fluctuated markedly, outlays (in constant dollars) declined by an average annual rate of 0.2 percent. Between 1973 and 1976, the decline averaged 7.8 percent a year.

Capital spending also varied significantly among the individual industries which make up the total electrical and electronic equipment industry. The electronic components industry led all industries in the group with $478 million spent for new plant and equipment in 1976. Expenditures in communication equipment were the second highest, $399 million in 1976. Combined, these two industries were the source of more than one-half of capital spending.

Research and development

The electrical and electronic equipment industry is a leader in research and development (R&D) spending. According to the National Science Foundation, R&D expenditures by the electrical and electronic equipment industry totaled $7.6 billion in 1979, up from the $2.9 billion allocated in 1963.[13] In 1979, this industry ranked second only to aircraft and missiles in total funds allocated to R&D. Federal Government R&D funds accounted for 42 percent of the $7.6 billion spent in 1979, and company funds, 58 percent. Since 1973, company funds for R&D in electrical machinery and communications have exceeded Federal Government R&D funds.

The electrical and electronic equipment and communication industries employed 94,700 R&D scientists and engineers (full-time equivalent) in 1980, leading all other major industry groups for which the National Science Foundation provides data.

Employment and Occupational Trends

Employment

The industry employed slightly over 2.1 million workers in 1980 compared to 1.4 million in 1960—a 1.6-percent annual growth rate (chart 9). More than one-half of the industry work force in 1980 was engaged in manufacturing communication equipment and electronic components.

The trend in employment, as in other measures for this group of industries, varied among the major industry sectors (table 6). Employment in electronic components increased at the greatest annual rate (3.4 percent) during 1960–80, a period of generally strong demand for these products, particularly integrated circuits (which include microprocessors). The average annual employment growth rate has been slowest in electric transmission and distribution equipment and radio and TV receiving equipment. Employment in these industries increased during the 1960's, then declined during the 1970's, so that by 1980 the level was about the same as in 1960.

Employment growth in the electrical and electronic equipment industry was highest during 1960–67, compared to the more recent 1967–80 period. As indicated in chart 9, employment increased at an annual rate of 4.1 percent during 1960–67, compared to an

Table 6. Average annual rates of change in employment, electrical and electronic equipment, 1960–80

SIC	Industry sector	Average annual percent change[1] (all employees)		
		1960–80	1960–67	1967–80
36	Total electrical and electronic equipment	1.6	4.1	0.6
361	Electrical transmission and distribution equipment	.1	2.3	-1.6
362	Electrical industrial apparatus	1.7	3.0	1.1
363	Household appliances	.8	2.5	-.3
364	Electrical lighting and wiring equipment	2.2	6.3	.6
365	Radio and TV receiving equipment	.0	6.8	-2.6
366	Communication equipment	.7	3.0	-.5
367	Electronic components	3.4	7.8	2.4
369	Miscellaneous electrical equipment	2.9	1.0	3.3

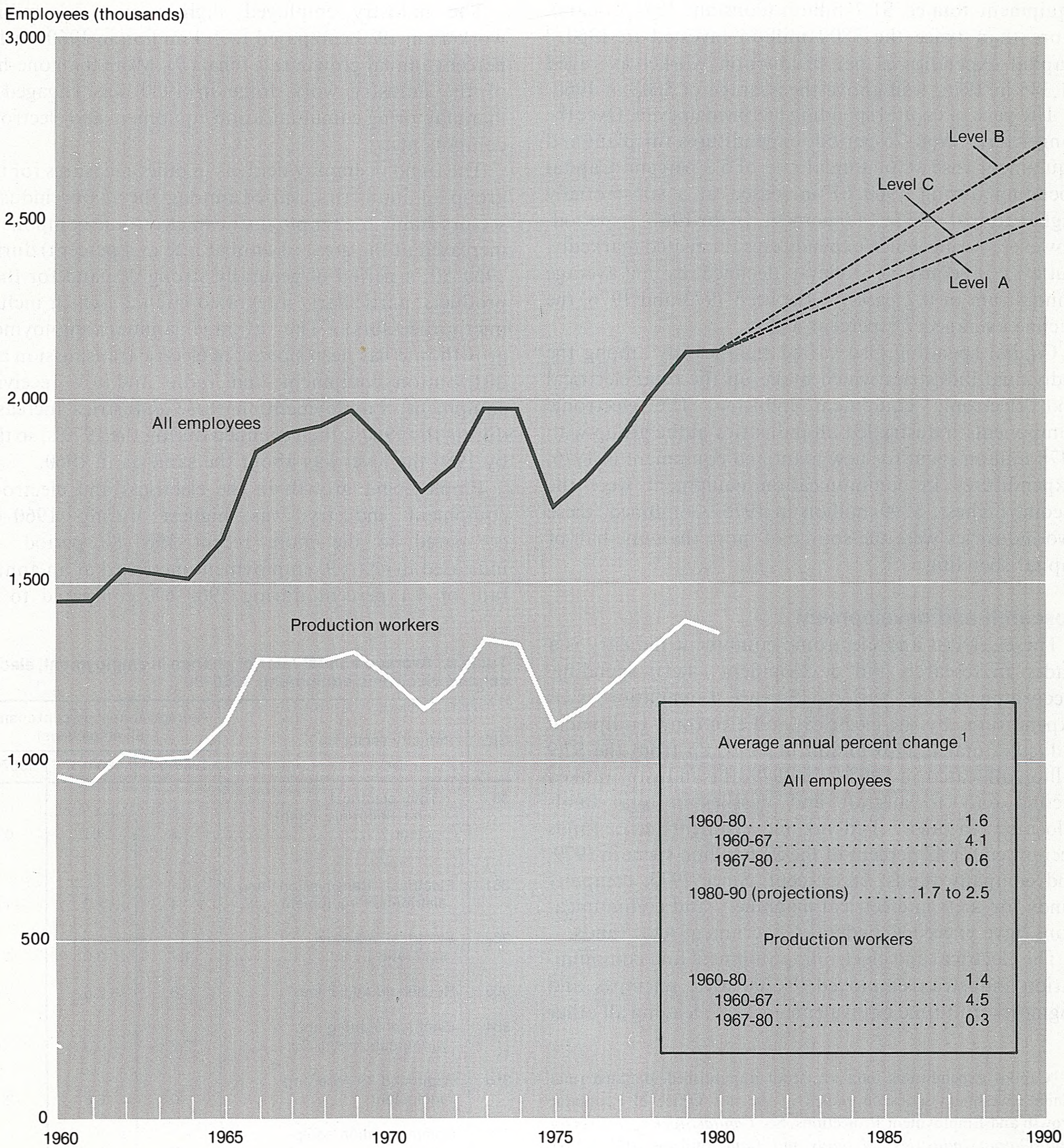
[1] Based on least squares trend method.

SOURCE: Bureau of Labor Statistics.

[12] Capital expenditures data are from unpublished, deflated total annual investment series developed in the BLS Office of Economic Growth and Employment Projections. See *Capital Stock Estimates for Input-Output Industries: Methods and Data*, Bulletin 2034 (1979). Expenditures for 1976 are the latest available.

[13] These are current-dollar data; the increase in real terms is not as great. Before 1978, the National Science Foundation published R&D expenditure data for both electrical and electronic equipment (SIC 36) and communications (SIC 48) as one combined figure. Very little R&D work is done in SIC 48. It is largely a service industry that uses equipment developed and manufactured in SIC 36. Beginning in 1978, R&D data for the two industries are published separately.

Chart 9. Employment in electrical and electronic equipment, 1960-80, and projections for 1980-90



[1] Least squares trend method for historical data; compound interest method for projections.

Note: See text footnote 14 for explanation of alternative projections.

Source: Bureau of Labor Statistics.

annual rate of 0.6 percent during 1967–80. Employment dropped sharply (by about 14 percent) between 1974 and 1975 as demand slackened. This pattern of employment growth—a higher rate during the earlier of the two periods discussed in this report, followed by a lower growth rate or a decline in employment during the latter portion—was experienced in all industry sectors except miscellaneous electrical supplies.

The outlook is for employment in this group of industries to increase at an average annual rate of 1.7 to 2.5 percent between 1980 and 1990, according to BLS projections based on three versions of economic growth.[14]

Occupations

The structure of occupations is expected to undergo change. As shown in chart 10, all the major occupational groups except sales workers are expected to increase between 1978 and 1990.

Operatives, the largest occupational group in the industry, accounting for about 45 percent of total employment in 1978, are projected to increase by more than one-fourth between 1978 and 1990. They will continue to be by far the largest occupational group (47 percent of total employment in 1990). Assemblers make up more than one-third of the operatives; they are expected to increase in number at a slightly higher rate than the average for all occupations in the industry. Although new technologies applicable to assembly operations will be diffused more widely, assembly of household appliances and other products is expected to continue to involve a high degree of manual tasks. In some assembly operations, however, manual tasks are expected to decline and job skills increasingly will involve more equipment monitoring, machine feeding and unloading, and equipment maintenance. In contrast to assemblers, employment of solderers is expected to decline by 30 percent and welders and flamecutters by 8 percent between 1978 and 1990 as automated equipment is diffused more widely. In craft occupations, employment of mechanics, repairers, and installers is expected to increase sharply as mechanization of production operations continues in the 1980's.

The rate of employment change in the major occupational categories presented in chart 10 is expected to vary among the industry sectors. Thus it is useful to examine BLS occupational projections for three industry groups: Household appliances (SIC 363); radio and TV and communication equipment (SIC 365,6); and a miscellaneous group that covers SIC 361, 2, 4, 7, and 9.

Less change in the composition of occupations is expected in the radio, TV, and communication equipment group than in the others. Employment of operatives, who account for more than one-third of the employees in this industry group, is expected to increase by about 12 percent between 1978 and 1990. However, fewer solderers will be needed. Professional and technical workers are expected to increase at a greater rate, while sales workers, service workers, and clerical workers are projected to decline.

Strong employment growth is expected in household appliances—numerically the smallest of the three industry groups. Sales workers is the only major occupational group in which a decline is expected. Professional and technical workers should increase, although at a lower rate than the other occupational groups.

Employment in all occupations except sales workers is expected to grow in the miscellaneous group. Large increases are expected for managers, clerical workers, craft workers, operatives, and laborers. Professional and technical workers and service workers should experience smaller employment increases.

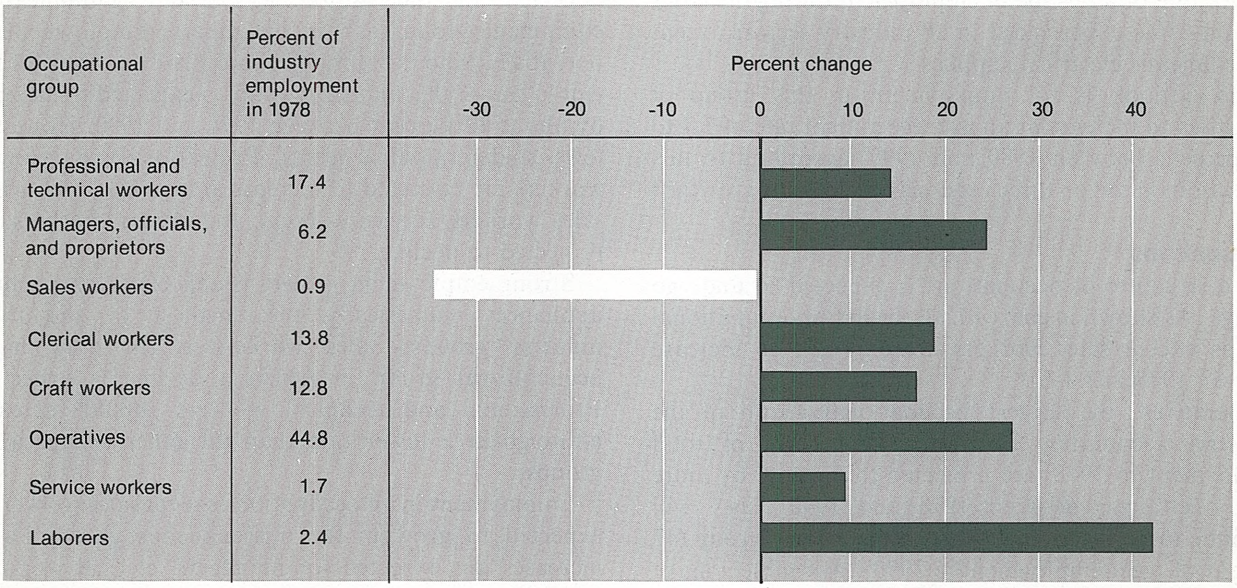
Adjustment of workers to technological change

Although new technology is not expected to result in major displacement, some collective bargaining contracts in the electrical and electronic equipment industry contain specific provisions concerning technological change. One such agreement requires that the company provide the union (the International Brotherhood of Electrical Workers) with at least 4 weeks' advance notice before installing numerical-control or computer-control equipment that will displace employees. The contract also requires that, where reasonable and practicable, the company will retrain displaced employees in order of seniority. The Communications Workers of America (CWA) and the International Brotherhood of Electrical Workers both have contracts with one large firm that contain a clause providing early retirement, under certain conditions, for workers displaced by technological change. A CWA contract recently negotiated with a large employer contains provisions for a joint labor-management Technological Change Committee to establish methods to avoid adverse impacts of technological change on the work force. The CWA contract also provides protection for employees downgraded because of technological change.

Where no specific provision relating to technological change is included in the contract, general provisions pertaining to seniority, retirement, training, supplemental unemployment benefits, and related topics can facilitate adjustment of employees to the requirements of new technology. About two-thirds of the industry's

[14] Projections for industry employment in 1990 are based on three alternative versions of economic growth for the overall economy, developed by BLS. The low-trend version is based on a view of the economy marked by a decline in the rate of expansion of the labor force, continued high inflation, moderate productivity gains, and modest increases in real output and employment. In the high-trend version I, the economy is buoyed by higher labor force growth, much lower unemployment rates, higher production, and greater improvements in prices and productivity. The high-trend version II is characterized by the high GNP growth of high-trend I, but assumes the same labor force as the low trend. Productivity gains are quite substantial in this alternative. On chart 9, level A is the low trend, level B is high-trend I, and level C is high-trend II. Greater detail on assumptions is available in the August 1981 issue of the *Monthly Labor Review.*

Chart 10. Projected changes in employment in electrical and electronic equipment by occupational group, 1978-90



Source: Bureau of Labor Statistics.

production workers are estimated to be unionized. The major unions, all AFL-CIO affiliates, are the International Brotherhood of Electrical Workers; the International Union of Electrical, Radio and Machine Workers; and the Communications Workers of America.

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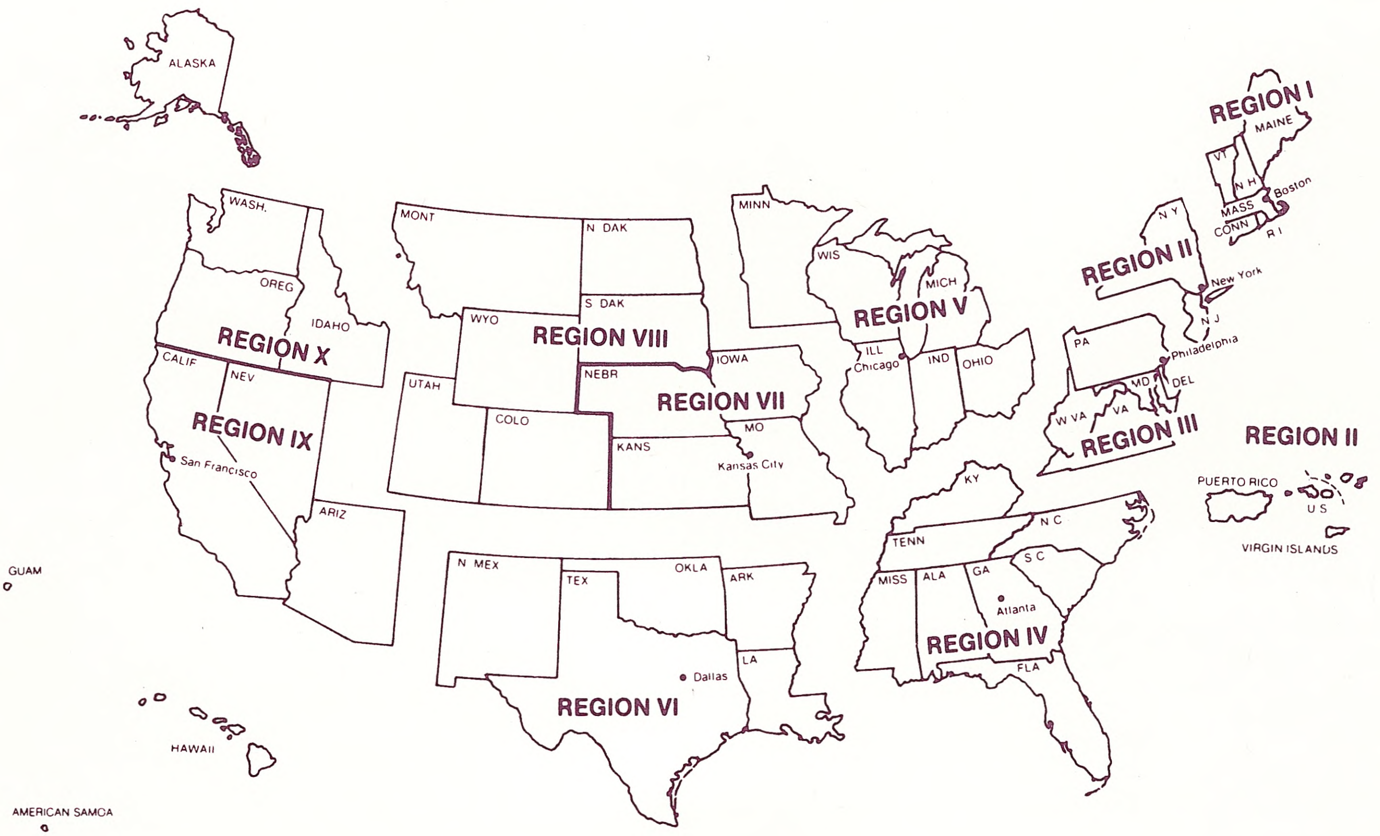

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