Technological Change and its Labor Impact in Five Energy Industries

Coal Mining/Oil and Gas Extraction
Petroleum Refining/Petroleum Pipeline Transportation
Electric and Gas Utilities

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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 five energy industries: Coal mining (SIC 111, 121); oil and gas extraction (SIC 13); petroleum refining (SIC 2911); petroleum pipeline transportation (SIC 4612, 4613); and electric and gas utilities (SIC 491, 492, 493).

This publication is the fourth of a series which updates and expands BLS Bulletin 1474, *Technological Trends in Major American Industries*, published in 1966, as a part of the Bureau's continuing research program on productivity and technological developments. 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: Coal mining, Mary L. Vickery; oil and gas extraction, Richard W. Riche; petroleum refining, Rose N. Zeisel and Michael D. Dymmel; petroleum pipeline transportation, Mary L. Vickery; and electric and gas utilities, Robert V. Critchlow.

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Contents

Introductory Note

The following discussions of technological change in five energy industries are accompanied by projections of employment levels and rates of change to 1985. These are "base" projections developed by the Bureau of Labor Statistics as part of a comprehensive set of projections for the economy as a whole.

In general, these base projections assume a moderately expanding labor force, a relatively slow decline in inflation and unemployment, and moderate government expenditure policies. The average annual rate of growth derived for real gross national product is 4.3 percent from 1977 to 1980 and 3.6 percent from 1980 to 1985 (compared with 3.5 percent from 1960 to 1977); the unemployment rate is 5.5 percent for 1980 and 4.7 percent for 1985. These are long-run projections of the U.S. economy and no attempt is made to forecast cyclical fluctuations during the projection period.

For further information about the projections and assumptions used in these studies, and for an alternative "high employment" version, see the articles in the December 1978 *Monthly Labor Review.*

Chapter 1. Coal Mining

Summary

Although improved integration of coal extraction, hauling, and cleaning processes, the development of special-purpose production equipment, and the use of new materials may assist the coal mining industry in opening and operating mines more efficiently, serious coal production and productivity problems are yet to be solved. The industry and the Federal Government, working both independently and jointly, have been developing and testing new coal mining technology during the 1970's in an effort to satisfy the requirements of legislation on coal mining health and safety, air and water pollution, and environmental protection of the land mined. Improvements in underground mining methods and modifications to surface mining equipment may increase output and productivity.

Technological change brings with it an increase in professional and technical staff. More trained engineers and specialized technicians are needed to plan and introduce advanced mine layout and production methods. Mining technologists, a new occupation, are working on such environmental problems as spoil bank placement and reclamation through refertilization and planting of grasses and trees. Maintenance mechanics increasingly require higher levels of skill to service new and more complex coal mining equipment. Finally, more operatives will be needed as production expands to meet increased demand for coal and as new technology is diffused more widely.

Output growth has been slowing and productivity has been declining during the 1970's in both underground and surface bituminous mining. However, the overall productivity decline has been moderated by the growth of surface mining relative to underground mining. Persistent and unresolved problems including wildcat strikes and other labor-management difficulties have contributed significantly to the industry's decreased productivity in the 1970's.

Other factors also are contributing to the productivity decline. In underground mining, productivity growth is inhibited because resources must be allocated to prevent accidents, black lung disease, and acid runoffs; in surface mining, productivity growth is also inhibited as resources must be allocated to meet land restoration standards and to present alternatives to proponents of exclusive agricultural use of mineral lands. Gains in productivity could be realized with future expansions in production. However, progress depends on many factors, including the availability of funds to open and equip new mines, adequate transportation facilities for marketing, a further increase in surface mining relative to underground mining, better labor-management relations, and the success of efforts for large-scale recruitment and training of workers.

Capital expenditures for the purchase of leases and for new plant and equipment to extract and process coal amounted to $1.3 billion in 1975, triple the 1970 level of capital spending and 60 percent greater than the 1974 level. Outlays rose further to $1.6 billion in 1976 and $2.0 billion in 1977. Major coal mining companies are expected to add capacity to fill new long-term delivery contracts with electric utilities. Also, 1975 Federal legislation guarantees loans to small operators for financing additional underground capacity. However, the rate of diffusion of technological advances in new mine construction and operation and their potential impact on 1985 tonnage and productivity are difficult to estimate.

Employment has been rising less rapidly for production workers than for other workers. Total employment was 217,500 in 1977; 82 percent were production workers compared to 88 percent in 1960. Gains have been larger in surface mining than in underground mining. Western surface mining expansion will require additional workers in such occupational groups as bulldozer, excavating, and grading machine operators and heavy equipment mechanics. Workers also will be needed in the West to mine deep seams recoverable only by underground extraction. Jobs for surface mining occupations will decline in Appalachia as surface deposits are depleted.

Technology in the 1970's

Advances in coal mining technology for opening and operating new mines and for modernizing old mines often involve, for professional, technical, and craft workers and operatives, changes in the layout of the work place, the equipment used, or the tasks performed. Engineers are making computer-simulation studies to compare the economic advantages of

Table 1. Major technology changes in coal mining

Technology	Description	Labor implications	Diffusion
More extensive use of computers	Computers are being used to design new mines and modify layouts, and to set up more efficient new mine operations and revise production and preparation methods at older mine complexes. A computer-controlled surveillance system is monitoring air quality and recommending corrective action.	Computerization of additional data for decisions concerning mine layouts and operations increases the workload for engineers and computer technicians. Computerized solutions affect the work of machine operators and heavy equipment mechanics in surface mines but have little impact on tasks of underground production crews.	For design and production decisions, computers are used principally by major companies which produced about 50 percent of total output in 1975.[1] Safety uses, originally limited to government sponsored research, are spreading to principal mines.
Room and pillar (including shortwall) and longwall systems for underground mining	Using two mining systems, room and pillar (including shortwall) and longwall, provides options for maximizing coal recovery at different sites and makes mining additional seams economically feasible.	Coal mining technologists are needed to solve technical and production problems involving, for example, facility planning, methods analysis, and quality control. Roof support labor is decreased with the longwall and modified longwall systems; crew training time also is reduced with the latter.	Longwall in retreat operations has been used to improve coal recovery at older mines, as has narrower continuous mining equipment introduced in recently opened mines. As a total system, longwall still accounts for only about 5 percent of total underground mining. Expansion is expected, to 10 percent within 5 years and 15-30 percent within 10 years.[2]
Continuous miners and slurry pipelines	Continuous miners are customized for the particular site, sometimes equipped with a roof bolter and automated. They frequently are joined (as are longwall shears) to a sectional belt to provide a more productive, safer continous haulage system. Transportation equipment is also designed and selected to improve safety and productivity.	Additional coal mining technologists are also needed as first-line and maintenance supervisors and as advisers for material and equipment procurement. Less servicing time is required for new machines. A slurry pipeline eliminates use of such underground transportation as driver-operated shuttle and rail cars.	62 percent of bituminous coal was mined by continuous mining machines in 1974, compared to 50 percent in 1969.[3] Hoists have been introduced recently but are limited to a few mines; one full-scale slurry system connecting underground mining machines to the preparation plant was expected to be in operation by mid-1978.
Improvements in surface mining	Innovations in designing slopes and hauling spoil material improve maintenance of topography; integration of stripping and haulage utilizes equipment with special features more efficiently.	As regulations become more rigorous, additional geologists, civil engineers, and environmentalists are required for planning operations. New requirements add to the workload of bulldozer, excavating, and grading machine operators and heavy equipment mechanics.	Recently enacted and proposed regulations cause operators to emphasize environmental preservation. Surface mining accounted for 3/5 of total production in 1977; an even larger proportion is likely in the near future.
Advances in preparation processes	Refuse is separated from run-of-mine coal which is washed with water or chemically bleached to reduce the number of operations. Screen heaters size coal more accurately and reduce dust.	In new facilities, engineers and technologists plan preparation plant operations which are programmed by computer specialists and monitored by technicians. Skill requirements of some workers tend to rise in line with increased quality specifications for usable coal.	Refinements in preparation processes are made to meet cleaner fuel burning standards through new capital investments. Also, clean air standards are upgrading cleaning requirements at old plants.
Improved maintenance	Downtime of equipment is being shortened by timely scheduling of servicing, by using longer lasting equipment with interchangeable parts, and by underground service stations.	The hourly output of craft workers and operatives may be improved through better equipment servicing scheduled by engineering technologists and performed by oilers, greasers, and other maintenance specialists.	Efficiency measures are expanding with the increase in engineering staffs. Scheduled programs for maintenance generally are restricted to larger mines.

[1] "Top 14 Coal-Producing Groups in 1975." *Coal Age*, Apr. 1976, p. 36.
[2] "Longwall Mining Promotes Itself," *Coal Week*, Nov. 1, 1976, p. 7.
[3] Based on Bureau of Mines data.

alternative underground mining methods and surface mining overburden removal techniques.

At some underground sites, gains in output are being achieved through the replacement of conventional equipment with continuous mining and longwall machines and the installation of haulage systems capable of moving more coal with less labor. Remote control of continuous mining and roof bolting operations and better lighting of the coal face are innovations designed to improve the productivity, safety, and mobility of underground workers. More extensive servicing of equipment by maintenance specialists is being undertaken at some mines in an effort to decrease productivity losses from equipment failures.

A slurry pipeline at one mine site has been demonstrated to require less labor per ton of coal moved from the mine face to the surface, and a planned slurry pipeline extension to the preparation plant should further benefit the mine's productivity. At a number of preparation plants, processing operations are fully automated and are being monitored by a single centrally located operator. Recently, however, as loadout operations have been speeded up to a very fast rate, a second operator has frequently been added to man the loadout station.

In surface mining, blasting techniques are being improved. Recently introduced hydraulic excavators are sometimes used to remove overburden; these are more efficient than conventional power shovels. The greater capacity of front-end loaders, shovels, and draglines also has decreased the workload of heavy equipment operators. Product quality is being upgraded by blending coal of varying physical and chemical properties to produce a more useful mix.

Computers

Computers are being used to raise output and advance safety in some recently opened mines. They are being used to design new mine sites, modify existing layouts, and revise production and preparation methods at older mine complexes. Computer-simulation techniques are being used by mining engineers in underground mining to maximize production by comparing the advantages of various types of mine entry and extraction methods, by civil engineers in surface mining to establish grades to determine tonnage cutoffs relative to stripping ratios, and to match capacity of the loading equipment with the capacity of haulage units. At preparation plants, mechanical and industrial engineers increasingly are using computers to check materials flow, maintain quality control, evaluate equipment, and relate changing costs to coal prices. The use of computer-generated data also helps line supervisors maximize production from the primary cleaning equipment. A computer-controlled surveillance system being tested in a demonstration mine, and expected to spread in use to principal mines, serves as a safety measure by monitoring methane, carbon monoxide, and hydrogen, air temperature, rate of temperature change, air velocity, and noise and smoke. The computer system analyzes the data, spots trends, and recommends corrective action. The location of seismic events within one test mine also is being printed out by a computer located at the surface, another new technique which enhances mine safety.

Although engineering and science technicians as well as engineers and computer specialists are using computers to handle a wider variety of tasks, computerization is not generally affecting the size or workload of underground production crews after the method of extraction and type of equipment have been selected. In surface mining, the application of computer-developed solutions to environmental problems adds to the workload of machine operators and heavy equipment mechanics. Computers are lessening the workload in scheduling equipment maintenance and truck loading.

Underground mining systems

Important changes are underway in underground mining. Since 1960, and especially since the passage in 1969 of legislation requiring coal mining health and safety standards, considerations for the layout and operation of new underground mines in the United States include the European longwall system as well as the room and pillar system (traditionally used in this country) and its recent variation, the shortwall system. Since each mine opened is unique, professional and technical staffs, including mining engineers, engineering and mining technicians, and accountants, develop comparative analyses of factors which affect efficiency and safety at the particular site. Managers use these analyses to determine the best mining method and equipment.

Safe, efficient underground mining requires minimal exposure of personnel and equipment to roof fall hazards as the equipment advances into the mine and, in longwall withdrawal, an orderly collapse of the overlying strata as rapidly as possible after the maximum quantity of coal has been removed. The room and pillar method, which includes shortwall, is universal in old mines and is used for about 95 percent of domestic underground production. Five different pieces of conventional equipment for coal drilling, cutting, roof bolting, loading, and hauling may be used in room and pillar. Only three pieces are needed when a continuous mining machine replaces the conventional equipment for drilling, cutting, and loading. When self-advancing hydraulic jacks are used as roof supports with a continuous mining machine, the system is referred to as "shortwall mining". Conventional equipment, which requires more labor per ton of output compared to continuous mining machine production, is still being used with room and pillar in many old mines. (Mining with conventional equipment declined from 46 percent of total production in 1969 to 33 percent in 1974.)

Longwall mining systems, generally used in Europe where coal seams are under a heavier depth of cover than in the United States, are expected to grow in importance compared with room and pillar systems. Through the mid–1970's, longwall installations were limited to about 80 systems in operation or on order in the United States, with longwall accounting for about 4 percent of total underground production. Longwall mining currently is restricted to seams 3 to 8 feet in height;[1] eventually seams 8 to 15 feet high may be longwalled. The first advancing longwall system in the United States, placed in operation in 1975 and designed to increase recovery and forestall rockfalls, reaches depths of 2,500 feet. Single-entry longwall may extract about 75 percent of a coal seam in a single operation and recover 90—95 percent of the minable seam. Tonnage mined by longwall amounted to about 5 percent of total production in 1976. Industry sources expect the longwall share to increase to 10 percent within 5 years and 15—30 percent within 10 years.

Mining height for shortwall depends on such factors as depth of support canopies, diameter of the cutting drum, required support resistance, and type and height of the transport system. Shuttle cars or continuous belt haulage are used to transport shortwall extraction. Engineers have proposed an innovative mining technique using a modified system of shortwall for advancing and longwall for retreating. This method improves efficiency compared to room and pillar by increasing recovery of the coal seam and providing continuous roof support to operators. However, health and safety regulations prevent its implementation at this time.

Mechanized longwall equipment consists of a standard complex comprising powered supports, a shearer loader or a plow, an armoured conveyor, and auxiliary devices. The cost of equipment generally limits longwall installations to mines of 1 million tons in annual capacity. The number of eastern longwall mines may double by 1981. Longwall with a single- or two-entry system is considered the preferable method by some coal experts for extraction of western deep coal reserves because of such advantages as minimal overall disturbance of virgin coal areas, elimination of chain pillars, crosscuts, and intersections, improvement of ventilation and roof support, and subsidence control.

[1] Joe Kuti, *Longwall vs. Shortwall Systems* (Pittsburgh, American Mining Congress, May 1975).

Underground face and haulage operations

The production methods and the equipment selected for extracting coal, i.e., working the face in underground mines, differ depending upon such factors as depth of overburden and thickness and height of the seam of coal. The haulage method is designed to integrate with the production method. The use of conventional equipment is now limited largely to special needs for room and pillar systems, The share of underground tonnage mined by conventional equipment is expected in the near term to continue to decline. A face crew using conventional equipment consists of 10 to 12 workers while a face crew using continuous equipment may consist of 8 to 10 workers.

Crew size in longwall operations may vary from 10 to 13 workers, depending on the width of the face; shortwall face crews may number 9 or fewer workers or as many as 12. Daily output per worker for longwall face crews usually exceeds that for shortwall crews.

Continuous mining machines are being used more extensively in room and pillar systems, Equipment standardized to comply with health and safety laws also is frequently customized to facilitate production at a particular site. The continuous miner shears coal from the mine face with a rotary cutting drum on which tungsten carbide steel bits are mounted. Cutter heads vary in width, and bits have different taper styles for different cutting conditions. Some recent models which include the latest safety features are designed to move on wide, heavy crawler treads to minimize ground pressure and are equipped with a cab or canopy and a centrifugal dust collector. Mechanics spend less time servicing the new machines since parts are more easily reached; however, as accessory options are expanded, workloads increase somewhat since parts inventories must be enlarged.

Continuous mining machine output at the start of the 1970's far exceeded the ability of the haulage system to handle it and of production planners to incorporate recently legislated safety requirements. At one plant, continuous miner output was 350 tons per shift, although its theoretical capacity was 4,000 tons per shift. Not only was the haulage system of shuttle cars, a belt, and a railway to the surface incapable of handling machine output, but it was necessary to shut the continuous miner down while the newly exposed roof area was bolted and newly dug footage was coated with limestone[2]

The introduction of remote controls may increase the productivity of a continuous miner by 10 to 15 percent.[3] Pillars of coal are more completely recovered in less time when the operator no longer rides in the machine but instead operates a control unit linked to the machine either by cable or radio from a location sometimes 100 feet behind the coal face.

As the continuous miner advances, roof bolting is necessary. Some models are now equipped with an onboard roof bolter so that the operator can install bolts while within the protective cab. Also, a bolter-conveyor remote control mining system has been developed and tested. Bolter operators continually bolt the roof as coal, mined by remote control, is passed through the bolter conveyor to the shuttle car. This advance speeds the installation of roof bolts, lessens labor requirements, and raises productivity by reducing machine downtime.

Mine safety is improved by the introduction of remote controls which allow two operators to leave the face area where most injuries occur. Since the continuous miner operator does not ride the machine, he is no longer in danger of being hit by moving equipment in the haulage system. Also, a mobile bridge operator working no closer to the face than 70 feet replaces a shuttle car operator usually situated 35 feet from the working face. The use of remotely controlled mining machines which take the miner off the machine (during either mine development or production) changes the job content for operators and helpers on continuous mining, longwall, and roof bolter machines.

In longwall mining, gamma rays are sometimes used to measure the thickness of the coal and signal the automatic steering equipment. This improvement

[2] Edmund Faltermayer, "It's Back to the Pits for Coal's New Future," *Fortune,* June 1974, p. 248.

[3] "New Techniques," *Coal Age,* February 1975, p. 118.

Operator controlling longwall planer

may eliminate cutting into rock and add extra inches of cut to a typical seam. As a longwall shearing or plowing installation advances along a face, a large roof beam with a caving shield and a shoulder-to-shoulder positioning feature protects the area. Bad tops and faulty zones are controlled more effectively, no timbering is required, and the complete roof is covered. Labor savings are realized since both production tasks and machine downtime are less than in traditional room and pillar mining.

A further development, reported by the Bureau of Mines, is an automated longwall system, equipped with minicomputers and electric sensors and manned by a face crew of six, which can mine coal more safely and productively than is possible using existing longwall techniques.

Underground haulage systems, designed to match the capacity of cutting machines, are now carrying coal more efficiently in a limited number of mines. Through the use of more durable extensible belts, conveyor systems require less maintenance and are extended even around corners as cutting operations advance. Also, a section foreman or face crew member, using a laser gun, is able to mount and align a belt conveyor without the engineering assistance previously required.

In some deep shaft mines, men, coal, and materials are being moved by fully automated hoists. Also, at one mine, coal is being transported underground by pipeline. A fully integrated hydraulic transportation system under construction will move coal directly from mining machines through a slurry pipeline 2.4 miles to a preparation plant. The immediate mixing of the coal with water and its continuous containment in the pipeline suppress coal dust and consequently reduce the danger of mine fires and explosions. Drivers for shuttle or railcars or utility helpers for loading are then no longer needed and the danger of accidents from moving equipment is diminished.[4]

Surface mining

Advances have been made in designing safer and more efficient surface mines through greater understanding of soil mechanics, particularly rock mechanics. Through the design change of steepening the slopes of open pits or spoil piles while at the same time maintaining their stability, rehandling of waste is reduced. Material is moved as excavated in a haulback system by front-end loaders, bulldozers, and trucks with high mobility.

Depending upon the topography, the material overlaying a coal seam is removed and the seam mined using such equipment as scrapers, crawler tractors, bulldozers, loaders, augers, and continuous miners. Machine capacity required for removing overburden is usually greater than for mining coal. Specialized stripping and underground equipment is available from manufacturers. Machines include a continuous cycling hydraulic excavator equipped with a long-arm option for an expanded digging range and a short-arm option for working extra-hard material; a walking dragline of modular design for fast jobsite erection and disassembly; loaders with 4-wheel electric drive, automatic transmission, and 25-bucket oscillation for rough terrain; tractors with bottom-dump trailer coal haulers which travel at speeds up to 40 miles per hour; and highway rear-dump trucks which vary in size from 35 tons to as much as 350 tons. Also available is a driverless truck operated electronically through an automatic master control unit which programs vehicle steering, direction control, braking, and speed.

The development of large-capacity earthmoving machinery has made possible a new method of mining mountaintop coal seams often considered inaccessible in the past and of recontouring the land. At one site, tractor loaders scoop up overburden with 24-cubic yard shovels, increased in capacity in the past 5 years from 10 cubic yards. End-dump haulers with more than a 100-ton capacity transfer the overburden to adjacent bottoms for fill in selected construction or agricultural sites. The coal is trucked to a fast-loading tipple for shipment by unit trains to powerplants.

At another surface mine servicing a mine-mouth powerplant, a recently installed haulage system follows a relay coal-handling principle which reduces labor requirements for trucking. From the pit, coal is short-hauled by bottom-dump trucks to a loading station or stockpile located at a railroad spur where front-end loaders reload it into railroad cars. As mining operations move to longer distances from the powerplant, the rail transportation network is extended.

A 273-mile slurry pipeline has been delivering coal through mountainous terrain from an Arizona mine to a Nevada electric generating plant since 1970. Additional pipelines are planned west of the Mississippi. Corporations which plan to build the longest pipeline, 1,030 miles from Wyoming to Arkansas, are acquiring legislative grants of eminent domain for the necessary right-of-way and expect to begin construction in 1980.

Preparation processes

Preparation plants equipped with technologically advanced processing equipment and materials are using innovative techniques to recover coal of the

[4] "Consol Installs Slurry Haul System," *Coal Age*, July 1977, p. 17.

desired quality for the utility, metallurgical, and general markets and to dispose of the refuse. Both the increased price of coal and existing and expected State and Federal government pollution control regulations are giving impetus to the industry's effort to produce a cleaner fuel more efficiently. As quality specifications for usable coal have increased, the skill level and diversity of the engineering, technical, and craft labor force for its preparation also have increased.

Tasks required to prepare coal for market after its transfer from the mine include breaking, cleaning, sizing, washing, drying, loading, and, finally, disposing of wastes. Technologically advanced preparation plants are fully automated. An operator located at a control station controls all handling and processing equipment from the raw coal-receiving hopper to the loadout station. Some of the workload of operatives and laborers is eliminated. Because of the extremely fast rate of loadout now in practice, a second operator frequently mans the loadout station. Inside the plant, the operator scans a panel and is able to determine if a unit is ready to run, is running, or is down due to mechanical or electrical failure. An audio system enables the operator to communicate with the plant rover and an on-shift repairer. However, despite the high level of automation, more efficient methods to maximize recovery are being sought by mechanical, chemical, industrial, and environmental engineers.

Preparation plants process coal to meet standards of size and burning quality. Changes in techniques and in design of equipment are improving productivity and product quality. A newly introduced cleaning technique called the Batac jig system stratifies particles according to their specific gravity. Cyclones are used for fine coal, and superfine coal is cleaned by froth flotation. As new methods increase usable product, output per employee is increased.

A new method which uses oxygen to desulfur coal has been demonstrated to remove nearly 100 percent of pyritic sulfur and in some instances up to 30 percent of organic sulfur. These results compare to best conventional preparation plant removal of up to 50–60 percent of pyritic sulfur for selected eastern coals, with a carbon loss of about 10 percent.[5] Also, a new technique using microwave radiation is being tested for sulfur removal.

Advances also have been made in pollution control. New types of screens being introduced resist wear under abrasive conditions and are quiet. Improved vibrating screens equipped with heated screencloth size the coal more accurately and cause less dust. A thermal dryer which transmits heat and evaporates water from fine coal with steel balls rather than hot air reduces air pollution at the preparation plant. Efforts to comply with existing and anticipated State and Federal regulations regarding the management and disposal of refuse have led to the trial of more advanced technologies for handling refuse slurry such as mechanical, thermal, and in-place dewatering and chemical solidification.

Refuse bulk from coal preparation is roughly equivalent to 30 percent of the raw coal washed. Although most of the 1,500 to 2,000 gallons of water required to process 1 ton of coal is recirculated, some water is discharged with suspended solids, i.e., clay or fine coal, and dissolved solids.[6] Coarse refuse sometimes serves as filler material in land reclamation, an additional process which increases the workload of some surface equipment operators.

Service activities

Efforts are being made to reduce downtime through improved methods and timing for servicing equipment. (Servicing requirements have increased partly as a result of new health and safety regulations.) New mining equipment is built of longer lasting materials and is designed to lessen maintenance labor requirements. Replaceable major components are enabling mechanics to repair crawlers more rapidly under field conditions. Interchangeable parts are also shortening downtime and extending service life of such equipment as rotary and percussion drilling rigs, portable and stationary air compressors, and high pressure slurry pumps. Automatic fast-fueling systems are being used increasingly to refuel off-highway equipment at surface mines, and tires are being changed more speedily with more powerful weightlifting devices.

Downtime for surface shovels and underground mining machines has been reduced through the use of more reliable and easier-to-maintain cables. In underground mining, damaged trailing cables are being replaced quickly without splicing through the use of coupling devices and a portable cold splice system. At surface mines, the safety and continuity of electrical transmission to draglines are being improved by maintenance electricians who mount cable couplers on portable skids.

In some mines, an underground bit-sharpening station insures a continuous supply of cutting bits. Additionally, preventive maintenance programs help avert equipment failure and unscheduled rebuilding by the early replacement of worn parts, including shovel and dragline teeth, bulldozer cutting edges, and scraper blades. Also, the number of machines to

[5] "New Techniques," *Coal Age*, February 1975, p. 126.

[6] *1974 Task Force Report, Coal Control Technology* (Federal Power Commission, 1974).

be maintained is reduced as mines convert from conventional to continuous mining machines. Maintenance labor requirements may be further lessened as refinements are made in equipment design.

Health and safety conditions in mines are being improved by new materials and methods. Maintenance workers are spraying the cutting tools of a boring miner directly with water to reduce dust concentration on coal face areas. The introduction of additional maintenance tasks to protect the health and safety of workers tends to lengthen the production process and may, to some extent, affect productivity adversely.

Output and Productivity Outlook

Output

Output of bituminous and anthracite coal and lignite grew at an average annual rate of 2.0 percent from 1960 through 1977. The yearly rate dropped to 1.5 percent during 1967–77 from 3.8 percent for the 1960-67 period.[7] Bituminous coal and lignite production has climbed steadily from somewhat less than 96 percent of total tonnage mined in 1960 to about 99 percent in 1977; the small remainder is anthracite.

Shifts also have occurred in the distribution of bituminous production between surface and underground mines. The share of total bituminous tonnage produced in surface mines (including strip and strip auger) rose from 31 percent in 1960 to 61 percent in 1970. The 1960–77 average annual growth rate of bituminous production was 2.5 percent. While output of bituminous coal from surface mines grew at a substantial 7.0-percent annual rate during 1960–76, underground output of bituminous coal declined 0.1 percent.[8]

In 1976, roughly 9 percent of U.S. bituminous coal consumption was accounted for by exports while 91 percent was used domestically; in 1960, exports amounted to 10 percent. (Because of stockpiling and inventory withdrawals there is some difference annually between production and consumption tonnage.) Between 1960 and 1976 the relative importance of different domestic users of bituminous coal shifted; consumption by electric utilities rose from 46 to 74 percent while consumption by oven coke plants fell from 21 to 14 percent, by steel and rolling mills from 2 to less than 1 percent, and by other manufacturing and mining industries from 23 to 11 percent. Although the tonnage of bituminous coal consumed domestically increased about 56 percent between 1960 and 1976 and its consumption by electric utilities grew about 155 percent, coal increased from 23 percent of gross U.S. energy input in 1960 to 26 percent in 1976 and is expected to rise to 29 percent in 1979, according to the Department of Energy (DOE). In 1985, DOE estimates that annual coal production will amount to between 994 million and 1,065 million tons.

The United States has reserves to meet projected higher levels of production. Recoverable coal reserves on January 1, 1974, totaled 434 billion tons; slightly more than one-half was located west of the Mississippi River. Using existing technologies, one-third can be mined from the surface; the remaining two-thirds require more labor-intensive underground extraction, according to a Bureau of Mines estimate.

At this time, however, many factors are delaying an increase in coal output. In addition to labor-management problems and an inadequate supply of trained labor, considerations retarding the opening of new mines and expansion of existing properties include Federal and local environmental restraints on surface mining, local controls on water usage for coal transportation, enforcement of air pollution standards, expanded mine health and safety protection requirements, State severance taxes on coal shipped outside the State, and uncertainty regarding the prices of competitive fuels and the availability of investment capital.

Productivity

Output per production worker hour in coal mining declined at an annual average rate of 0.1 percent between 1960 and 1977. During 1967–77, output per production worker hour decreased at a 3.8-percent annual rate in contrast to a 5.8-percent annual rate of increase during 1960–67 (chart 1).

The 1967–77 decline in productivity is a result of the sizable increase of 5.6 percent in production worker hours compared to a substantially lower gain of 1.5 percent in output. Output per nonproduction worker declined at an annual rate of 1.1 percent during 1960–77 and at a 5.9-percent rate during 1967–77.

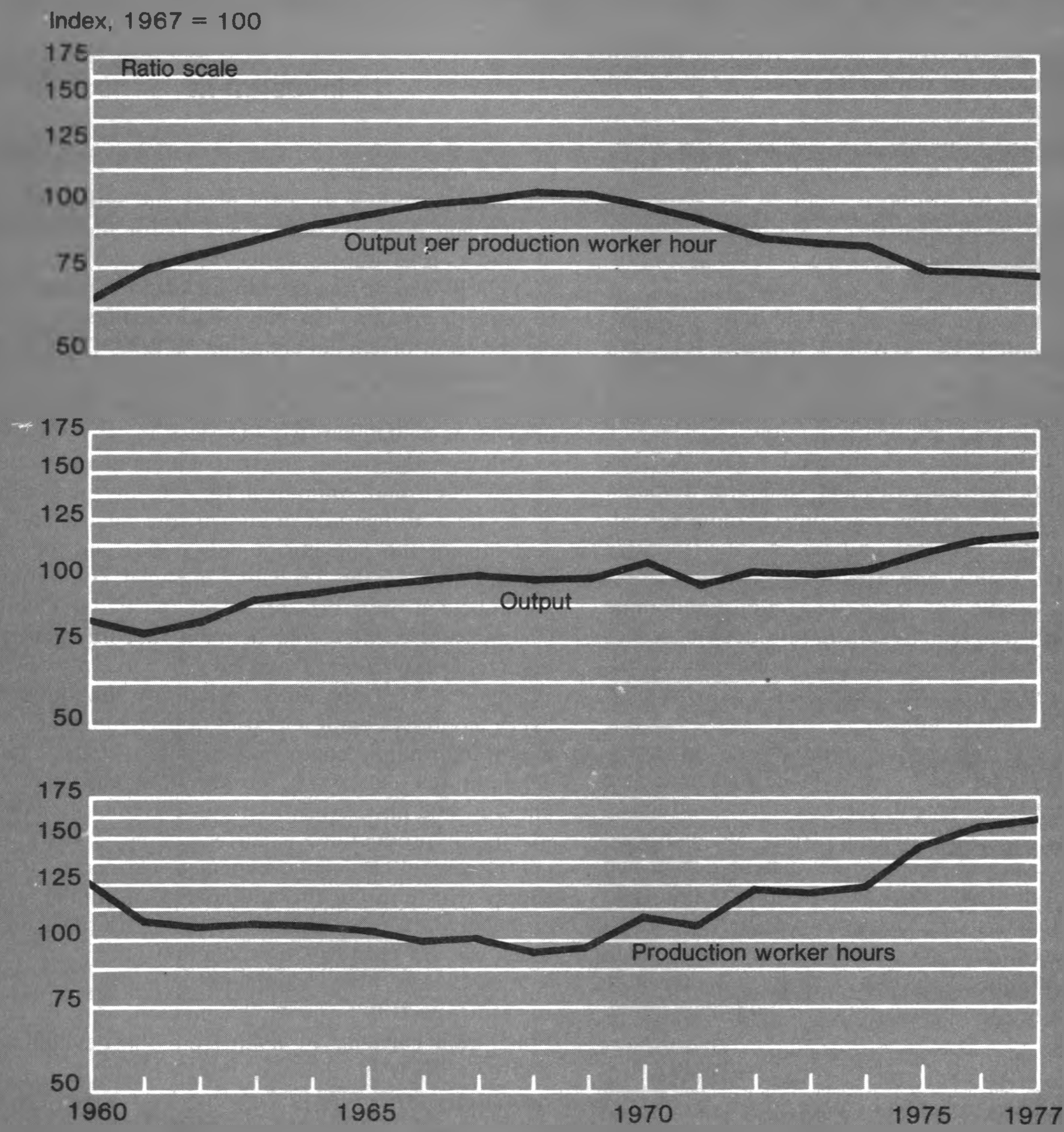
From 1960 through 1970, daily output of workers in surface bituminous mines was consistently more than double the daily output of workers in underground bituminous mines, according to Bureau of Mines data. During 1971–76, despite a decline in surface mining productivity, the daily output of surface bituminous workers amounted to about three times the daily tonnage mined by underground workers. Preliminary DOE data for 1977 show a 2-percent increase over 1976 in surface mining produc-

[7] Based on Bureau of Mines data.

[8] Surface mining tonnage west of the Mississippi will probably continue to rise. In contrast, in Appalachia, an increased proportion of underground production is likely as surface resources east of the Mississippi are further depleted, coal desulfurization methods are improved, and additional eastern utilities convert to burning coal.

Chart 1

Output per production worker hour and related data, coal mining, 1960-77[1]



[1] Data for 1977 are preliminary.

Source: Bureau of Labor Statistics.

tivity and a decline of 4 percent in underground productivity. Coal mining productivity, consequently, has benefited by the continuous rise in importance of surface bituminous production relative to total bituminous output, a rise from 31 percent of total output in 1960 to 44 percent in 1970 to 61 percent in 1977.[9]

Recent declines in productivity reflect, in part, numerous work stoppages, interruptions or slowdowns in production stemming from more stringent safety and health regulations, and a shortage of trained workers. Labor unrest, evident during the mid-1970's in a series of wildcat strikes in eastern coal fields, culminated during the winter of 1977–78 in the longest coal mining strike in history.

Also, workers' attitudes have changed. The median age of working members of the United Mine Workers (UMW) has dropped from 46 in 1966 to 34 in 1974 and to about 30 in 1977. The average miner is younger, better educated, more mobile, and more independent than in the past.

Productivity also is affected by additions to capacity. In anticipation of increased demand for coal, more new mines have been opened; these have not yet reached peak production. Also, more old mines of marginal efficiency are operating now.

The 1969 Coal Mining Health and Safety Act has required additional tasks to meet standards for dust suppression, mine lighting, gas control, mine subsidence, and surface control and treatment. The 1977 Federal Mine Safety and Health Amendments Act expands provisions for mine inspections and mine job and safety training. Resulting productivity losses from the added workload may be counterbalanced, in part, by fewer accidents and improved workmanship of better trained miners.

Although over time productivity will be adversely affected when reserves are so reduced that mine size and depth are less efficient, the near-term productivity performance could benefit from an increased demand for coal, advances in equipment design and automation, improved linkage of production and haulage systems, a more experienced, better educated work force, and more constructive labor-management relations. A further near-term increase in the proportion of surface mining could also immediately benefit coal mining productivity. Table 2 shows, by State, the percentage of production mined at the surface in 1975 and the average daily change in tonnage per miner from 1969 to 1975. Productivity gains were sizable in three western States engaged almost exclusively in surface mining, while in the eastern United States, where surface mining is more limited, productivity consistently declined. The impact of the 1977 Federal Surface Mining Act may affect productivity in States whose surface mining regulations have been less strict than the new Federal requirements.

[9] Compared to underground, open-pit (surface) mining can recover a higher percentage of a coal seam, is an economical method of recovering surface deposits, and eliminates accidental roof cave-ins. Western strip-mined coal, however, is a low energy subbituminous coal with only about 75 percent the British thermal unit (Btu) value of eastern or midwestern coal. Despite the poorer productivity in deep mines, the cost difference per Btu between strip-mined western coal and deep-mined eastern seaboard coal is comparatively narrow because of the lower energy quality of western coal and its higher transportation cost for shipment by unit train and transshipment by barge.

Investment

Capital expenditures

Capital spending for new plant and equipment to extract and process coal, as well as for the purchase of leases, rose during 1970–75, with the exception of 1973.[10] The 1975 expenditure of $1.3 billion was 60 percent greater than the 1974 investment and triple the level of capital spending in 1970. (These current-dollar figures do not take into account price rises; the increase in capital outlays since 1970 measured in constant dollars would be less.)

Although the dollar amount of capital investment in new plant and equipment for opening new mines in the next 10 years is unknown, the high degree of certainty of the opening of new mines and the substantial size of the probable financial commitment are indicated by a 1977 report of the Federal Power Commission. Utility coal demand, according to the report, is expected to expand 90 percent between 1976 and 1985. Only after closing firm long-term delivery contracts with electric utility companies do major coal mining companies usually risk the sizable expenditures necessary to add new capacity. An underground mine typically requires about 4 years to reach full production, a surface mine 2 years. By mid-October 1976, coal companies had contracted to supply two-thirds of the anticipated additional utility coal demand of 243 million tons, one-third again as much as their entire 1976 production.

An industry survey completed in mid-January 1978 by McGraw-Hill projects 996 million tons of additional coal capacity by 1986 from the development and expansion of 169 new mines planned to begin operations during the 1977–86 period. Added capacity, according to the survey, will be 28.5 percent underground and 71.5 percent surface. West Virginia is expected to account for 18 percent of new underground capacity, Kentucky 18 percent, Utah 16 percent, Illinois 12 percent, and Colorado 11 percent.

[10] *National Energy Outlook—1976* (Federal Energy Administration, Feb. 1976), p. 296.

Table 2. Comparison of coal mining productivity in western and eastern States, 1969 and 1975

State	Average daily tonnage per miner			Percentage of total 1975 production from surface mines
	1969	1975	Percent change, 1969-75	
West:				
Montana	87.64	127.25	39.6	100.0
North Dakota ...	76.62	86.86	10.2	100.0
Wyoming	39.25	61.78	22.5	98.2
East:				
Illinois	28.99	17.61	-11.4	46.5
Kentucky	23.68	16.99	-6.7	36.0
Ohio	25.87	15.13	-10.7	53.3
West Virginia ...	15.96	9.15	-6.8	15.4

SOURCE: U.S. Department of the Interior, Bureau of Mines.

Of new surface mining capacity, 41 percent is reported to be located in Wyoming, 13 percent in Montana, and 10 percent each in Texas and New Mexico.

Research and development programs

The 1977 law establishing the Department of Energy (DOE) transferred to the new department research and development relating to increased efficiency in the production technology of solid fuel minerals. The law also provided that research relating to mine health and safety and to environmental and leasing consequences of solid fuel mining remain in the Department of Interior.

Prior to the creation of DOE, the coal utilization program directed by the Energy Research and Development Administration (ERDA) sponsored important research projects concerned with correcting the limitations of coal as a product and expanding its usefulness as a clean energy source. Efforts included projects for more effectively removing sulfur from coal, developing a stack cleaning technology which meets pollution standards, converting coal into synthetic gaseous and liquid fuels, and gasifying coal underground for power generation.

The Bureau of Mines, a second Federal agency concerned with coal-related research, supports a cooperative research program with the coal mining industry to improve safety and, traditionally, productivity, through fully funded or cost-sharing contracts. R&D projects have studied such dangerous conditions as fire and explosions, methane, respirable dust, noise, and postdisaster survival and rescue. Recent projects include the testing of longwall shield supports and of a self-powered boring system for driving mine entries. The industry also does independent research on improving productivity and safety.

The 1978 fiscal year DOE budget for coal research and technology development allowed an estimated outlay of $483 million; the department was reported to be seeking over $500 million for fiscal 1979. The Bureau of Mines expended about one-fifth of its $35 million budget in fiscal 1977 on health-related areas and about four-fifths on safety problems. Roughly one-third of the budget supported projects at the Bureau's research centers while the remainder financed outside contracts and grants. Technological advances in equipment, materials, and methods developed through these and other R&D efforts undoubtedly will have an impact on productivity, staffing, and job requirements in coal mining.

Employment and Occupational Trends

Employment

Employment in coal mining dropped from 186,100 in 1960 to 132,300 in 1968, a low for the decade, before rising steadily to a high of 217,500 in 1977. The average annual rate of increase for the 1960–77 period was 1.5 percent. During 1960–67, employment fell by an average of 3.6 percent annually, but rose by 5.5 percent a year, on average, during 1967–77. The rise in production worker employment was somewhat slower—1.2 percent annually for 1960–77—reflecting an average annual drop of 3.8 percent for 1960–67 and an average annual rise of 5.1 percent from 1967 through 1977. The share of total employment accounted for by production workers declined from 88 percent in 1960 to 85 percent in 1976 and 82 percent in 1977. The number of production workers declined by 3,500 (1.9 percent) between 1976 and 1977; nonproduction workers increased by 6,700 (21.3 percent) over the period (chart 2).

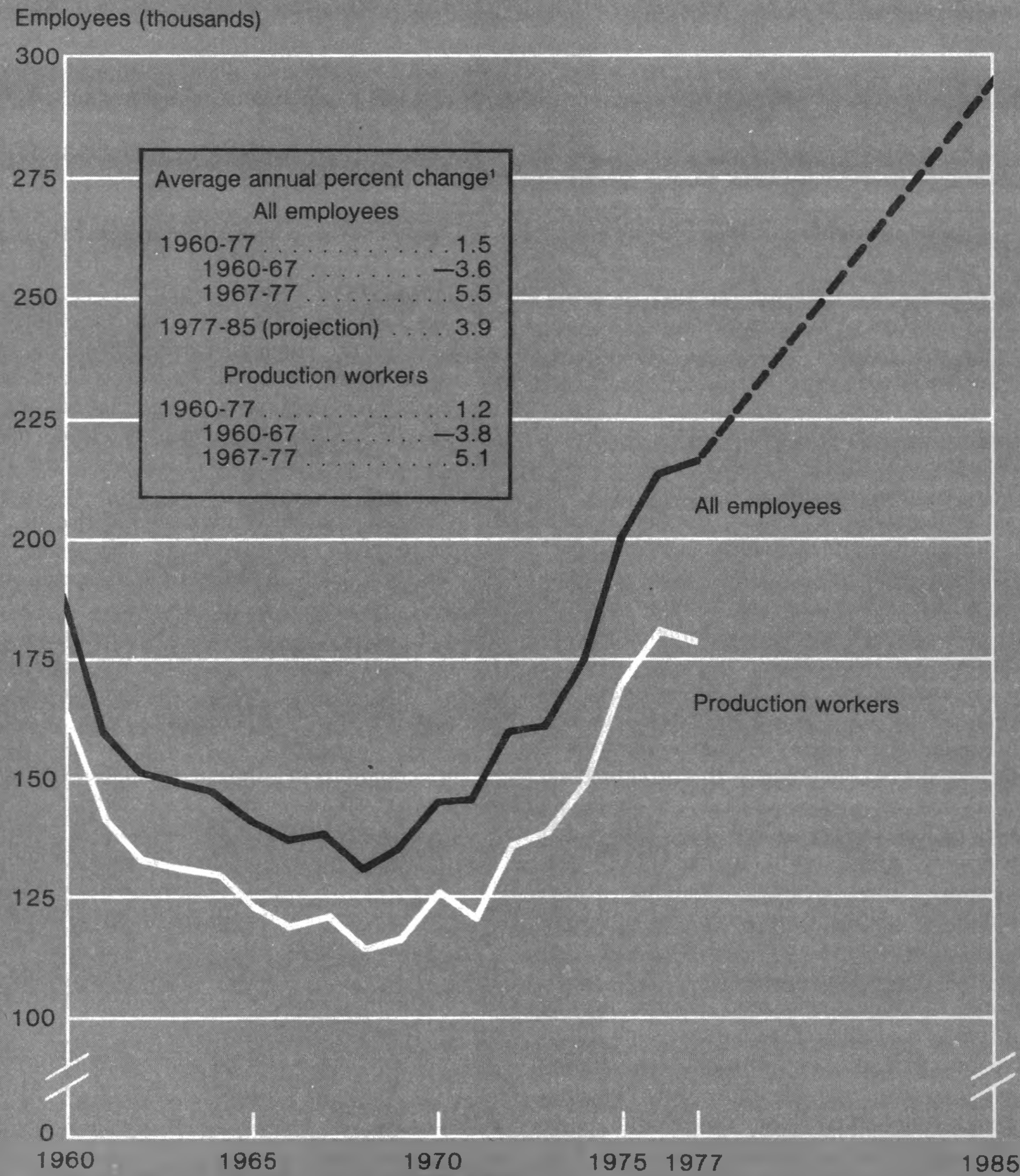
The employment gain in bituminous and lignite mining, which accounted for about 91 percent of total industry employment in 1960 and over 98 percent in 1977, was more rapid, an average annual rate of 2.0 percent for 1960–77, with a 3.0-percent annual rate of decline occurring during 1960–67 and a 5.9-percent annual rate of increase from 1967 through 1977. The average annual rate of job growth for production workers, 1.7 percent in 1960–77, was slower than for total employment.

Employment has shifted between underground and surface mines, according to Bureau of Mines and Department of Energy data. Surface mining has grown in importance—from 16 percent of total mining employment in 1960 to 29 percent in 1976.

Women workers in the industry totaled only 3,000 in 1960, 2,000 in 1968, 4,700 in 1976, and 5,400 in 1977, or roughly 2 percent of total employment in each year. Openings for women in the past have usually been limited to secretarial, typing, and cleri-

Chart 2

Employment in coal mining, 1960-77, and projection for 1977-85

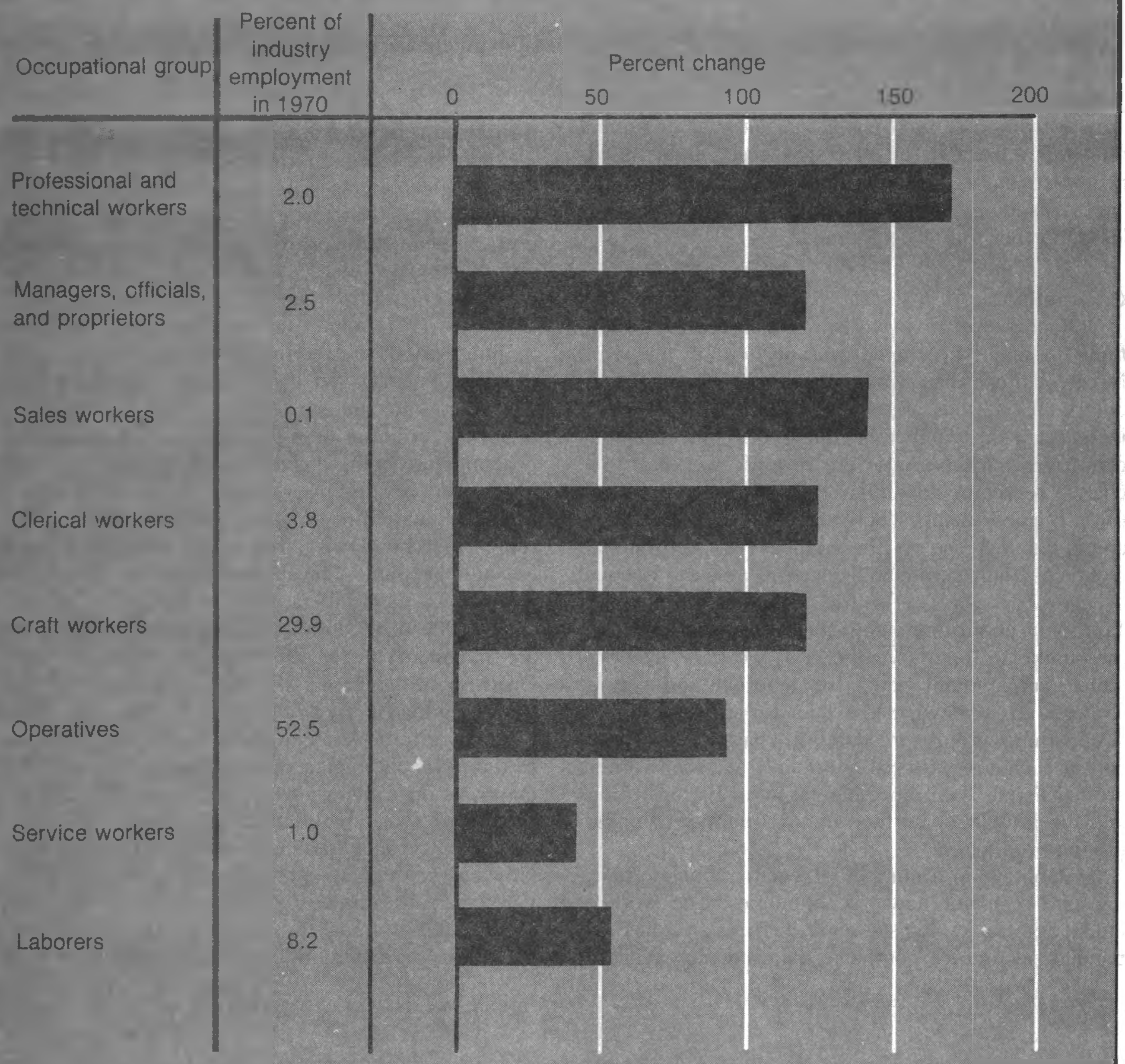


[1] Least squares trend method for historical data; compound interest method for projection.

Source: Bureau of Labor Statistics.

Chart 3

Projected changes in employment in coal mining, by occupational group, 1970-85[1]



[1] Based on the latest occupational data for 1985 adjusted for revisions of the 1985 employment projections.

Source: Bureau of Labor Statistics.

cal work. Men usually perform not only the tasks required for extraction, transportation, and preparation of coal, but also hold managerial and administrative posts and engineering and technical jobs. Recently, however, there has been limited entry of women into production and engineering and technical jobs. Underground, women are employed in such positions as inside laborer, roof bolter, machine repairer trainee, and shuttle car operator and in work related to mine inspection and safety.

The outlook for coal mining employment (see introductory note for assumptions) is for continuing growth from 1977 through 1985 at an average annual rate of 3.9 percent for all employees. Output is expected to increase significantly during the next decade, especially in surface mining, which requires less labor per ton of coal mined.

Occupations

Craft and operative workers are expected to continue to make up the largest portion of the work force, or more than 4 out of every 5 jobs in the industry. Indications are that through 1985 the largest increase in the number of employees will be among operatives, closely followed by craft workers. (See chart 3 for percentage distribution of all groups and for projected changes between 1970 and 1985.) The combined increase in the number of professional, technical, managerial, and clerical workers is equal to about 11 percent of the total net employment gain, only about one-eighth the projected increase in the number of operative and craft workers. The projected employment gains for laborers and service workers are somewhat less than for the other major occupational groups presented in chart 3. Such occupational changes for laborers and service workers are consistent with more capital-intensive operations and the growth of surface mining relative to underground production.

Job content in a number of occupations is changing as a result of newer technologies. The work of engineers, technologists, and technicians has expanded as more complex data, made available through computers, can be used for decisions concerning mine openings and operations. Greater specialization within the engineering field is required as more stringent regulations for health and safety, pollution control, and environmental protection are enforced. A new occupation, the environmentalist, has been added to participate in planning and carrying out site restoration. Also, more complex mining equipment requires a higher level of skill on the part of maintenance mechanics.

Adjustment of workers to technological change

Some displacement of workers resulting from technological changes in coal mining may be absorbed in the near term through attrition, as a disproportionate number of workers are approaching retirement age. Also, supplying the anticipated increased demand for coal will require more workers.

Under 1977 mine safety legislation, minimum training periods are required for inexperienced workers. The Federal and various State governments as well as private industry have appropriated funds or facilities for labor training, and mining technology programs are being included in college curricula and in schools operated by large mining companies.

The United Mine Workers of America (UMWA) represents about two-thirds of all coal mining workers and accounts for about 50 percent of all coal produced. In Montana, Wyoming, and Colorado, some 1,000 surface-mine heavy equipment operators are members of the International Brotherhood of Operating Engineers (AFL–CIO). The 3-year contract negotiated by UMWA with the Bituminous Coal Operators' Association in March 1978 recognizes the potential impact of technological change in its emphasis on training to facilitate adjustment to new or altered work requirements. Included are agreements concerning training preference for senior employees, protection and training for inexperienced workers, paid training for maintenance jobs, company-financed training for safety commissioners, and mandatory safety training for all employees.

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Chapter 2. Oil and Gas Extraction

Summary

Major technological changes in oil and gas extraction (SIC 13) are underway throughout the industry, particularly in the development of oil and gas production offshore and in enhanced recovery from existing fields. Offshore drilling will continue to require additional support personnel compared to onshore operations, and the trend toward more sophisticated equipment for exploration, rig monitoring, and other operations will contribute to the projected increase by 1985 in professional and technical employees. Technology and methods in seismic exploration also are being improved. Research to develop synthetic fuels, including oil from shale, is being accelerated, but synthetic fuels are not expected to contribute significantly to U.S. energy sources by 1985.

Production of both crude petroleum and natural gas has slowed significantly, with exploratory drilling for oil and gas during the 1960–77 period well below the level of activity during the 1950's. Discovery of oil and gas has continued to fall behind consumption. The extent to which the upsurge in drilling that began in 1974 will continue is uncertain and will depend on factors such as the price of imported and domestic crude oil, national energy policies, environmental concerns, and the capability and incentive for petroleum companies to generate capital to locate and develop new sources of oil and gas. The national goal to reduce dependence on imported petroleum will require ever-increasing expenditures as the search for oil extends offshore and into the Arctic and other areas where exploration and development costs are high. Total industry capital requirements during 1978 through 1984 may reach as high as $145 billion (in 1978 dollars), according to the U.S. Department of Energy.

Employment in oil and gas extraction increased at an annual rate of 0.8 percent during 1960–77 and is projected to increase by an annual rate of 1.7 percent during 1977–85. (See introductory note for the basic assumptions underlying these projections.) Employment of engineers, geologists, and other professional and technical workers is projected to increase between 1970 and 1985; the number of drill-crew and related production workers is also expected to be higher. Among the major occupational groups, only sales workers are expected to decline by 1985.

Technology in the 1970's

Technological changes are underway in a wide range of activities associated with oil and gas extraction. (See table 3 for a brief description of major innovations.) Some of the most significant changes are taking place in the production of oil and gas offshore. Extraction facilities are being expanded with technological improvements in drill ships, drilling and production platforms, and subsea production systems extending exploration for and production of oil and gas into deeper waters. Major efforts also are being made to recover additional oil from existing wells through enhanced recovery methods. In drilling operations, rig monitoring systems using onsite computers are being introduced more widely, and improvements are continuing in drilling fluids, drill pipe, drill bits, and related equipment. In exploration, new seismic technology and methods of computer data analysis are being applied. Efforts to achieve commercial production of oil from oil shale are expected to continue but production will still be negligible by 1985.

Although these changes are not expected to bring about extensive modifications in the size and structure of exploration, drilling, and well operation and maintenance crews, the industry increasingly will require better trained workers with a knowledge of advanced production technology.

Offshore operations

Offshore production of oil and gas has been increasing for many years. Annual production of crude petroleum from offshore operations (U.S. Bureau of Mines and U.S. Geological Survey data) rose from 116.8 million barrels in 1960 to 461.9 million barrels in 1976—a gain of nearly 300 percent. Crude oil production from offshore facilities rose from 4.5 percent of total production in 1960 to 15.5 percent of the total in 1976. Crude oil production in waters off Louisiana accounts for about two-thirds of total U.S. offshore production. Offshore gas production also increased from 1960 to 1976, rising from 3.4 percent to 21.5 percent of total gas production.

Major improvements in offshore exploration and development technology have contributed greatly to the expansion of production. Drill ships and drilling and production platforms with better stability in

Table 3. Major technology changes in oil and gas extraction

Technology	Description	Labor implications	Diffusion
Offshore production	Offshore production of oil and gas is expected to continue to grow in importance. Between 1960 and 1976, total offshore crude production rose by nearly 300 percent and accounted for 15.5 percent of total output in 1976. Offshore production of gas also rose significantly. New technology is being introduced to extend offshore operations to greater depths. The "Bright Spot" seismic method has been particularly useful in exploration for natural gas in the Gulf of Mexico.	Although the size and occupational structure of drill crews on offshore rigs are the same as those onshore, a wide range of workers in additional occupations is required, including radio operators, cooks, ships' officers and crews, and pilots and crews for drilling vessels, platforms, barges, and helicopters.	Oil and gas produced offshore will make up a steadily rising share of total U.S. output through 1985.
Enhanced recovery methods	Efforts are increasing to extract additional oil from existing wells through the injection of water, gas, air, chemcal additives, or heat. In natural gas extraction, hydraulic fracturing and other methods are being used on a limited basis in western States in attempts to recover gas from tight sandstone formations.	The expansion of enhanced recovery operations will require a higher level of skill and additional engineering, operating, and field staff.	According to the National Petroleum Council, the potential daily producing rate in 1985 from enhanced recovery methods other than primary or secondary could vary from 0.3 million barrels per day at $5 per barrel to 1.7 million barrels per day at $25 per barrel (in 1976 dollars). Peak production of 0.25 to 3.5 million barrels per day is estimated for 1995.
Innovations in exploration and drilling	New seismic methods are raising efficiency in exploration. New and improved drilling and production systems are being introduced as offshore operations expand. Computers and instrumentation systems are being applied on drilling rigs for monitoring and analysis of operations. Special equipment that can withstand extreme weather conditions is being used to carry out exploration and drilling in the Arctic.	As exploration for oil and gas is intensified, more petroleum geologists, geophysicists, and related workers will be required. During 1970-85, the number of geologists is expected to more than double. The proportion of the work force involved in offshore operations is expected to continue to increase. Computer monitoring systems being adopted more widely will require more engineers and technicians at drilling sites.	Technological changes in offshore exploration, drilling, and production will be extensive over the next decade as drilling depths increase and subsea production systems are improved and used more widely.
Oil shale development	Efforts to develop lower cost methods to extract oil from the vast oil shale deposits in the West continue. Factors which will determine the pace of development include the environmental impact, availability of water for production operations, rate of return on investments, and Federal policies and regulations.	The composition of occupations in aboveground oil shale operations differs from conventional drilling for petroleum in that perhaps 50 percent of the work force may be involved in mining operations. According to the U.S. Department of Energy, labor requirements for a 50,000 barrel per day oil shale production facility would vary by type of process, with an estimated 1,100 workers required for a mining and surface retort facility, 200 workers for an in-place operation, and 700 workers for a modified in-place installation.	According to the Federal Energy Administration, no commercial-size oil shale plants are anticipated before 1985 unless Federal financial assistance is forthcoming. The U.S. Bureau of Mines estimates that oil shale will account for less than 1 percent of total energy consumed in 1985 and 3.5 percent in 2000.

rough seas and the capability to drill to greater depths are being introduced. Subsea production systems are being developed which will enable crews to complete wells and perform other operations at the greater depths of the outer continental shelf. These systems are expensive, however, and U.S. operators surveyed do not expect extensive use of these systems on the outer continental shelf until the 1980's.[1] New equipment is being developed to monitor and control subsea production operations from remote locations; a corresponding reduction is anticipated in the use of workers in undersea operations.

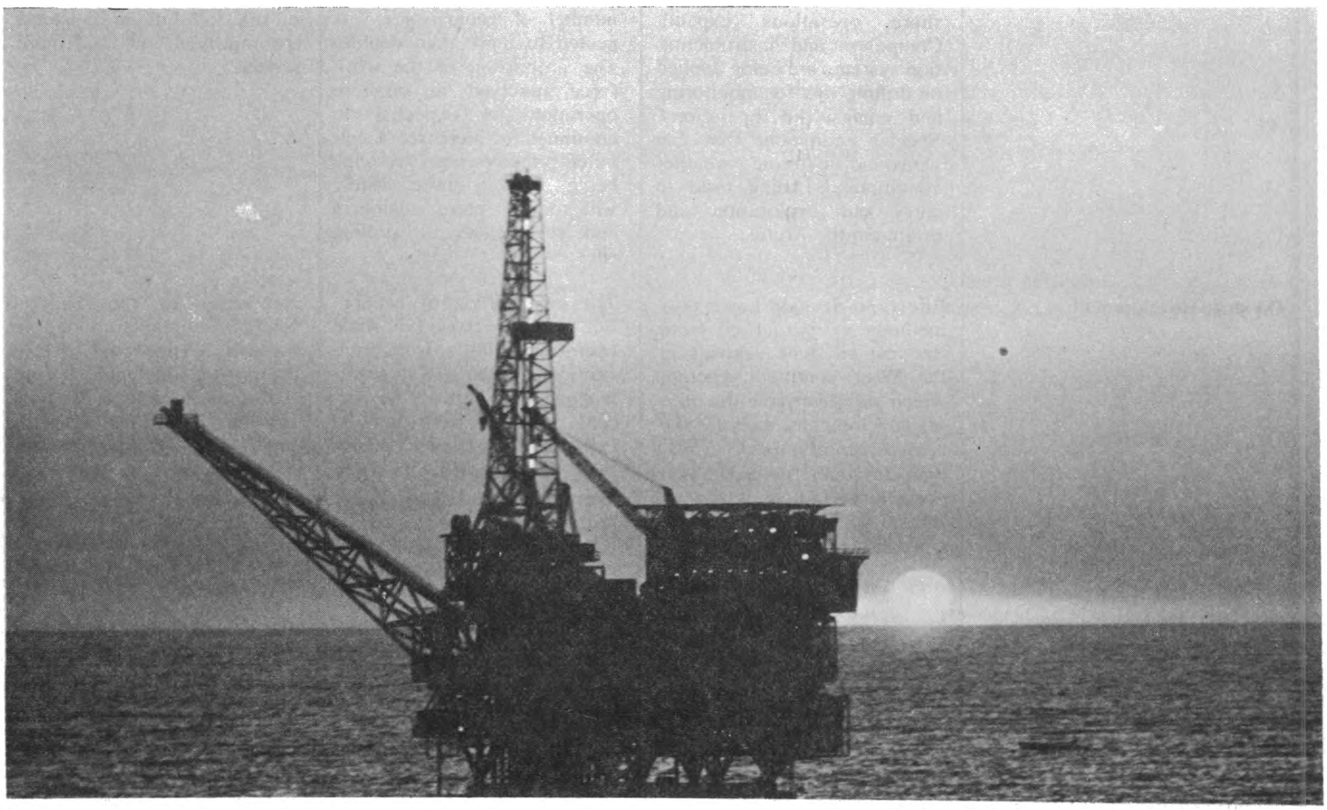
Subsea pipelines of increased diameter and strength are being laid in deeper waters further offshore to transport oil to storage and processing facilities. Several new production facilities designed for operation in very deep water are being tested. These include different types of platforms for operations above and below the surface of the ocean. One prototype subsea production system being developed and tested in the Gulf of Mexico illustrates evolving technology in offshore operations. The production complex is first lowered and anchored on the sea floor. Next, a drill ship anchored above the unit completes a number of wells through special openings on the submerged structure. The system is designed to pipe oil and gas to facilities onshore or to an offshore tanker. The system features remote monitoring, control, and maintenance from a ship or shore facility and contains special devices to control or prevent oil leaks.[2]

As the proportion of oil and gas produced offshore continues to increase over the next decade, additional large numbers of workers will be needed to undertake and support exploration and production operations extending to ever-greater water depths offshore. Although drill crew size and occupational structure in offshore operations generally are the same as in onshore operations,[3] additional support workers essential in offshore operations include radio operators, cooks, ships' officers and crews, and pilots and crews for drilling vessels, platforms, barges, and helicopters. Moreover, additional management and technical support are required to main-

[1] "U.S. Operators See Delay for Subsea Systems," *Oil and Gas Journal*, Apr. 21, 1975, p. 42.

[2] "Exxon Installs Subsea System in Gulf of Mexico," *Petroleum Engineer International*, Jan. 1975, p. 17.

[3] A typical drill crew on a rotary rig consists of a driller, a derrick operator, an engine operator, and two helpers or "roughnecks."



Offshore production platform

tain, select, and design equipment. The expansion of offshore drilling activity will continue to require substantial and increasing capital outlays. According to the Bureau of Mines, completing a well offshore in the Gulf of Mexico costs as much as nine times the average for a well completed onshore.[4]

Enhanced recovery methods

Efforts are increasing to extract additional petroleum from wells which have ceased to produce profitably as recent higher prices for oil make enhanced recovery operations more economically feasible. The expansion of enhanced recovery operations will require a higher level of skill and additional engineering, operating, and field staff. The U.S. Department of Energy states that enhanced recovery methods must be accelerated to extend the life of U.S. oil and gas reserves and to provide vital additional sources of oil and gas over the next decade and beyond.

Secondary recovery involves the injection of water or gas into oil-bearing sands in order to recover oil which can no longer be extracted during primary recovery operations. Tertiary recovery, in limited but growing use, involves heat, chemical additives, or other techniques to increase recovery of oil. In natural gas recovery, massive hydraulic fracturing and other methods are being used on a limited basis in Colorado and elsewhere to make available gas presently locked in sandstone formations with low permeability.[5]

Anticipated advances in recovery methods are expected to raise average recovery rates over the next decade and bring about major additions to supply. According to the National Petroleum Council (NPC), the proportion of total domestic production achieved by secondary and tertiary fluid injection methods increased from 30 percent in 1960 to an estimated 39 percent in 1970.[6] This proportion reached about 50 percent by 1976, according to a more recent report by the NPC.[7] The NPC report also states that the potential daily producing rate in 1985 from enhanced recovery techniques other than conventional primary and secondary methods could vary from 0.3 million barrels per day at a price of $5 per barrel to 1.7 million barrels per day at $25 per barrel (in 1976 dollars). Peak production of 0.25 to 3.5 million barrels per day is estimated for 1995.[8]

[4] *Offshore Petroleum Studies—Historical and Estimated Future Hydrocarbon Production from U.S. Offshore Areas and the Impact on the Onshore Segment of the Petroleum Industry*, Information Circular 8575 (U.S. Department of the Interior, Bureau of Mines, 1973), pp. 22–23.

[5] J. E. Kastrop, "Can Massive Frac Unlock Big Gas Reserves?" *Petroleum Engineer*, Feb. 1975, pp. 27–31.

[6] National Petroleum Council, *U.S. Energy Outlook—Oil and Gas Availability* (Washington, D.C., Dec. 1972), p. 317.

[7] National Petroleum Council, *Enhanced Oil Recovery* (Washington, D.C., Dec. 1976), base-case estimate.

Exploration and drilling

Innovations in exploration and drilling are opening up new areas for petroleum development. In exploration, advances in seismic technology and methods are improving depth penetration, and advanced computer methods are being used more extensively to process and interpret data. Marine seismic activities are increasing in importance as offshore exploration activities are expanded. Other developments underway in exploration include the evaluation of photographs obtained by satellite, the use of aircraft equipped with high-sensitivity magnetic devices to survey vast areas in the Arctic and elsewhere, and further research on techniques to detect earth formations likely to contain oil which are difficult to detect by conventional seismic methods.

Although research to develop new methods of drilling is in progress, rotary drilling is expected to retain its prominence, with improvements possible from the wide range of technological advances underway in drilling fluids, drill pipe, drill bits and rig equipment, and instrumentation. The outlook is for drilling rig efficiency to increase as the average age of operating rigs declines. Many technological improvements are below the surface rather than aboveground, such as the anticipated use of "down hole" motors. Drill-crew size would remain largely unaffected, but the new technology may require that drill-crew workers increasingly monitor rather than manually manipulate drilling and related equipment. Automated equipment for racking drill pipe and mixing fluids used in drilling, for example, could ultimately reduce physical involvement in these labor-intensive operations, but widespread diffusion of these technologies is not imminent.

Important and costly innovations in exploration and development are underway in Arctic areas. These include techniques to package drilling and related equipment for transport by air, the use of air cushion vehicles for transportation across vast land expanses, the use of helicopters and specially equipped launches to carry out seismic monitoring, and the erection of structures to protect crews and equipment from severe weather conditions. Special equipment to store and transport oil, including tankers with ice-breaking capability, also is associated with Arctic operations.

Computers and instrumentation in drilling

Sophisticated data collection and analysis systems using onsite computers are being introduced on a

[8] Ibid. p. 6.

limited but growing basis in drilling operations, particularly in deep well, wildcat, and offshore drilling.[9] A major advantage of computer data analysis in drilling operations is the capability it provides for measuring and correlating a wide range of variables with increased accuracy. Modern monitoring systems reportedly achieve operating economies by making possible greater drill penetration rates, a reduction in chemicals used in drilling operations, the extension of drill-bit life, and a reduction in testing activities. They may also improve safety and provide advance indication of potential drilling interruptions.

The number of employees required to staff a complete computer monitoring and analysis system ranges from one to three persons per shift, depending upon drilling rates and the number of variables monitored. The less complex monitoring systems that are in general use to measure basic drilling parameters also are being improved, but these systems do not incorporate computers or require special technical staff.

Although experts differ regarding the extent of future use of computer monitoring systems, most expect technology to improve and its application to expand over the next decade.

Oil shale development

Oil derived from oil shale deposits in Colorado, Wyoming, and Utah has a long-range potential to become a supplement to crude petroleum if environmental problems can be resolved and if production costs can be lowered. Experimental work on shale oil production has been underway in the United States for many years. The U.S. Bureau of Mines and private company pilot and demonstration facilities are presently staffed by a relatively small number of employees. A significant step toward commercial development was taken in 1974 with the lease of Federal lands in the West to private companies for prototype development.

One major method of oil shale production involves either surface or underground mining of shale and the subsequent crushing and transport of the shale to vessels called retorts. In the retort, heat turns a substance called kerogen, embedded in the shale, into a form of heavy crude oil. A second method receiving increased attention is in-place processing whereby shale is heated underground and the oil and gas drawn up to the surface. Surface mining and retoring operations are not required. One large company is developing a modified in-place process which involves some surface mining but underground retorting.

The work force required to produce oil from shale by surface mining methods differs markedly from requirements in conventional crude petroleum drilling and production operations. In oil shale operations, about 50 percent of the work force in a mining and surface retorting operation reportedly would be engaged in mining operations. The remaining 50 percent typically would be engaged in administrative, technical, retorting, and maintenance activities.

Although the potential of oil shale is widely recognized, the timetable for commercial development remains uncertain. Factors which will vitally affect the pace of commercial development include the impact of oil shale development on air pollution, water quality, and land use; availability of water and other resources to develop the industry; future costs of petroleum and other energy sources; ultimate rates of return on investments in production facilities; and Federal policies and regulations related to oil shale development. According to a Federal Energy Administration report, no commercial-size oil shale plants are expected to be built by 1985, unless Federal financial assistance is forthcoming.[10] The U.S. Bureau of Mines also foresees a relatively small role for oil shale over the next 25 years and estimates that Government-supported oil shale production will be the source of less than 1 percent of total energy consumed in 1985 and 3.5 percent in 2000.[11]

Production Outlook

Oil and gas production rose at an average annual rate of 2.7 percent between 1960 and 1976.[12] This reflected an increase in crude petroleum production of 1.5 percent per year over the period; natural gas of 3.7 percent; and natural gas liquids of 4.0 percent. Oil and gas field services (SIC 138) increased by 5.1 percent during 1960–76, but rose at a substantially higher average annual rate of 15.7 percent during the

[9] "On-Site Instruments Help Avoid Troubles, Optimize Drilling", *Oil and Gas Journal*, Sept. 24, 1973; John L. Kennedy, "Data Monitoring on Today's Rig," *Oil and Gas Journal*, Sept. 24, 1973; W. D. Moore III, "Computer-Aided Drilling Pays Off," *Oil and Gas Journal*, May 31, 1976, pp. 56–60.

[10] *National Energy Outlook—1976*, (Federal Energy Administration, Feb. 1976), p. 315.

[11] Walter G. Dupree, Jr., and John S. Corsentino, *United States Energy Through the Year 2000 (Revised)* (U.S. Department of the Interior, Bureau of Mines, Dec. 1975), pp. 27–28.

[12] Federal Reserve Board (FRB) index of production for SIC 13, Oil and gas extraction. In preparing this measure, the FRB uses value-added weights to combine the individual series. Value added is calculated by subtracting from each industry's gross value of products the costs of materials, supplies, containers, fuels, purchased electrical energy, and contract work, but not the cost of purchased business services.

period 1970-76 as firms expanded operations.

Production of both crude petroleum and natural gas has slowed significantly in recent years. Crude petroleum output peaked in 1970 and declined at an average annual rate of 2.9 percent between 1970 and 1976. Natural gas output was highest in 1973 and declined between 1973 and 1976 at an annual rate of 5.1 percent. During the earlier period, 1960–70, however, production of crude oil increased at an annual rate of 3.4 percent. Natural gas production increased during 1960–73 at an annual rate of 5.2 percent.

According to U.S. Department of Energy projections, domestic production of crude oil in 1985 may range between 8.3 and 9.5 million barrels per day, compared to 8.2 million in 1977. Production of natural gas in 1985 is projected to range between 15.1 and 18.9 trillion cubic feet annually, compared to 18.7 trillion produced in 1977.[13]

The outlook is for the recent upsurge in drilling activity to continue. The number of wells drilled in the United States in 1977 (an estimated 46,000) exceeded the number of wells drilled in 1973 by 67 percent, but this total is still significantly below the record of about 58,000 wells drilled in 1956. However, the number of exploratory holes drilled in 1977 was the largest since 1966.[14] Incentives for accelerated drilling activity include higher prices for petroleum, increased leasing of offshore areas, higher prices for intrastate natural gas, and approval of the trans-Alaska pipeline. A number of oil companies continue to plan for high levels of spending for exploration and development.[15]

Some shortages of production equipment and workers could result if drilling activity remains at high levels. Tubular goods (casing, drill pipe, etc.) and drilling rigs, reportedly difficult to procure during late 1974 and early 1975, could once again become in tight supply if projected higher levels of drilling are realized. Demand for offshore production equipment is expected to remain strong into the 1980's, although a surplus of offshore drilling rigs existed in the fall of 1975. In addition, some experts foresee a shortage of trained personnel to carry out exploration, drilling, and production operations. Production companies and drilling contractors are expected to accelerate programs to recruit and train new employees.

Manufacturers of equipment for the oil industry are expanding capacity to assure an adequate supply of oilfield machinery to sustain increased exploratory and development drilling. According to the U.S. Department of Commerce, shipments by the oilfield machinery industry are projected to reach $4 billion in 1978, more than triple the shipments in 1972.[16]

Imports

Imports of crude petroleum have been increasing as domestic consumption of crude petroleum continues to exceed U.S. production. By 1977, imports of crude oil were equal to nearly 50 percent of total domestic petroleum consumption, compared to 19 percent in 1960.[17]

Oil imports are projected by the U.S. Department of Energy to range between 9.1 and 12.5 million barrels per day in 1985.[18] The level of imports will be influenced to some extent by measures undertaken within the United States to increase domestic supply and to conserve energy. Specific actions which could contribute to reduced dependence on imported oil include increasing Federal leasing on the outer continental shelf, the opening of naval petroleum reserves to commercial development, removing impediments to nuclear power development, and reducing demand for petroleum through actions such as improving the fuel efficiency of new automobiles and providing incentives for fuel conservation in industrial plants, offices, and homes.

Investment

Finding and producing crude petroleum and natural gas require vast capital outlays. Capital expenditures by the oil and gas industry totaled $18.5 billion in 1977, more than triple the $5.4 billion spent in 1967.[19]

The outlook is for higher levels of capital spending since the cost to discover and develop oil and natural gas is expected to continue to increase significantly. Costs will rise with the shift of activity to offshore and remote land areas in Alaska and elsewhere, the more widespread application of enhanced recovery methods, the general trend toward drilling to deeper depths, and increased spending for conservation and pollution control. Cumulative capital re-

[13] *Projections of Energy Supply and Demand and Their Impacts, Annual Report to Congress, Vol. II, 1977* (U.S. Department of Energy, Energy Information Administration), chaps. 6 and 7, pp. 127–75.

[14] *Oil and Gas Journal*, Jan. 30, 1978, p. 143.

[15] "Fast U.S. drilling Pace to Carry Over into Early '77," *Oil and Gas Journal*, Nov. 29, 1976, pp. 19—22.

[16] *U.S. Industrial Outlook, 1978* (U.S. Department of Commerce, Industry and Trade Administration, Jan. 1978), pp. 372–74.

[17] *National Energy Outlook—1976* (Federal Energy Administration, Feb. 1976), p. XXVIII.

[18] *Projections of Energy Supply and Demand, Executive Summary*, p. 1.

[19] *Projections of Energy Supply and Demand*, p. 50.

quirements in the oil and gas industry for the period 1978 through 1984 are projected to range from $114 to $145 billion (1978 dollars).[20]

Employment and Occupational Trends

Employment

Total employment in oil and gas extraction reached a record high of 404,500 in 1977, up by about 31 percent over 1960 (chart 4). The significant rise in exploration and drilling activities during 1971-77 resulted in the net addition of 140,000 workers, a reversal of the steady decline in employment which occurred during the decade of the 1960's.

Although the number employed in the industry was significantly higher in 1977 than in 1960, the average annual rate of change over this period increased by only 0.8 percent. Between 1967 and 1977, however, employment increased at the substantially higher average annual rate of 3.5 percent; for the last 6 years of this period, employment ceased to decline and turned up sharply at a rate of 7.6 percent. In contrast, employment had declined at an annual rate of 1.5 percent between 1960 and 1967. Production worker employment during 1960–77 increased at an annual rate of 0.4 percent, but, following the pattern for total employment, increased at an annual rate of 8.7 percent during 1971–77. The proportion of production workers to total employment in oil and gas extraction declined from 73 percent of the work force in 1960 to 70 percent in 1977.

Total employment in the crude petroleum, natural gas, and natural gas liquids components of the industry (SIC's 131, 132) declined at a rate of 0.5 percent during 1960–77; in oil and gas field services (SIC 138), however, employment rose at a rate of 2.2 percent in 1960–77 and 11.5 percent during the 1971–77 period as the number of wells drilled rose sharply.

The outlook is for total employment in oil and gas extraction to further increase as exploration and development activities are accelerated. The average annual rate of employment increase is projected to be 1.7 percent during 1977–85, as indicated in chart 4. (See introductory note for basic assumptions underlying these projections.)

Occupations

The structure of occupations in oil and gas extraction is expected to undergo change between 1970 and 1985. All of the major occupational groups presented in chart 5 are projected to increase, with the exception of sales workers, who accounted for less than 1 percent of total industry employment in 1970.

Professional, technical, and kindred workers are expected to achieve the greatest gains, increasing by 94 percent between 1970 and 1985 as additional petroleum engineers, geologists, and other professional and technical employees are required for more extensive and complex exploration and development activities. This may continue to tax the industry's ability to train and develop technical employees and may result in severe competition among employers for experienced professional and technical personnel. The largest occupational group in oil and gas extraction—operatives—accounted for 37 percent of total industry employment in 1970 and is expected to increase by 63 percent during 1970-85 as employment in drill-crew and other operative occupations is expanded. Managerial workers are projected to increase by 73 percent, clerical workers by 64 percent, and craft workers by 55 percent. As indicated in chart 5, smaller gains are anticipated for service workers and laborers who, combined, account for only slightly more than 3 percent of industry employment.

According to the NPC, the upsurge in exploration and drilling since about 1971 could result in a continued shortage of qualified workers in a wide range of exploration, drilling, and production activities, with personnel skilled in the interpretation of geophysical data in especially short supply.[21] Some firms are expanding programs to recruit and train new employees, particularly for assignment to drilling crews, where turnover traditionally is high because the work is difficult and must be carried out in all types of weather. One result is that the productivity of previously inactive drilling rigs recently brought into operation is lower because of shortages of skilled workers for drilling crews. The NPC report also points out concern within the industry that near-term shortages of skilled workers in firms which produce equipment for the oil industry, including welders, machinists, and pipefitters, could slow delivery of equipment.

Adjustment of workers to technological change

Innovations in equipment and processes in crude petroleum and natural gas extraction are not expected to bring about layoffs, downgrading, or reassignments over the next decade and, consequently, formal provisions in collective bargaining agreements relating to seniority, wages, job security, and related topics are not expected to be called into effect.

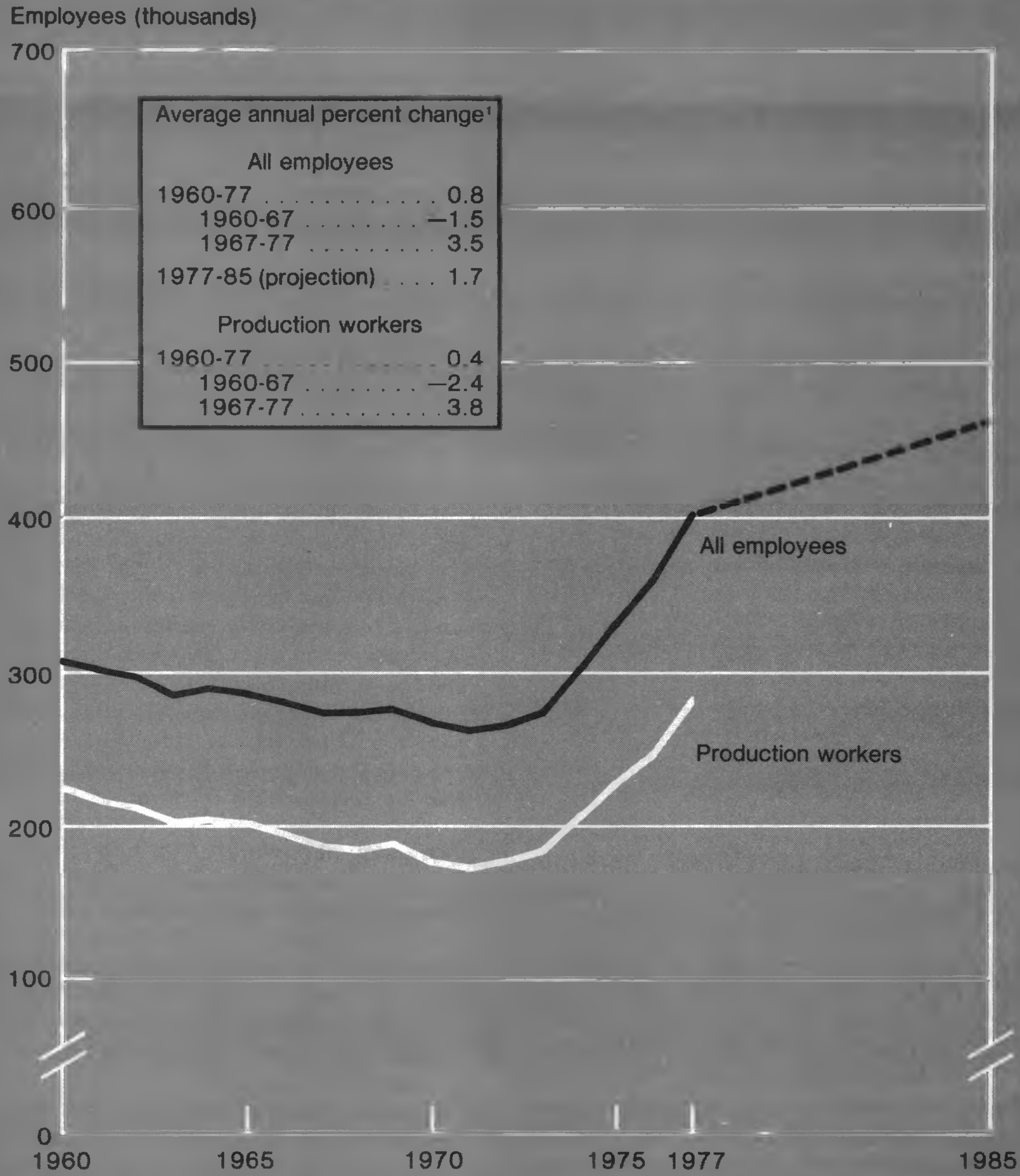
The oil and gas extraction industry is not highly unionized. According to a BLS study of the crude petroleum and natural gas component of the industry (SIC 131), only about 40 percent of the work force is employed in establishments having collective bar-

[20] Ibid, p. 54.

[21] National Petroleum Council, *Availability of Materials, Manpower and Equipment for the Exploration, Drilling and Production of Oil—1974–76* (Washington, D.C., Sept. 1974), p. 21.

Chart 4

Employment in oil and gas extraction, 1960-77, and projection for 1977-85

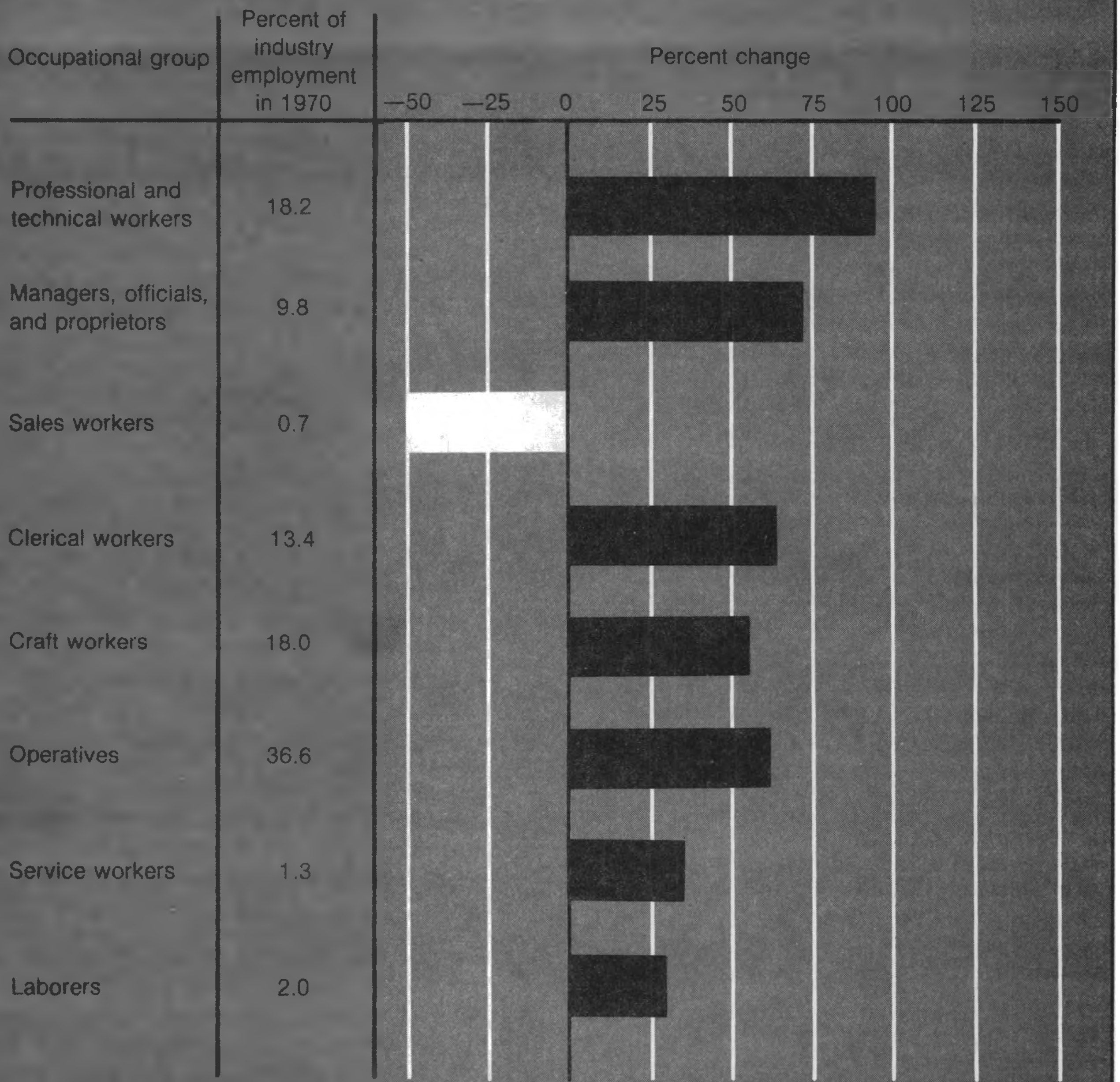


¹ Least squares trend method for historical data; compound interest method for projection.

Source: Bureau of Labor Statistics.

Chart 5

Projected changes in employment in oil and gas extraction, by occupational group, 1970-85[1]



[1] Based on the latest occupational data for 1985 adjusted for revisions of the 1985 employment projections.

Source: Bureau of Labor Statistics.

gaining agreements covering a majority of their production workers.[22]

The degree of unionization in the crude petroleum and natural gas industry varies by region. In California, about three-fourths of the work force in 1972 was in establishments where labor-management agreements covered a majority of production workers; in Louisiana and Oklahoma—two leading oil-producing States—the proportion was slightly more than one-fourth, and in Texas, about one-half. Most workers in establishments with collective bargaining provisions are represented by independent unions (those not affiliated with the AFL–CIO) or by the Oil, Chemical and Atomic Workers Union, an AFL–CIO affiliate.

[22] *Industry Wage Survey—Crude Petroleum and Natural Gas Production, August 1972*, Bulletin 1797 (Bureau of Labor Statistics, 1973).

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Chapter 3. Petroleum Refining

Summary

Technological changes in the refining industry are being made in response to shifts in crude oil supply, changing demand for petroleum products, and environmental and energy considerations, in addition to the usual incentives of greater productivity and lower costs. These changes are primarily in the areas of cracking, hydrotreating, and reforming, in association with advanced instrumentation and computer control. The outlook is for greater emphasis on processes for desulfurization and octane improvement. Because the industry is capital intensive, the short-run effects on labor are likely to be minimal, but in the longer run they will alter job content and may reduce employment growth.

Productivity rose sharply from 1960 to 1977, at an average rate of 4.3 percent annually compared with 2.6 percent in all manufacturing. From 1967 to 1977, the rate was 3.0 percent. The outlook to 1985 is for productivity to rise but at a slower rate than in the last decade. Many uncertain variables affect the outlook including crude imports, gas supplies, and government environmental and energy policies. But for the most part, the industry's productivity in the next decade will depend on the Nation's economic growth and consequent energy needs. Changes in government policies or in the international situation are not dealt with in this chapter.

Capital investments have been increasing almost steadily since the 1960's. By January 1977, operable capacity had risen 50 percent over the decade and 20 percent since January 1973, reversing concerns about capacity shortages. Due to uncertainties of supply and demand and rapidly rising costs, however, there is no general agreement on future capital outlays for capacity expansion. But large investments are anticipated to accommodate changing demand for the industry's products and government environmental and energy policies.

About 160,000 people were employed in the industry in 1977, the largest number since 1962. Following a sharp decline in the first half of the 1960's reflecting very rapid productivity growth, employment was relatively stable until 1973. Since 1973, however, employment has been moving up as technology changes require more unit labor and as the number of very small refineries increases. The outlook to 1985 is for a resumption of the decline.

Technology in the 1970's

Petroleum refining is a series of processes of physical separations and chemical reactions. It involves three major groups of processes: Separation, conversion, and treating. First the hydrocarbon compounds in the crude oils are separated through heating and distillation to recover the lighter products such as gasoline, kerosene, and distillate fuels. Some compounds heavier than gasoline may be "cracked" or chemically converted into higher quality products. Desired products may also be built up by chemical reactions such as alkylation. Others are chemically rearranged, by catalytic reforming, for example. In addition, at some stage of manufacture the products may be treated to remove impurities such as sulfur or metals.

In the past, the objective of U. S. refineries was to maximize gasoline production rather than the output of heavier fuels. Consistent with this objective, they were geared, primarily, to producing high-octane gasoline from low sulfur (sweet) crude petroleum. Moreover, in general, there were no restrictions on levels of sulfur and other impurities in petroleum products.

However, the picture is changing. First, there appears to be a long-term shift in emphasis from gasoline to heavy fuels based on a projected slowdown in gasoline demand and an increase in the market for heavy fuels as a result of the natural gas shortage. Second, environmental protection regulations encourage or require low-sulfur, low-lead products, as well as the reduction of noxious wastes from the refining process itself. At the same time, however, the availability of low-sulfur varieties is declining. As a result of these conditions, refineries must make adjustments to accommodate product changes.

In addition, changes are taking place in the structure of the industry. Although a number of small refineries are being built, in general, process units are becoming larger, and functions are being consolidated to increase productivity. Average capacity has increased very sharply to over 60,000 barrels per day (as of January 1977), and the labor implications (discussed in the employment section) are significant. Capacity varies considerably among refineries, however, ranging from 500 to 640,000 barrels per day. In general, the smaller plants consist of a crude oil distillation unit plus the necessary auxiliary units, while the larger refineries are considerably more complex. They include, in addition to distillation facilities, cracking, reforming, coking, hydrogen-treating, alkylation, fuel desulfurization, and other processing units. Key advances in the basic refining processes in the last decade, their labor impact, and their rate of difusion are presented in table 4 and discussed in greater detail below.

Computer control

High-speed digital computers improve production efficiency and raise quality through more precise control of the production process. Other benefits also are often cited, such as better technical and operating data and improved plant safety.

In process control, digital computers are applied to various refining processes ranging from crude distillation to on-line gasoline blending. Open-loop con-

Table 4. Major technology changes in petroleum refining

Technology	Description	Labor implications	Diffusion
Computer control	High-speed digital computers, in association with highly complex instrumentation, monitor and/or control various refinery processes; they are used in testing and research laboratories and for management information. Use minimizes costs and improves product quality.	Affects operator's duties primarily, assuming earlier installation of sophisticated instrumentation; requires computer-related technicians.	Installation in one-fourth of refineries constituting more than two-thirds of industry crude capacity.
Improved cracking	Improved riser-cracking techniques use catalysts with more tolerance to feedstocks of higher metal content to provide greater yields of desired products and higher octane ratings. Improved hydrocracking provides more feedstock flexibility.	Increased labor productivity; direct effects are minimal.	Riser method constitutes approximately 40 percent of U.S. cracking capacity. Hydrocracking capacity is equal to 16 percent of the total. Diffusion is expected to be relatively slow.
Desulfurization advances	High-activity catalysts and other advances efficiently reduce sulfur content. Hydrogen-based processes enable refineries to process sour crude, to make low-sulfar feedstocks for modern catalytic reforming units, to produce residuals and distillates to environmental specifications, and to meet pollutant emission controls.	Additional processing increases unit labor requirements for technicians and maintenance personnel.	Process units being built into new refineries. Diffusion will depend on environmental protection requirements and type of crude available. Hydroprocessing capacity increased 30 percent between 1975 and 1978, and is expected to increase another 5 percent by 1980.
Octane-improving processes	Catalytic reforming, alkylation, and isomerization increase gasoline octane ratings without lead additives. New bimetallic catalysts are improving all reforming methods. Continuous reforming eliminates periodic shutdowns for catalyst regeneration.	Direct labor effects depend on refinery complexity. Small plants may need additional operators and maintenance workers. In all cases, productivity would be adversely affected.	By 1978, reforming accounted for 22 percent of crude capacity; isomerization, 2 percent; alkylation, 5 percent. Low-lead requirements suggest increased importance of octane-improving processes.
Energy conservation methods	Increased use of heat exchangers, furnace air preheaters, thermal insulation, gas and hydraulic turbines, waste-heat steam generation, process improvements.	Increases maintenance labor, particularly in older refineries; also increases demand for engineering skills.	By early 1976, energy use was cut 10 percent below 1972. Expectations are for an additional 15-percent cut by 1985.
Preventive maintenance technologies	Use of ultrasonic testing, X-ray testing, infrared cameras, magnetic particle testing, and corrosion probes to determine equipment reliability.	Newer sophisticated preventive maintenance equipment requires highly trained personnel, but may require fewer unit employee hours as downtime is reduced. Maintenance craft consolidation also reduces unit labor requirements.	New testing methods are widely used; use depends on complexity and age of equipment.

trol is most common: data received from plantwide on-stream sensors are monitored and the operator is notified when machine changes are required. However, closed-loop control is increasing in use in the newest installations. The trend is toward use of mini- or microcomputers which, while linked to a central control center, control separate functions. Required adjustments in the production process are made automatically, thus eliminating some of the operator's functions.

Digital computer use is generally more common in large complex plants. Approximately one-fourth of American refineries use digital computers in various applications,[1] but these plants constitute more than two-thirds of total U.S. capacity.[2] With current trends towards the construction of larger, more complex plants, it is expected that practically all future refineries will incorporate one or more process control digital computer systems.

The use of very sophisticated instrumentation generally precedes or accompanies computer installation, and so the labor implications of the computer cannot be easily sorted out. In a refinery visited by the BLS staff, the computer monitored information from more than 1,000 electronic instruments, such as chromatographs, mass spectrometers, and octane analyzers, that are located at the process unit and continuously measure product quality. Their importance lies in the speed with which problems can be corrected, and also in their tie-in to computer control. All U.S. refineries use analyzers, but the number and sophistication of the instruments vary with the size and complexity of the plant.

The effect on employment is associated largely with the degree of sophistication of the refinery's instrumentation. For example, fewer analyzer repairers, operators, and lab technicians may be required where on-line monitoring is possible.[3] In a modern plant, one technician may take the place of three or four technicians or operators in an older plant which still maintains sample testing and manual recording. On the other hand, jobs such as programmers and

[1] *International Petroleum Encyclopedia*, 1977, pp. 443–44.
[2] Ibid., pp. 316–20.

[3] "Process Computers—They Do Pay Off in Refineries," *Oil and Gas Journal*, Dec. 3, 1973, p. 62.

Operators checking level and flow of fluid at a petroleum refinery

systems analysts increase with the installation of computers. A BLS study[4] shows, however, that the number of some computer-related jobs in a plant may decrease after the initial phases of installation and programming are completed.

With the installation of computer process control, changes are necessary in the operator's duties. One example is clearly shown in a BLS survey of employment implications of computer process control.[5] The duties of an operator of a fluid catalytic cracking unit before computer control were to manually adjust automatic analog controllers at the control console and to monitor automatic data logging equipment. After installation, the computer controls and monitors a large part of the process and automatically logs the data, although the operator still performs manual control. In case of emergency, the operator can take control of any part or all of the process.

Improved cracking

Fluid catalytic cracking is a refining process that converts heavier oils into lighter, more valuable products such as gasoline, primarily by chemical reaction in the presence of a catalyst. The technique of riser cracking was developed concurrently with a new generation of highly active catalysts in the early 1960's. Considered more efficient than older techniques, this method presently is in use in over 40 percent of U.S. cracking capacity.

Hydrocracking, an older, but greatly improved method of cracking, has several advantages over the conventional "cat-cracker." These include the capability to meet environmental specifications of low sulfur and nitrogen more efficiently and flexibility to handle variations in crude stock and in products desired. Currently, however, hydrocracking accounts for only about 16 percent of cracking capacity, and the diffusion is expected to be slow, due primarily to the very high investment and energy usage required for this process.

For both types of cracking, continually improved catalysts and regeneration methods enable more efficient processing of oils with high contents of sulfur and metals. To meet new product specifications and increased use of high-sulfur crudes, refineries with older cat-crackers may need to change over to the more efficient processing methods.

In general, the effect on labor utilization of improved cracking procedures in place of older cracking methods is minimal.

[4] *Computer Manpower Outlook*, Bulletin 1826 (Bureau of Labor Statistics, 1974), pp. 36–37.

[5] *Outlook for Computer Process Control: Manpower Implications in Process Industries*, Bulletin 1658 (Bureau of Labor Statistics, 1970), p.29.

Desulfurization advances

Hydroprocessing to reduce impurities, particularly sulfur, will become increasingly important as demand increases for low-sulfur residual and distillate fuels. In addition, stricter environmental protection regulations and greater utilization of high-sulfur crudes due to dwindling supplies of sweet crudes will lead to strong growth in desulfurization capacity.

Desulfurization is an important factor in better enabling refineries to process sour crudes. For this purpose, sulfur removal may follow initial crude distillation. Desulfurization is also performed downstream to meet the stringent requirements of catalytic reformers and to control pollutant emissions from the catalytic cracking process. Residual and heavy gas-oil desulfurization, the smallest but most rapidly growing segment of hydroprocessing capacity in the United States, is performed as the last step in the production of those fuels. New refineries are being designed to produce low-sulfur products from high-sulfur crudes, and existing plants are revamping their process units when changes become necessary.

Various hydrogen-based processes (hydrodesulfurization, hydrorefining, hydrotreating) are used for sulfur removal. All are based on chemical reactions between oil and hydrogen in the presence of a catalyst. Advances involving separate demetallization processes and new high activity catalysts are reducing problems related to metals accumulation and need for frequent catalyst regeneration. However, the costs are still quite high. With some desulfurization processes, off-site regeneration of catalysts by specialized companies is increasing as an economical solution to catalyst-related problems.

The trend is clearly toward an increasing capability of refineries to process sour crudes. Total hydroprocessing capacity increased 30 percent between 1975 and the start of 1978 and is expected to increase an additional 5 percent by 1980. Residual and heavy gas oil desulfurization capacity more than tripled from 1975 to 1978.[6]

Since additional processing is required for desulfurization and demetallization, unit labor requirements for operations and maintenance personnel may increase. These increases may be temporary, however, as the processes become integrated into the overall operation of the refinery.

Octane improvement

Catalytic reforming, a process which improves the octane rating of gasoline or fuels, is particularly important today in view of the Federal Govern-

[6] "Federals Shape U.S. Refining Industry," *Oil and Gas Journal*, Mar. 20, 1978, pp. 63–66.

ment's requirements for lower lead and lead-free gasoline. To increase yields of high-octane gasoline without lead, low-sulfur feedstock is necessary. The desulfurization of feedstock, discussed in the previous section, is therefore necessary.

New bimetallic catalysts are making all reforming processes more efficient, increasing yields and octane ratings over those possible with conventional catalysts. In addition, the process of continuous reforming eliminates periodic shutdowns because, unlike other reforming methods, it continuously regenerates the catalyst.

To meet the low-lead requirements, refiners increased their reforming capacity by roughly 19 percent between 1972 and 1978. In that period, the use of bimetallic catalysts more than doubled, to over 60 percent of total reforming capacity. At the start of 1978, continuous reforming accounted for 4 percent of total catalytic reforming capacity compared with about 69 percent for semi-regenerative reforming, and almost 27 percent for the older process of cyclic reforming.[7]

In addition to reforming, the processes of alkylation and isomerization provide increased octane ratings in gasoline. Developed in the early 1940's to produce aviation fuels, these processes are not widely used now, representing only about 5 percent and 2 percent, respectively, of crude capacity (compared to 22 percent for reforming). However, they will become increasingly important as leaded gasoline is phased out.

Although the phasedown of leaded gasoline may not be as severe for the large refineries capable of wide process adjustment, it will be particularly difficult for smaller, older refineries, geared primarily to producing leaded gasoline. Some of these smaller refineries may have problems associated with capital acquisition or procurement and construction of the needed equipment. In addition, more operators may be needed in refineries lacking process control systems. More maintenance labor may also be required by the small plant. In all cases, however, productivity would be adversely affected by the additional processes required to increase octane ratings.

Energy conservation

Because of the high costs of new refining technologies, particular emphasis is being placed on reducing costs through energy conservation—the more efficient utilization and generation of fuel and power.[8] Current technologies such as heat exchangers, furnace air preheaters, gas and hydraulic turbines, waste-heat steam generation, and thermal insulation are now being improved. Minor process adjustments, automatic instrumentation, increased maintenance, and intensified surveillance of operations are also important in reducing refinery energy consumption.

The labor implications of energy conservation in the refinery are considerable. Some companies have set up energy systems departments whose managers closely control energy use. In addition to managerial and engineering skills, more employee hours of skilled craft and maintenance workers may be required for efficient energy utilization, particularly in the older refineries.

Preventive maintenance

Special emphasis is being placed on preventive maintenance, particularly the use of electronic instruments to locate defects in and measure the deterioration of equipment before problems arise. Through the use of ultrasonics, X-rays, and electrical corrosion probes, wear and corrosion in pipes and vessels can be measured on- or off-stream, sonic testers can detect high-frequency sounds generated by gas leaks from valves and fittings, and magnetic particle tests and infrared cameras can also pinpoint structural defects in some equipment.

Preventive maintenance reduces downtime and maintenance costs, but the effect on labor is difficult to assess. Maintenance labor requirements vary with the complexity and age of the refinery, the sulfur in the crude, and the extent to which maintenance is subcontracted. Newer refineries may have less maintenance because modern materials, e.g., corrosion resistant, are more fully utilized. In general, however, important changes are occurring which are reducing unit labor requirements for maintenance personnel. These are discussed in the section on employment and occupational trends.

Production and Productivity Outlook

Output

The steady growth in petroleum refining output since World War II was interrupted only by small declines in 1949 and 1958 and again in 1974 and 1975. Overall, from 1960 to 1976, output rose at an average rate of 2.9 percent annually.[9] (See chart 6.) The growth rate, however, was considerably more rapid in the strong economy of 1960–66 (3.2 percent) than in the 1966–76 period (2.4 percent). The latter period included the embargo and the 1974–75

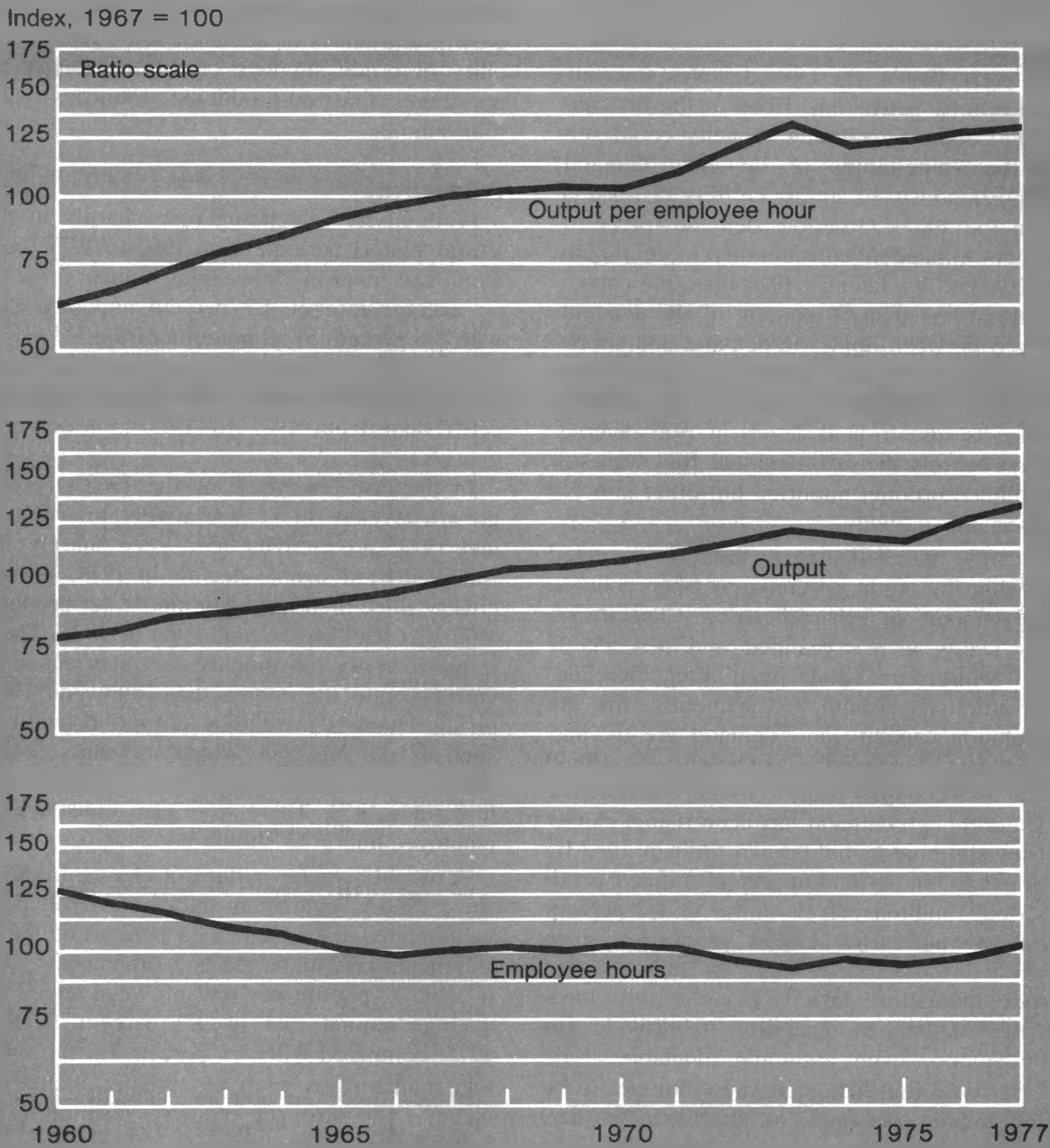
[7] Ibid.

[8] *Oil and Gas Journal*, Mar. 29, 1976, p. 74.

[9] *Productivity Indexes for Selected Industries, 1977 Edition*, Bulletin 1983 (Bureau of Labor Statistics, 1977). Output measure based on Bureau of Mines data.

Chart 6

Output per employee hour and related data, petroleum refining, 1960-77[1]



[1] Data for 1977 are preliminary.

Source: Bureau of Labor Statistics.

production cutback associated with the economic recession and energy conservation. But in 1976 and 1977, output jumped to peak levels, recording the most rapid annual rates of growth since 1955.

There is no general agreement on the level of domestic demand for refinery products in 1985.[10] Many observers expect gasoline demand to peak out in the next few years, while demand for distillate and residual fuels is expected to increase as utility and industrial users substitute fuel oil for natural gas.

Imports

Until the early 1960's, the United States was self-sufficient in refined petroleum. Even in the first half of the 1960's, domestic refining capacity could supply more than nine-tenths of domestic demand; product imports consisted almost entirely of residual fuel. But in the 1965–73 period, demand for petroleum products expanded considerably more rapidly than capacity, and by January 1973 operable capacity could supply less than 80 percent of the demand. Thus, the gap between domestic demand and supply had been growing for years when the crude oil embargo and price increases intensified the problem. Product imports rose to peak levels in 1973, averaging 3 million barrels daily.[11] Residual fuel was still the major refined product imported but other imports had also risen substantially.

However, the demand/supply situation reversed itself following the crude oil embargo when concern rose sharply about our self-sufficiency. Capacity increased as plants were expanded and new plants were built, while demand declined after three decades of continuous growth. Consequently, the gap between refining capacity and demand greatly narrowed, and our dependence on imported refined products in 1975 dropped back to roughly that of the mid-1960's. Although demand has been rising, capacity increases continue to hold down the gap filled by product imports. In 1976, imports of refined products averaged 2 million barrels daily, 11 1/2 percent of domestic demand, the lowest proportion since 1967.

But crude distillation capacity alone is not a measure of the industry's capability to provide for domestic demand, even assuming available crude supplies. Residual fuel has been and continues to be our major import because, as discussed earlier, domestic refineries have not been interested in or geared to processing residuals. The problem is now complicated by government regulations which require low-sulfur residuals, sometimes necessitating changes in technology. Nevertheless economic incentives and the outlook for rising demand have resulted in more domestic processing of residual fuel—from 30 percent of domestic demand in 1973 to about 56 percent in 1977. Imports of residual fuel hit a low of 1.2 million barrels a day in 1975 and have not increased greatly since then, in spite of a sizable increase in demand.

The outlook for imports of refined products is not clear.[12] Opinions differ as to domestic capacity growth and shifts in demand, aside from the availability of crude supplies or, in the longer run, the possibility that oil-producing countries will move into refining.

Productivity

Productivity in refining rose sharply in the post-World War II period. From 1960 to 1977, output per employee hour in the refining industry increased at an average rate of 4.3 percent annually, compared with 2.6 percent in all manufacturing.[13]

Productivity growth was considerably more rapid and steadier, however, from 1960 to 1967 (7.1 percent) than from 1967 to 1977 (3.0 percent). (See chart 6.)

In the last few years of the 1960's, productivity growth leveled off at a relatively low rate. In 1972 and 1973, productivity rose very sharply; this was followed by a sizable decline in 1974. While the recovery since then has been moderate, productivity in 1977 was back to the high level of 1973. These erratic productivity movements were associated with the embargo and the events that followed. There were erratic changes in refining output, discussed above, such as the unusually steep increases in output in 1973, 1976 and 1977, and the decline in 1974, the first since 1958. There were also unusual changes in employee hours, as shown on chart 6.

A roughly similar pattern of change in the industry since 1960 is evident in data on payroll per unit of value added, i.e., labor as a percent of the value of shipments less materials and other costs. As shown in table 5, payroll per unit of value added fell at an average annual rate of 3.2 percent from 1960 to 1975, compared with 1.1 percent for all manufacturing, indicating a relatively greater increase in efficiency. The stronger industry position in the first half of the period 1960–66 is evident in the sharp decline in payroll/value added of almost 6 1/2 percent annually. In contrast, the ratio showed only a minor change of about 1 percent in the 1966–75 per-

[10] See *Projections of Energy Supply and Demand and Their Impacts: Annual Report to Congress. Vol. II, 1977* (U.S. Department of Energy, Energy Information Administration, 1977), ch. 6, pp. 127–53.

[11] Bureau of Mines data.

[12] *Projections of Energy Supply and Demand*, p. 137.

[13] *Productivity Indexes, 1977 Edition*, pp. 75–76.

Table 5. Indicators of change in petroleum refining, 1960-75

Indicator	Average annual percent change[1]		
	1960-75	1960-66	1966-75
Payroll per unit of value added	-3.2	-6.3	-1.0
Capital expenditures per production worker	13.4	9.1	10.7

[1] Linear least squares trends method.
SOURCE: Bureau of the Census.

iod, having registered sizable increases for several years.

Productivity differences

Data on productivity differences among establishments in an industry with a high degree of specialization may provide some insight into the factors associated with high productivity performance within the industry. In a study of 1967 Census data,[14] petroleum refineries were ranked by value added per production worker hour to provide a rough indication of the range of productivity differences. In this industry, average value added per production worker hour in the highest quartile was almost 11 times greater than in the lowest quartile.

Wide productivity differences in the refining industry may reflect differences in size, management, complexity (type of processing), labor, capital outlays, etc., but the limited data preclude general conclusions. Nevertheless, the 1967 data suggest that size may be important (table 6). Establishments in the highest quartile had an average employment almost four times greater than those in the lowest quartile. This is verified by studies[15] which show that labor productivity increases with capacity and with employment, up to a point. Small plants must maintain a minimum staff of operators and maintenance and technical personnel to run the refinery; as capacity increases, the number of production workers needed per thousand barrels of output declines sharply. But at some point, the advantages of size may be offset by duplication of process units.

Capital expenditures

Capital expenditures for refining plants increased 11.2 percent annually from 1960 to 1975 to a total of $2.2 billion—more than four and one-half times the outlay in 1960. The increase, however, was not even over those years. In the first half of the 1960's, annual outlays declined or remained relatively constant; from 1965 to 1971 they rose extremely rapidly; in 1972 and 1973 they declined; and in 1974 and 1975 they jumped very sharply. The average outlay in the 1960–75 period was $917 million.

Table 6. Value added and employment in petroleum refining: Ratios of "highest quartile" to "lowest quartile" plants and to average plant, 1967

Measure	Ratio of highest quartile to lowest quartile	Ratio of highest quartile to average
Value added per production worker hour	10.7	1.8
Average employment per establishment	3.7	1.5

NOTE: Establishments were ranked by the ratio of value added per production worker hour.

SOURCE: Based on unpublished Census Bureau data prepared for the National Center for Productivity and Quality of Working Life.

These data, however, reflect costs unadjusted for changes in prices. Adjusting the dollar figures by the Nelson index of refinery construction costs[16] reveals that real investment barely doubled from 1960 to 1975. From 1966 to 1975, real investment rose one and one-half times compared with three and one-half times for dollar outlays. However, increases in refinery costs were offset by the greater efficiency of plant and equipment. When adjusted for productivity changes by Nelson's "true cost" index, adjusted real capital outlays rose two and one-half times in those 9 years, and almost three and one-half times from 1960.

Petroleum refining is highly and increasingly capital intensive. Labor costs were less than 13 percent of the value of the product in 1975 (compared with 48 percent in all manufacturing), having dropped sharply and steadily from 34 percent in 1960. As capital expenditures rose sharply and the number of production workers declined from 1960 to 1975, capital outlays per production worker rose almost sevenfold. After adjustment for price and productivity increase, real outlays per production worker rose almost fivefold.

These large capital expenditures resulted in additions to daily capacity of 3.2 million barrels, an increase of 24 percent in the 5 years from January 1972 to January 1977. From January 1974 to January 1977, 28 "grass roots" plants were built, accounting for slightly over 20 percent of the total increase in operating capacity in those years.[17] However, almost

[14] Based on unpublished data prepared by the Bureau of the Census for the National Center for Productivity and Quality of Working Life.

[15] Studies by W.L. Nelson published in the *Oil and Gas Journal.* See "Maintenance Material and Labor", Jan. 13, 1975, pp. 57–59.

[16] Nelson Index published in the *Oil and Gas Journal.* See issue of Jan. 26, 1976.

[17] *Trends in Refinery Capacity and Utilization* (Federal Energy Administration), June 1976, pp. 4 and 7, and June 1977, p. 14.

all of these were very small, of very simple design and limited flexibility. With incentives available to small refineries, 19 of these new plants had less than a 10,000-barrel daily capacity. Only one had a capacity of more than 40,000 barrels.

There is no general agreement on the outlook for capital expenditures for expansion. In addition to judgments on the need for additional capacity, capital outlays for expansion will be influenced by the increasingly heavy costs of new plant and equipment. In general, however, there is agreement on the necessity to modify existing facilities to cope with changing demand and supply conditions. Even in this, there is a wide range of views relating to the future course of gasoline demand and likely developments in coal gasification and liquefaction. In addition, future government environmental and energy policies will affect capital outlay decisions. Of great concern is the increase in environmental protection costs, which averaged 12 percent of the total petroleum industry's outlay in 1975;[18] data for the refining sector alone are not available.

Employment and Occupational Trends

Employment

About 160,300 people were employed in the refining industry in 1977, the largest number since 1962 (chart 7). A decline starting in the late 1940's continued unabated through the mid-1960's, reflecting the very sharp increase in productivity through most of the period. After 1973, however, employment turned up again.

In the first half of the 1960's, the sizable employment decline was associated with a sharp reduction in the number of refineries and a productivity growth rate which was more than double the rate of growth of output. From the mid-1960's to 1973, employment was relatively stable, although it dipped to a low point of 145,000 in 1969. After 1973, however, several years of rising employment brought the level up to that of the early 1960's. This change in the direction of employment reflected, in addition to technology changes which required more unit labor, an increase in the number of very small refineries. Overall, from 1960 to 1977, a relatively moderate annual average employment decline of 0.3 percent was registered.

Refinery employment to 1985 is projected to resume its decline. Based on the economic assumptions stated in the introduction, the BLS projects a decline to 137,000 employees in 1985, or a drop of 1.9 percent annually from 1977 to 1985.

These data reflect the technological, structural, and skill changes which have affected employment in the industry. A modern refinery today with an input of 100,000 barrels per day employs about 300–350 workers on three shifts. An older refinery with that capacity which has been modernized employs about 700 workers; that same plant would have employed almost 1,000 persons in the 1950's.

[18] Data from the Bureau of the Census.

Occupations

As discussed earlier, technological and structural changes are altering traditional concepts of job content and duties. More importantly, duties are being consolidated, as in the case of maintenance crafts, or partially removed from the refinery, as in the case of contract maintenance.

Maintenance craft consolidation is an important labor development of the last decade which increases the flexibility of the work force while it reduces the number of workers required per processing unit. Under most maintenance consolidation plans, skilled workers who have attained journeyworker status in one craft are trained to handle other crafts (for example, a boilermaker who learns pipefitting), thus eliminating the need for several workers, each with a specific craft duty. Such consolidation is becoming more widespread. Of 104 refineries studied by BLS in 1976, about one-fourth reported craft consolidation plans, double the number reported in 1965.[19] In most plants, consolidation was limited to two designated crafts but in many plants consolidation incorporated all maintenance crafts. These skill combinations fall into a single job classification, "general mechanic." A further development of this practice is the combination of operative and maintenance skills by one worker, who may be known as a "running operator." Two running operators can handle a processing unit of 100,000-barrel capacity, compared to three operators and a maintenance worker required in the average refinery of similar capacity.

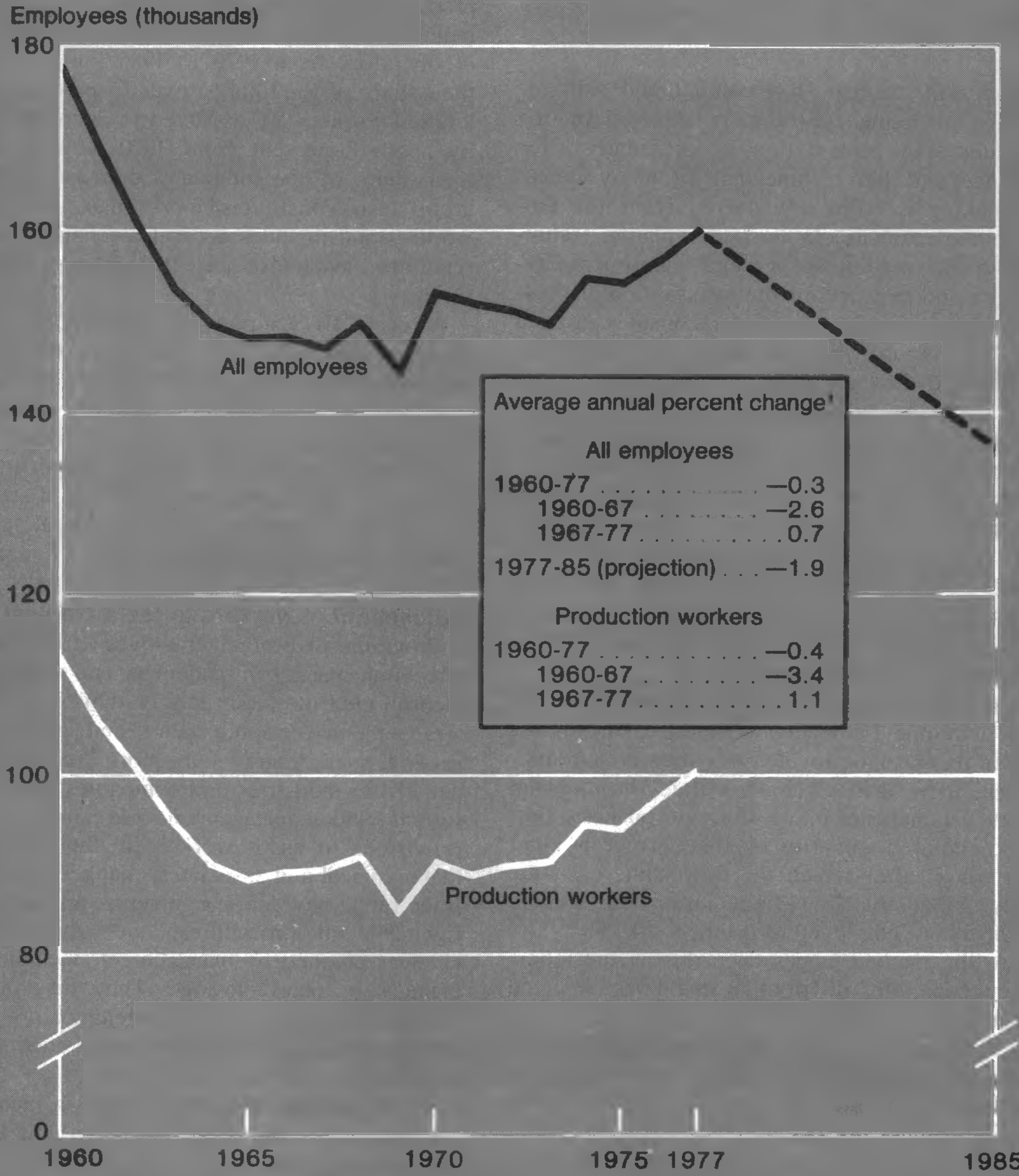
The trend to maintenance craft consolidation may in time contribute most importantly to revising job content and standard occupational patterns. By eliminating the lines of craft duties, craft consolidation practices generally establish new single job classifications with new duties and training.

Contract maintenance is performed by workers supplied by outside firms on a contract basis, and permits a refinery to have a relatively small year-round maintenance staff. Although contract workers are generally used for special peak work periods such as during shutdown, they may also be employed year round on regular maintenance. Prior to the practice of contract maintenance, a refinery

[19] *Industry Wage Survey; Petroleum Refining, April 1976*, Bulletin 1948 (Bureau of Labor Statistics, 1977). See also BLS Bulletin 1741, p. 2, for April 1971 data.

Chart 7

Employment in petroleum refining, 1960-77, and projection for 1977-85



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

Source: Bureau of Labor Statistics.

might have had a ratio of 2 maintenance workers to 1 operator. Now, excluding contract workers, the ratio of maintenance workers to operators in that refinery may be 1 to 2.

The practice of contracting out is reducing employee hour requirements in the refinery, but data are not available on its extent. The importance of this practice is evident in the fact that in this industry 9 of 13 labor-management contracts (covering 1,000 workers or more) studied by the BLS in 1975 contained provisions limiting subcontracting.[20]

Job and skill changes. Job content and skill requirements are being substantially changed by the sophisticated instrumentation, particularly for maintenance and lab technicians. In many cases, decisionmaking is being transferred from the employee to the machine. In the older plants, technicians may take readings of various instruments every 4 hours and may record the information manually. In modern refineries, computer consoles in each process unit record the data from on-line instruments and feed the data into a central computer system. As many as a thousand signals can be received by the computer and checked against limits for problem areas. In blending, for example, several products must go into the finished gasoline in proper proportions. To do this, the operator merely sets the controls for the specified percentages, etc. Samples from the stream are then automatically analyzed; changes can be made by the operator. The computer will continuously monitor the process and report information on demand.

Manual skills, already at minimum levels in the refinery, continue to decline. Even the truckdriver who loads the gasoline for delivery uses an automated system. The driver removes the cover of the tank, puts a punchcard into a slot, and pushes a button. The required quantity of the correct product fills the truck, after which the flow shuts off automatically. When this job is not automated, loaders and pumpers are employed to do the work.

Due to the many changes occurring in the industry, the occupational distribution in 1985 is expected to be significantly different from the 1970 pattern. In the BLS projections of occupational employment, professional and technical workers, more than one-fifth of all refinery workers, are expected to decline moderately from 1970 to 1985 but to retain about the same share of total employment (chart 8). This is in contrast to the pattern of the 1960's, when professional and technical workers rose very sharply both in number of jobs and as a proportion of total employment. The major occupations in this group are chemical engineers, chemical technicians, and computer personnel. Other occupations are chemists and engineers.

Operators constituted almost one-fourth of all refinery workers in 1970, approximately the same proportion of total employment as professional and technical workers. Chief operators, numerically one of the largest groups of workers, are the highest paid production workers in the refinery. BLS projections indicate a decline of about 8 percent in the number of operators from 1970 to 1985 but an increase in their share of the total to over 25 percent. Craft and kindred workers are expected to decrease in number by about 7 percent from 1970 to 1985; however, their share of the total may increase slightly. This group also constitutes more than one-fifth of all workers and includes general mechanics, instrument repairers, machinists, electricians, pipefitters, and welders.

A recent BLS survey[21] of occupations in this industry reaffirms the very large proportion of skilled workers. Skilled maintenance workers constituted one-fifth, and chief and assistant operators one-fourth, of all production workers in 1976.

Laborers constituted a small proportion of employment—only 3 percent in 1970—and are expected to decline further by 1985 as manual handling of materials becomes obsolete.

Adjustment of workers to technological change

Programs to protect employees from the adverse effects of changes in machinery and methods 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. 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, including machine changes or plant closings. They may also include various types of income maintenance programs such as supplementary unemployment benefits or severance pay.

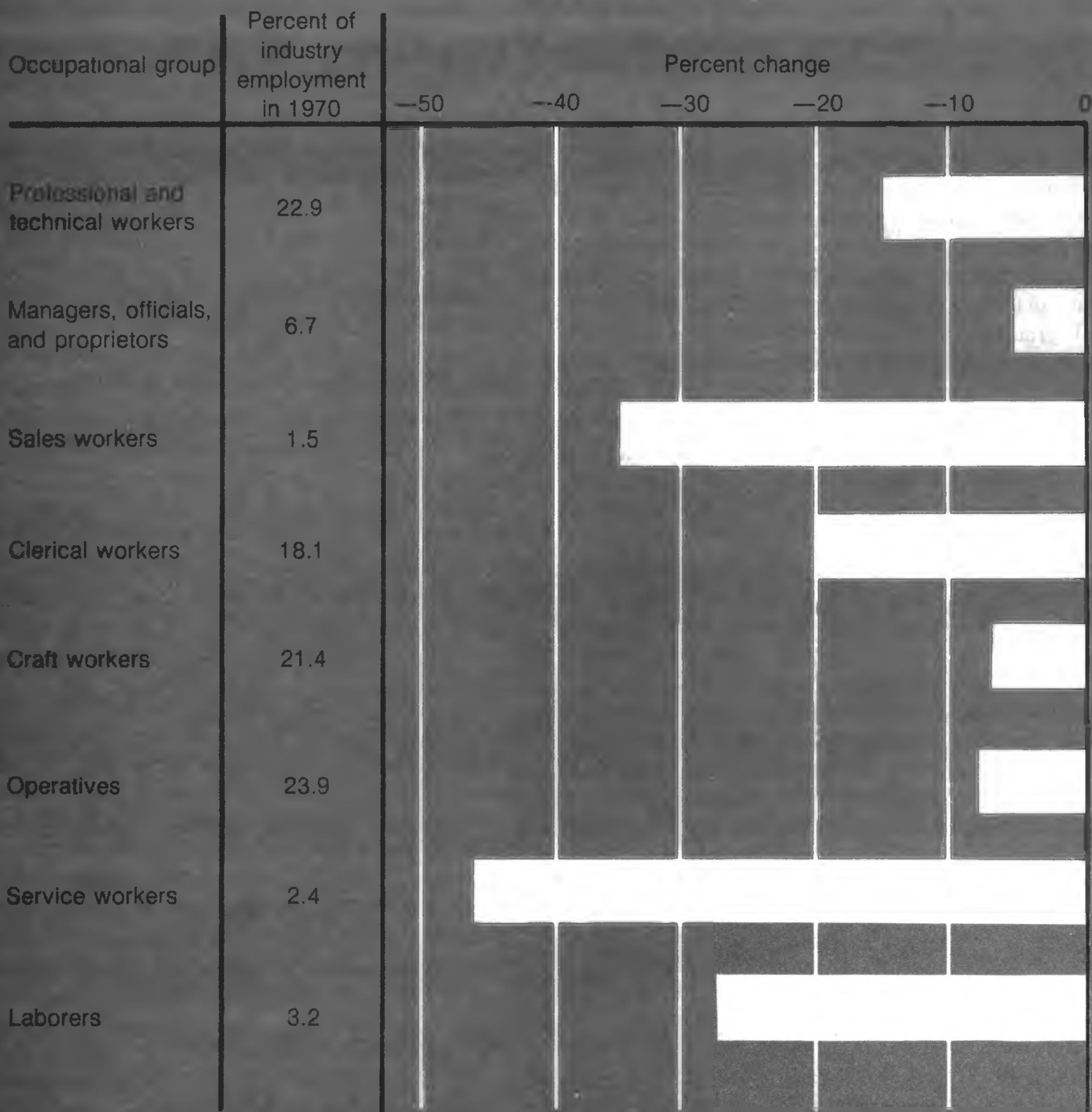
In the refining industry, there is a high degree of unionization; approximately 90 percent of the employees are covered by collective bargaining agreements. Contracts usually run 2 years, and negotiations are conducted on a company basis, with the first settlement establishing the pattern for later bargaining. The Oil, Chemical and Atomic Workers

[20] *Characteristics of Major Collective Bargaining Agreements, July 1, 1975,* Bulletin 1957 (Bureau of Labor Statistics, 1977), p. 86.

[21] *Petroleum Refining, April 1976,* BLS Bulletin 1948, table 1.

Chart 8

Projected changes in employment in petroleum refining, by occupational group, 1970-85[1]



[1] Based on the latest occupational data for 1985 adjusted for revisions of the 1985 employment projections.

Source: Bureau of Labor Statistics.

Union (OCAW) represents about two-thirds of the workers covered; the other third are covered by several independent unions—the Teamsters, the Operating Engineers, and an affiliate of the Seafarers' Union.

As mentioned earlier, 13 major agreements covering 1,000 workers or more were studied by the BLS in 1975.[22] In these contracts, covering 25,000 workers, employee seniority was generally the determinant in the order of layoff and recall, assuming equal ability. Interplant transfers and preferential hiring opportunities for displaced workers were mentioned in 8 of the 13 agreements, covering 13,200 workers. Four agreements provided relocation allowances for transferred workers.

Training for new skills and changing job content is a continuous process in most refineries. Of the 13 agreements studied by the BLS, 4 had apprenticeship provisions, and 7 provided for on-the-job training. In refineries visited by the BLS staff, training is required for 4 years or more for a senior technician. In one plant, the new worker, generally a high school graduate, receives 4 months of classroom training covering refinery equipment and the math and chemistry needed for the job. The trainee is then assigned to a shift but continues with on-the-job training, spending about 5 months on each of four assignments. After 2 years, the trainees are qualified as refinery technicians. In some refineries, the ladder of promotion may be from technician I to technician IV, with perhaps 1 year or more between grades.

Although seldom cited specifically, technological change is often the major factor in job reclassification provisions. One contract stated, "If during the term of this agreement, a significant change in job content has been effected by the Employer to the extent that a wage rate is considered to have become inappropriate . . . , the union may request in writing a study and analysis of the job involved . . . , any dispute arising in regard to the wage rate of such job shall be the subject of negotiations and shall not be subject to the grievance procedure."

[22] *Major Agreements*, BLS Bulletin 1957, pp. 86,87,89.

Advance notice to the workers of plans for layoff or plant shutdown or relocation was required in 10 of the 13 contracts studied by the BLS, a considerably larger proportion of contracts and of workers than in all manufacturing in the case of plant shutdown or relocation and somewhat larger in the case of layoff. However, in only one contract was there specific mention of advance notice of plans for technological change.

Changes which can result in a reduction in force, possibly from technological change, were covered in one contract as follows: "The company will give the union 14 days notice when job classifications are to be eliminated or when changes are to be made . . . in a classification." Severance pay provisions were more common in petroleum refining contracts than in most other manufacturing industries. All refinery contracts had provisions for grievance and arbitration, procedures found in almost all major collective bargaining agreements in manufacturing.

Cooperation between workers and management was reaffirmed in the "Memorandum of Agreement" of one of the major contracts which concerned the "job security of employees who may be affected by technological improvements, the construction of new units or the establishment of new processes." This agreement stated that the union "will continue to cooperate in adopting more efficient work practices . . ." and the company "will manage its operations and its work force in such a way that layoff . . . will not occur." When the company decides layoffs are unavoidable, 60-day written notice is required. If, after discussion, labor and management are unable to resolve the problems," . . . then either party may at any time terminate the basic agreement upon 60 days written notice."

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Chapter 4. Petroleum Pipeline Transportation

Summary

Refinements in the application of existing technologies rather than new inventions are expected to continue to be the primary source of productivity gains in the petroleum pipeline transportation industry.[1] Expanded use of improved computer applications are anticipated for pipeline delivery scheduling, field process control, and administrative business and auditing work. Occupations affected by advanced computer applications include process control operators located at field stations, whose responsibilities are being transferred, in part, to headquarters control, and schedulers, gaugers, and accounting clerks whose job duties also are being modified as computers increasingly perform more complex tasks. Additional improvements in plant and equipment, such as wider diameter pipe of higher tensile strength and pumping stations of standardized design, will probably permit faster throughput of a larger volume of product and require fewer technicians to maintain the pipeline.

The diffusion of technological refinements, combined with expected increased demand for petroleum products and more capital stock per worker, should promote productivity growth by making possible both a larger output and increased productivity of production workers. However, the higher level of capability of the physical plant requires a wider technical background for such workers as schedulers, dispatchers, and technicians.

As the demand for crude oil and other petroleum products has grown, pipelines have increased their share of the petroleum transportation payload by expanding their trunkline capacity through the addition of mileage and of pumping stations. The outlook for petroleum pipeline transportation starting in the mid-1980's depends mainly on the volume of offshore and Alaskan production, the level of imports, construction of deepwater ports, and the availability of refinery capacity in the lower 48 States.

Employment, after declining steadily from 1960 through 1973, rose slightly in 1974 and the two following years to a total of 16,700 and then dropped to 16,600 in 1977. Production worker employment followed a similar pattern through 1974, but declined starting in 1975 to 12,100 in 1977. A small increase in total employment is projected through 1985. A decline is expected for craft workers, operatives, service workers, and laborers, while employment gains are anticipated for professional and technical, managerial, sales, and clerical workers.

Technology in the 1970's

Improved computerized scheduling and linking of on-line and central control computers are helping move a larger volume of crude oil and petroleum products more efficiently through pipelines with less workload for schedulers, accounting clerks, and dispatchers. Productivity for complex pipeline scheduling is being increased through better computer programs for data base updating, original and revised scheduling, and shipment report preparation. Further computerization of nonoperating functions such as engineering calculations for pipeline design and accounting tasks will probably effect additional labor savings. For many pipelines, monitoring and regulatory tasks, including the operation of unmanned pumping stations, are performed by headquarters dispatchers using solid state electronic telecommunications equipment and computers. When the central control computer at headquarters does not receive operating data, workers using minicomputers at online stations take over control on recently constructed or renovated lines. Efficiencies such as interchangeability of parts, more economical space utilization, and uniform work plans which reduce the workload of maintenance workers are being introduced in new plants. Advances are also being made in plant and equipment design and installation methods, which further reduce maintenance workload. (See table 7 for a brief overview of the major technological changes in petroleum pipeline transportation, their labor implications, and expected diffusion.)

[1] This study covers SIC 4612, 4613, establishments primarily engaged in the pipeline transportation of crude petroleum and of refined products of petroleum such as gasoline and fuel oil. Data on employment and occupations are for SIC 46, pipeline transportation (except natural gas), which approximates SIC 4612 and 4613, since only a limited number of employees are associated with slurry pipeline operations and other activities included in the broader SIC 46 definition. A typical pipeline is owned by more than one oil company and in the past has operated as a public carrier under Interstate Commerce Commission (ICC) regulations. Starting Oct. 1, 1977, the Federal Energy Regulatory Commission (FERC), Department of Energy, became the interstate oil pipeline regulatory agency.

Computer scheduling

The efficient and safe receiving, handling, and delivery of a variety of petroleum products owned by different shippers require the collection of a mass of information and its coordination into a pipeline delivery schedule. The schedule must be precise or output and productivity of the pipeline will be affected adversely. Computer scheduling had been introduced by about 10 percent of the pipelines in 1971 and since has spread to many of the larger companies. A method superior to manual scheduling has been developed whereby the computer tabulates a 60-day advance schedule and incorporates changes anticipated more than 5 days in the future. The process consists of assembling a set of pumping instructions for the dispatcher and a guide for the shipper's shipping and delivery departments indicating when to supply petroleum products for entry into the pipeline and when to anticipate delivery at various terminals. Three computer subsystems are necessary to operate the scheduling program—a data base, a forecast schedule, and a report generator. Once the computer data base necessary for scheduling has been set up, the workload of computer specialists, schedulers, and clerical assistants is reduced.

One company reports that, despite a doubling of petroleum transported through the pipeline, an advance from a first- to a third-generation computer required the addition of only one scheduler and one clerk to a staff of three schedulers, a coordinator, and a supervisor—a substantial gain in petroleum throughput per employee. A single scheduling task previously requiring 3 days is now completed in 6 hours.

Other nonoperating functions performed in central offices and generally computerized by pipeline companies involve administrative and business work. Business-related data are frequently received directly from stations in the field; consequently, some tasks of accounting clerks are eliminated. The increased workload handled by computers may result in more jobs for machine servicers and computer technicians.

Centralized computer process control

By linking on-line computers at pipeline receiving and booster stations and delivery facilities to a central computer, processes are being controlled from the headquarters location of an increasing number of larger pipeline companies. The data received by the central computer from on-line readings of temperatures, pressures, gravity, and flow rates provide a base for the centralized performance of specific tasks—whether in monitoring the total operation or in storing information. Calculations required to keep track of tankage and line inventory, receipt and delivery volume moving in and out of the line, and batch arrival and delivery time are updated by the central computer, and instructions are communicated to remote supervisory control equipment on the line for the operation of pumping units, valves, and setpoint controllers. Also, upsets and abnormal operating conditions are sensed quickly at the headquarters location and corrected.

A monitoring program keeps the on-line system under continuous surveillance by scanning all readings and checking valve positions and unit running status. In addition, the computer checks the validity of the readings by analyzing their deviations, ranges, and rate of change. Data are transferred to a centrally located computer control panel whose operator (dispatcher) controls unmanned pumping stations. Before automatic devices were installed to measure the quantity of oil gathered for shipment, pipeline employees took readings of producers' tanks regularly and opened and closed pumping station valves manually. With automatic metering of transfers from the fields to refineries and connecting pipelines, labor requirements for reading gauges are reduced.

Generally, as scheduling and control functions are increasingly computerized, relatively fewer technicians are needed at the central control location but their required skill level is higher. Also, as more complex tasks are transferred to computer control, the demands on data processing support services are increased. Programmers and analysts are needed not only to prepare the scientific research and development work of engineers and pipeline designers for computer processing but also to introduce the technological innovations developed.

Plant and equipment

Improvements in physical plant, including pipe, pumps, communications systems, and equipment housing, combined with better installation methods, make possible productivity gains by permitting greater throughput. They also lead to improved safety, reduced maintenance, and better field control of the movement of petroluem products through the pipeline if central headquarters loses communication. Planning these improvements and putting them into effect require more work by engineers.

Pipe size. The size of mainline pipe has risen steadily over the years, from the 36-inch diameter pipe used by one company in 1962 to the 48-inch pipe used for the Alaskan pipeline. Since line capacity is determined by the diameter of the pipe raised to the 2.65 power, larger diameters result in significant economies of scale with little or no additional labor. Under code requirements, with larger diameters the thickness of the pipe wall must increase to

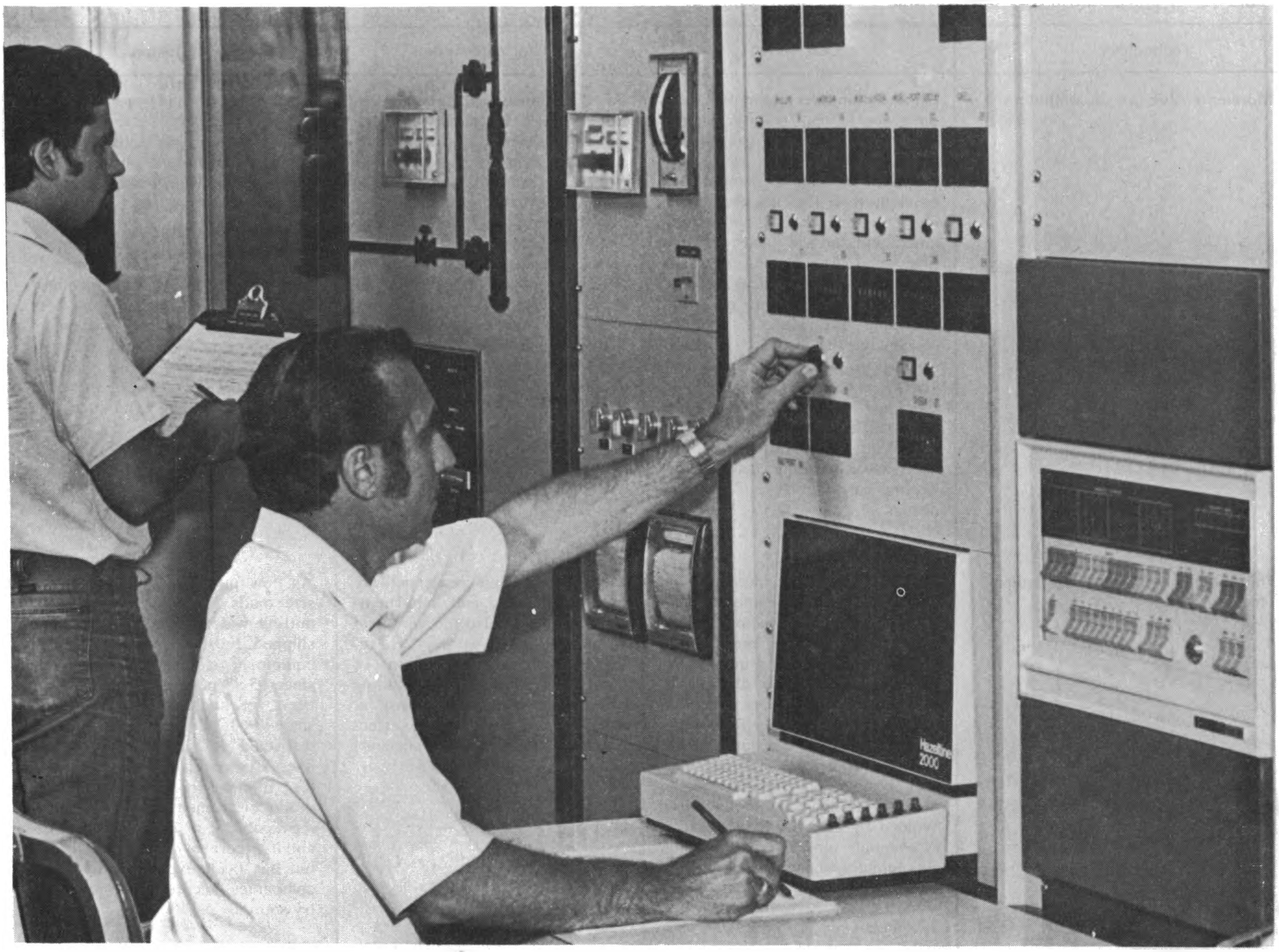
Table 7. Major technology changes in petroleum pipeline transportation

Technology	Description	Labor implications	Diffusion
More extensive use of computers	On-line computers read temperatures, pressures, gravity, and/or flow rates from tank gauges and meters. These data are transferred to the central computer at headquarters for tracking tankage line inventory, batch volume, and arrival and delivery time, and for making dispatch calculations. The central computer stores information, performs operating procedures such as sequencing the insertion of batch separators and scraper traps, starting a pump unit at a specific time, and picking up the status of alarms. The cental computer also carries out nonoperating functions such as accounting tasks, engineering calculations, and pipeline design.	Some workload at the cental location declines for schedulers and accounting clerks; shifts of tasks from the field to dispatchers at central control, in general, tend to reduce the workload of process control operators; work is lessened for gaugers in the field and for accounting clerks at central headquarters with direct input of data. The need for computer specialists and technicians skilled in the operation of computer equipment rises as computerization expands.	According to the most recent available industry survey (1971), 22 percent of pipeline companies acquire data through on-line computers. 7 percent make dispatch calculations using data acquired on line and 9 percent perform control functions and make status inquiries from a cental control location. 78 percent of all pipeline companies use computers for accounting, 69 percent for engineering calculations and 51 percent for pipeline design.[1] Since 1971, computer use has spread widely, according to an industry source.
Improvements in plant and equipment	Mainline pipe has increased in diameter, wall thickness, and strength. Pumping station design and equipment have been standardized, with pumping units combined by size to allow changes in operating capacity depending on viscosity of product. Delivering stations use storage tanks with built-in protective features and also drainage techniques as a warning system. Contamination is avoided by design advances such as adequate pipe size and heating and pumping capacity.	More engineering personnel are used in planning and implementing efficiencies; also the workload of maintenance workers is reduced with standardization of layout and equipment. Upgrading safety protection and control at stations lessens the tasks of electrical and mechanical technicians.	As new pipelines are built, pipe size tends to be increased, permitting wider latitude in volume shipped. Further gains in pumping equipment efficiency are limited since 95-98 percent efficiency has been reached, up 5-10 percent since 1960.[2] Design advances are restricted to newly constructed lines. Computerization is required for minimal contamination of product in transit and for scheduling flexibility; in 1971, restricted to about 9 percent of the pipelines[3] but has been expanded to many companies, according to an industry source.
Improvements in pipeline installation methods and materials	More station equipment is installed outdoors, and highway crossings are better marked. Automatic welding is used for joining many line pipe sections and for laying down filler and cap passes in the field. Girth welds are examined radiographically. Specially designed pneumatic bending mandrels shape pipe to ground contours without buckling or loss of roundness. Pipe coating materials are more specialized for protection according to soil and water conditions.	Construction methods which reduce somewhat the number of structural failures lessen the tasks of mechanical and corrosion technicians and utility workers.	In new pipeline construction, the most recent advances in materials and methods are implemented. Also, as lines are located in areas with unfamiliar climatic conditions, experimental testing precedes the actual laying of pipe.

[1]C. T. Carter, "What's Ahead for Liquids Pipe Line Automation," *Pipeline Industry*, Part I, April 1973, p. 25.

[2]Information provided by M. U. Bagwell, Pipeline Engineering Specialist.

[3]Carter, op. cit., p. 25.



Engineers measure, control, and monitor pipeline shipments by minicomputer

meet the added stress. The quality of steel pipe has advanced in strength and weldability to meet these more rigid standards. The combination of wall thickness and grade of pipe steel may vary according to the location of the pipe section along the line, with higher specifications indicated for the discharge side of pumping stations, congested areas, and river crossings. In general, the cost of steel per unit of product transported decreases as the pipeline diameter increases, since the number of tons of steel required per mile for 1,000 barrels of daily capacity also decreases.

Pumping stations. Pumping stations throughout some systems have been improved by the standardization of layout and equipment. Consequently, the building to house station switchgear and controls, some office and repair facilities, and station piping may be prefabricated, reducing construction labor requirements and overall construction costs.

Larger capacity pumping units have been designed and built to service the more sizable pipelines recently constructed. The number and size of pumping units per station are standardized, and several large units are combined with a smaller one. By cutting off the smaller unit when pumping oils of higher viscosity, both flow speed and risk of equipment damage may be reduced. As larger diameter pipe is installed, the capacity of each unit is increased. Consequently, expansions in capacity do not require comparable expansions in maintenance crews, as the number of units of equipment does not usually increase.

Centrifugal pumps and auxiliary equipment at main line stations of newly constructed pipelines typically are interchangeable from one station to another. As standardization is introduced, uniform programs result in labor savings for technicians.

Delivery stations. A new type of tank has been designed to store petroleum temporarily removed from the pipeline and awaiting delivery to the customer. Automatic firefighting equipment and an improved warning system for leakage protect the storage tanks. These built-in safety factors reduce output losses and tend to lessen routine maintenance work.

Communication systems. Central headquarters of major pipelines are usually linked to on-line pumping and delivery stations and storage tanks by an automated communication system equipped with two process control computers. One computer actively runs the system while the second provides standby capacity in case the primary computer fails. The automated communication system may use ultrasonic controls to monitor the flow level of the pipeline and of inventory stored in tanks at remote locations and to report immediately any malfunction or power failure. Surveillance of every line at central control is facilitated for dispatchers by equipment sequenced automatically to stop all valves. The operator is able to throw a switch on the console to block the line and stop the problem.

The automated control system shifts the workload from the minicomputer operator at the on-line station to the dispatcher at headquarters and eliminates the need for continuous local manning (usually three one-man shifts). With the advance in telecommunications from mechanical relays to solid state electronic equipment, a higher skill level is required of technicians doing the servicing as well as of headquarters dispatchers manning the control system.

Installation methods

Advances in pipeline construction tend to decrease maintenance requirements. More stations are now built with equipment installed outdoors (where weather permits). The marking of highway crossings is being improved to lessen the frequency of accidental ruptures of the line and thus to reduce repair requirements. In laying the pipe, the number of joints which must be welded onsite is minimized by joining as many line pipe sections as possible with automatic welding equipment in special yards. Welders using fully automatic welding machines at these yards complete pipe welds at more than double the rate possible with the conventional manual arc welding methods used onsite. Girth welds are examined radiographically and pipeline weld crews also make gamma ray inspections. Pipes are shaped to the contour of the terrain without buckling or loss of roundness by especially designed pneumatic bending mandrels. All these advances in pipe installation methods are expected to reduce maintenance labor requirements. Also, new techniques for coating, laying, and testing pipe at the time of installation improve the durability of the pipeline and reduce the workload of mechanical and corrosion technicians and utility workers in repairing defects.

Product quality control. Precautions against losses from pipeline shutdowns include measures to reduce product contamination and leakage. Engineers are combining knowledge of scientific principles, materials, and equipment (computers, geiger counters, airplanes, etc.) to maximize deliveries with minimum contamination. Systems are being designed using pipe of adequate size to maintain a turbulent flow, batches are scheduled in the largest possible quantities to minimize the number of connections required, and products are cycled in the most advantageous sequence. By adding furnaces and horsepower to plant equipment, crude oil may be heated to reach flow speed.

When on-line computers are used in the field to track separate batches of petroleum flowing through the pipelines, the standard procedures used by technicians to identify a batch change—comparing color differences between two products or spotting a dye tracer—are no longer required. Hence one task of technicians at some delivery stations is eliminated. Further, on-line computerization has advanced so that process control operators in the field are able to schedule the passage through the pipeline of a batch separator, an automatic scraper, or a polyurethane cleaning tool to remove waxy coating, water, or sediments from interior walls. These changes reduce the workload of mechanical technicians.

A computer-controlled leak detection system has been developed which displays leaks to dispatchers monitoring the pipeline. More conspicuous pipeline location indicators are being posted to avert ruptures from earthmoving equipment and other sources which interrupt production and damage the environment. Also, inspection from the air is being increased. Every week an air patrol inspects the entire pipeline to discover excavation work, locate spots indicating leaks, and check fences and cathodic protection units. The patrol also makes two additional weekly flights over congested areas. Inspectors patrol water and telephone circuits in metropolitan regions to narrow the danger of ruptures. These methods to protect output are expected to reduce labor requirements of maintenance crews for repair work.

With the upgrading of measures to avoid ruptures and improved product control at a station, the duties of operators and maintenance staff usually become more diversified. For example, electrical and mechanical technicians with some operating duties also perform preventive maintenance. Or field personnel may assume additional responsibilities usually performed by minicomputers when communication with headquarters is interrupted. Conversely, the introduction of advanced computerization results in a transfer of some routine workload from the field to personnel at central headquarters.

Extension of a main pipeline or of delivery feeder lines requires acquisition of a right-of-way. The real estate and legal work involved in acquiring the right-of-way is currently being subcontracted by some pipelines to specialists, with a consequent decline in the tasks of their professional personnel.

Production and Productivity Outlook

Output

Output, defined as the total number of barrel-miles of crude oil and other petroleum product traffic handled in trunk lines, grew at an average annual rate of 5.9 percent from 1960 through 1977, based on Interstate Commerce Commission data. The yearly rate reached 7.7 percent in 1960–67 and declined to 3.9 percent during the 1967–77 period (chart 9).

Growth in output during 1960–76 was attributable to continuous expansion in demand for crude oil and other petroleum products and steady additions through 1974 to total trunk line mileage in operation. (A 3-percent drop in mileage operated occurred in 1975.) For the 1960–76 period, demand expanded over 80 percent[2] and miles of trunkline in operation increased about 30 percent.[3] Pipeline transportation also was gaining in importance over the railroad, trucking, and maritime industries as the mover of petroleum products. Its share of total tonnage of crude petroleum and products rose from 43 percent in 1960 to 48 percent in 1976.[4]

Significantly, trunkline capacity increased more than would be indicated by the rise in the number of trunkline miles in operation. The new steel pipe of larger diameter and higher tensile strength (which allow more rapid throughput) also contributed.[5] For example, between the start of 1962 and 1965, petroleum pipeline capacity measured in miles increased 5 percent but pipeline fill measured in barrels increased 17 percent. Line capacity was also enlarged by the addition of pumping stations which improved the flow rate.

Productivity

Productivity (output per hour for all employees) grew at the average annual rate of 7.9 percent in the 1960–77 period, peaking at a 10.7 percent rate for 1960–67 and dropping off to 5.3 percent for 1967–77. The 1960–77 increase exceeded the gain in output, reflecting a 1.8-percent average annual decline in all-employee hours. Petroleum pipelines ranked seventh in productivity growth between 1970 and 1975 among the more than 50 industries in the private economy for which BLS publishes indexes. The industry's superior performance is probably closely related to its sustained high ratio of capital stock per worker and its high rate of capacity utilization.[6]

Output per production worker hour for 1960–77 rose at an average annual rate of 8.9 percent, a higher rate of increase than for output per all-employee hour. Average annual hours of production workers fell at a 2.7-percent rate, a sharper decline than for all-employee hours, reflecting the introduction of advanced pipeline technology.

Investment

Net capital stock (in constant dollars) increased in the 1960–75 period by about 150 percent.[7] For each employee in 1975, net capital stock reached $354,000 compared to $98,000 in 1960, and for each production worker, $463,000 in 1975 compared to $115,000 in 1960.[8] Further increases are anticipated with the completion of the Alaskan pipeline and proposed additions to existing lines. In 1977, 205 miles of pipelines for crude petroleum and 3,322 miles of line for petroleum products were laid in the United States.[9] An additional 2,619 miles of crude lines and 2,196 miles of product lines were planned for 1978.[10] (In 1977, 159,268 miles of pipeline were in operation of which 51 percent were product lines.)[11]

Employment and Occupational Trends

Employment

Some 16,600 persons were engaged in petroleum pipeline transportation in 1977, a drop of over 28

[2] Data source is the U.S. Department of the Interior, Bureau of Mines.

[3] Data source is the Interstate Commerce Commission.

[4] Data sources are the U.S. Department of the Interior (oil pipelines and motor carriers), U.S. Department of the Army (water carriers), and the Interstate Commerce Commission (railroads).

[5] Data source is the U.S. Department of the Interior, Bureau of Mines.

[6] Pipelines operate at about full capacity as shipments are continuously adequate to fill the line through prior arrangement. When new pipeline transportation is needed, a group of oil companies usually form a joint venture to engage in interstate transportation of crude oil and petroleum products subject to Interstate Commerce Commission regulations as common carriers. Pipelines are designed and constructed to handle throughput over a specified route and are projected for many years into the future. Load factor is a primary consideration in decisionmaking since almost all pipeline operating costs are fixed with the exception of fuel. Each member of the joint venture guarantees to ship a fixed percentage of the load and thereby operations at full capacity are virtually assured.

[7] Source for capital investment is the Interstate Commerce Commission and for its deflator the U.S. Department of Commerce.

[8] Net capital stock per employee or production worker is derived by dividing net capital stock (in constant dollars) by the total number of employees or production workers. Source for employment is U.S. Department of Labor.

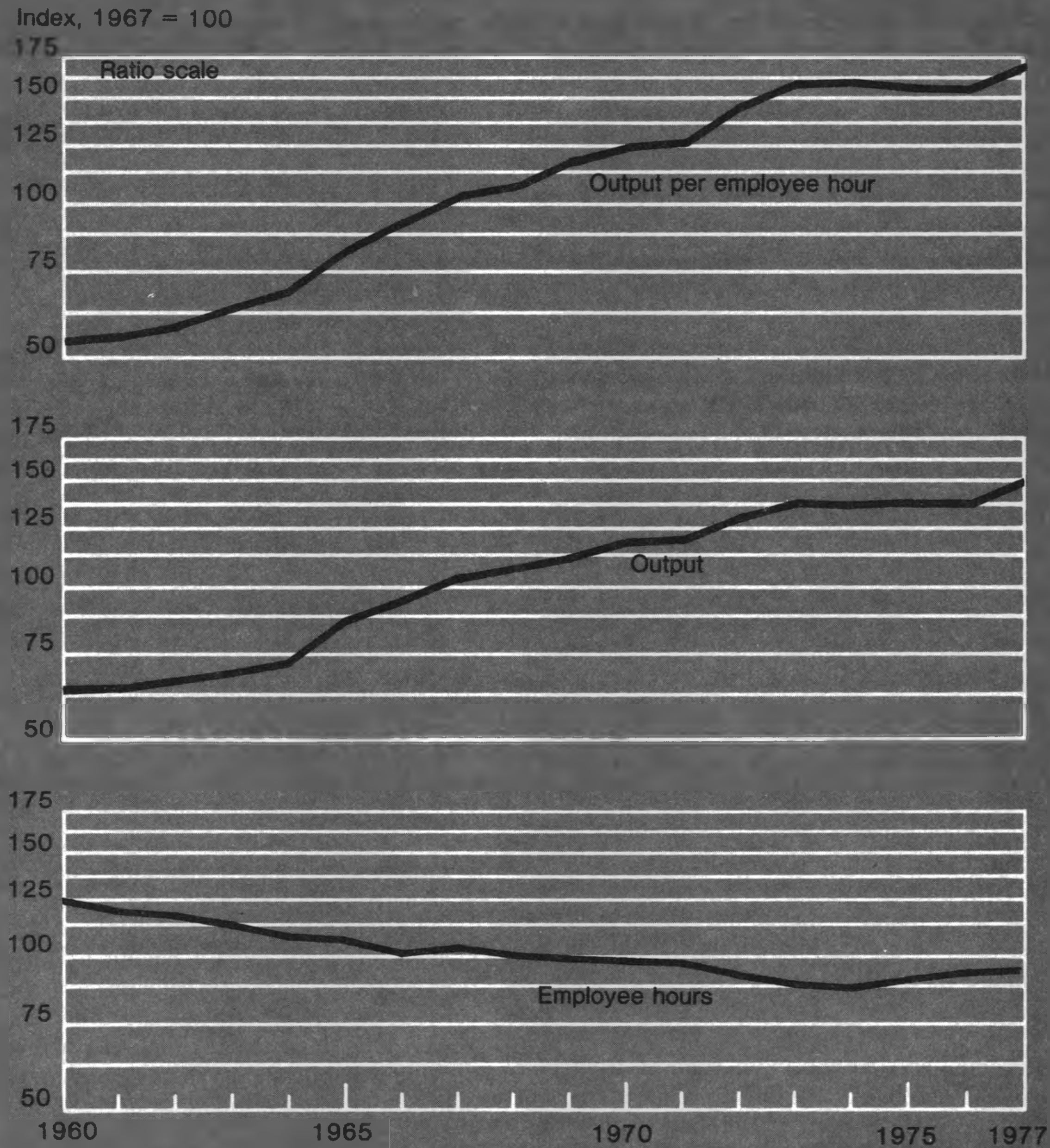
[9] "Total 9,540 Miles Line Laid in U.S.A.-Canada; 15,402 Miles Foreign," *Pipe Line News,* January 1978, p. 24.

[10] "27,585 Miles of New Lines Planned Worldwide," *Pipe Line News,* January 1978, p. 8.

[11] Data source is U.S. Department of Energy, Energy Information Administration.

Chart 9

Output per employee hour and related data, petroleum pipeline transportation, 1960-77[1]



[1] Data for 1977 are preliminary.

Source: Bureau of Labor Statistics.

percent since 1960 and an average annual decline of 2.0 percent (chart 10). The decline in employment averaged 3.1 percent a year for 1960–67 and 1.4 percent a year for 1967–77. Production workers declined at a 2.9-percent annual rate between 1960 and 1977 and decreased as a proportion of total employment from 86 percent in 1960 to 73 percent in 1977. An increase of 0.3 percent a year in total employment is projected for the 1977–85 period. (See introductory note for assumptions underlying projections.)

The decline in employment over the past two decades is explained partially by the introduction and diffusion of advanced automated equipment. As described earlier, computers have substantially reduced hours worked on line and at central headquarters for both operating and office tasks. Efficiencies in plant design and equipment together with improved installation methods have also contributed to the reduction of unit labor requirements. However, additions to trunkline mileage are expected to add jobs in the future.

The proportion of women employees in the industry fluctuated within the 7- to 9-percent range between 1960 and 1977.[12] The jobs held by women are typically located at central headquarters and tend to be concentrated in secretarial and clerical positions.

Occupations

As control of pipeline operations has been more completely centralized with advanced computerization, and as local manning of on-line facilities has been reduced, managerial jobs such as assistant regional manager and products manager have been eliminated. Also, as technology has advanced, the job content of a number of occupations has changed. Generally, persons with more education are being sought for entry level positions such as process control operator and maintenance technician. More knowledge is needed to handle routine and emergency tasks associated with more complex and costly technology.

Manual scheduling is becoming obsolete so a scheduler must be trained in both pipeline operations and computers. Dispatchers also require such dual training as they monitor the whole system centrally and must be able to isolate and shut down every line through computers (with backup support from on-line field operators). As the use of computers and telecommunications expands, additional technicians to program and service machines and to analyze data will be needed. Maintenance technicians increasingly will need both a thorough skill in their specialty and pipeline experience. A knowledge of electronic solid state communication systems, for example, will be necessary for electricians. Mechanical work also is more complex. Technology advances eliminate some gauging jobs in the field. In the office, some work of accounting clerks is becoming obsolete as many accounting entries are made directly through central control linkage with computers in the field.

The outlook is for an increase between 1970 and 1985 in the number of professional and technical, managerial, sales, and clerical workers, and a decline in craft workers, operatives, service workers and laborers (chart 11). Consistent with anticipated growth in pipeline mileage, more drafters, electrical and electronic engineers and technicians, inspectors, airplane pilots, and support personnel such as administrators, secretaries, and bookkeepers are expected to be needed. Conversely, fewer job possibilities seem likely for construction laborers, stationary engineers, and operatives such as oilers and greasers.

Adjustment of workers to technological change

The decline in employment resulting from technological change in petroleum pipeline transportation will probably be absorbed through attrition. Vacancies are frequently filled by promoting employees and supplementing the appointee's qualifications by company training. Also, as the technology advances, the industry conducts training programs.

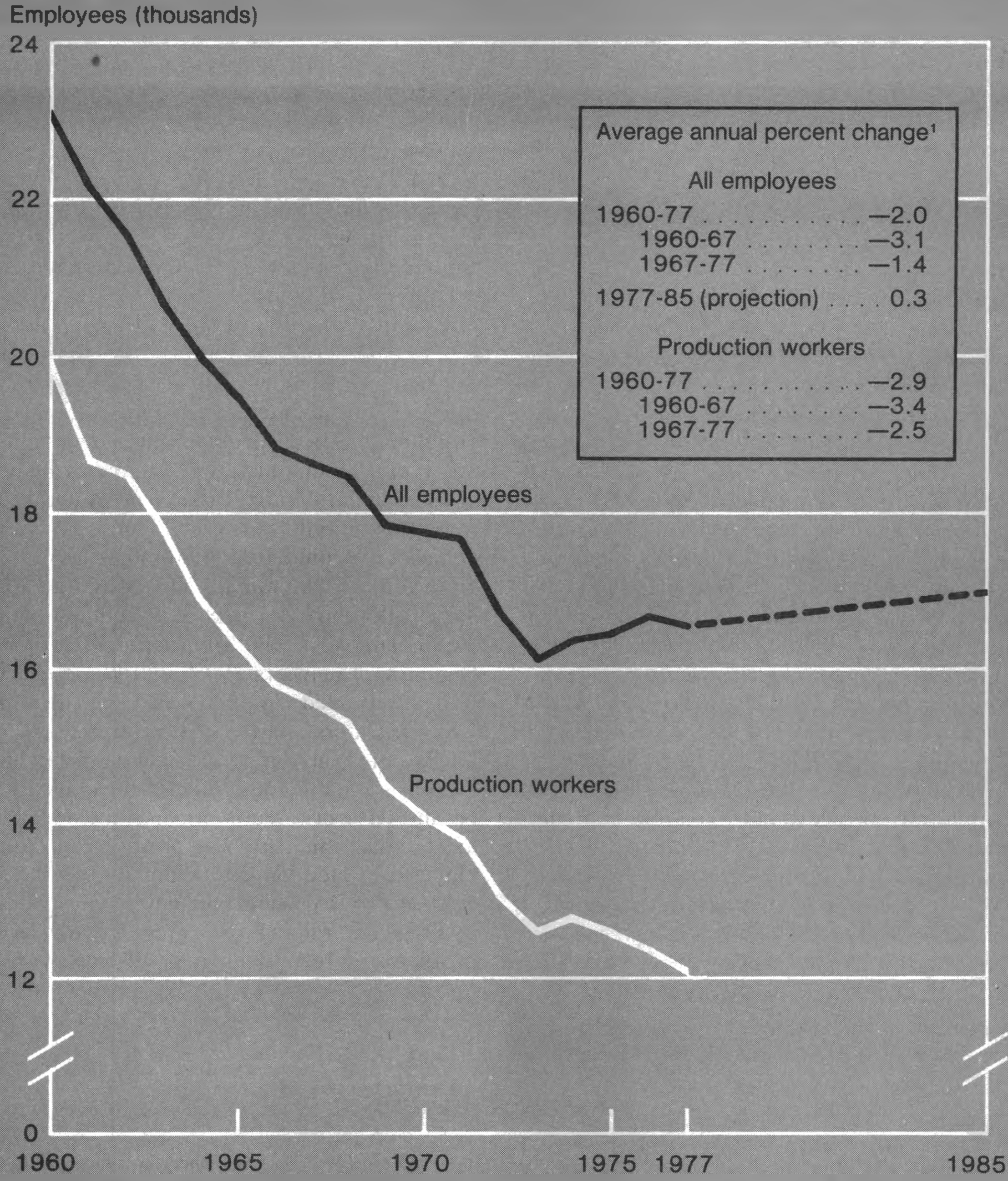
Unionization of pipeline transportation workers has been hindered by their geographic dispersion and the sizable number of small companies. Pipeline workers are represented (on a vertically integrated industry basis) by the Oil, Chemical and Atomic Workers International Union (AFL–CIO), by craft unions affiliated with the AFL–CIO, such as the International Union of Operating Engineers, and by unaffiliated independents.

Collective bargaining agreements in the petroleum industry typically call for negotiation of wage practices and supplementary benefits, job and union security, working conditions, and other employer-employee relationships. Although the agreements may not refer to adjustments that are required when technological changes occur, it is likely that, under such conditions, the seniority provisions of the contract apply.

[12] Data source is Bureau of Labor Statistics.

Chart 10

Employment in petroleum pipeline transportation, 1960-77, and projection for 1977-85

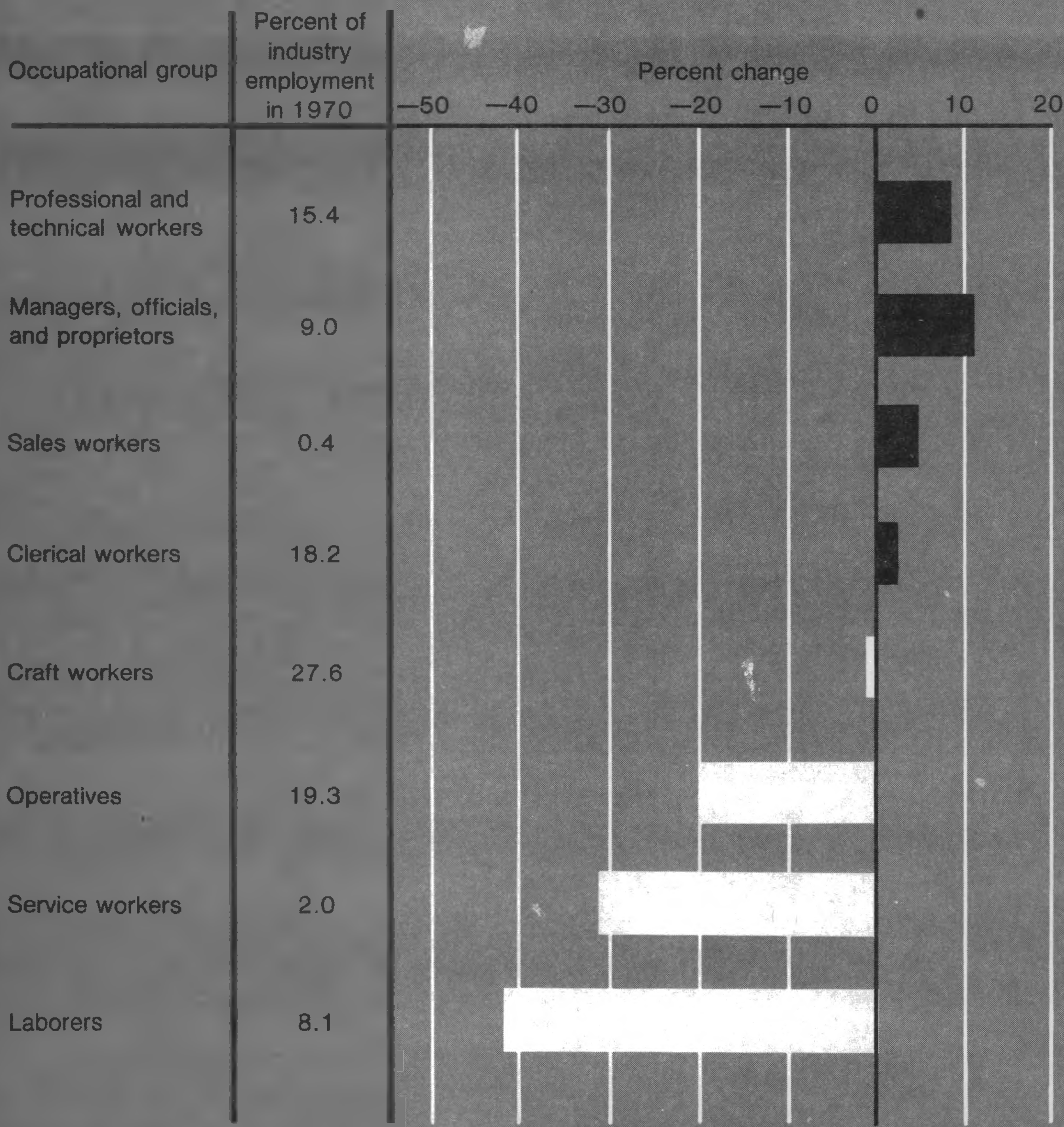


¹ Least squares trend method for historical data; compound interest method for projection.

Source: Bureau of Labor Statistics.

Chart 11

Projected changes in employment in petroleum pipeline transportation, by occupational group, 1970-85



Source: Bureau of Labor Statistics.

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Chapter 5. Electric and Gas Utilities

Summary

Technological changes in the electric power and gas industry continue to lower labor requirements in some occupations and raise productivity. Major innovations underway include the more widespread use of computers to assist generating plant control room operators in logging data, monitoring equipment, and performing calculations; an increase in the number of nuclear power stations, which generally require a more highly skilled work force than conventional plants of similar capacity; and the return to coal as a major fuel source. The development of highly mechanized vehicles for power line construction and repair has changed the size and occupational makeup of power line work crews. The more widespread use of extra-high-voltage transmission also has brought about changes in power line repair techniques.

Capital expenditures have increased considerably since 1960, reaching a level of $25.8 billion in 1977. (In real terms, however, the increase is not this great because the price of new plant and equipment has increased.) Electric utility companies account for most of the industry's expenditures—about 84 percent in 1977. Capital spending is expected to increase fairly steadily over the next decade. Electric utilities cancelled or postponed part of their planned capital expenditures for 1974 and 1975 for a combination of reasons, including unfavorable economic conditions, forecast reductions in demand, and problems with regulatory and environmental concerns, but expenditures rose again in 1976 and 1977.

Output per all-employee hour increased at an average annual rate of 4.6 percent from 1960 to 1977, with the most rapid increase occurring between 1960 and 1967. Due in part to technological changes, labor requirements for operating and maintenance employees in electric generating plants have declined since 1960, and are lower per kilowatt of capacity for large plants than for small plants. Employment grew at the rather slow rate of 1.2 percent a year between 1960 and 1977, reaching a peak of 684,200 workers in 1974 and declining to 673,000 in 1977. Employment is expected to continue to increase at an average rate of 0.7 percent a year between 1977 and 1985. Occupational requirements may change somewhat in response to changes in the size of electric generating plants and the type of fuel used: Nuclear plants, for instance, will require a larger proportion of scientists, engineers, technicians, and security staff compared to fossil-fuel plants. The construction and maintenance of nuclear power plants require highly skilled welders and other craft workers. Some concern exists that possible labor shortages in some craft and technical occupations could delay construction of nuclear generating plants, and, if exhaust gas scrubbers become mandatory on coal-fired plants, the number of engineers, technicians, and maintenance personnel could increase substantially.

Technology in the 1970's

Major technological changes are taking place in the electric power and gas industry which directly affect the industry's work force and productivity. These include the more widespread use of electronic computers, nuclear power generation, and coal as a major fuel for electric generating plants. Extra-high-voltage transmission will continue to make possible the economical transmission of large quantities of electric power. In constructing and maintaining transmission lines, labor requirements are being reduced through the more efficient utilization of skilled workers and fleets of mechanized vehicles by computerized scheduling of work assignments. The mechanized fleets, however, require an increase in vehicle maintenance crews. Innovations such as process control computers, being introduced in an already highly instrumented environment, will have a less extensive impact on employment and occupations than such changes as nuclear power installations, which require substantially more scientific and technical staff than conventional installations of similar capacity. Research now underway on coal liquefaction and gasification processes may ultimately provide a clean-burning fuel from an abundant energy source to replace oil and natural gas.

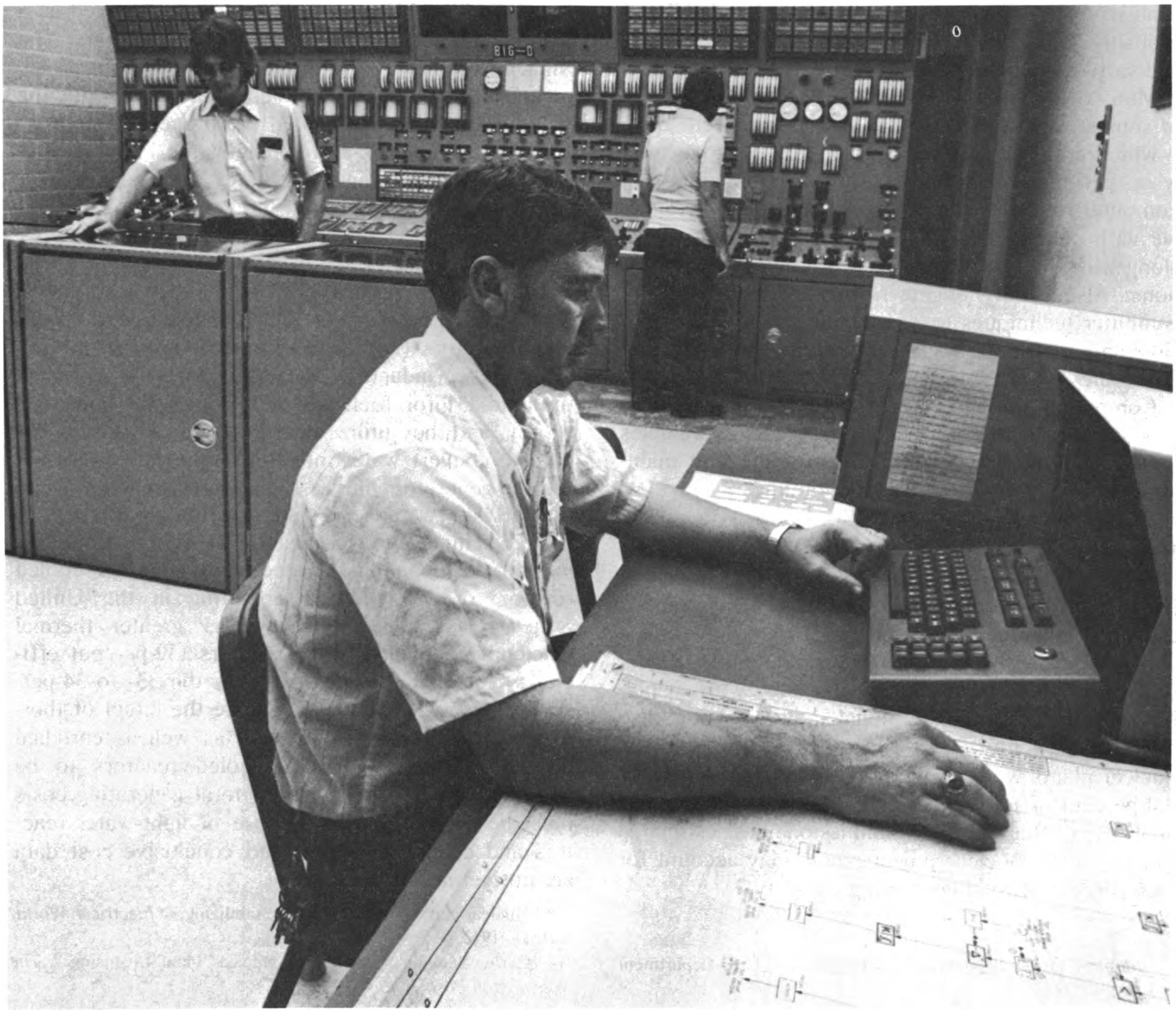
Electronic computers

Computers are used extensively in the utilities industry. In addition to their now commonplace use in business operations, computers are being applied to generating plant operations, control over transmission systems, and scheduling of work assignments for line crews.

Process control computers in generating plants provide assistance to control room operators in start-up operations, data logging, monitoring, and performance calculations, and they are becoming standard equipment in new plants and in many older large plants. Of the plants sampled in a recent survey, nearly 76 percent used automatic data collection for computerized performance calculations, and 24 percent had computers with control-function capacity.[1] Fuel savings, increased safety and reliability, reduced chance of operating errors leading to equipment damage, and improvements in equipment utilization are claimed. Many large plants have operations that are so complex that a substantial amount of automatic control is required for safety and reliability.

Process control computers are commonly applied to economic dispatch and automatic load control—operations principally concerned with dispatching power over transmission lines and the coordination of power generation and interchange. These operations have become so complex that dispatching personnel have difficulty assimilating the vast amount of data available. The solution has been the development of automatic control systems typically consisting of digital computers, local and remote cathode ray tube (CRT) terminals, animated diagram boards, and a network of telemetering devices. These systems provide dispatchers with the information and control necessary to supply power economically at proper voltage and frequency throughout the power system. The optimization of power production, continuous control of generating units, and

[1] Gordon D. Friedlander, "20th Steam Station Cost Survey," *Electrical World*, Nov. 15, 1977, p. 51.



Generating plant control room with direct digital control computer system

improved reliability and accuracy of the system provide direct economic benefits. Indirect benefits include the improved coordination of loads between interconnected utilities.

There are some applications of process control computers to full closed-loop control of generating plants—although this is generally limited to hydroelectric stations. In one such application, a 4-unit 285-megawatt (Mw) hydroelectric plant can be operated automatically, either locally or by remote control from a central dispatching center. In another application, a 4-unit 225-Mw hydro plant is controlled from a location 8 miles away; the only personnel at the plant are security guards. The extent to which closed-loop remote control of generating plants is used is not known, but, where used, it allows some reduction in operating personnel.

Computers can be applied to a number of other operations, such as plant design, long- and short-term planning, fossil-fuel scheduling, and nuclear core analysis. The range of computer applications will probably grow in the future as computer hardware and software technology continues to develop.

Many of the computer applications require the use of sophisticated mathematical models and techniques —which, in turn, require programmers, systems analysts, peripheral-equipment operators, and others in computer-related occupations. The demand for people with computer-related job skills should increase along with the increasing range of computer applications. Also, utility engineers must have training in computer techniques to use computers for transmission and distribution (T&D) systems planning and for studies of T&D operations.

Computers are also being used more widely to schedule line crews with highly mechanized vehicles to reduce time and cost in constructing and maintaining transmission and distribution lines.

Nuclear power

Nuclear generation of electric power has become increasingly important over the past several years as costs of commercial power generation have risen and as concern has mounted over the future availability of petroleum. Problems associated with air pollution caused by conventional power plants also have been a factor. By the end of 1977, 49 licensed nuclear plants were in operation, with 49,881 Mw, or 9.0 percent of total generating capacity.[2] The Federal Energy Regulatory Commission has estimated that, by 1985, nuclear power plants may account for 18.6 percent of total generating capacity.[3]

The increase in the number of completed nuclear power plants over the past several years has been less than anticipated. Inflation, combined with tight money markets and uncertainty as to future demand growth, has caused postponements and cancellations in the construction of a number of nuclear plants. Opposition to nuclear power plants based on concern over safety and environmental factors, nuclear fuel reprocessing, and waste disposal also has caused delays and cancellations. In addition, the lead time for bringing a nuclear plant on line has increased as a result of the growing complexity and size of the plants themselves, changing Federal regulations concerning construction and operation procedures, and problems in finding suitable sites. In late 1972, lead time was about 7 years;[4] by mid–1977, lead time had increased to roughly 10–12 years.[5] Most nuclear plants are virtually custom built, which is time consuming and expensive. Standardized plant designs (perhaps based on previously approved designs) that can be mass produced and approved as a group could shorten lead times by several years. The Nuclear Regulatory Commission is encouraging such an approach, and standardized plants are beginning to be constructed. To hasten the process of approving sites for nuclear power plants, the Federal Government is proposing that States create, in effect, "site banks" by approving areas for nuclear plant construction in advance of any licensing requests by utility companies.[6]

There are several types of nuclear reactors in commercial operation or under development. Light-water reactors (LWR's) presently dominate the nuclear power industry. These reactors use enriched uranium-235 for fuel, which is somewhat limited in supply, and they utilize heat energy from the reactor core to convert water into the steam that drives the turbine-generator units. Light-water reactors with over 1,000-Mw capacities are now in operation.

High temperature gas reactor (HTGR) technology is well developed in Europe. Only one gas-cooled reactor, of 330 Mw, is operating in the United States. Gas-cooled reactors offer greater thermal efficiency than light-water reactors (39-percent efficiency for HTGR's, compared to the 33- to 34-percent efficiency of LWR's), reduce the effect of thermal pollution, and use thorium as well as enriched uranium for fuel. For gas-cooled reactors to be commercially successful, their total generating costs must be competitive with those of light-water reactors and coal-fired plants, and conclusive cost data are not yet available.

[2] *Monthly Power Plant Reports*, FPC Form 4, U.S. Department of Energy, 1977.

[3] Department of Energy estimates.

[4] "Nuclear Survey: Lead Times Stabilizing," *Electrical World*, Oct. 15, 1972, p. 7.

[5] "Carter Seeking Speed-Up of Nuclear Plant Licensing," *The Washington Post*, Aug. 4, 1977, p. A4.

[6] Ibid.

Table 8. Major technology changes in electric and gas utilities

Technology	Description	Labor implications	Diffusion
Electronic computers	Process control computers in generating plants are used for data logging, monitoring, and performance calculations, providing fuel savings, increased safety and reliability, and improvements in equipment and labor utilization. Process control computers are commonly used in dispatching power over transmission lines and coordinating generating and interchange operations. Computer scheduling of labor and vehicles has reduced time and costs in maintenance and construction operations.	Reduces the time control room operators and system load dispatchers spend reading instruments, logging data, and performing calculations. Load dispatchers would have difficulty assimilating the amount of available data without computer assistance. Increased demand for people in computer-related occupations. Some utility engineers required to learn computer techniques.	Seventy-six percent of generating plants use automatic data collection for computerized performance calculations, and 24 percent have computers with control function capacity.
Nuclear power generation	Light-water reactors currently dominate the industry and one high-temperature gas reactor is in use. Some development work has been done on breeder reactors. Efforts are underway to standardize nuclear power plant design in order to facilitate the increasingly complex licensing procedures.	Greater demand for scientific and technical specialists and security personnel than conventional power plants. Higher skill requirements for control room operators and construction and maintenance crews.	By the end of 1977, 49 licensed nuclear plant were in operation, providing about 9 percent of total generating capacity.
Exhaust gas scrubbers for solid coalburning plants	Exhaust gas scrubbers remove sulfur dioxide by forcing exhaust gases through a water and limestone slurry or some other chemical process prior to venting the gases into the atmosphere. Scrubbers still have a number of problems that must be solved before they can be considered completely successful.	Increased labor requirements for construction, operating, and maintenance activities.	More than 24 scrubbers were installed or under construction in 1974, according to Federal Power Commission data. The number of installations is expected to increase.
Extra-high-voltage (EHV) transmission of electric power	EHV technology has made possible the economical transmission of large blocks of power, facilitating the development of regional power pools.	Some increase in difficulty of work due to use of higher towers and need to use heavier equipment on higher voltage lines. Use of "barehand" maintenance techniques speeds repairs but requires special training.	EHV technology now dominates the transmission of electric power.
Mechanized vehicles for construction and maintenance of power lines	Productivity has been increased in the construction and maintenance of transmission and distribution lines by the combination of small, highly trained line crews with a large number of especially developed work vehicles.	Line crews now handle a greater amount of work than was previously possible; consequently the number of people in this occupation has not grown as rapidly as the size of the transmission and distribution network. Demand has increased for vehicle maintenance personnel.	Presently in wide use.

A third type of reactor—the breeder reactor—is in the development stage. The breeder reactor converts uranium-238 or thorium-232 to fissionable plutonium-239 or uranium-233 at a faster rate than it consumes fuel, in effect creating more fuel than it uses. Most of the development work has been concentrated on the liquid-metal fast-breeder reactor, as this type of reactor has the fastest conversion rate. The future of breeder reactor technology is uncertain, however, since development work is expensive and technically difficult and requires extensive use of plutonium.

Labor requirements in nuclear plants differ from those in fossil-fuel plants of similar capacity. Nuclear plants tend to have more highly trained staffs, including a larger number of scientists, engineers, and technicians. More security personnel are required at nuclear plants—a service which used to be contracted out to private guard and detective agencies but is now being handled to a larger extent by the utility firms themselves. Nuclear plant operators must be trained to work with fissionable material and must be licensed by the Federal Government. Construction and maintenance work in nuclear plants is done to very exacting specifications and requires craft workers with very high levels of skill. Maintenance crews may be slightly larger at nuclear plants because maintenance procedures are more complex. Regulations concerning radiation exposure sometimes necessitate the use of protective clothing, which might hamper working ability and decrease efficiency to some extent.

Coal for fuel

Coal is the most abundant energy source in the United States and was the primary fuel for steam generating plants before 1965. Between 1965 and 1972, many utility firms switched from coal to oil. Initially, this switch occurred because oil was less expensive, but during the latter part of this period pollution control also became an important consideration. Much of the coal available in the United States has a high sulfur content and is a major source of air pollution from generating plants. Oil is a cleaner burning fuel. By 1974, the problems inherent in heavy reliance upon oil became clear: limited domestic supplies and dependence upon foreign sources. Coal, therefore, has become important again to electric utilities.

The sulfur dioxide emissions that result from burning solid coal remain a major air pollution problem. There are several possible solutions. There is low-sulfur coal available, primarily in the western part of the United States. This coal generally has a lower Btu (British thermal unit) content than high-sulfur coal, requiring a greater quantity to be burned for the same energy input. The differences in quantity used would have an impact on generating plant storage capacity and on fuel and ash handling. There are also transportation expenses involved when using western low-sulfur coal in the eastern part of the country.

A somewhat controversial solution is the installation in generating plants of exhaust gas scrubbers, which are cleaning devices that remove much of the sulfur dioxide from exhaust gases. Scrubber technology is still developing and needs further refinement to be fully effective. Scrubbers are expensive—they can add up to 50 percent of the cost of a boiler-generator system. They also consume from 1.5 to 5 percent of the plant's output.[7] Reliability has also been a problem. The solution so far has been to build in redundant equipment or to step up maintenance operations—both of which are expensive procedures. In one of the earliest scrubber installations, the plant maintenance force had to be increased by 50 percent to handle equipment breakdowns and corrosion problems.[8] Many scrubbers produce large amounts of watery sludge as a waste product. The disposal of this sludge is a major unresolved problem.

The number of scrubber installations will probably increase because, in spite of the problems and expenses involved, scrubbers do provide control over some of the pollutants caused by generating plants. Scrubbers are complex equipment, and, as the number of installations increases nationwide, the number of maintenance workers needed in the industry also will rise.

An alternative to the direct burning of coal is the conversion of coal to a gas or a liquid. For electric utilities, advantages include the capability to remove sulfur and ash during the conversion, thereby reducing air pollution when the converted coal is burned. The coal converted by at least some of the several gasification and liquefaction procedures that have been proposed can be transported by pipeline. At present, however, coal gasification and liquefaction on a large scale are not commercially available, and the cost and reliability of the processes have yet to be proven. Given the present technology, these alternatives are more expensive than the installation of exhaust gas scrubbers in generating plants.[9]

Some generating plants that were designed to burn oil or natural gas can also burn coal in liquid or gaseous form. Converting these plants to burn solid coal, however, would be prohibitively expensive and, in some cases, where insufficient land is availa-

[7] Paul H. Weaver, "Behind the Great Scrubber Fracas," *Fortune*, Feb. 1975, p. 112.

[8] Ibid.

[9] Lawrence H. Weiss, "Clean Fuel and Scrubbing Compared," *Electrical World*, Oct. 1, 1976, pp. 70–73.

ble for coal storage and for coal and ash handling equipment, technically impractical.

Labor requirements in coal-fired plants tend to be higher than those in oil- or gas-fired plants. Using coal requires moving it from storage areas near the plant to furnaces in the plant and cleaning out the ash residue after the coal is burned. This work is performed by "fuel and ash handlers," a semiskilled occupation. The future use of coal in liquid or gaseous form, if ultimately proven commercially attractive for U.S. utilities, would eliminate the need for this occupation (as has occurred in gas-fired plants) and reduce total utility industry labor requirements. Research on conversion of coal into synthetic gas or to liquid form has been intensified because of vast coal resources available within the United States and concern over future availability of oil and natural gas.

High-voltage transmission

Extra-high-voltage (EHV) technology now dominates the transmission of electric power. Developments that have facilitated the growth of EHV transmission include the introduction of bundles of two or more conductors, insulator strings set in "V" configurations to control swing, the use in some instances of guyed structures in place of self-supporting towers, the use of aluminum and special steels in line structures for reduced maintenance requirements, and the use of helicopters to facilitate construction. As of August 1977, there were almost 117,000 miles of EHV transmission lines in service.[10] The development of EHV technology makes possible the economical transmission of large amounts of electric power over long distances, with significant reductions in right-of-way requirements and corresponding reductions in right-of-way maintenance operations compared to what would have been required using lower voltage lines. EHV interconnections presently cover most of the country.

The higher voltages involved in EHV transmission have caused some changes in work techniques. Line crews work on higher towers using longer, heavier "hot sticks" and the more modern "barehand" technique. "Barehanding" is a process in which the worker handling an energized circuit becomes a part of the circuit, with precautions against grounding (such as working in an insulated fiberglass bucket or on a fiberglass ladder suspended from the line tower). Under the proper circumstances, barehand repairs can be completed in a fraction of the time required by more traditional methods.

[10] Department of Energy, Federal Energy Regulatory Commission.

Power line construction and maintenance

Construction and maintenance techniques continue to improve, with crew size and productivity undergoing change. The use of helicopters in rough terrain, chemicals to control brush on rights-of-way, and lighter metals in structures are among changes that have reduced construction time and maintenance requirements for line crews.

The vehicles used in constructing and maintaining transmission and distribution (T&D) lines have undergone considerable technological change over the past 10-15 years—a change that has had quite an impact on T&D workers. These vehicles (mostly truck chassis weighing 22,000 to 40,000 lbs.) carry hydraulically operated equipment, such as 360-degree rotating derricks and pole hole diggers, or aerial lifts with booms that can range from 20 to 150 feet high, or plows, backhoes, earth augers, cable pullers, etc. This mechanization of mobile equipment was well underway by the early 1960's and has continued to grow rapidly, as illustrated by the increased use of aerial lifts: The average utility used 10 aerial lifts in 1962 and 97 lifts in 1974.[11]

Vehicle mechanization grew so rapidly because utilities needed to keep up with increasing construction demands with minimum increases in cost and in the size of construction work crews. Additionally, the cost of labor was increasing more rapidly than the cost of construction equipment. In the mid-1960's, for example, the price of a 1/2-ton pickup truck was equal to a top line crew worker's pay for 455 hours of work. In 1974, the cost of a new pickup truck was equivalent to a top line crew worker's pay for only 325 hours.[12]

Mechanized mobile equipment has made possible a reduction in the size of construction work crews and T&D line crews. Large, all-purpose line trucks are used where work is concentrated in one area—but generally with crews of 6 people rather than the traditional 8- to 9-person line crews. A fleet of smaller special-purpose vehicles with 2 or 3 crew members each, equipped with 2-way radios and backed by computerized scheduling of work assignments, can generally provide the greatest productivity for work scattered over large areas. A modern transmission line crew might typically consist of 4 aerial lifts, an earth auger, and a digger/derrick truck with 2 crew members each, and a pickup truck for the supervisor—7 specialized vehicles and a crew of 13 highly skilled workers.

The growing mobile fleet requires an increasing commitment of resources—labor, equipment, and

[11] "Mechanization Revolutionizes Construction," *Electrical World*, June 1, 1974, p. 164.

[12] Ibid.

managerial skill—for maintenance and repair operations. Over 90 percent of the utilities that own their vehicle fleets operate service and repair facilities (although some major repair work may be contracted out).[13] Scheduled maintenance programs are necessary to maximize vehicle availability and minimize fleet operating costs. Managerial ability, sometimes combined with computerized scheduling and record-keeping, is necessary to operate such programs. Maintenance personnel need to be familiar with both automotive and hydraulic servicing and repair.

Investment

Capital expenditures

Expenditures for new plant and equipment in the major industry group electric, gas, and sanitary services (SIC 49)[14] rose from $5.2 billion in 1960 to $25.8 billion in 1977, an average annual increase of 11.6 percent. (In real terms, however, the increase is not as great since the price of plant and equipment has risen over this period.) Most of the growth occurred after 1967, with expenditures increasing at an average rate of 10.8 percent a year between 1967 and 1977. The average rate of growth between 1960 and 1967 was 7.8 percent a year.

Capital expenditures per nonsupervisory worker in the industry have grown almost fivefold over the past 17 years, from $10,143 per worker in 1960 to $46,638 per worker in 1977—an average increase of 10.8 percent a year. The average annual growth rate was 7.9 percent during 1960–67 and 10.0 percent during 1967–77.

Electric utilities account for the largest portion of the industry's capital expenditures, with 69.1 percent of 1960 expenditures and 83.7 percent of 1977 expenditures. Electric utilities spent $3.6 billion in 1960 and $21.6 billion in 1977—an increase averaging 13.2 percent a year. The average annual growth in spending during 1960–67 was 8.9 percent; the rate during 1967–77 was 12.1 percent.

The industry went through a period of economic uncertainty during the mid-1970's which had an impact upon its capital spending activities. This is a highly capital-intensive industry which for more than 15 years had a steady, predictable growth in demand averaging 7.4 percent a year[15] —a situation that allowed an orderly growth in capital expenditures. However, in 1974 and to a lesser extent in 1975, construction and fuel costs rose rapidly while the growth in demand was well below the historical rate. High interest rates and low stock market prices limited the ability of utilities to raise funds in the money market. Problems with regulatory and environmental concerns continued. In response to this situation, electric utility firms cancelled or postponed a considerable part of their planned capital expenditures. According to *Business Week*, 170,000 Mw or 47.2 percent of a planned 360,000-Mw generating capacity were cancelled or significantly delayed in 1974.[16] *Electrical World* noted that in 1975 capital spending declined for the first time in the industry's history.[17]

Expenditures turned upward again in 1976 and 1977. This resumption of capital spending reflected the general improvement in economic conditions after 1975, the inability of utility companies to further postpone to a significant degree generating plant construction in the face of growing demand, and concern over power shortages and service reliability.

The outlook over the next several years is for a continued increase in expenditures. McGraw-Hill's 1977 annual survey of business plans for capital spending[18] indicated that the electric utility industry planned to spend $25.2 billion for new plant and equipment in 1978, $27.5 billion in 1979, and $29.2 billion in 1980. Approximately 87–88 percent of these funds were to be for machinery and equipment; the balance was for buildings and vehicles.

A slower rate of growth in demand could ease the pressure on generating capacity. Demand (kilowatt-hour sales) actually dropped slightly in 1974—a short-run response to conservation efforts, the economic downturn, and unexpectedly large increases in the price of all energy sources, including electric power. After a period of adjustment to higher energy costs, demand began to grow again, but at less than the historical rate of 7.4 percent a year. The Federal Energy Regulatory Commission's Bureau of Power considers a growth rate of 5.7 percent a year to be likely between 1977 and 1986.

[13] Michael G. McGraw, "Fleet Management Becomes More Sophisticated," *Electrical World*, Aug. 1, 1975, p. 38.

[14] Data are available from the Department of Commerce only for this broader SIC 49 industry grouping, which, in addition to including establishments which generate, transmit and/or distribute electricity, gas, or steam (SIC 491, 492, and 493), also includes establishments which distribute water, provide sanitary services, supply steam, and operate water supply systems for irrigation.

[15] Carol J. Loomis, "For the Utilities It's a Fight for Survival," *Fortune*, Mar. 1975, p. 97.

[16] "Utilities: Weak Point in the Energy Future," *Business Week*, Jan. 20, 1975, p. 46.

[17] "27th Annual Electrical Industry Forecast," *Electrical World*, Sept. 15, 1976, p. 58.

[18] *Business Plans for New Plants and Equipment, 1977–80*, 30th Annual McGraw-Hill Survey (New York, McGraw-Hill Publications Co., Economics Department) May 6, 1977.

Funds for research and development

There are several sources of research and development funds in the electric power industry: Equipment manufacturers, the Federal Government, and the utility companies themselves. Equipment manufacturers perform much of the basic research and development (R&D) work applicable to the electric power industry, recouping their costs by selling the equipment they develop to the power companies. Federal R&D funds have been largely concentrated in the development of nuclear power.

According to the Federal Energy Regulatory Commission, annual R&D expenditures for class A and class B electric utilities[19] were in the range of $37 million to $47 million between 1966 and 1970, rising to $239 million in 1973. Expenditures declined slightly to $234 million in 1974, but rose again to $290 million in 1976. Only about 20 percent of these funds were spent directly by utility companies. The majority of the funds went to organizations such as the Edison Electric Institute, the Electric Power Research Institute, and the Battelle Memorial Institute.

Production and Productivity Outlook

Output

Output in electric power and gas (BLS weighted index) increased at an average annual rate of 5.9 percent between 1960 and 1977 (chart 12). During the 1960–67 period, growth in output averaged 6.9 percent a year, while the 1967–77 period experienced a lower average annual growth rate of 4.2 percent.

Output has grown steadily for many years. In 1974, however, demand for electricity declined in response to price increases, economic conditions, and conservation efforts. This contributed significantly to the first drop in this industry's output since at least 1947. In 1975, output returned roughly to the 1973 level, and increased again in 1976 and 1977.

Output will probably continue to increase through the coming decade for the industry as a whole. Demand for electricity, as discussed earlier, is expected to increase steadily. For gas utilities, however, the outlook is not so positive. The supply of domestic natural gas is declining and synthetic gas is not expected to be available in significant quantity until the late 1980's. Use of imported natural gas can be increased to some extent. The net result is a projected slight decline in the gas supply through 1985.[20]

[19] Class A and class B electric utilities have accounted for roughly 80 percent of total kilowatt-hour sales over the past decade.

[20] *United States Energy Through the Year 2000 (Revised)* (U.S. Department of the Interior, Bureau of Mines, Dec. 1975), p. 65.

Productivity

Output per employee hour increased at an average annual rate of 4.6 percent from 1960 to 1977 (chart 12). The growth rate was higher during the 1960–67 period (6.3 percent per year) than between 1967 and 1977 (3.0 percent per year).

There may be a long-term decline occurring in the rate of productivity growth. Although output continues to rise at a faster rate than employee hours, the rate at which output is growing peaked in 1970 and declined through 1977, while the rate of change for employee hours continued to grow steadily through 1974 and was only slightly lower in 1975, 1976, and 1977. Hence, output per employee hour is growing, but the average annual rate of growth has been gradually declining since reaching a peak in 1964. The productivity growth rate for nonsupervisory workers has been higher, and the increase in employment has been lower, than for all employees.

Electrical World publishes a continuing survey of generating costs for electric utility steam plants that includes data on the number of operating and maintenance employees per Mw of net output. In 1960, 0.306 employees were required per Mw of net output.[21] By 1976, however, labor requirements had declined by 60 percent to 0.122 employees per Mw.[22] The survey indicates that labor requirements tend to be lower for larger generating plants. The survey also indicates that labor requirements vary by type of generating plant. Nuclear plants have the greatest labor requirements per Mw, needing more people in all occupations (except fuel and ash handlers) than the other types of generating plants. Coal-fired plants have the second highest level of labor requirements, oil-fired plants the next, and gas-fired plants the lowest.

The size of generating units is not likely to increase as rapidly in the future as over the past 20 years, and nuclear and coal-fired plants are expected to be the main sources of electric power in the future. Labor requirements per Mw, therefore, may not continue to decline as much as they have over the past decade.

Employment and Occupational Trends

Employment

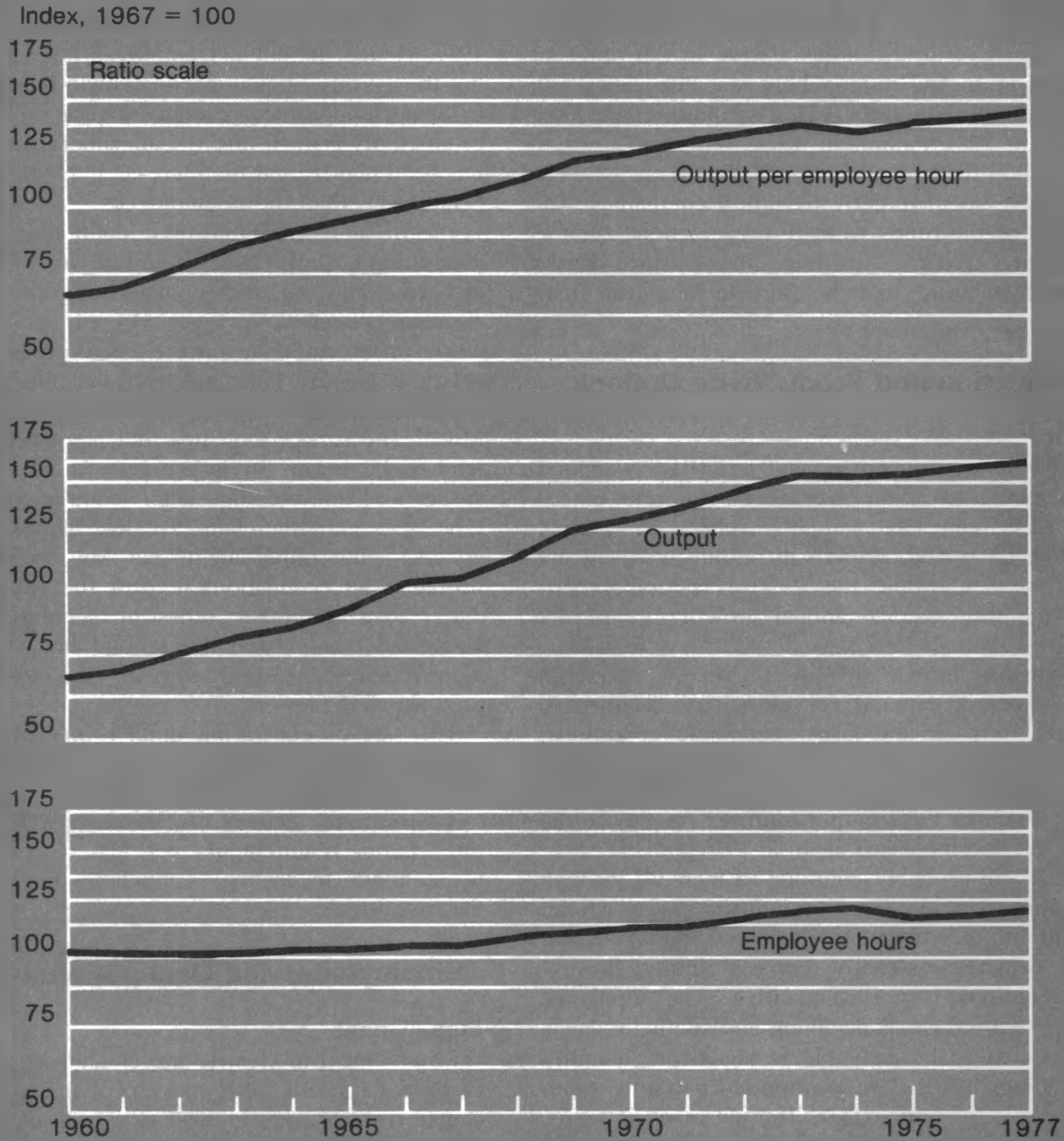
Employment in electric power and gas, according to BLS data (SIC 491, 492, 493), increased rather slowly from 582,300 in 1960 to a peak of 684,200 in 1974 and then declined to 673,000 in 1977. The average annual growth rate over the 1960–77 period was

[21] Leonard M. Olmsted, "14th Steam Station Cost Survey," *Electrical World*, Oct. 18, 1965, p. 104.

[22] Friedlander, "20th Steam Station Cost Survey," *Electrical World*, Nov. 15, 1977, p. 44.

Chart 12

Output per employee hour and related data, electric and gas utilities, 1960-77[1]



[1] Data for 1977 are preliminary.

Source: Bureau of Labor Statistics.

1.2 percent, with most of the growth occurring after 1967. The average annual rates of change for 1960–67 and 1967–77 were 0.4 percent and 1.3 percent, respectively. BLS projections to 1985 indicate that growth in employment may average 0.7 percent a year between 1977 and 1985 (chart 13).

Employment growth for nonsupervisory employees has been slower than for all employees; nonsupervisory workers increased at an average rate of 0.8 percent a year between 1960 and 1977. The number of nonsupervisory workers was about the same in 1960 and 1967 but then grew between 1967 and 1977 at an average annual rate of 0.8 percent.

Occupations

Technological and other factors are altering to some extent the occupational structure in the electric power and gas industry. One area of change is in the balance of supervisory and nonsupervisory workers: Nonsupervisory workers have declined from 89 percent of total employment in 1960 to 83 percent in 1976.

A comparison was made of labor costs for various occupations between a group of large generating plants (averaging 2,626 Mw) and a group of smaller plants (340 Mw) in 1975.[23] Labor costs per net Mw for the smaller plants were approximately 35 percent higher for supervisors, 315 percent higher for operating personnel, 48 percent higher for maintenance personnel, 200 percent higher for fuel and ash handlers, and 188 percent higher for clerks.

The types of fuel used by generating plants also affect occupational requirements. Fuel and ash handlers are not required for plants using natural gas but are needed in plants that burn coal and, to some extent, in plants that burn oil. Also, nuclear plants require more specialists than any type of fossil-fuel plant. As nuclear plants and coal-fired plants are expected to become the dominant types of power plants over the next decade, the occupations of specialist and fuel and ash handler should become more important.

Employment is projected to increase in six of the eight major occupational groups, with the largest increases expected to occur among professional and technical workers, managers and administrators, and craft workers (chart 14). Specific occupations in which increases are expected include electrical engineers, electronic technicians, computer specialists, computer peripheral equipment operators, construction electricians, plumbers and pipefitters, boilermakers, machinists, line and cable workers, and truckdrivers. Some of the occupations for which declining employment is projected are keypunch operators, furnace tenders and stokers, cleaning service workers, and construction laborers (except carpenters).

Some decline in the number of power plant operators is anticipated. Larger and more efficient equipment is expected to create increases in output with little or no increase in labor requirements. The same number of people, for instance, can operate a large generator or a small one.

The occupational structure at a fossil-fuel generating plant visited by BLS staff tends to support this projection. This plant utilizes three generating units: Two small units (175 Mw each) operated from one centralized control room and one large unit (850 Mw) that has its own control room. Both control rooms are run by four-person operating crews, although the skill requirements are higher for the larger generating unit.

However, a nuclear generating plant also visited by BLS staff has somewhat different occupational requirements. This plant uses larger and more highly skilled control room operating crews—seven to eight people, including a minimum of five operators licensed to work with fissionable fuel. Additionally, there is an ongoing training/retraining program at the plant to which operators are assigned on a rotating basis. If this plant is representative of nuclear plants in general, then an increase in the number of nuclear plants could reduce the projected decline in the number of power plant operators.

There has been some concern in the electric power industry about possible shortages of skilled construction and operating personnel during the coming decade. Such shortages would have greater impact upon nuclear generating plants because of the many special skills involved. Among the occupations critical for constructing and operating nuclear plants, where shortages are possible, are nuclear, mechanical, and electrical engineers, reactor operators, health physics/radiation monitor technicians, millwrights, and nuclear-qualified welders (most of whom come from the ranks of steam/pipe fitters and boilermakers).[24]

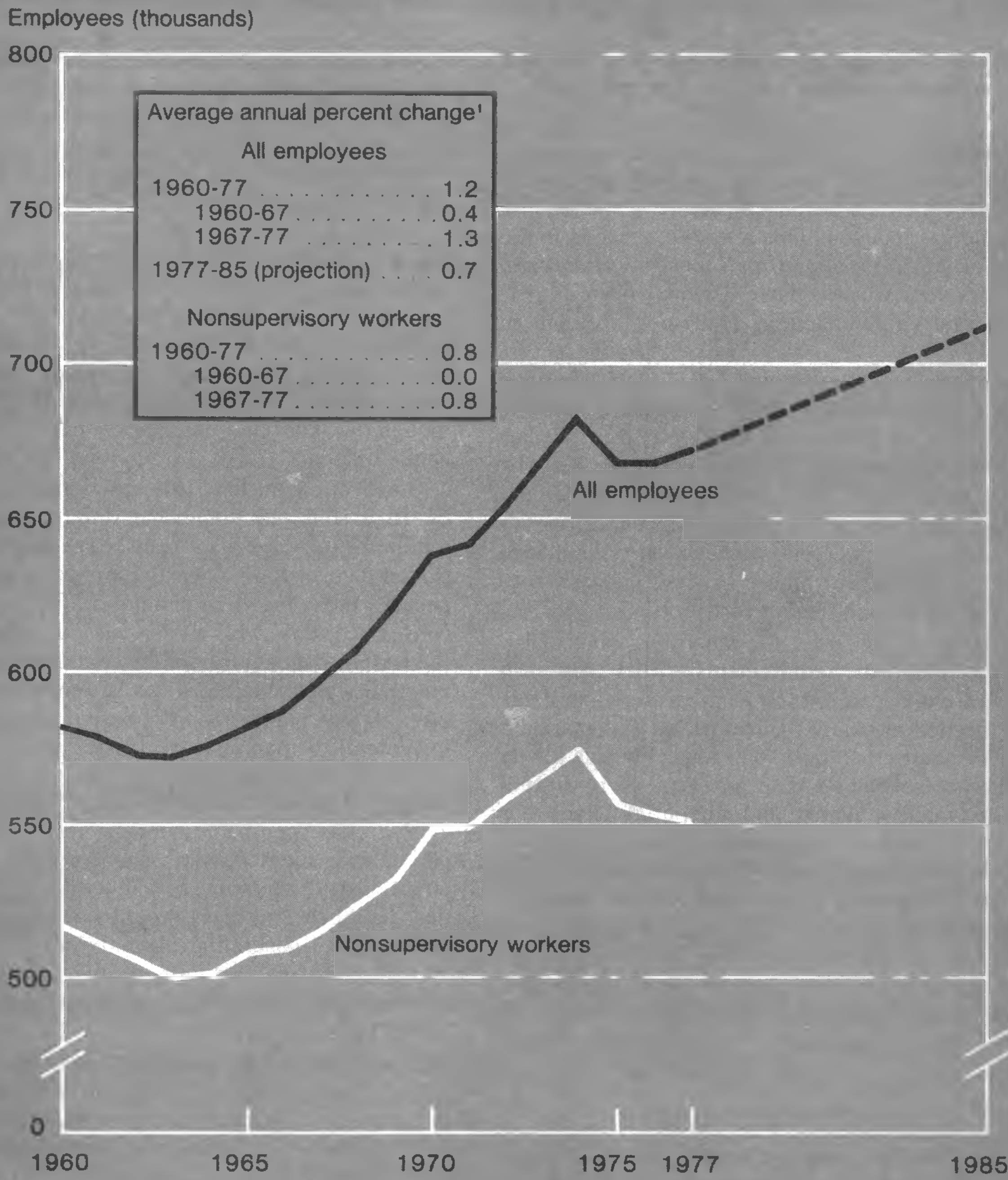
A new labor demand model that forecasts power plant construction employment has been developed

[23] Results from the survey of steam generating plants by *Electrical World* indicate that the cost of operating and maintenance employees per Mw of net output declined steadily from 1960 to 1970, then rose somewhat in 1972, and declined again in 1974 (although not returning to the 1970 level). In this study, 1960 data are from the 14th Steam Station Cost Survey, *Electrical World*. Data for 1962–72 are from Leonard M. Olmsted, "19th Steam Station Cost Survey," *Electrical World*, Nov. 15, 1975, p. 44. The 20th Cost Survey, in 1977, did not have such detailed information for labor cost.

[24] *Project Independence* (Federal Energy Administration, Nov. 1974), pp. 61–72.

Chart 13

Employment in electric and gas utilities, 1960-77, and projection for 1977-85

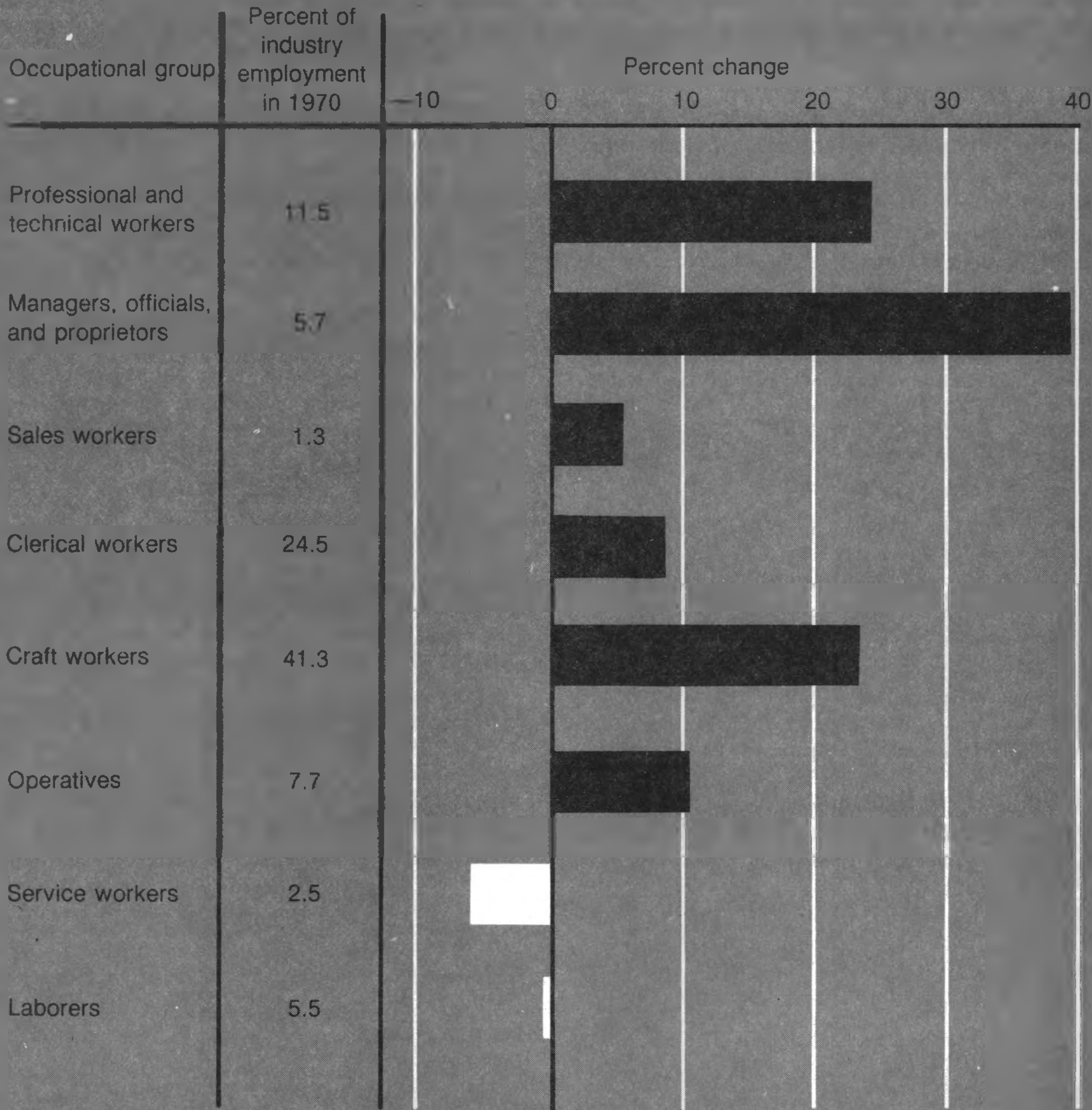


[1] Least squares trend method for historical data; compound interest method for projection.

Source: Bureau of Labor Statistics.

Chart 14

Projected changes in employment in electric and gas utilities, by occupational group, 1970-85[1]



[1] Includes steam utilities. Projections are based on the latest occupational data for 1985 adjusted for revisions of the 1985 employment projections.

Source: Bureau of Labor Statistics.

by the Departments of Labor and Energy and the Tennessee Valley Authority.[25] The model covers 1978–81 and breaks employment estimates down by region, occupation, and type of generating plant. This model could be a useful tool for utility companies in estimating their employment needs.

Some increase is expected in occupations concerned with the transmission and distribution of electric power. The number of line and cable workers should increase. Increased use of automatic equipment in substations—allowing more remote control operations—may cause a decline in regular substation operators but an increase in the more highly skilled mobile substation operators, who travel from one remote-controlled substation to another.

Adjustment of workers to technological change

Training programs are being established to facilitate adjustment of employees to the requirements of new technology. Control room operators in nuclear generating plants, for example, are licensed by the Nuclear Regulatory Commission (NRC) to manipulate the controls of a nuclear reactor. The training program used in the plant visited by BLS staff to prepare operators for the NRC licensing test requires between 6 months and a year to complete and includes extensive training in nuclear physics, radiation protection, and power plant operations. The NRC operator's license must be renewed every 2 years; since nuclear power generation is a rapidly evolving technology, the power company maintains an ongoing retraining program for its operators. Some utilities are installing simulators that will be used to train nuclear operators. Control room supervisors are required to hold a senior operator's license which, in the company visited, requires an additional 6 months of training.

About one-half of the workers in electric and gas utilities are unionized. Of the several unions representing utility industry employees, the largest are the International Brotherhood of Electrical Workers and the Utility Workers Union of America.

Specific provisions relating to technological change are not commonly found in collective bargaining contracts for this industry. There are, however, contract provisions pertaining to seniority, layoffs, job training, and promotions that could be applied to job losses resulting from technological change.

[25] Willis J. Nordlund and John Mumford, "Estimating Employment Potential in U.S. Energy Industry", *Monthly Labor Review*, May 1978, pp. 10–13.

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Other BLS Publications on Technological Change

Bulletins still in print may be purchased from the Superintendent of Documents, Washington, D.C. 20402, or from regional offices of the Bureau of Labor Statistics at the addresses shown on the inside back cover. Out-of-print publications are available at many public and school libraries and at Government depository libraries. Publications marked with an asterisk (*) also are available on microfiche and in paper copy from the National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, Virginia 22161.

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Appraises major technological changes emerging in apparel, footwear, motor vehicles, railroads, and retail trade and discusses their present and potential impact on productivity and occupations.

Technological Change and Manpower Trends in Five Industries (Bull. 1856, 1975), 58 pp.
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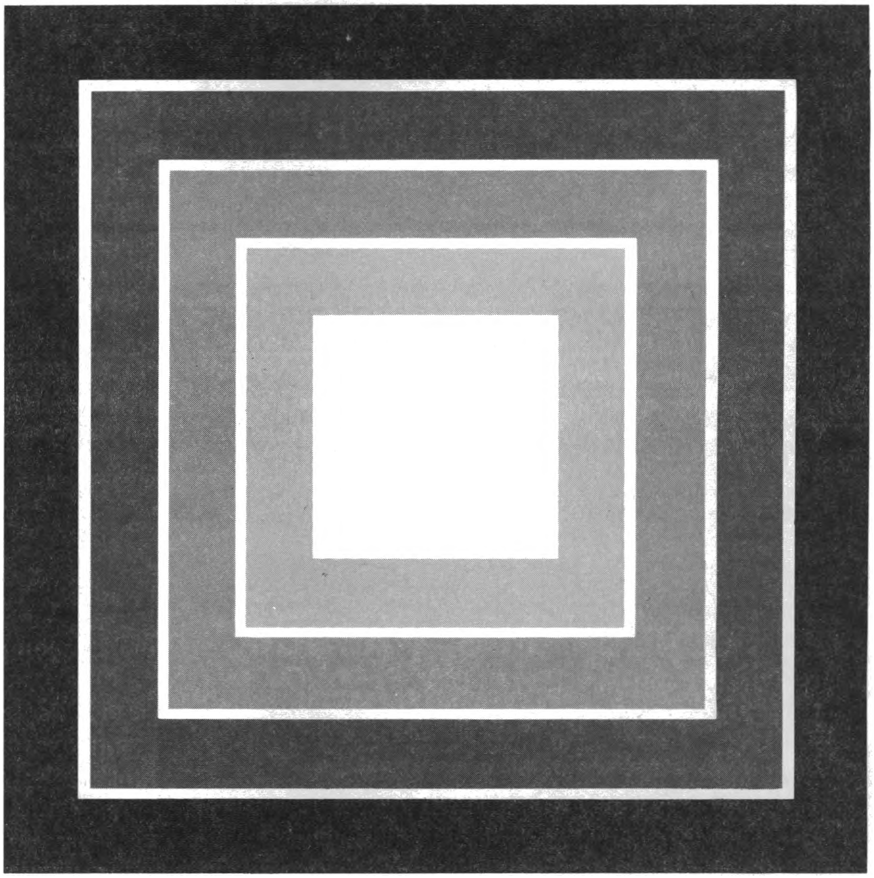
Productivity Indexes for Selected Industries, 1978 Edition



This bulletin updates through 1977 indexes of output per employee for the industries currently included in the United States' government program of productivity measurement. Data are presented for these industries:

- Iron Mining
- Copper Mining
- Coal Mining
- Nonmetallic Minerals
- Canning and Preserving
- Grain Mill Products
- Bakery Products
- Sugar
- Candy and Confectionery
- Malt Beverages
- Bottled and Canned Soft Drinks
- Tobacco Products
- Hosiery
- Sawmills and Planing Mills
- Paper, Paperboard, and Pulp Mills
- Corrugated and Solid Fiber Boxes
- Synthetic Fibers
- Pharmaceuticals
- Paints
- Petroleum Refining
- Tires and Inner Tubes
- Footwear
- Glass Containers
- Hydraulic Cement
- Structural Clay Products
- Concrete Products
- Ready-mixed Concrete
- Steel
- Gray Iron Foundries
- Steel Foundries
- Primary Smelting and Refining of Copper, Lead, and Zinc
- Primary Aluminum
- Copper Rolling and Drawing
- Aluminum Rolling and Drawing
- Metal Cans
- Major Household Appliances
- Radio and TV Receiving Sets
- Motor Vehicles and Equipment
- Railroad Transportation
- Intercity Trucking
- Air Transportation
- Petroleum Pipelines
- Telephone Communications
- Gas and Electric Utilities
- Retail Food Stores
- Franchised New Car Dealers
- Gasoline Service Stations
- Eating and Drinking Places
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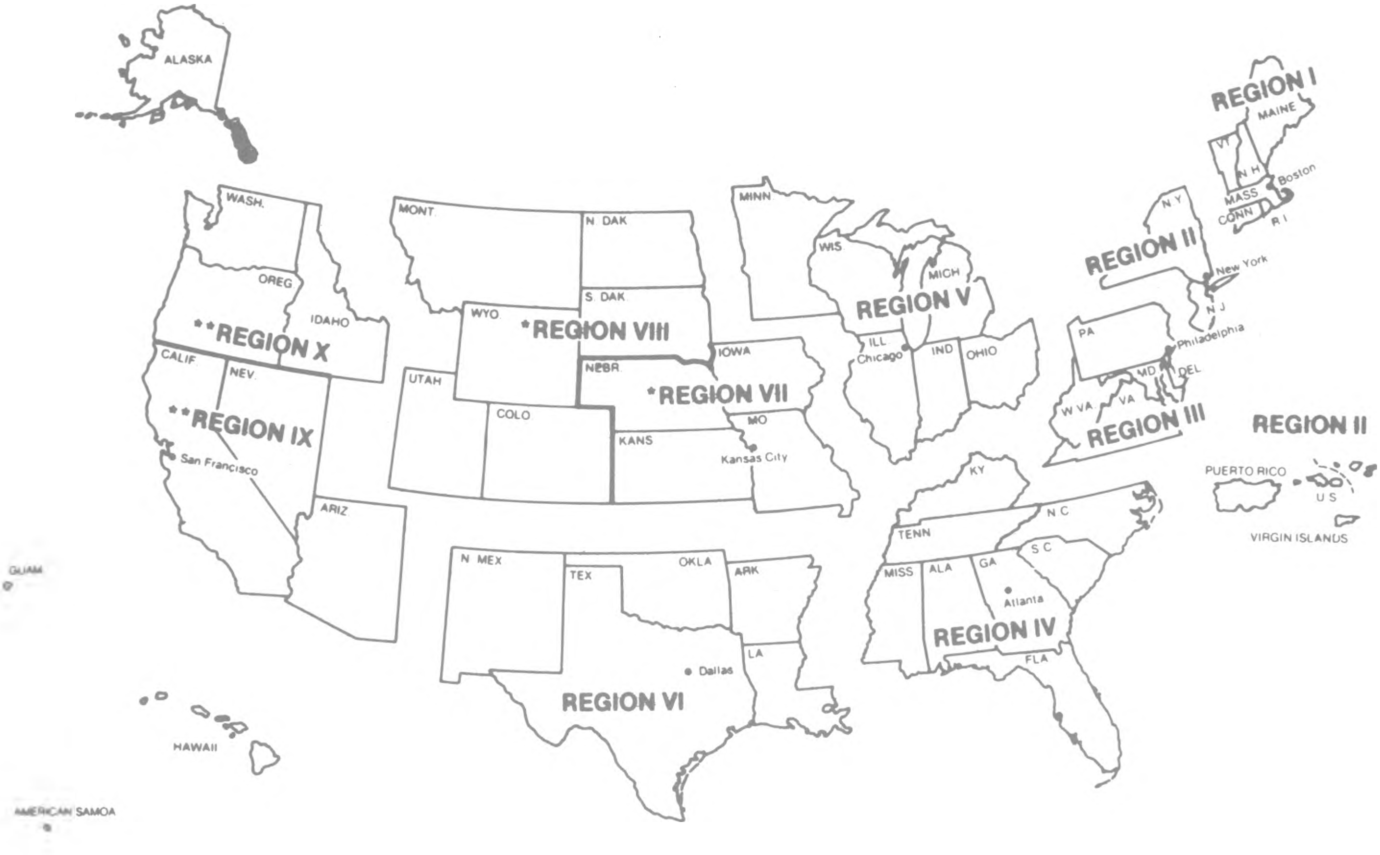

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