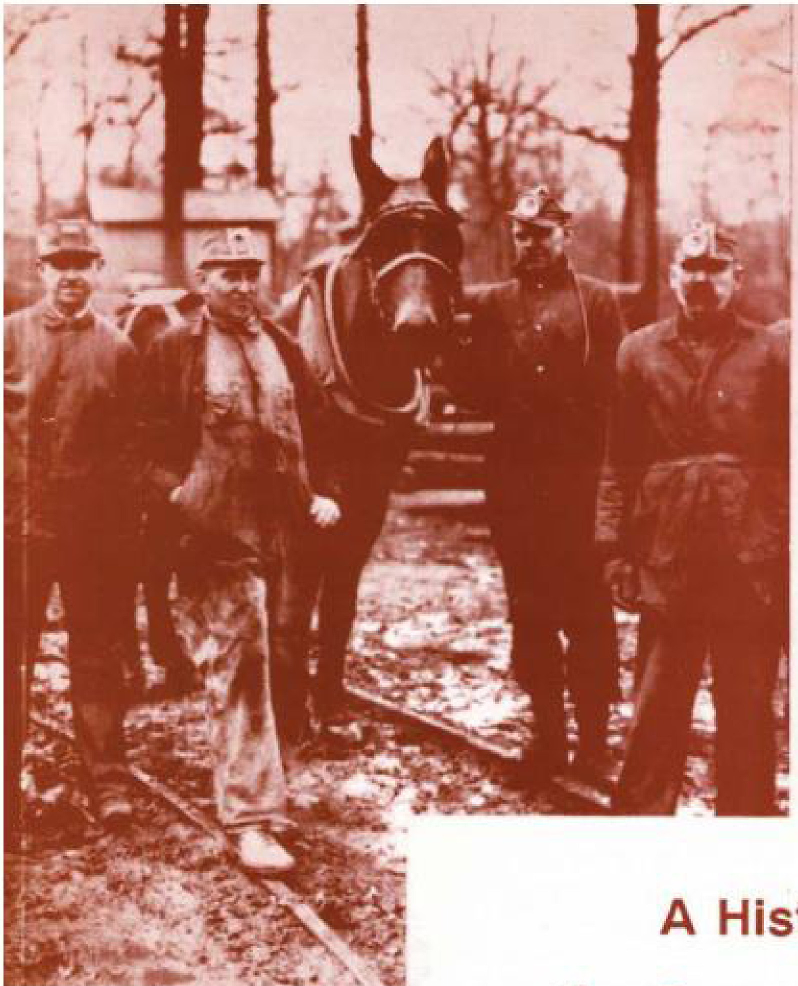
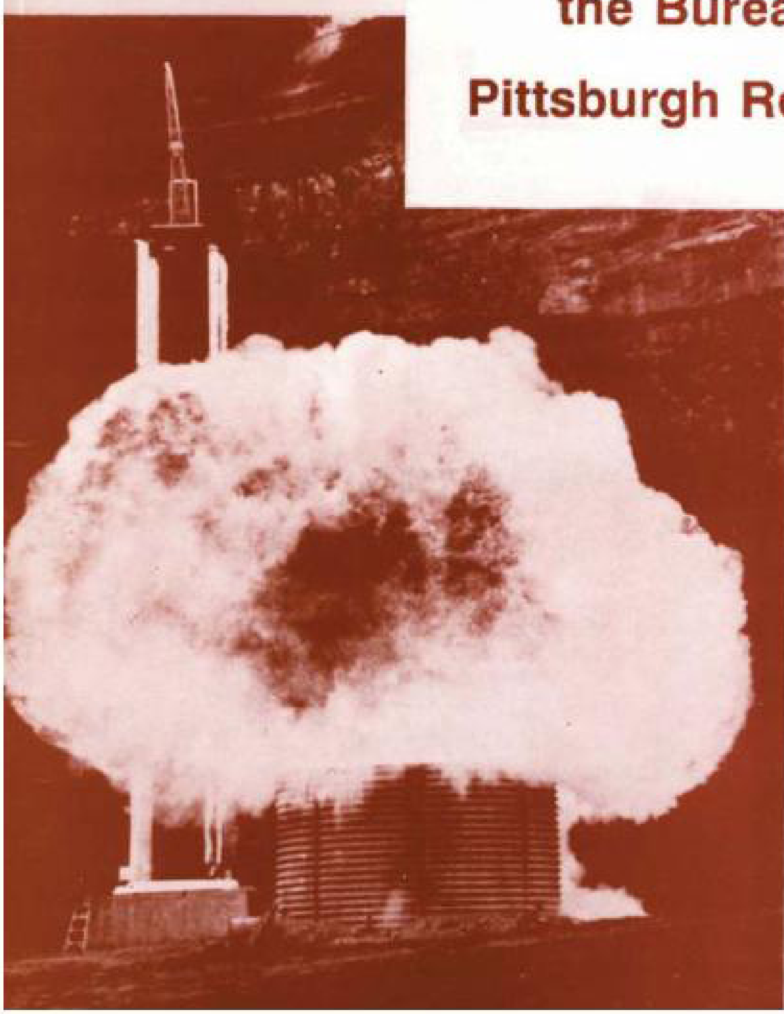
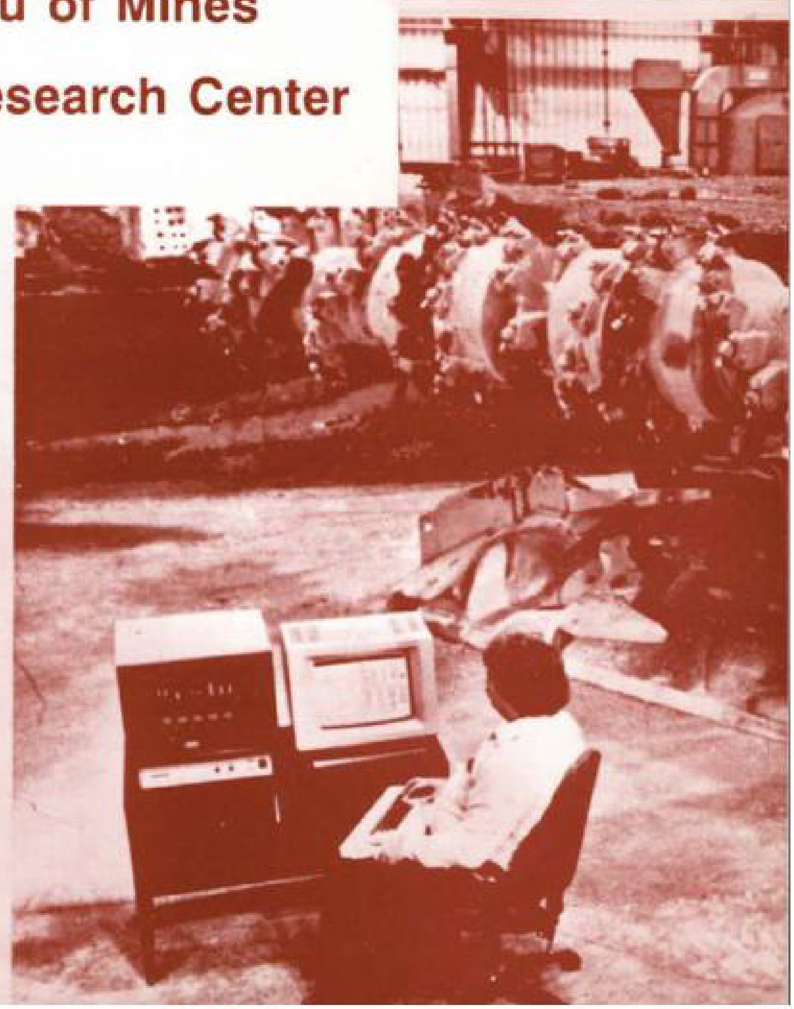


A History of the Bureau of Mines Pittsburgh Research Center





A HISTORY OF THE BUREAU OF MINES PITTTSBURGH RESEARCH CENTER

By Robert J. Tuchman and Ruth F. Brinkley

UNITED STATES DEPARTMENT OF THE INTERIOR
Manuel Lujan, Jr., Secretary

BUREAU OF MINES
T S Ary, Director

CONTENTS

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By Robert J. Tuchman[1] and Ruth F. Brinkley[2]

ABSTRACT

This report presents the origins of the Bureau of Mines and the evolution of the Pittsburgh Research Center from its inception to its present form. Areas of major research emphasis over the years, as well as administrative reorganizations, are discussed.

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INTRODUCTION

The Pittsburgh Research Center is the largest of the Federal mining research centers operated by the Bureau of Mines under the U.S. Department of the Interior (fig. 1). It is also the oldest, being descended in direct line from the original Bureau of Mines established on July 1, 1910, in response to the alarming number of fatal explosions and fires in U.S. underground coal mines. Administrative headquarters for the Bureau were in Washington, DC, while mining research was centered in Pittsburgh, PA. Over the course of time, the Pittsburgh Research Center has undergone several administrative mergers and reorganizations, but its mission has remained essentially the same—to improve health, safety, efficiency, and productivity in the mining industry. This report summarizes the evolution of the Center to the present day, with reference to both administrative structure and research program emphasis.

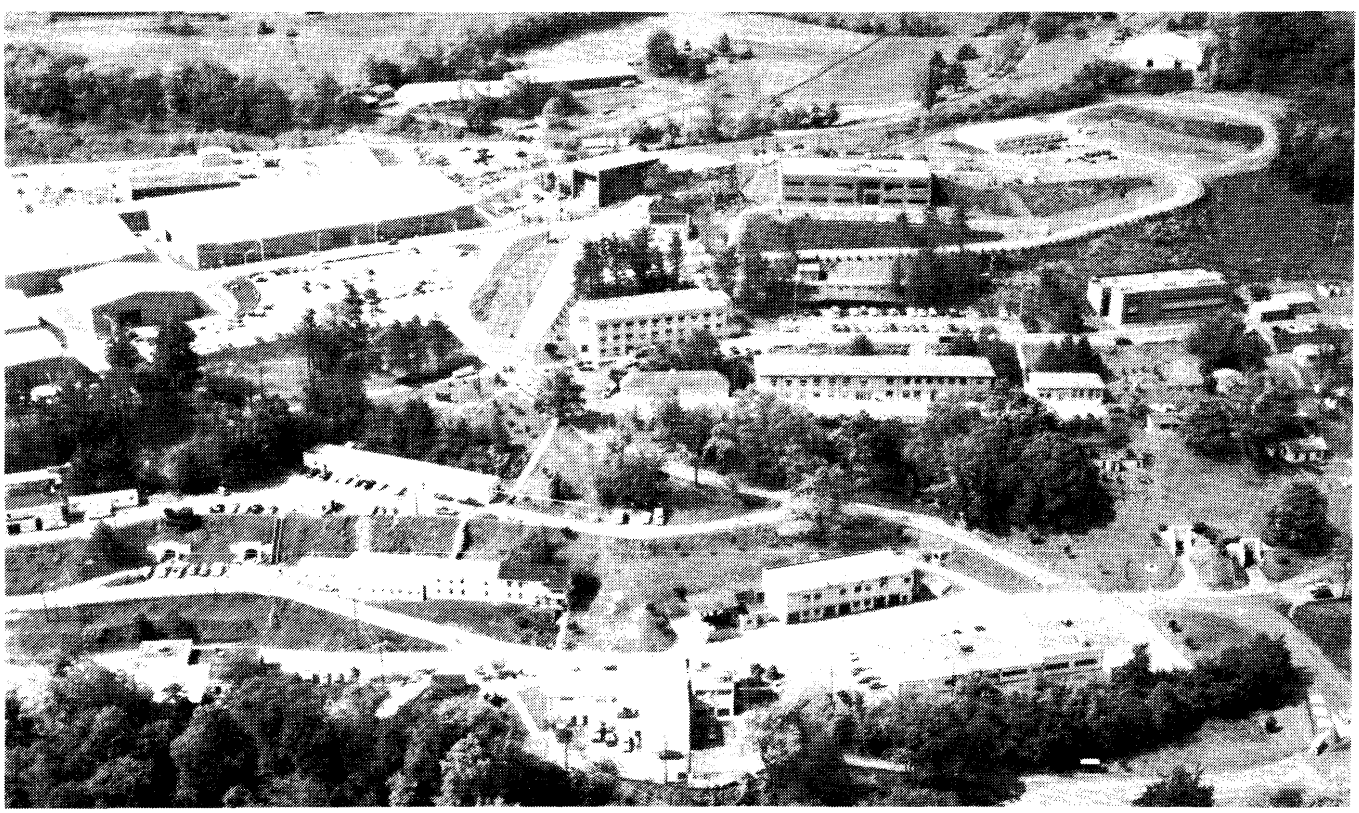

FIGURE 1. - Aerial view of the Pittsburgh Research Center.

ACKNOWLEDGMENTS

This history of the Pittsburgh Research Center represents a project that has spanned a number of years. Grateful acknowledgment is given to the following former Bureau employees at Pittsburgh: Dr. Robert W. Van Dolah, Research Director; Norman E. Hanna, Deputy Research Director; Dr. Bernard Lewis, Chief, Explosives and Physical Sciences Division; and Earle P. Shoub, Regional Director. Without their valuable historical input, this seemingly endless task could not have been completed.

A NEW AGENCY IS BORN

The original mission of the Bureau of Mines was to provide the mining industry with information on blasting materials and techniques that could be used safely in the presence of flammable mine gases and dust. This meant identifying the chemical and physical characteristics that allowed explosives to perform usefully without initiating disastrous fires and explosions. These considerations defined the two main objectives of the Bureau's initial research and development: Safer blasting materials for underground coal mines, and prevention of underground mine gas and dust explosions.

Initially, this work had been assigned in 1908 to the Technologic Branch of the U.S. Geological Survey of the Department of the Interior under the direction of Dr. Joseph A. Holmes. However, in 1910, an act of the 61st Congress created the Bureau of Mines under Richard A. Ballinger, Secretary of the Interior. Although administratively headquartered in Washington, DC, the principal research activities were conducted by the Pittsburgh Mining Experiment Station, under Dr. Holmes, who had been appointed the first Director of the newly created Bureau. According to the act (Public Law 179), the Bureau was, among other things, "to make diligent investigation of the methods of mining, especially in relation to the safety of miners, ...the use of explosives, ...the prevention of accidents." This reflects the origin of what is today known as the Pittsburgh Research Center.

In establishing the Bureau of Mines, U.S. Congress undoubtedly was mindful of similar test stations established earlier in England, Germany, Belgium, Austria, and France, whose work had done much to reduce the frequency and severity of coal mine accidents. Recognizing this, the then Secretary of the Interior, James R. Garfield (1907-9), had requested a delegation of foreign experts to visit U.S. mines to make recommendations to improve safety and efficiency. Thus, the groundwork for the birth of the Bureau had been laid.

THE EARLY YEARS

The Bureau's Pittsburgh Mining Experiment Station, as it was then called, was located at the Government Arsenal in the Lawrenceville section of Pittsburgh, where the War Department had graciously allotted a portion of grounds and buildings to the U.S. Geological Survey. A 100-foot-long test passage, or gallery, that simulated an underground coal mine entry had been installed at the arsenal. It was similar to galleries already established in Courrières, France, and Altofts, England. Although primarily intended to test explosives, it also became the site of numerous coal dust explosion demonstrations, which were necessary to alert the public as to the severity of such explosions. However, many observers were not convinced that a rather short gallery could recreate actual mine conditions. Accordingly, in 1910, the newly created Bureau of Mines leased a 38-acre tract of land from the Pittsburgh Coal Co. in Bruceton, about 13 miles south of Pittsburgh. Here, a new mine, known as the Experimental Mine, was opened (fig. 2). One of the early experiments in the Experimental Mine demonstrated that coal dust by itself was capable of propagating an explosion even in the absence of any methane gas. This demonstration was contrary to the old belief widely held at the time that coal dust could not explode without gas. This view had led to the very dangerous and widespread practice of using loose coal dust in mines to pack explosives in boreholes, which had cost many thousands of lives. These early experiments clearly proved that such a practice was too hazardous to continue.

One of the first objectives of the new Pittsburgh Mining Experiment Station was to test and approve explosives whose detonation products had temperatures low enough and flames short enough in duration to be considered safe in flammable mine atmospheres. Such explosives were then classified as permissible, or approved, for use in coal mines. At first, there were no safe, permissible types of explosives nor certified permissible equipment of any kind for use in U.S. coal mines. To be classified as permissible for use in underground coal mines, explosives now had to pass a series of scheduled safety and performance tests. Some of the original tests are still in use; others have been replaced by more sophisticated testing procedures.

FIGURE 2. - Dedication of the Experimental Mine, which opened in December 1910.

In 1910, the following Bureau projects were underway in Pittsburgh:

- Installation of equipment for testing explosives similar to that used in European testing stations, and certification as permissible of a number of "short-flame" U.S. explosives that had been developed by manufacturers for use in gassy coal mines;
- Operation of an electrical section to develop permissibility requirements for electrical equipment, safety lamps, and electrical types of methane indicators;
- Investigation of the occurrence of methane gas in U.S. coal mines and the adequacy of ventilation to prevent the accumulation of dangerous concentrations of the gas;
- Laboratory research on the flammability of coal dust and quenching of flame by the presence of rock dust.

In addition to work on safer blasting materials and prevention of underground gas and dust explosions, mine postdisaster survival and rescue was another concern of the young Bureau of Mines. Director Holmes initiated the scheme of equipping railroad cars, one of which was headquartered at Pittsburgh, as movable safety and rescue stations (fig. 3). These cars—purchased second-hand, and refitted and equipped at a total cost of $5,000 each—toured the Nation's coalfields, training miners in first aid, rescue work, and mine safety. In a mining emergency, the cars could be immediately dispatched to the accident scene. On October 30-31, 1911, the first national mine safety demonstrations were held at Pittsburgh "as an object lesson to those who had not adopted first-aid instruction or instruction in the use of artificial breathing devices and life-

FIGURE 3. - Bureau of Mines mine safety railroad cars, which were equipped as movable safety and rescue stations.

saving apparatus."[3] Nearly 2,000 persons witnessed the demonstrations and exhibits of the Bureau of Mines at the Arsenal grounds on the morning of October 30, 1911. Nearly 1,200 persons visited the Bureau's Experimental Mine at Bruceton despite exceptionally inclement weather to observe a demonstration of the explosion of coal dust. At a public demonstration of mine rescue work on October 31, 1911, which was attended by President William H. Taft, about 15,000 persons, chiefly miners, were present. The demonstration took place at the former Forbes Field, the use of which had been graciously tendered by the Pittsburgh Baseball Club (fig. 4). President Taft handed Red Cross medals and first aid packages to the rescue team captains, saying: "We must stamp out the spirit of carelessness and the happy-go-lucky idea that I am afraid is too common with Americans generally."[4]

[3]Wilson, H. M., and A. H. Fay. First National Mine-Safety Demonstration, Pittsburgh, PA, October 30 and 31, 1911. BuMines B. 44, 1912, p. 8.

[4]Page 52 of work cited in footnote 3.

At the Experimental Mine, work focused on identifying the processes associated with initiation, growth, and eventual extinguishment of mine fires and explosions. There, under conditions similar to those of a working mine, it was learned how weak methane explosions can initiate violent coal dust explosions and how rock dust, water, and other quenching agents can be applied to arrest these explosions (fig. 5). Instruments were developed for the early detection of open flames and incipient fires due to spontaneous combustion.

Much of this work had wider application that resulted in an important body of information on the flammability and explosibility of numerous other gases, liquids, and dusts, as well as on the toxicity of their combustion products. Early research at the Experimental Mine, in support of construction of the Holland Tunnel between New York and New Jersey, had established ventilation requirements for maintaining carbon monoxide from automobile exhaust at maximum allowable levels. This was accomplished through construction of an oval track in the Experimental Mine,

FIGURE 4. - First national mine rescue demonstration held at Forbes Field, Pittsburgh, PA, on October 31, 1911.

FIGURE 5. - Early test for methane gas in the Experimental Mine using flame safety lamp.

whereby test cars were run around the track while observations were made of the effects of temperature, humidity, airflow rate, smoke, and exhaust gases on the drivers. A carbon monoxide detector installed in the Liberty Tubes in Pittsburgh was the first of a long series of atmospheric monitors and detectors developed by the Center. Another extensive investigation into the spark ignition of anesthetic gases virtually eliminated the risk of explosions in hospital operating rooms. A later study for the American Gas Association resulted in burner designs capable of maintaining stable flames for a range of gas compositions, giving utilities greater flexibility in exchanging gases to meet peak commercial and private demands.

In 1917, a major landmark in the Bureau's history occurred when the Pittsburgh Mining Experiment Station was moved from Lawrenceville to the newly constructed Central Experiment Station at 4800 Forbes Avenue, adjacent to what is now Carnegie Mellon University, in the Oakland section of Pittsburgh (fig. 6). For reasons of safety, the explosives testing activities were moved to Bruceton, where additional buildings were erected to house the Explosives Experiment Station, later

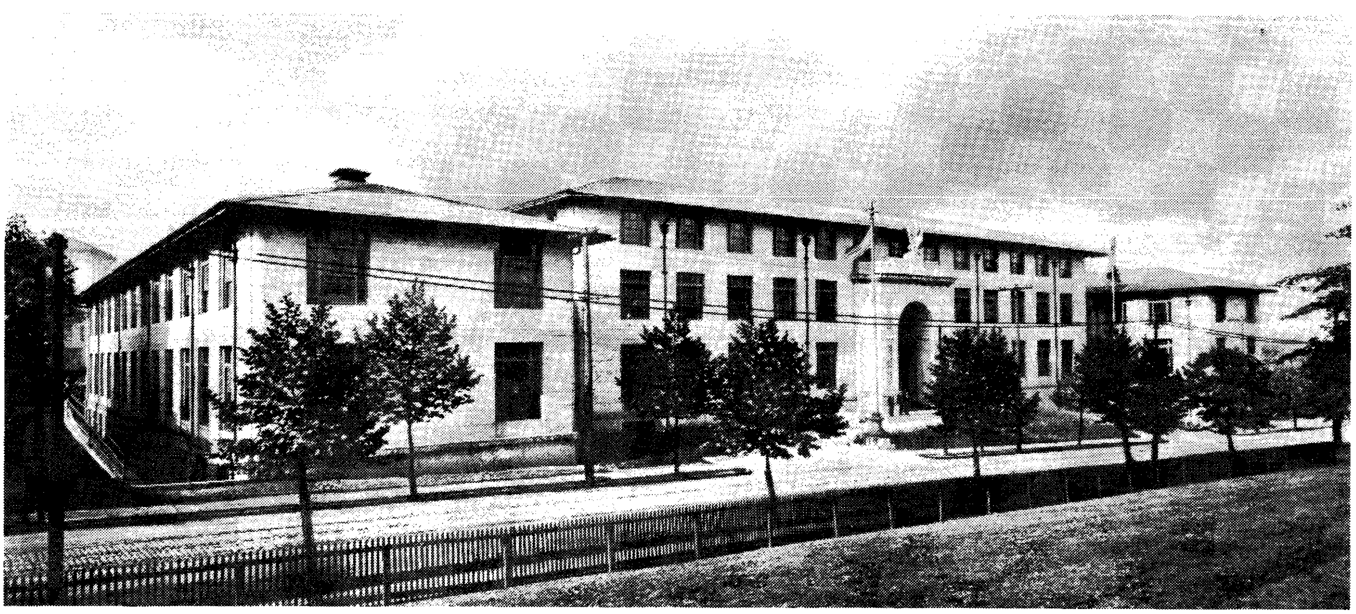

FIGURE 6. - Central Experiment Station at 4800 Forbes Avenue, in the Oakland section of Pittsburgh, PA.

to be known as the Explosives Testing Station. All of the land occupied by the Bureau at that time, including the Experimental Mine, was purchased in 1924.

The earliest major organizational change for the Bureau of Mines occurred in 1925, when President Calvin Coolidge transferred the Bureau from the U.S. Department of the Interior to the U.S. Department of Commerce. The reason for this transfer is not apparent except that it was expected to bring the activities of the two entities into closer coordination. This shift proved to be short-lived, for in 1934 President Franklin D. Roosevelt returned the Bureau to the U.S. Department of the Interior, where it has remained since.

In 1928, Dr. Arno C. Fieldner, Chief Engineer, Experiment Stations Division, described the Pittsburgh Mining Experiment Station as consisting of:

- The health laboratory section charged with control of mine gases and dusts, disposal of mine waste waters, mine sealing against acid mine drainage, and catalytic treatment of automobile exhaust;
- The explosives section;
- The fuels section;
- The metallurgical section;
- The physical section;
- The Experimental Mine section;
- The mining research section;
- The falls of roof and coal section.[5]

With the exception of the fuels and metallurgical sections, all of the above functions are part of the Pittsburgh Research Center today.

FOCUS ON FIRES, EXPLOSIONS, AND EXPLOSIVES

By 1936, research emphasis was placed on explosives, explosions, and combustion. Wilbert J. Huff was Chief of what was then known as the Explosives Division, followed by Dr. Bernard Lewis in 1946. Under Dr. Lewis' leadership, the division became the Explosives and Physical Sciences Division, and its function was substantially expanded to include fundamental research in the structure of flames, explosions, and detonations.

Over the years, the Bureau sought to reduce the use of unsuitable explosives, as well as the improper use of explosives, through research, training, and demonstrational programs. The introduction of permissible explosives to the coal mining industry had been a major step in increasing safety in gassy and dusty coal mines. Even though these early permissible explosives met with initial acceptance by the coal mining industry, it required about 30 years of unceasing effort in the form of education and developmental endeavors before mounting acceptance of permissibles eclipsed the use of black powder, the principal blasting explosive used in underground coal mines, to which many mine disasters were directly attributed (fig. 7). Additionally, in 1948, after extensive experimentation, an increase in the permissible charge limit from 1½ to 3 pounds, as requested by the industry, was authorized, which greatly improved productivity. Also paralleling these developments has been the introduction of water-filled stemming bags, single- and multiple-shot blasting machines, and short-delay detonators.

Further improvement in the safety of explosive formulations without the loss of necessary strength and reliability of ignition continued to be a longstanding objective. During 1955 to 1960, a major advance in this direction was achieved when it was established experimentally that the

[5]Fieldner, A. C., and A. H. Emery. Work of the Experimental Stations of the Bureau of Mines. BuMines IC 6060, 1928, 29 pp.

FIGURE 7. - Former gallery for testing explosives at Bruceton, PA. Here, black powder—a nonpermissible explosive— produces a violent explosion.

addition of sodium chloride to an explosive formulation significantly reduces the probability of a methane explosion. As a result of this research, by 1962 all active permissible explosives were modified by the manufacturer to include approximately 10% sodium chloride. A low-strength permissible explosive that included sodium chloride in its formulation was specially designed by the Bureau for use in small coal mines as a substitute for black powder, which was ultimately outlawed in 1966. Bureau research also led to the development of slurry and emulsion explosives, which are less subject to accidental initiation, thereby improving safety in explosives handling, transport, and storage.

Growing interest in field-mixed explosives raised problems as to the potential hazards of ammonium nitrate-fuel oil (ANFO) compositions used in open pit mines and underground metal and nonmetal mines. These were resolved in various studies leading to recommendations for safe practices with these blasting agents. These studies also resulted in the development of a new table of safe distances, adopted internationally, for the bulk storage of ammonium nitrate and ammonium nitrate-fuel oil compositions.

Dr. Fieldner was able to report at an international conference that since the inauguration of the Bureau's explosives testing program, there had not been a single coal mine explosion in the United States definitely chargeable to permissible explosives when used in a permissible manner. It is noteworthy that these results had been obtained without any appreciable loss in blasting efficiency. The permissible explosives initially developed by U.S. industry generally did not require large amounts of inert diluents or inert sheaths, as used in Europe, to pass the scheduled tests prescribed by the Bureau at that time. The use of these relatively strong permissible explosives had materially aided in maintaining the coal production rate in the United States. Meanwhile, fundamental research, made possible by electronic instruments and ultra-high-speed and x-ray photography, provided much-needed insight into the high-temperature, high-pressure reactions associated with efficient detonation and the factors responsible for effective explosive performance. In 1967, Dr. Robert W. Van Dolah, the Center's Research Director from 1954 to 1978, had the singular honor of being awarded the Nitro-Nobel Gold Medal for theory he developed to explain the accidental initiation of liquid explosives.

Technology initially developed for the coal mining industry was extended to a wide range of potentially explosive and flammable materials of interest to other industries and Government agencies, including the U.S. Department of Defense, U.S. Air Force, U.S. Department of Transportation, U.S. Coast Guard, and the National Aeronautics and Space Administration (NASA). Preliminary work on the explosives trigger for the atomic bomb, specifically, the first experimental work on cylindrical implosions, was conducted at the Bureau of Mines explosives laboratory in Bruceton. During World Wars I and II and thereafter, major contributions were made to the formulation of new military explosives and to the development and safe use of fuels and fluids for conventional aircraft, jet engines, and space vehicles. Projects for the military and NASA ranged from the destruction of earthen tunnels used by the Viet Cong to the effect of the extraterrestrial environment on Apollo attitude control engines. Investigations on the safe handling of hazardous materials ranged from routine loading of oil tankers, and the storage and transport of liquid natural gas, liquid hydrogen, and liquid chlorine to the safest method of ejecting burning fuel from a space capsule at an altitude of 100,000 feet. The effect of extraterrestrial atmospheres on the performance of explosives was also investigated. Dr. Van Dolah was one of an eight-member board that investigated the disastrous fire aboard Apollo 204 in 1967 wherein three astronauts perished. Other Bureau scientists developed methods for determining flammability hazards of combustible materials. Standard tests to determine autoignition temperatures, flammability limits, and minimum ignition energies, developed by Bureau personnel, were adopted by the American Society for Testing and Materials. Fundamental and highly innovative research into the manner in which flames and explosions originate, propagate, and are quenched assured the Center and the United States an authoritative place in the international scientific community, a posture that has continued to grow since.

THE CENTER'S MISSION BROADENS

Passage of the 1969 Federal Coal Mine Health and Safety Act by the 91st Congress (Public Law 91-173) marked a major reorientation and expansion of the Center's mission and responsibilities. To the traditional work on fires, explosions, and explosives were added the health, safety, and productivity problems associated with the increasing use of mechanized mining, the introduction of longwall mining, and the exploitation of deeper, less accessible resources. The aforementioned new concerns of the Center were divided into two subprograms, health and safety, with respective activities listed below:

Health	*Safety*
Respirable dust	Fire and explosion prevention
Ventilation	Methane control
Noise	Ground control
Industrial hygiene	Postdisaster survival and rescue
	Explosives

In addition to the above, increased emphasis began to be placed on conservation and the environmental impacts of mining.

In the area of respirable dust, the primary approach was at-source control. Deeper, slower cutting by specially designed bits in conjunction with water sprays reduced dust formation. Control of generated dust was achieved with machine-mounted water sprays and improved ventilation, cutting sequences that kept machine operators in clean air, and by improved dust collectors. Research into high-pressure water-jet-assisted cutting also achieved significant dust reductions (fig. 8). Personal protection was attempted by canopies that surrounded machine operators with clean air. In silica sand processing plants, new hardware greatly reduced worker dust exposure during bag filling and handling. New respirable dust monitors that continuously recorded the wearer's dust exposure attested to the significant reductions in respirable dust that had been

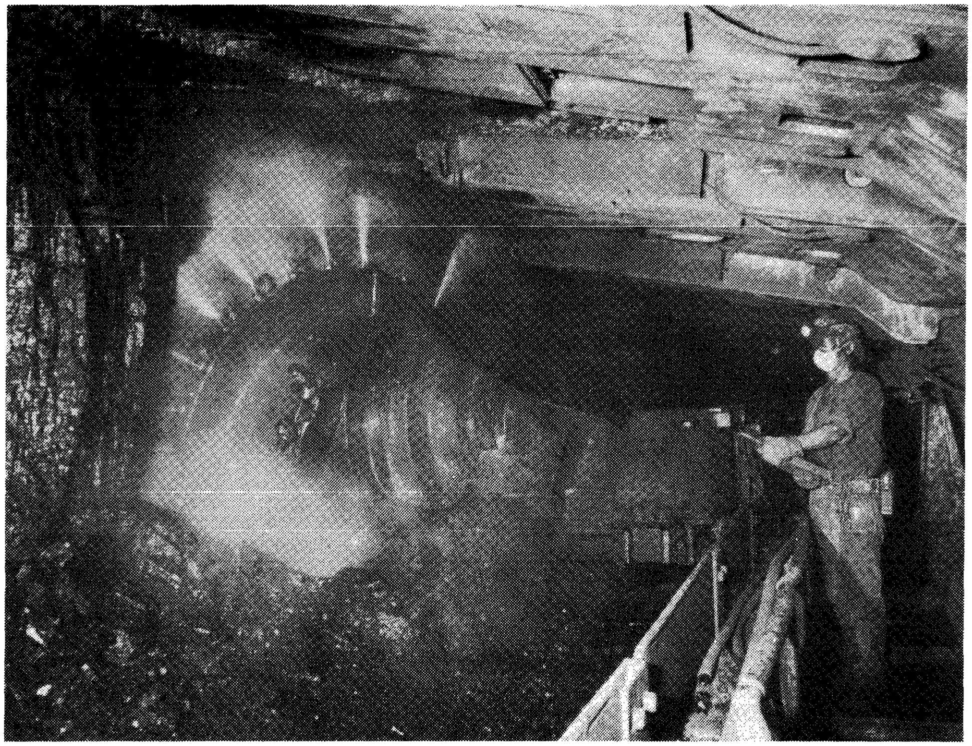

FIGURE 8. - Water-jet-assisted cutting utilized on a longwall shearer to reduce respirable dust.

achieved. However, more sophisticated analytical instruments revealed a high incidence of unsuspected quartz concentrations, necessitating current research to comply with increasingly strict standards. The effect of somewhat coarser particles known as thoracic dust also became a matter of concern and research.

The respirable dust area received considerable support from the Center's ventilation research, characterized by simple, low-cost procedures for maintaining sufficiently clean, cool air in mine workings. Typical developments have been the use of a series of temporary cloth stoppings that are readily installed and easily repaired, a rapid brush-on method for sealing permanent masonry stoppings, and simple, reliable techniques for determining airflow patterns and detecting leakage using a tracer gas (sulfur hexafluoride) to follow airflows.

Ventilation air must be not only adequate in quantity but also healthful. The Center's industrial hygiene research has produced a number of small, lightweight samplers and analyzers that have helped to ensure that potentially hazardous products from blasting, diesel engines, and other underground operations do not exceed safe levels. The Center also has developed and/or tested fire sensors that are capable of detecting carbon monoxide and smoke particles at low levels, thus providing early warning of developing fires in underground mines.

In the always critical area of roof control, roof bolting has become the accepted support practice. Introduced by the Bureau of Mines as an adjunct to timbering, roof bolting proved its effectiveness in preventing roof fall fatalities. Advances in drilling and bolting techniques have contributed greatly to the spread of roof bolting. The long-term objective of predicting and forestalling catastrophic roof and rock falls was being met through identification of the responsible geological factors (fig. 9). More immediate results were obtained with techniques that eliminated the need for working under unsupported roof, such as automated temporary roof support systems for use on roof bolting machines, now federally mandated for all coal mines, and machine-mounted cabs and canopies. The Bureau also took an active part in the evolution of longwall mining, including developing one of the first shield faces in the United States, the first lemniscate-type shields, and the first shields in steeply pitching coalbeds, which contributed to a downward trend in ground control-related accidents.

FIGURE 9. - Conducting a geologic study in a coal mine roof fall area.

Techniques were developed that allowed mining companies to determine the gassiness of coalbeds. Armed with this new technology, Bureau researchers conducted a number of geological studies that identified the gassiness of most major coal basins. This information was, and still is, used by most coal mining companies as a planning tool for methane control systems. New developments for methane control included advance surface drainage of coalbeds through vertical boreholes, with commercial recovery of the drained gas; underground drainage through long, horizontal boreholes, accurately controlled by wireless surveying of the hole trajectory; and cross-measure drainage of gob gas where surface drainage was not feasible. Additionally, analytical techniques such as direct core analysis and computer modeling now made it possible to predict methane control needs.

The Center's industrial-type hazards research used a double approach to a wide variety of safety problems. The first was aimed at preventing human errors through heightened awareness of safety problems, such as recognition of unstable ground and training in dealing with perceived hazards. The second approach was to provide a better working environment through safer equipment and electric power systems, better lighting, mine-wide monitoring and communication, and mechanization of materials handling. Self-paced computerized training programs and equipment models for hands-on experience became available for numerous tasks. Much was learned about organizational and personal factors that affect performance and safety, such as job satisfaction and absenteeism. As the number and size of mobile machines increased, so did the need for electrical power. Considerable progress was made toward intrinsic electrical safety, the elimination of spark ignitions and electrical shocks, and the development of explosion-proof electrical housing, intrinsically safe hardware, circuit breakers, cable-fault detectors, and warning devices. Problems of severely inadequate illumination in underground mines were resolved through the introduction of portable, stationary, and machine-mounted lighting systems, and a lighter-weight nickel-cadmium battery for the miner's cap lamp. Safety and efficiency of mobile equipment operators were enhanced by the development of human-engineered compartments and control panels. Stability indicators on surface equipment reduced rollover hazards. Inadequate materials handling practices in mines and plants, long recognized as a source of injuries, were relieved with the development of training and mechanical devices.

Although noise control research gave some attention to personal protection with earmuffs, the emphasis again was on at-source control. Cutting and drilling equipment, such as pneumatic drills and auger miner heads, were redesigned for lower noise levels. Dozers, loaders, and similar mobile equipment were provided with mufflers, sound barriers, and vibration absorbers. Workshops and handbooks on simple, "do-it-yourself" noise treatments were made available to industry.

Both routine and emergency operations were significantly improved by whole-mine monitoring and communication systems that provided continuous, two-way exchange of verbal and visual information between underground workings and the mine office, supported by extensive data display, storage, retrieval, and analysis. A vest with a built-in, two-way radio and portable phones and pagers kept roving miners in touch with all parts of the mine.

Rescue apparatus for application in mines continued to become more sophisticated. In earlier years, a Bureau-approved self-rescuer made by Mine Safety Appliances Co. was available that could be carried in the pocket or worn on the belt. This protected the wearer against carbon monoxide for about one-half hour, but did not supply any oxygen. However, since passage of the 1969 Federal Coal Mine Health and Safety Act, considerable emphasis has been placed on supplying the missing oxygen. To the filter self-rescuers that protected against toxic gases, postdisaster research has now added self-contained self-rescuers that supply the wearer with oxygen.

A second crucial, postdisaster action is locating and communicating with miners trapped underground. Here, of course, speed is of the essence. Major advances in electromagnetic technology now permit two-way, through-the-earth communication. At the same time, television cameras and other instruments lowered down boreholes can assess the underground environment and the presence and condition of trapped survivors.

The Center's long experience in mine fires and explosions was applied in generating new and more quantitative knowledge on the burning behavior of a wide variety of dusts, gases, fluids, and solids, and on the relative merits of flame inhibitors, quenching agents, and high-expansion foam. Large-scale research in the Experimental Mine produced much basic information on the origin, growth, and suppression of fires and explosions (fig. 10). Passive barriers designed to

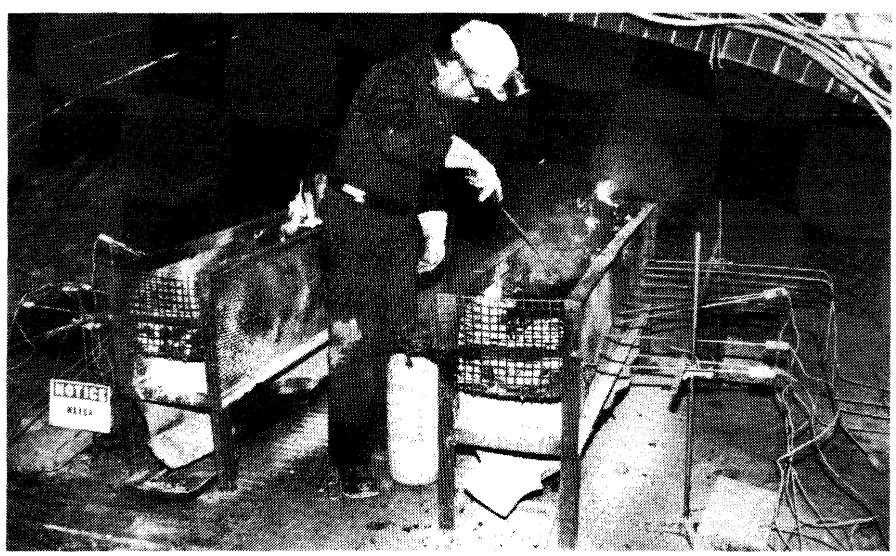

FIGURE 10. - Coal fire extinguishment test in the Experimental Mine.

disperse a quenching agent under the action of an oncoming explosion were successfully demonstrated in a working mine. Improved cutting bits, directed water sprays, and machine-mounted ignition suppression systems were developed to combat the growing problem of frictional methane ignitions associated with modern, mechanized coal cutting equipment.

The Center's explosives research continued along established lines, identifying factors that influence the safety and performance of explosives and other blasting agents, as well as developing innovative explosives and evaluating candidate permissible explosives. Proposed revisions in delay blasting regulations led to an extensive evaluation of commercial delay blasting relative to the hazards of explosive misfires.

The effects of mining on the environment had been a concern of the Bureau for some time, one that became intensified with the growing national effort to conserve the quality of land and water. Surface stability research by the Center pioneered methods for controlling subsidence over mined-out areas. Waste fly ash from electric power plants, injected in various forms, has been used successfully in some cases to stabilize the ground under residential and other structures. It was also effective as a base for revegetating mined surface lands. At the same time, significant progress was made in developing models to predict the amount of subsidence to be expected over a mining operation.

Resource conservation research resulted in several promising approaches to the problem of acid mine drainage from mines and waste piles. Treatment of contaminated areas with surfactants successfully inhibited the action of iron-oxidizing bacteria that perpetuate acid mine drainage. Electrical conductivity surveys identified buried sources of acid. For acid mine drainage from active mines, an in-line treatment system was developed that combined aeration and neutralization in a single, low-cost operation. Pneumatically stowed limestone was also used successfully to seal openings into abandoned mines.

A new approach to the control of abandoned mine fires, another environmental concern, was demonstrated in an abandoned underground mine. In this controlled burnout process, combustion is carefully accelerated until all the fuel is consumed; heat from the operation generates revenue or can be recovered for industrial use.

THE PRESENT-DAY CENTER EMERGES

A major organizational change had occurred in 1954 that divided the field activities of the Bureau of Mines into five Regions. Region V, headquartered in Pittsburgh under Harold P. Greenwald as Regional Director, was itself divided into six divisions, as follows:

- Division of Mineral Technology (College Park, MD);
- Division of Solid Fuels Technology (Pittsburgh, PA);
- Division of Explosives Technology (Pittsburgh, PA);
- Division of Petroleum Technology (Morgantown, WV);
- Division of Mineral Industries (Pittsburgh, PA);
- Division of Administration (Pittsburgh, PA).

The Division of Explosives Technology underwent several name changes: Explosives Research Laboratory (1959-63) and Explosives Research Center (1963-69). Mr. Greenwald had been followed as Regional Director by his deputy, Earle P. Shoub. Another reorganization had abolished the regional network structure, and in 1963 the Eastern Administrative Office in Pittsburgh and the Western Administrative Office in Denver were formed. The former covered the 27 Eastern States and was headed by Arlow L. Julian. In July 1969, the Explosives Research Center and the Health and Safety Research and Testing Center, both in Pittsburgh, merged to form the Safety Research Center. In March 1971, following a merger with the Pittsburgh Mining Research Center, the Safety Research Center became the Pittsburgh Mining and Safety Research Center.

Notwithstanding the growing importance of the Bruceton complex, for many years the activities of the Pittsburgh Research Center had remained headquartered at 4800 Forbes Avenue. However, their rapid expansion made the need felt for space and larger facilities. By the early 1970's, activities essentially became concentrated at Bruceton, where new buildings were erected to house new laboratories and a steadily growing staff. The Bruceton underground facilities had been expanded by enlarging the Experimental Mine. A small mine, previously operated by the Bureau's Health Branch, was incorporated into the Experimental Mine and became a part of a new Safety Research Coal Mine. This mine is now used to test new equipment and procedures before transferring them to industry.

Following the oil embargo in 1973 by the Organization of Petroleum Exporting Countries, emphasis on energy self-sufficiency as a national priority accelerated efforts to improve production of our Nation's abundant coal reserves. The Mining Equipment Test Facility (METF), unique in the United States, was designed and constructed on 9 acres of land at Bruceton to evaluate new designs of equipment, systems, and techniques needed to effect substantial increases in coal productivity. Major features of the METF are the mine roof simulator, capable of 3 million pounds of force for load tests of various roof supports and for studies of dynamic roof mechanics, and full-scale facilities for research and development of coal cutting and in-mine mechanical haulage equipment (fig. 11).

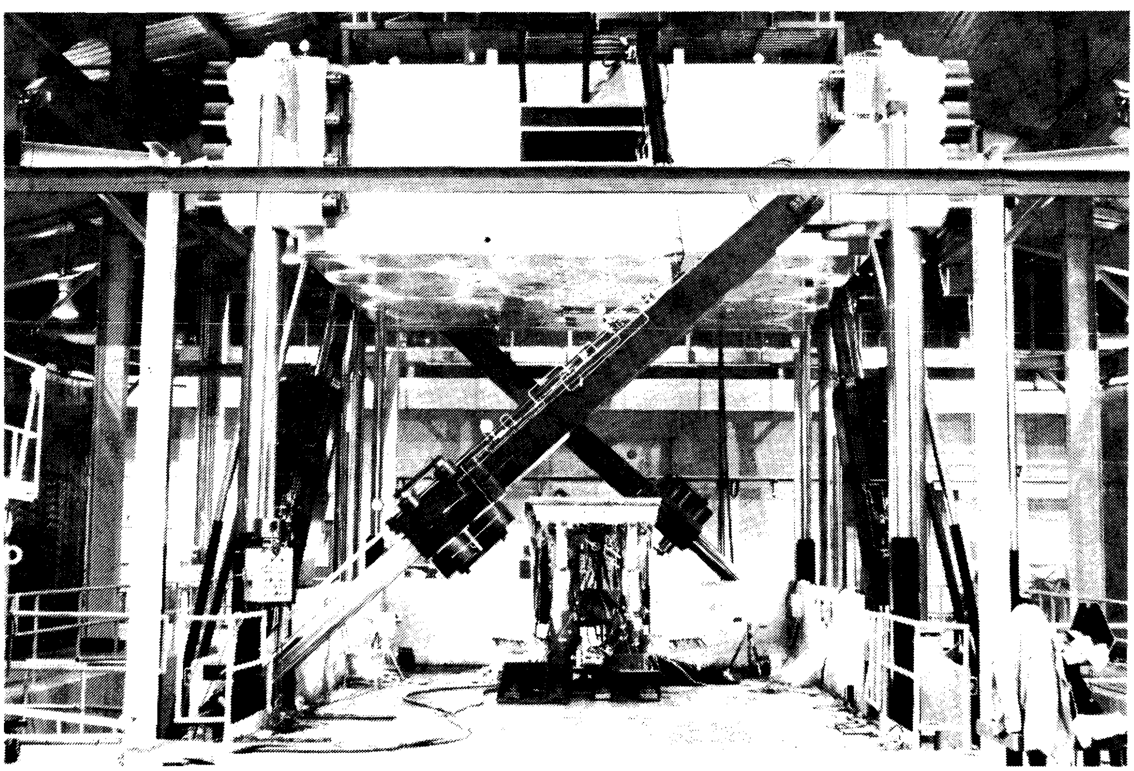

FIGURE 11. - Mine roof simulator in the Mining Equipment Test Facility.

The responsibility of mine inspection, which had belonged to the Bureau of Mines since 1941 (Public Law 49), was transferred in 1973 to a new U.S. Department of the Interior agency—the Mine Enforcement and Safety Administration (MESA). In 1978, MESA was transferred to the U.S. Department of Labor and was renamed the Mine Safety and Health Administration (MSHA).

Meanwhile, in 1975, the growing national concern with energy led to the transfer of Bureau of Mines energy research activities to the newly created Energy Research and Development Administration (ERDA). In 1977, President Jimmy Carter created the U.S. Department of Energy, which included ERDA facilities and the Bureau of Mines coal mining technology program.

In August 1979, the Pittsburgh Mining and Safety Research Center received its present title—the Pittsburgh Research Center (PRC)—under John N. Murphy, who has served as Research Director since 1978.

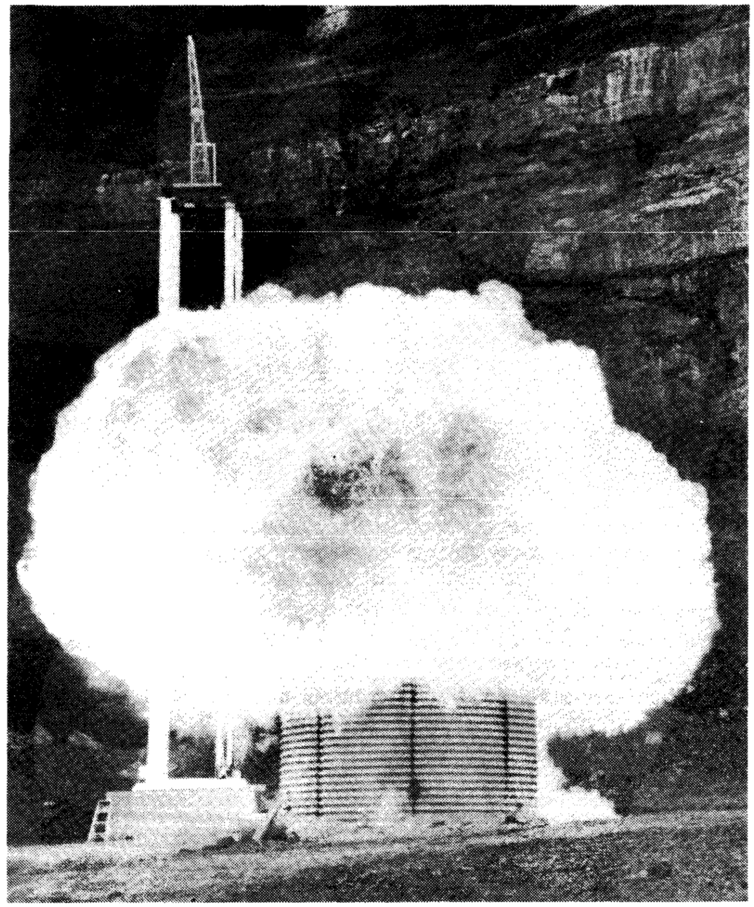

FIGURE 12. - Demonstration of grain dust explosion at Lake Lynn Laboratory.

Lake Lynn Laboratory, a 400-acre Bureau of Mines underground laboratory located near Fairchance, Fayette County, PA, became operational in early 1982. It was developed in a limestone bed adjacent to an abandoned limestone mine. Lake Lynn is a highly sophisticated laboratory and experimental mine that provides an isolated setting for large-scale explosion tests and mine fire research (fig. 12). At Lake Lynn, Bureau of Mines researchers can ignite and monitor massive explosions of gas and coal dust in the mine to determine how the explosions propagate, how to stop them, and how to prevent them from happening at all. Lake Lynn is designed to be representative of the newest coal mines, in which relatively wide entries are made possible by modern roof support techniques. The long entries also can simulate the layout of longwall operations, allowing full-scale tests of explosions like those that might occur in the growing number of U.S. mines with longwall sections. Also at Lake Lynn is the Subsidence Abatement Investigation Laboratory, which is utilized for the evaluation of remote backfilling methods for controlling subsidence in abandoned mined lands (fig. 13).

Effective September 1982, the Bureau of Mines coal mining technology program, which had been assigned to the U.S. Department of Energy, was returned to the Bureau, including the Mining Equipment Test Facility. Lastly, in May 1983, the Bureau of Mines complex at 4800 Forbes Avenue was sold to neighboring Carnegie Mellon University.

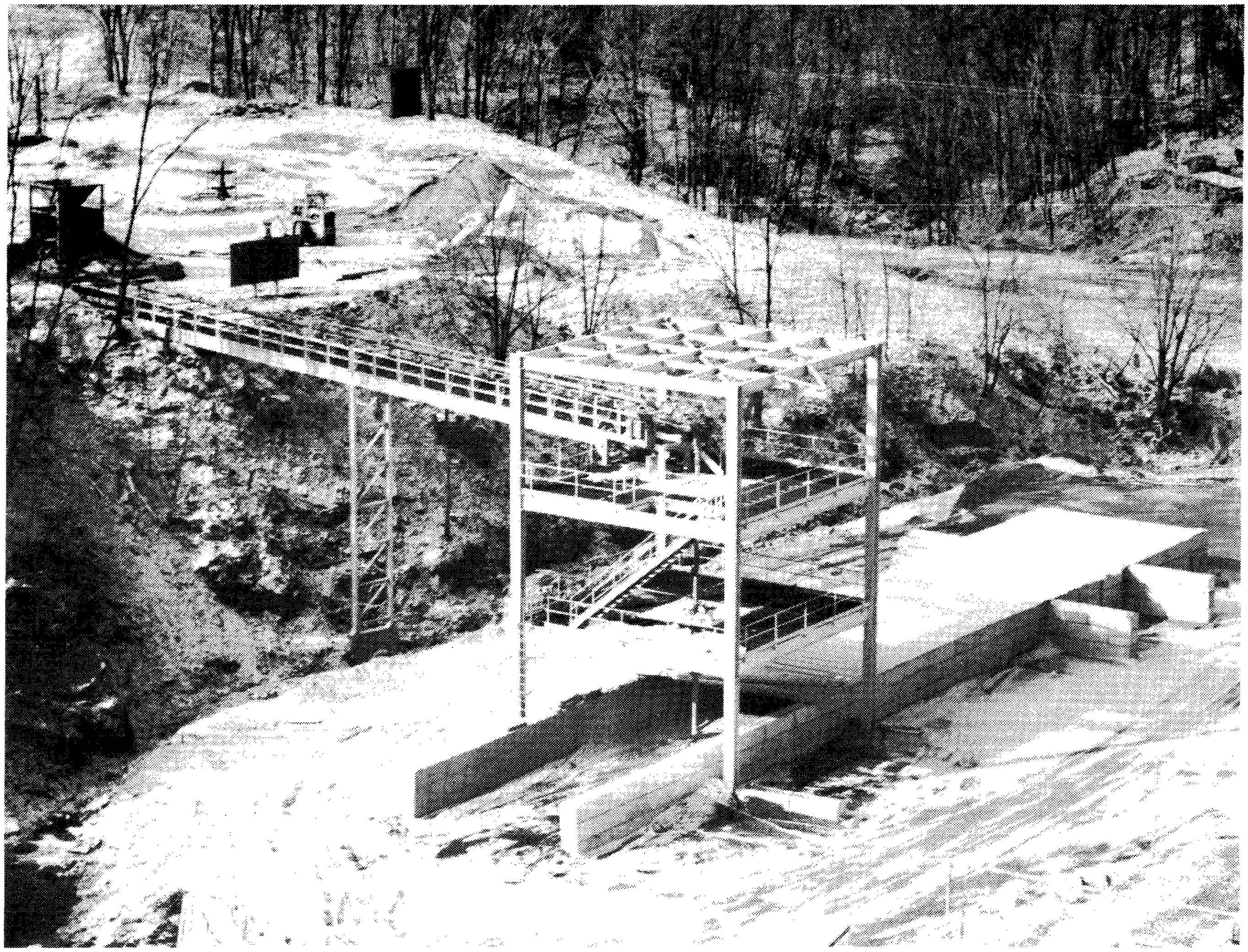

FIGURE 13. - Subsidence Abatement Investigation Laboratory at Lake Lynn.

THE PITTSBURGH RESEARCH CENTER TODAY

Today, the Pittsburgh Research Center occupies 180 acres at Bruceton, PA, and continues to pursue an aggressive, innovative program of research to promote the safety and health of the Nation's miners, to improve mine productivity and enhance the recovery of mineral resources, and to minimize the environmental impact of mining. The Center has gained prominence in a number of areas of expertise in which advances continue to be made. Improving disaster survival capability constitutes an area of special technical competence at the Center. Lightweight breathing apparatus with a life-support capacity of up to 2 hours have been devised for rescue team wear, to be used either alone or interfaced with a rescue team helmet equipped with a communication system. An automatic breathing and metabolic simulator has been developed by the Bureau that has proved to be more reliable for evaluation of respirators than human subjects. A remote methane detector is under development to warn the individual wearer when the content of the mine atmosphere becomes hazardous. The Center continues to work to improve the safety of explosives, initiating systems, and blasting practices. A sheathed rock-breaker explosive charge (fig. 14) suitable for unconfined

FIGURE 14. - Evaluating a commercial version of the Bureau-developed sheathed rock-breaker explosive charge.

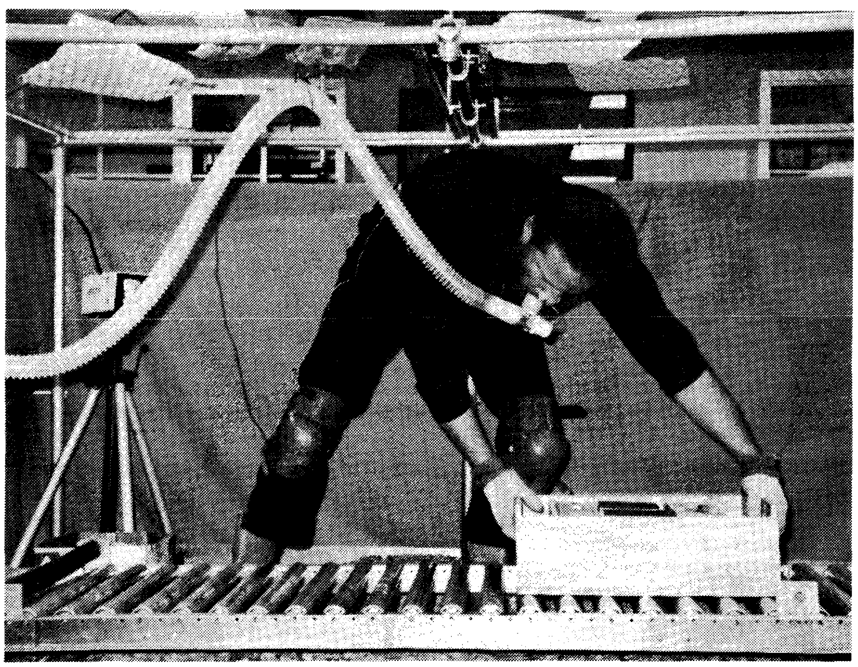

FIGURE 15. - Part of an ergonomic study on avoiding back injuries by determining acceptable weights for lifting in low-coal seams.

underground coal mine blasting has become available as an alternative to the hazardous practice of mudcapping, whereby an explosive is placed on top of the rock and covered by a cap of mud or earth. Current research also has confirmed the feasibility of safely extending the total delay time of a shot pattern beyond the present 500 milliseconds and is studying the effect of temperature and pressure on explosive sensitivity and the premature initiation of explosives by lightning.

Another important mission of the Center remains the control and prevention of underground mine fires and explosions through safer equipment and more effective quenching techniques. Research is being conducted into a detection system that can distinguish between smoke from mine fires and diesel exhaust particulate. Major attention also is being given to perfecting inflatable and expansion-type seals that can be used for rapidly sealing mine fire areas. Ergonomic studies are aimed at providing a more efficient mine working environment through systematic training and greater safety in manual materials handling (fig. 15). Recent investigations have dealt with methods of providing more effective training for procedural tasks such as donning self-contained self-rescuers. Research to improve safety and economy in the hoisting of personnel and materials in underground mines is conducted in the Center's Wire Rope Research Laboratory (fig. 16).

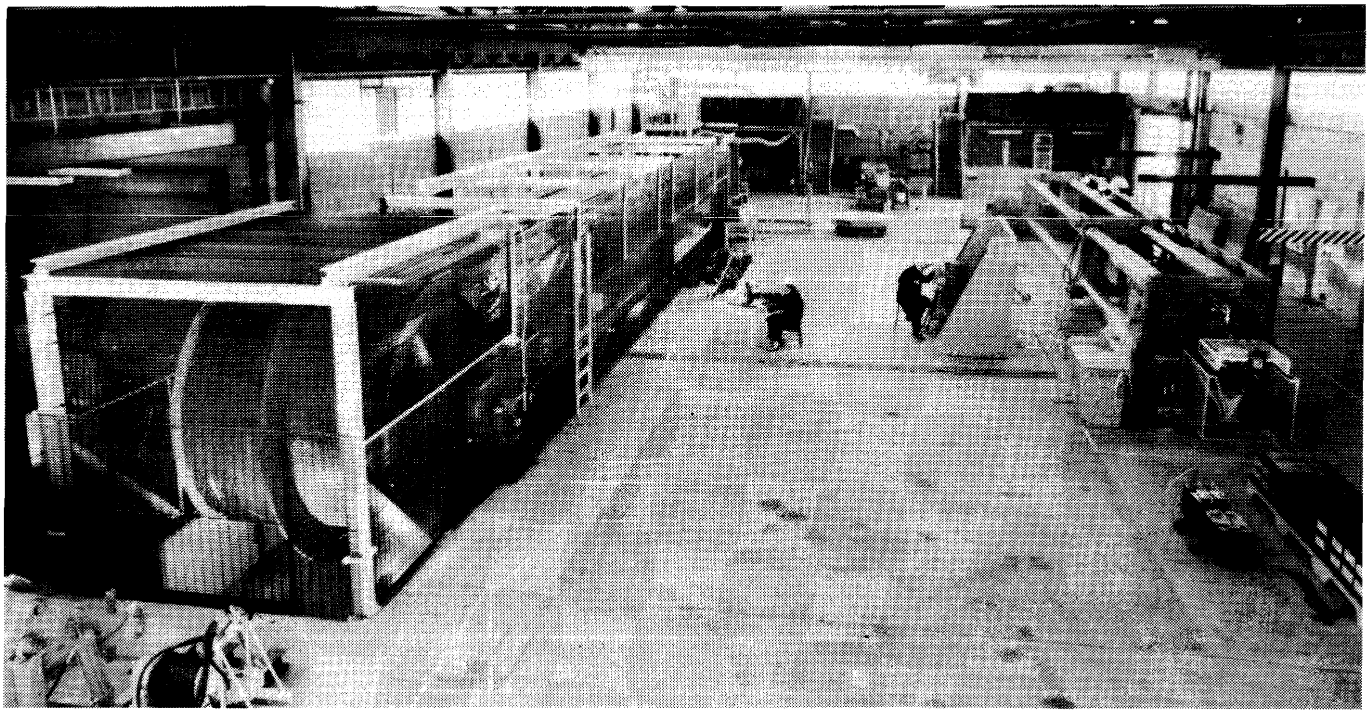

FIGURE 16. - Wire Rope Research Laboratory.

FIGURE 17. - Bureau researchers examine a constructed wetland designed to biologically control acid mine drainage.

In its environmental activities, the Center continues to undertake research into prediction of ground subsidence and control of acid mine drainage. Most recently, the use of natural and artificial wetlands has become a widely used technique for biologically controlling acid mine drainage (fig. 17). Grouting of stream beds over mines is also a promising approach to eliminating excess mine water.

In addition to its more traditional activities in health and safety research mentioned above, the Pittsburgh Research Center is increasing its efforts in advanced mining systems. A long-term objective is to reduce personal exposure and to increase productivity and the percentage of the resource recovered. Several innovative concepts, now in various stages of development, are expected to increase productivity significantly. Studies also will address new methods to exploit very thick, thin, and/or steeply pitching seams, multiple seams above or below a previously mined seam, and difficultly accessible coal reserves.

A continuous miner equipped with a temporary roof support system and auxiliary ventilation, known as the Automated Extraction System, has been developed to eliminate the hazard of working under unsupported roof, reduce roof bolting time, and maintain clean air at the workplace. In the rapidly growing area of longwall mining, a better understanding of the effect of longwall extraction on ground stability has been obtained. New criteria have been established for shield support systems that are expected to accelerate the expansion of longwall mining in the United States. Various promising approaches to the problem of moving out extracted coal include: A 250-foot train of self-propelled conveyor cars, known as the Multiple-Unit Continuous Haulage (MUCH) system, which requires only two operators to tram continuously through a room-and-pillar mine (fig. 18); a microprocessor-controlled train of conveyor cars to follow the continuous miner; and a monorail bridge conveyor suspended from the mine roof. A conveyor belt service machine has facilitated the time-consuming and hazardous task of extending or retracting belts as the mine face advances or retreats. In conventional shuttle car haulage, car capacity has increased, and a fly wheel used as an on-board power source offers an alternative to the more hazardous trailing electric cable.

Much of the technology developed today by the Pittsburgh Research Center has been adopted either permanently or experimentally by the mining industry, contributing substantially to bringing the industry into compliance with Federal and State regulations and advancing industry productivity. In so doing, conferences, demonstrations, convention proceedings, seminars, and publications have proved to be powerful technology transfer tools (fig. 19). To date, the Pittsburgh Research Center has published a wealth of scientific literature summarizing its research and findings. These usually appear in the Bureau of Mines own series of publications called "Reports of

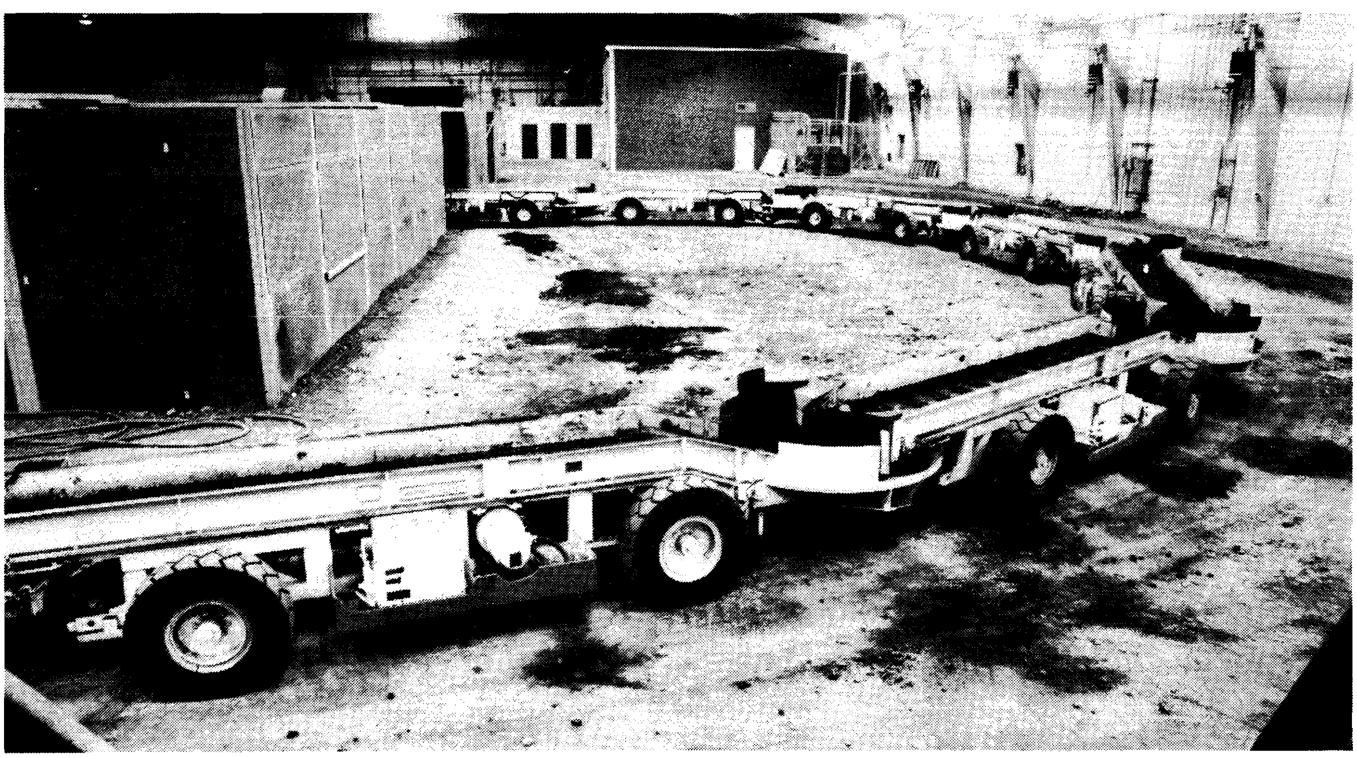

FIGURE 18. - Intermediate vehicles of the Multiple-Unit Continuous Haulage system.

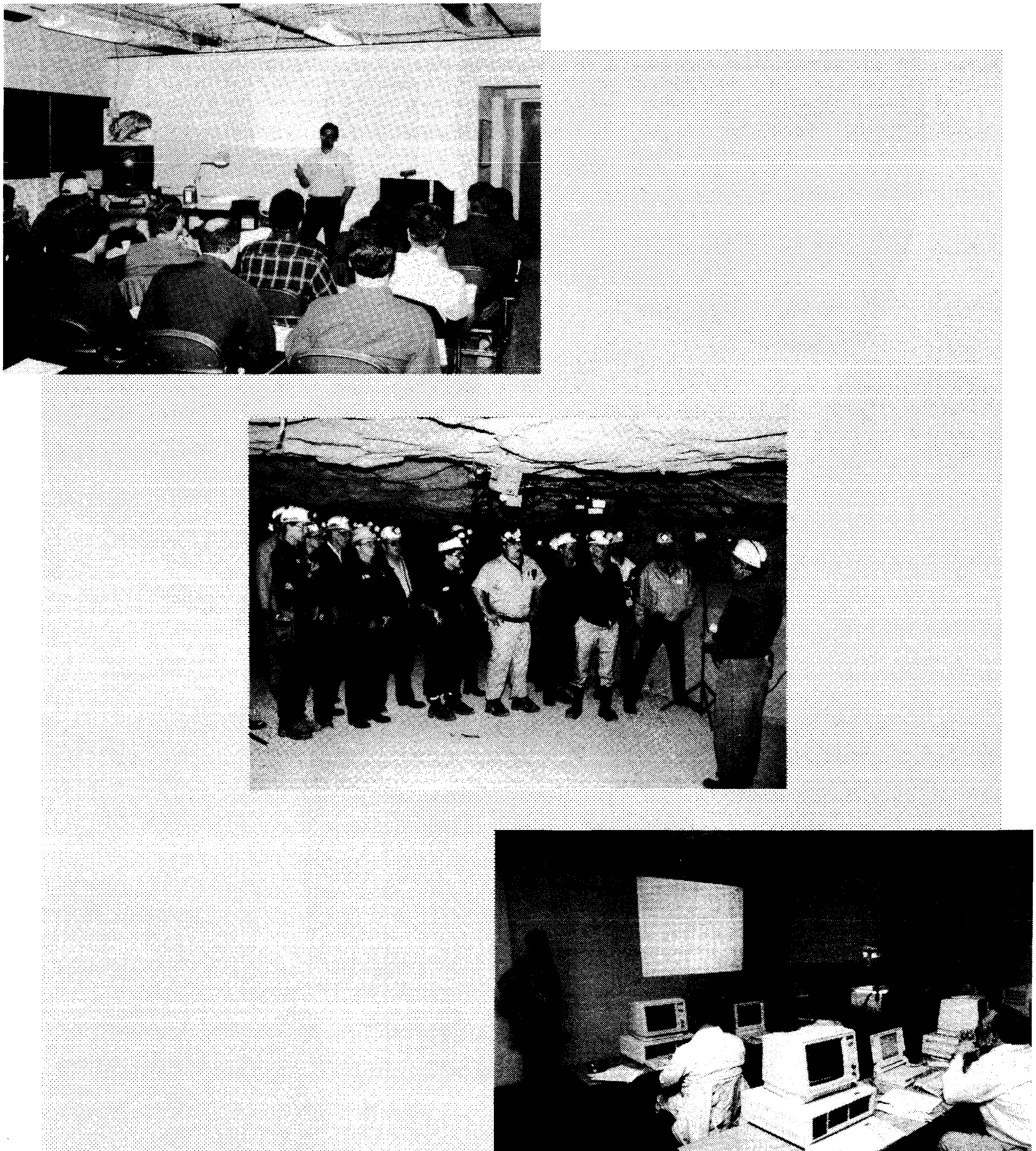

FIGURE 19. - Conferences and seminars have proved to be powerful technology transfer tools for the Pittsburgh Research Center.

Investigations" (RI's), "Information Circulars" (IC's), and "Bulletins." These publications are received by many libraries in the United States and abroad. Additionally, the Center works in a cooperative spirit with many companies, universities, and other government agencies through Memorandums of Agreement and Memorandums of Understanding in order to pursue avenues of investigation in mining research that are of mutual benefit.

Close cooperation with European and Asian counterparts dating from its earliest days has kept the Pittsburgh Research Center abreast of developments and problems in world mining. The Bureau of Mines has served repeatedly as program host to the prestigious International Conference of Safety in Mines Research Institutes, most recently in September 1989 in Washington, DC.

Programmatic changes have begun to appear in the Bureau of Mines' plans to reflect the growing national concern over strategic and critical minerals and the desire for independence from foreign imports. Research on mine health and safety continues and is expanding to all aspects of mining. Long experience had shown that a safe mine is a productive mine. Ultimately, one objective is to remove humans from the hazardous tasks involved in one of the dustiest, noisiest, and most dangerous work environments—that of the working face. To this end, adoption of the dramatic advances realized in other industries through computer-assisted technology is one of the current major objectives of the Pittsburgh Research Center (fig. 20). Already, some progress has been made in the remote computer control of machines and the development of "intelligent" equipment capable of planning its own path and forestalling its own breakdowns. For coal mining specifically, one of the major problems is "teaching" cutting machines to detect the interface between coal and rock.

In sum, it has been a long path from the Center's first tentative approach to coal mine fires and explosions, but it has been a steady and consistent one, and promises to remain so.

FIGURE 20. - Computer-assisted mining systems allow the relocation of workers from hazardous tasks and improve worker safety and productivity.

THE CENTER'S GREATEST RESOURCE

In the years that have passed since the Bureau of Mines was established in 1910, the research and technologic investigations conducted by Bureau personnel, many of whom have worked at the Pittsburgh Research Center, have helped significantly in improving health and safety in the mineral industries and have contributed substantially—through improved techniques in the mining and treatment of mineral commodities—in conserving the Nation's mineral resources. This is the reason the Pittsburgh Research Center's own greatest resource has been, and remains, its employees. Today, the Pittsburgh Research Center team has grown to more than 350 employees trained in many different disciplines, including engineering, geology, physics, chemistry, industrial hygiene, psychology, and computer science. These fine men and women are dedicated to conducting quality mining research and disseminating the results of their research nationwide to ensure that our mineral resources are developed wisely for the greatest benefit of all American citizens. To this end, their research helps guarantee that America's mineral heritage will endure and guide us well into the 21st century.