KEYNOTE SESSION

"Results From Some Innovative Health and Safety Research and Development Programs"

by

Thomas V. Falkie[1]

It is a pleasure to be here. This Institute is a well-known catalyst for new developments in coal mine health, safety, and research. Judging from the program for the next couple of days, I can see that this year's session will live up to the Institute's fine reputation.

Meetings like this serve as a marketplace of ideas and information on coal mine health and safety. Through such exchanges we can advance both the concepts and the technology that will make coal mining safer and more healthful.

This is especially important in view of the Nation's growing commitment to coal. As we all know, coal is America's most abundant energy resource, and more and more of it will have to be mined in the coming decades to supply an increasingly larger share of the Nation's energy requirements. But coal mining is still a dangerous occupation. We do not want coal mine accidents and injuries to rise along with coal production. It is imperative that tomorrow's production technology be improved over today's.

Fundamentally, there are three avenues to improved health and safety in our nation's coal mines:

- Enforcement of coal mine health and safety laws
- More and improved education and training at all levels for the people who work in mines
- Building more and better technology into improved and new mining systems.

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Many people feel that there may be a limit to the results achievable through increased enforcement. Most of the evidence seems to indicate that there will be high payouts from education and training efforts. There is a definite trend away from "seat-of-the-pants" approaches and towards more engineering in building and operating mines. In the area of developing new and improved mining technology through research, development and demonstration, the mining community is beginning to see a surge of progress. Clearly much of this is the result of the impetus provided by major expenditures of the Bureau of Mines. Today I want to give you a brief progress report on some of the Bureau's mining research, specifically on the Health & Safety research program, highlighting some of the most significant results to date.

Total Bureau of Mines mining R & D including metal and non-metal will be over $115 million in FY 1977. Of this, $30 million is line-itemed as coal mine health and safety R & D and about $6 million is line-itemed as metal, and non-metal health and safety R & D. The remainder includes about $71 million for improving mining technology in coal, metal, non-metal and oil shale (i.e., including production/productivity and about $8 million for environmental correction work. In the mining technology program significant amounts will be spent for surface mining R & D with an environmental orientation.

Let me make it clear, however, that I do not believe it is technically or managerially possible in mining to separate "health and safety" R & D from "production/productivity" R & D or "environmental control" R & D. Stop and think about it for a minute: For example, underground mining systems are designed basically around the need to provide adequate ground support and ventilation for the mine and the miner. Thus, the Bureau takes an integrated (or systems) approach in its coal and other mining R & D programs embracing health & safety, production/productivity and environment.

The Bureau's involvement in coal mine health and safety research goes back to 1910, when the Bureau was created. The passage of the Federal Coal Mine Health and Safety Act of 1969, however, intensified the Bureau's work by several orders of magnitude, authorizing and funding our research and development program at unprecedented levels.

The program is multi-faceted. We are taking some new—and we think innovative—approaches to some old problems—respirable dust, noise methane, materials handling, and ground control, among others. We believe that some creative solutions are emerging.

An increasingly important aspect of our health research is the work on noise control. The Bureau is trying to protect the hearing of workers in both underground and surface coal mines by finding ways to control noise more effectively at the source.

That has been done, in some cases, by retrofitting noise control devices on existing equipment. In Figure 1, for example, you see an integral muffler enclosure with constrained layer damping, developed through Bureau in-house and contract research. It reduces the noise level of the 75-pound-class of pneumatic stoper drill from about 115 dbA to 100 dbA, without significant loss in drilling performance. This add-on device, which weighs only about six pounds and costs about $25, has received wide-spread acceptance by drill operators. It appears to have few maintenance problems.

Another major source of noise in underground coal mines is the conveyor system on loading machines and continuous miners. The Bureau found that this noise can be reduced by fitting such equipment, like the conveyor shown in Figure 2, with sound-absorbing panels on the machine frame, and with wear strips under the conveyor flights. Tests of such modified equipment showed a 7 dbA decrease in noise, which would allow the machine to operate more than twice as long as conventional models without exposing the operator to excessive noise.

Although the Bureau has had much success in retrofitting equipment to control noise, that is not a long-range solution. Rather, we must redesign existing equipment to eliminate noise, and then begin to design new machines that are inherently noise-free. Today, the Bureau is at work in both of those areas.

Environmental monitoring in underground mines is another area in which Bureau research is having significant success. Because existing equipment for measuring concentrations of gases, toxic and otherwise, was for the most part unreliable, the Bureau has developed accurate samplers for a wide range of gases, including carbon monoxide, nitrogen dioxide, nitric oxide, and carbon dioxide.

For example, the Bureau-developed continuous dosimeter alarm shown in Figure 3 is now available for measuring an individual's cumulative exposure to carbon monoxide. That is hard to do with the current method of spot checking at random intervals—especially if the source moves, as it does with vehicles. The alarm part of the device warns of unusually high carbon monoxide levels due to fire, which in turn indicates the need for a self-rescuer and immediate investigation.

Another Bureau-developed instrument provides an almost instantaneous spot measurement of carbon monoxide at two ranges—0-50 parts per million and 9-250 parts per million—with an accuracy range of about five percent. The device is pocket-sized and operates effectively in all temperatures and humidity levels encountered in mines. The Bureau plans to have four of these instruments in the hands of MESA and mine operators by the end of 1976.

FIGURE 1. Integral muffler enclosure with constrained layer damping (Bureau of Mines, U. S. Department of the Interior).

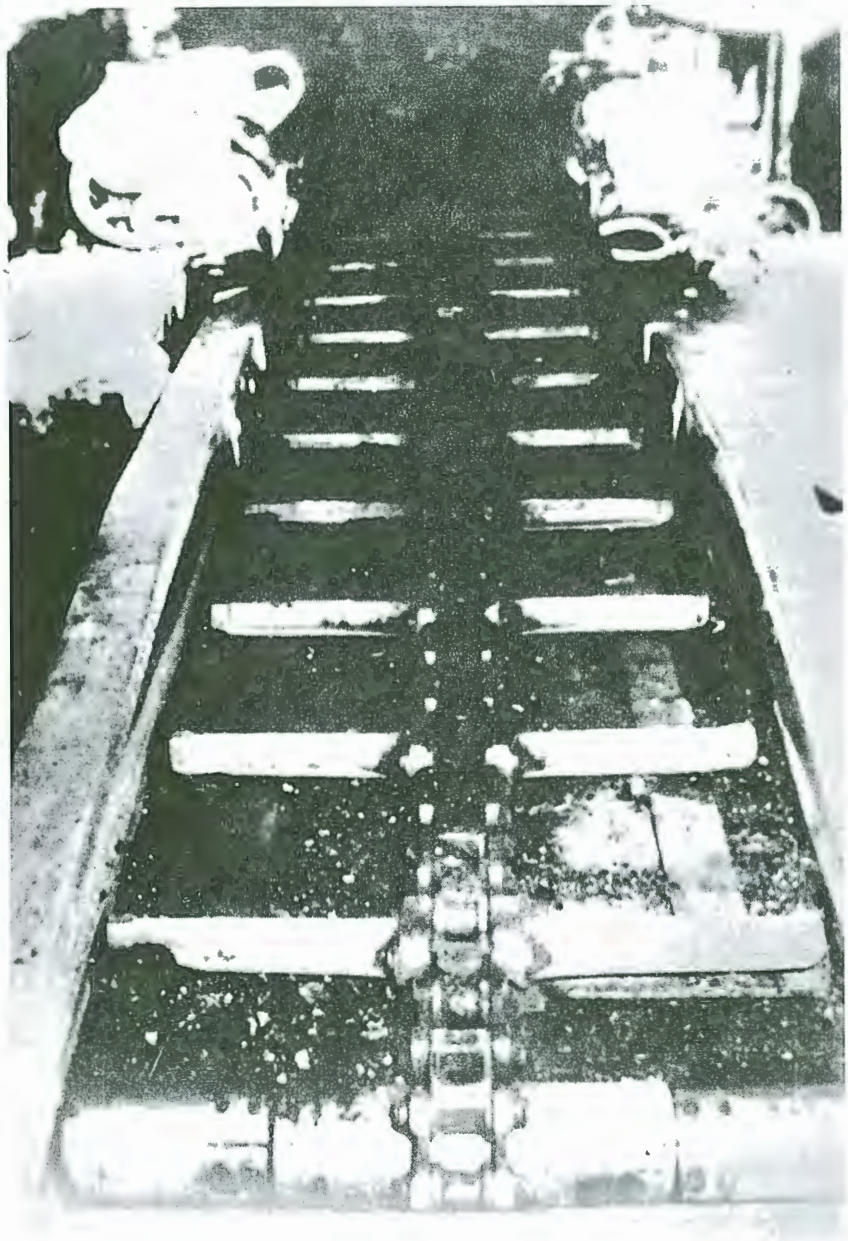

FIGURE 2. Conveyor with sound-absorbing panels on the machine frame and wear strips under the conveyor flights (Bureau of Mines, U. S. Department of the Interior).

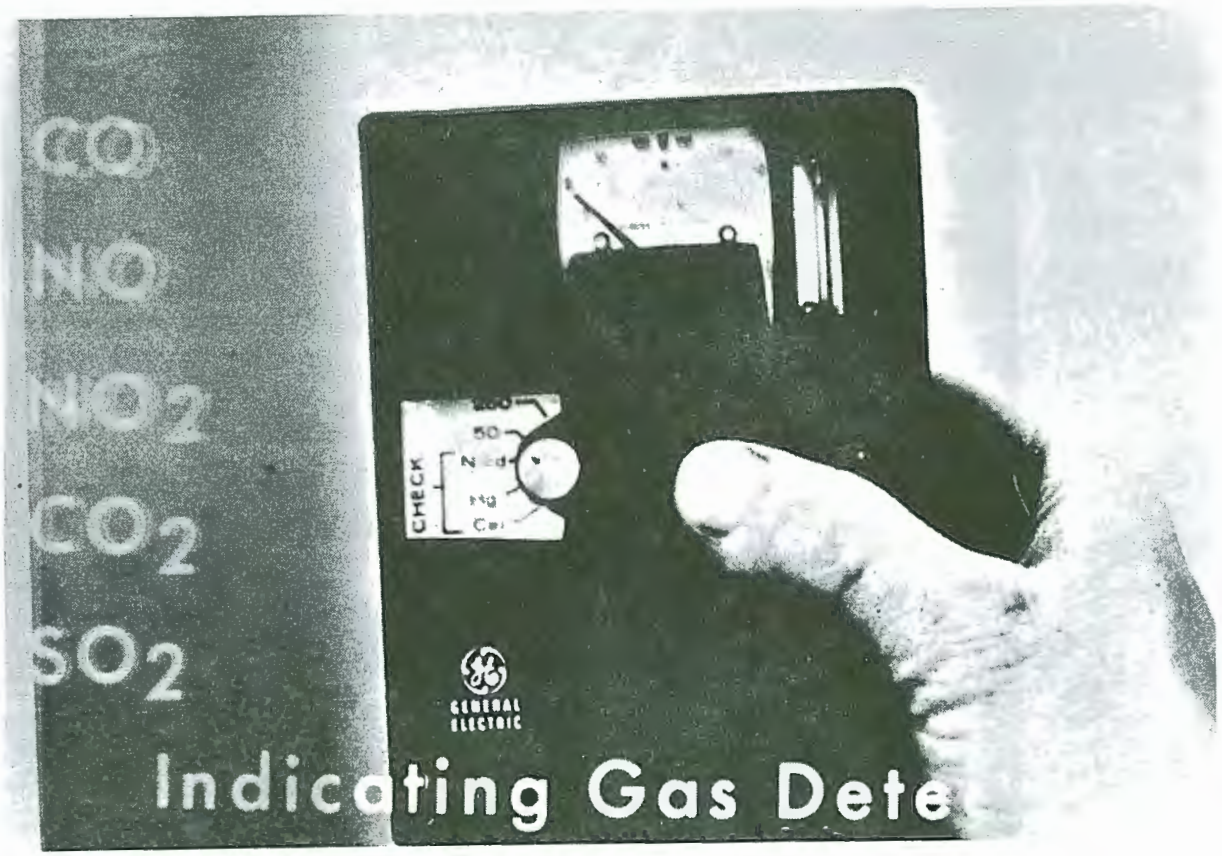

FIGURE 3. Bureau of Mines-developed continuous dosimeter alarm (Bureau of Mines, U. S. Department of the Interior).

One of the most outstanding samplers developed so far is a lightweight, inexpensive dosimeter for measuring a worker's average exposure to nitrogen dioxide shown in Figure 4. Developed under a Bureau grant to the New York University Medical Center, the sampler is an acrylic tube about three inches long and three-eights inches wide, sealed by plastic caps. One end of the tube contains three stainless steel screens coated with a chemical collector, which reacts with the nitrogen dioxide. The material formed by the reaction can be removed chemically from the screens, and measured to determine exposure levels.

Operating the device, which costs less than a dollar to make, is simple. The tube is clipped vertically on a worker's hardhat, and the plastic cap from the non-screen end is removed, admitting mine air into the tube. The tube is re-capped at the end of the shift, and sent to the laboratory for analysis.

About 1,000 such samplers were field-tested during the past year, and nitrogen dioxide levels were consistently calculated to within 10 percent of actual concentration. Exposing pairs of samplers on the same individual showed highly reproducible results. Samplers for testing purposes are still available on a limited basis from the Bureau's Pittsburgh, Pennsylvania Mining and Safety Research Center. The Center will also analyze exposed samplers without charge.

A third area of health-related research in which the Bureau has made significant advances is in the development of self-rescuers. As you know, all miners are required to carry a self-rescuer, or have one nearby. There are only two models currently approved for use in coal mines; both have several well-known deficiencies. In the process of converting toxic carbon monoxide to carbon dioxide, both generate a great deal of heat. Neither provides any protection against other toxic products, or oxygen-deficient atmospheres.

To combat those problems, the Bureau funded the development of two new self-rescuers—one, with a 10-minute supply of oxygen, is small enough to be worn by the working miner; the other, with a one-hour oxygen supply, would be stored in an easily-accessible place. Both use potassium superoxide to absorb carbon dioxide and supply oxygen to the user. In this way the wearer can breathe oxygen comfortably regardless of the toxic inhalants in the mine atmosphere.

The 10-minute version, developed under a Bureau research contract by the Mine Safety Appliances Company, is about the size of a thick paperback book and weighs less than three pounds. Tests show the device is reliable, maintenance-free, lightweight, and easy to put on. This is shown in Figure 5. It is designed for one-time use only, has a shelf life of five years, and a carryling life of three years. To protect the miner's eyes from irritating gases and smoke generated by mine fires and explosions, each 10-minute self-rescuer comes with a pair of lightweight goggles.

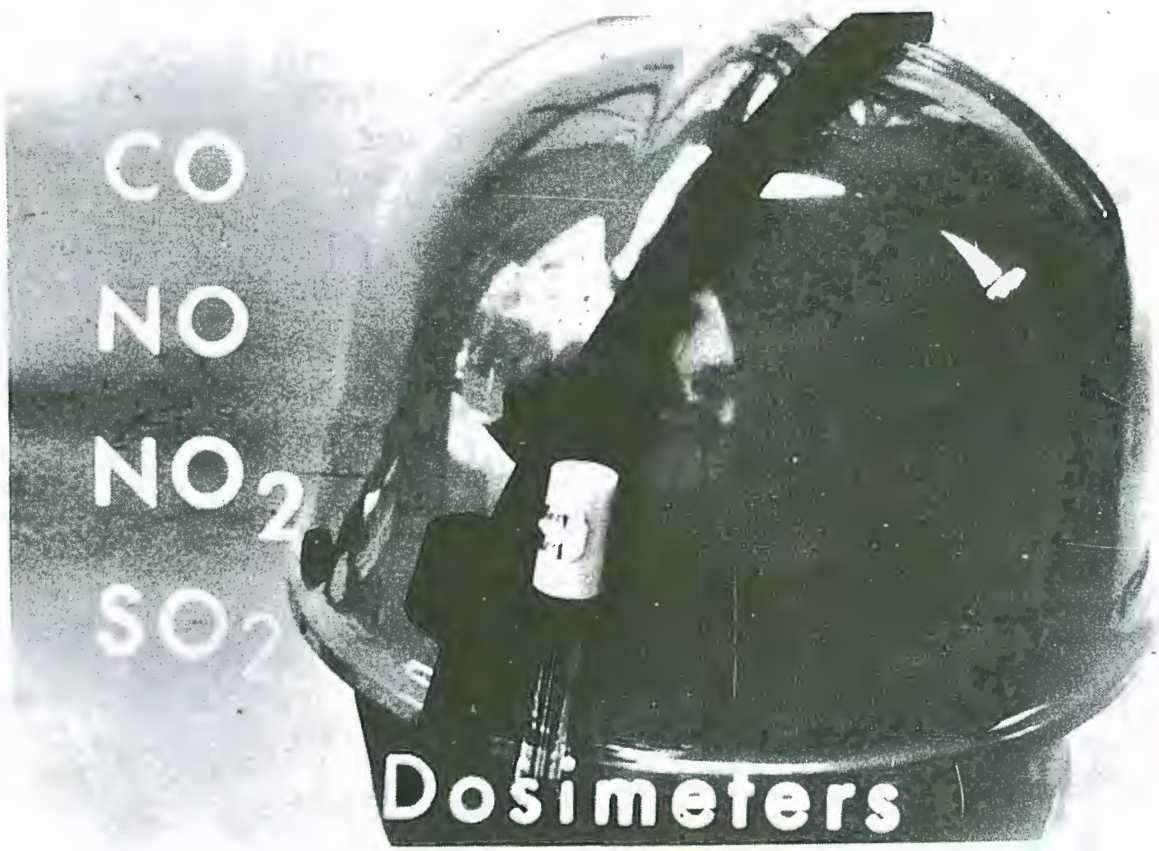

FIGURE 4. Dosimeter for measuring a worker's average exposure to nitrogen dioxide (Bureau of Mines, U. S. Department of the Interior).

FIGURE 5. Ten-minute self-rescuer developed under a Bureau research contract by the Mine Safety Appliances Company (Bureau of Mines, U. S. Department of the Interior).

The one-hour version shown in Figure 6 was developed under a Bureau research contract by the Lockheed Missile and Space Company. It is about the size of a shoe box and weighs about 4.5 pounds. Shelf life, carrying life, and donning time are about the same as for the 10-minute self-rescuer. Currently, Germany's Dragerwerk AG is developing a production model of the one-hour self-rescuer that is expected to be available commercially in about a year.

The two self-rescuers are designed to be used sequentially. The 10-minute unit would allow a miner time to reach the place where his one-hour device was stored. The miner would have to hold his breath during the changeover, however. Because of the obvious problems with such a system, the Bureau has contracted with the Mine Safety Appliances Company to design and build an oxygen self-rescuer with two plug-in canisters (Figure 7)--an initial canister, with a 10-minute oxygen supply, that can be replaced by a 60-minute canister without removing the unit's mouthpiece. In addition to offering a less hazardous changeover, the plug-in canister would be less expensive than a complete one-hour self-rescuer.

Another area of innovative, health-related research the Bureau is pursuing is respirable dust control. Our work in that area will be discussed in detail in the technical session tomorrow afternoon. There are, however, two accomplishments I would like to briefly describe.

The first is a high-productivity continuous coal miner that produces significantly less dust by reducing the bit speed and increasing the depth of cut. Developed under a Bureau research contract by the Ingersoll-Rand Institute, the new miner, the cutting head of which is shown in Figure 8, operates at a cutting speed of only 9 rpm, with a 3-inch depth of cut and eight-inch bit spacing, compared to the conventional 51 rpm, 1.5-inch depth of cut and two-inch bit spacing. Tests of the slow-speed, deep-cutting miner show that respirable dust per ton of coal was reduced by 40 percent in return air, and 81 percent at the machine operator's position, compared to conventional miners. Dust testing is now nearing completion, and the next step will be to demonstrate the production capability of this deep cutting machine at the optimum set of machine cutting parameters.

Another development that should help protect miners against respirable dust is the canopy-mounted air curtain shown in Figure 9, developed under a Bureau research contract with the Donaldson Company. This system draws mine air through a blower and filter mounted on the machine canopy. The clean, filtered air is passed through a canopy-mounted manifold, so that clean air flows down over the head of the machine operator. Tests have shown the system is capable of reducing a miner's exposure to respirable dust by up to 75 percent, depending on the amount of time he spends under the canopy. This system is now commercially available.

The Bureau has also had success with water sprays to reduce respirable dust, and you'll hear more about them tomorrow.

FIGURE 6. One-hour self-rescuer developed under a Bureau research contract by the Lockheed Missile and Space Company (Bureau of Mines, U. S. Department of the Interior).

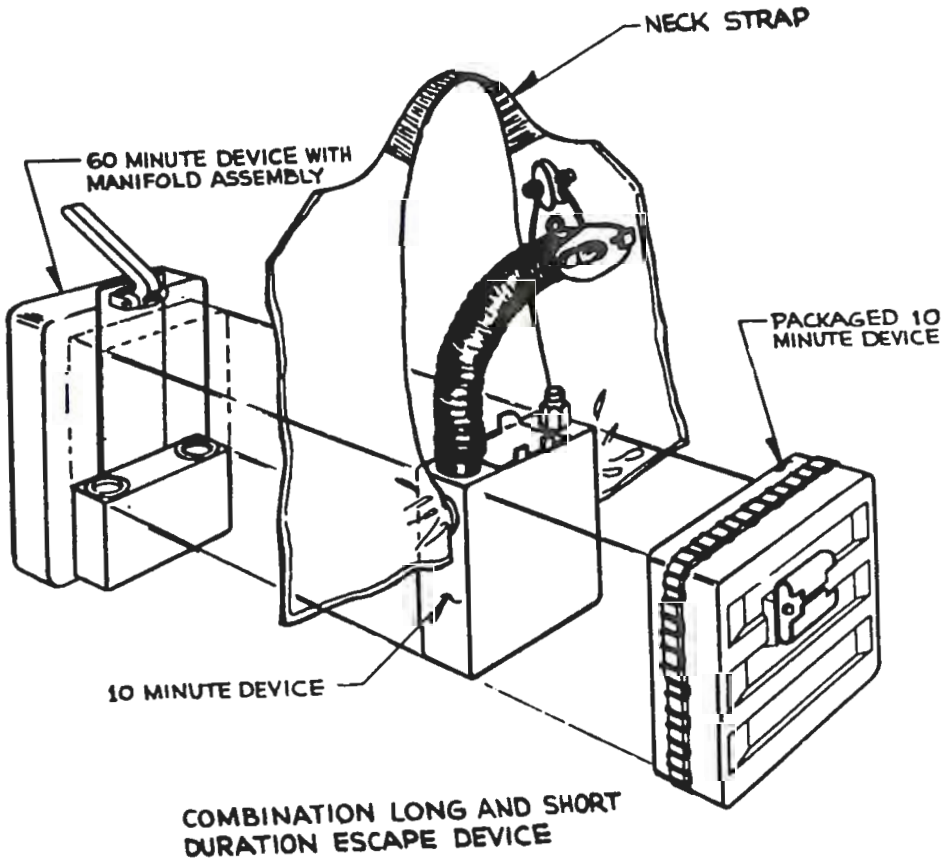

FIGURE 7. A self-rescuer with an initial canaster developed under a Bureau research contract with the Mine Safety Appliances Company (Bureau of Mines, U. S. Department of the Interior).

FIGURE 8. Cutting head of a high-productivity continuous coal miner developed under a research contract by the Ingersoll-Rand Institute (Bureau of Mines, U. S. Department of the Interior).

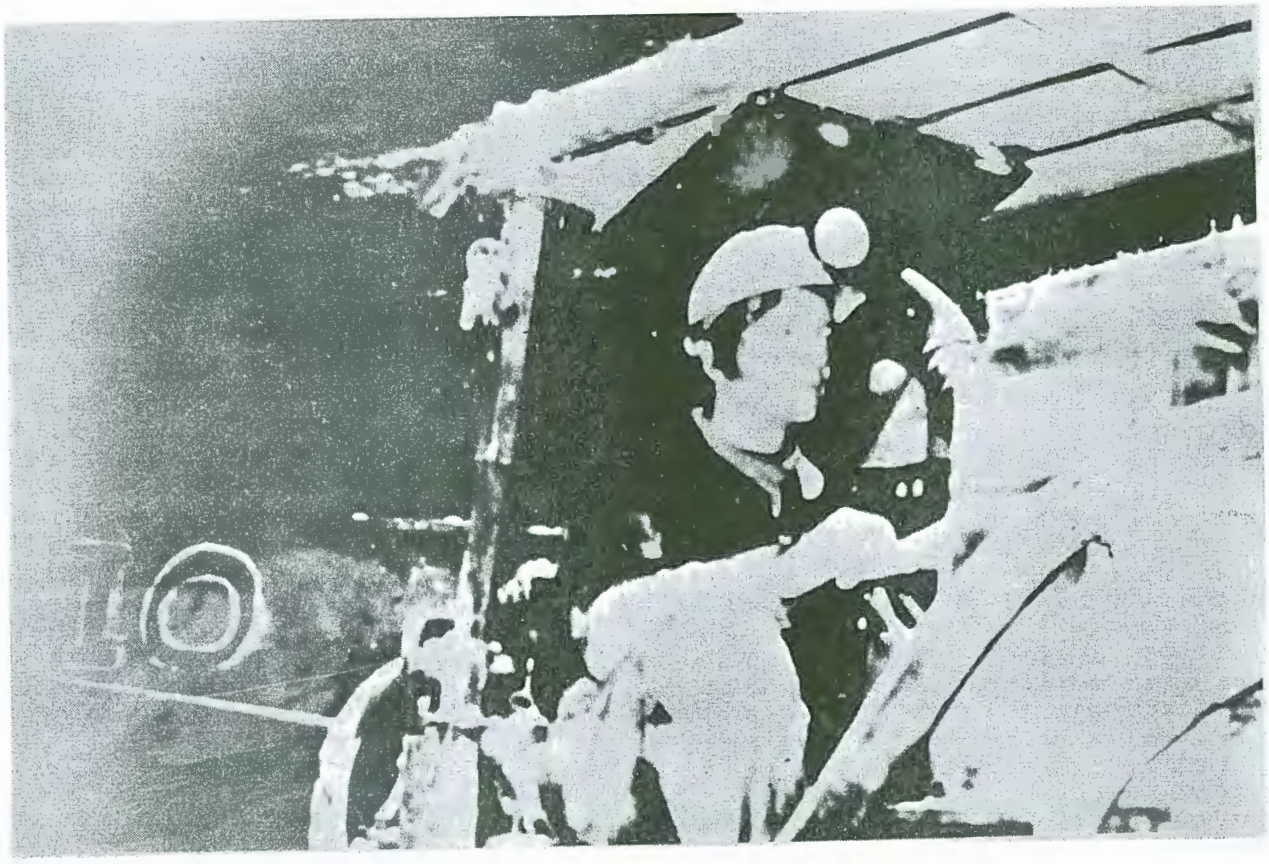

FIGURE 9. Canopy-mounted air curtain developed under a Bureau research contract with the Donaldson Company (Bureau of Mines, U. S. Department of the Interior).

Now, I'd like to tell you about some of our accomplishments in coal mine safety research.

One of the most serious coal mine safety hazards is the explosive methane gas released by the mining process. Current practices for coping with methane emissions, and for reducing the chances of accidentally igniting methane-air mixtures, treat the symptoms of the problem, not the cause. For several years, therefore, the Bureau has been conducting research aimed at safely and economically mining methane-laden coalbeds. Results of that research have proved successful in several areas.

Perhaps most noteworthy are the Bureau-developed methods for draining explosive methane from coalbeds in advance of mining. Vertical boreholes, hydraulically stimulated, have proven effective in draining significant quantitites of the gas from more permeable coalbeds. This technique has worked well in the Pittsburgh seams, and shows promise for use in the Mary Lee, Beckley, and Hartshorne seams.

Another way of draining methane from coalbeds in advance of mining is through long, small-diameter holes drilled radially into the coalbed from the bottom of a shaft as shown in Figure 10. In one test, a ventilation shaft, sunk into the Pittsburgh seam in advance of mining, was made available to the Bureau by the Eastern Associated Coal Corporation about three years ago. Methane flows from five small holes drilled horizontally into the coalbed at varying depths, shown in Figure 11, have totaled about 770 million cubic feet since then. And methane emissions in the mine workings that are now approaching that shaft are about half of what would normally be expected. I think we are entitled to call this one an outstanding success.

The safety benefits of draining such large quantities of methane from coalbeds in advance of mining are fairly obvious. However, the Bureau's degasification techniques have another important benefit—they can help extend the Nation's natural gas supplies. That is because methane is essentially identical to natural gas, and can be substituted for it in a number of household and commercial applications. Instead of venting the methane drained from the coalbed, under certain circumstances, it can be captured and put into a commercial natural gas pipeline. The gas from the Eastern Associated shaft I just mentioned is pipeline quality, and 130 million cubic feet of it have been pipelined for use in the nearby community of Wadestown, West Virginia.

In an entirely different approach to the methane problem, the Bureau invented a water-infusion technique to block the flow of methane from the face. This method has been demonstrated successfully in the Pittsburgh and Kittanning coalbeds, and is standard practice for longwall panels in Island Creek Coal Company mines in the Pocahontas No. 3 coalbed.

Another innovative aspect of the Bureau's mine health and safety program are an extended loading machine, and an auger cutter. The loader,

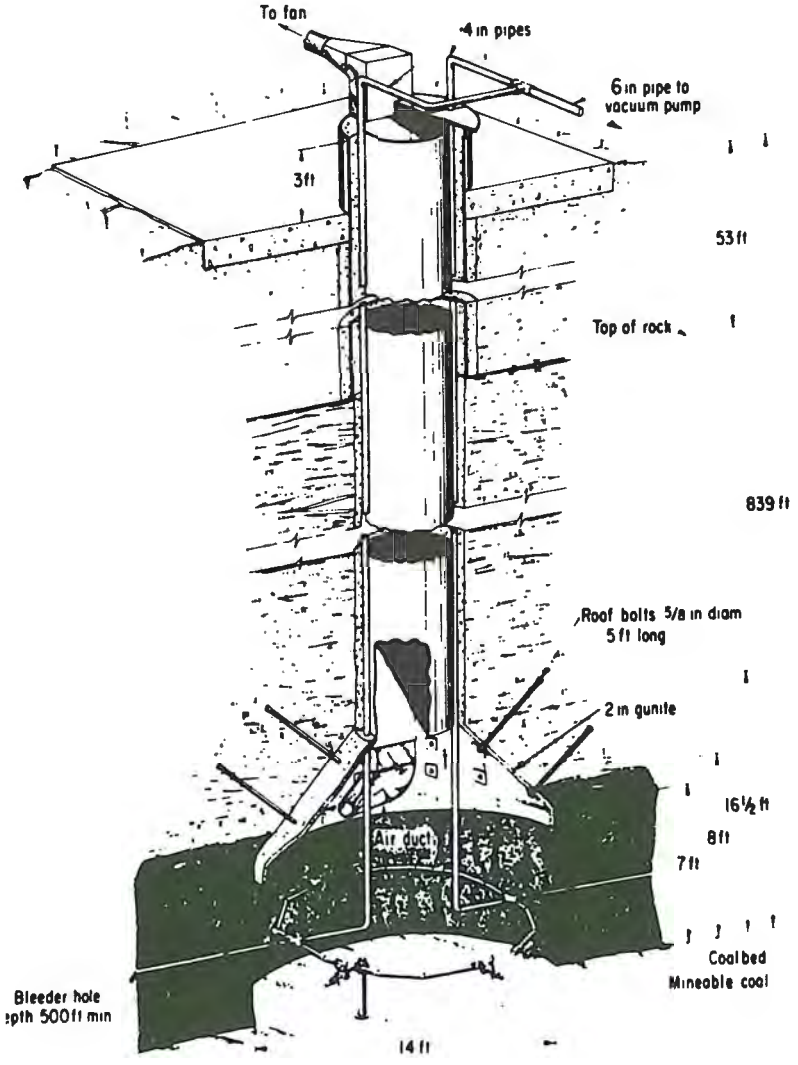

FIGURE 10. Multipurpose borehole for degasification of virgin coal (Bureau of Mines, U. S. Department of the Interior).

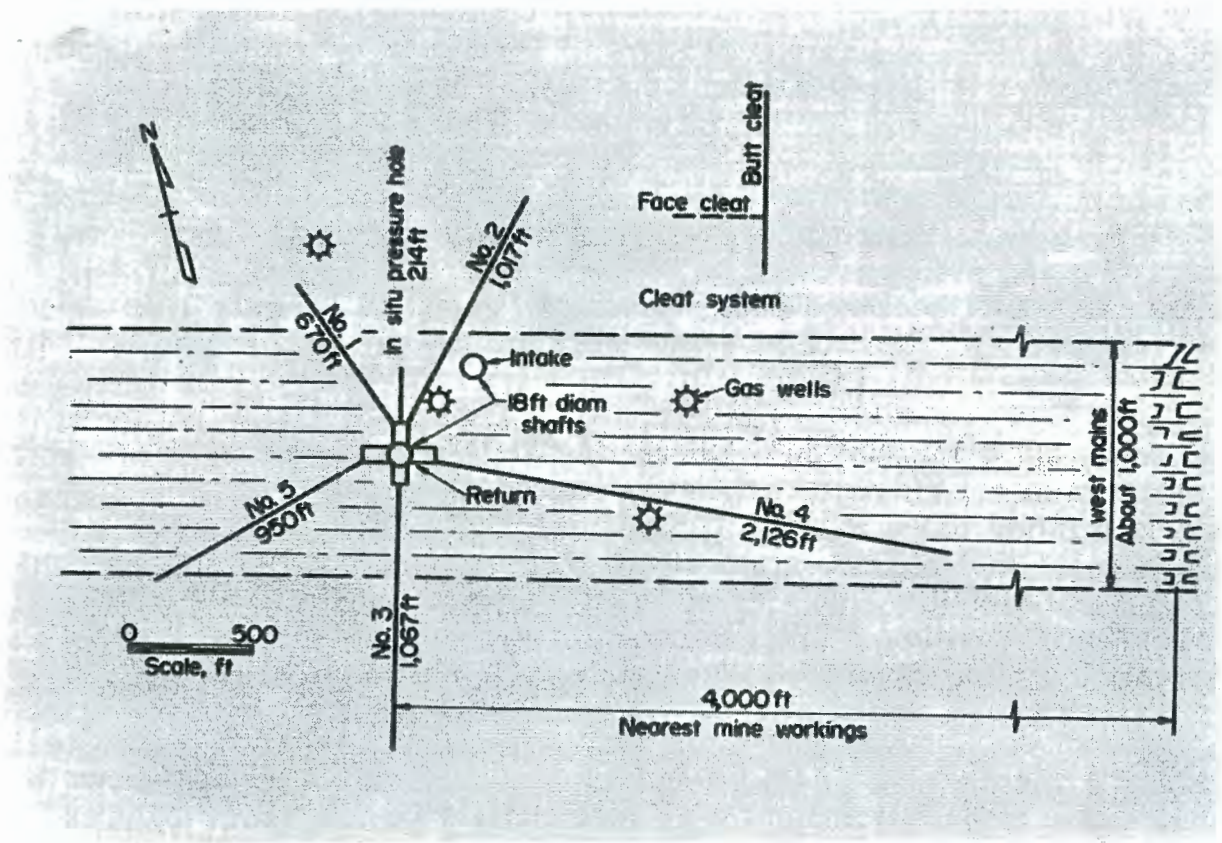

FIGURE 11. Ventilation shaft of the Pittsburgh seam of Eastern Associated Coal Corporation for draining methane in advance of mining (Bureau of Mines, U. S. Department of the Interior).

as shown in Figure 12, combines the best features of existing loaders with several innovative ideas, including the mounting of the cab—and transverse to—the tail boom. The cab can also be elevated above the tail boom, so the operator can take maximum advantage of available roof heights. The resulting view from the elevated cab assures visibility under all positions of the shuttle car, as well as the gathering table. Built-in on-board automatic storage of the tailing cable and water hose are also important safety features. The cab does not extend beyond the main frame, allowing the loader to be trammed and operated close to and parallel to the rib, as well as increasing the machine's safety and productivity.

Long-range productivity gains with such a loader are possible if the machine is paired with a longer-cut face drill. With the loader cab back on the tail boom, 13- and possibly 15-foot cuts could be loaded without exposing the operator to unsupported roof. The aguer cutter I just mentioned, shown in Figure 13, could perform that task. Moreover, the auger cutter could replace two machines—a cutter and a face drill—by combining the functions of both machines into a single unit.

Such innovations are important, and will contribute greatly to coal mine safety and productivity. But if our country is to fully realize its goal of safer and increased coal production, complete systems must be developed that offer protection to the worker through improved equipment design.

One such is the Bureau's Inherently Safe Mining System (ISMS). This is an effort to rebuild key elements of conventional and continuous mining systems to offer safer working conditions for miners. The concepts developed under the ISMS program afford machine operators greater safety, comfort, and visibility, thus encouraging them to remain on the machine in a protected position. ISMS demonstrations were completed nearly a year ago after lengthy underground trials in Kentucky and Illinois.

In the ISMS conventional mining demonstration at Island Creek Coal Company's Jenny Mine, in Prestonsburg, Kentucky, all face equipment in the four-foot seam had human-engineered cabs with adjustable features for maximum visibility and comfort as shown in Figure 14. All controls were standardized, and, wherever possible, followed automobile control designs to capitalize on intuitive reactions during emergencies. A communication system interconnected all equipment operators and the roving section supervisors with the central mine office on the surface. The equipment and all fixed working locations, such as the belt feeder station, were fully illuminated with advance mercury vapor and fluorescent lights as shown in Figure 15.

The most innovative piece of equipment there was the automated roof bolting machine shown in Figure 16 which could install bolts up to 18 inches less than seam height. The operator, under a protective canopy, could also manually install longer bolts by bending them in the normal fashion.

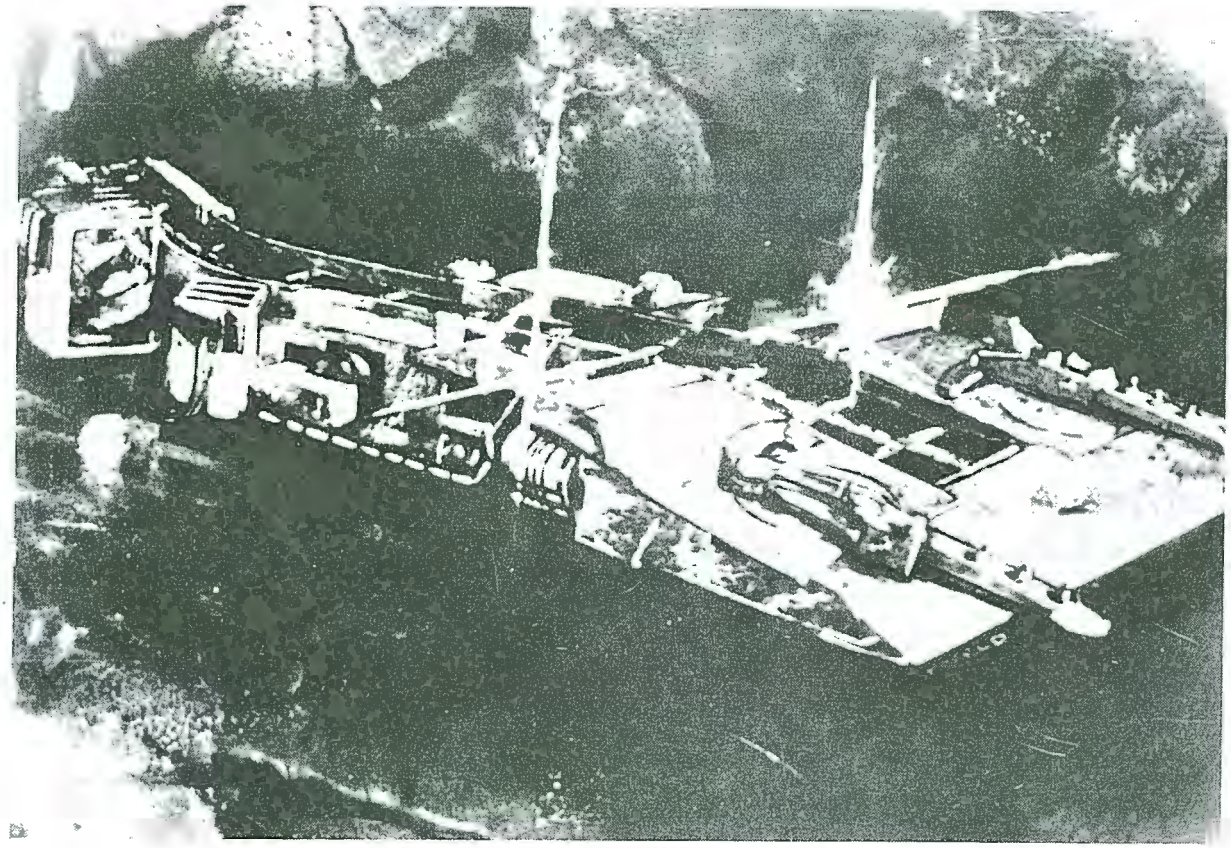

FIGURE 12. Extended loading machine with several innovative design features (Bureau of Mines, U. S. Department of the Interior).

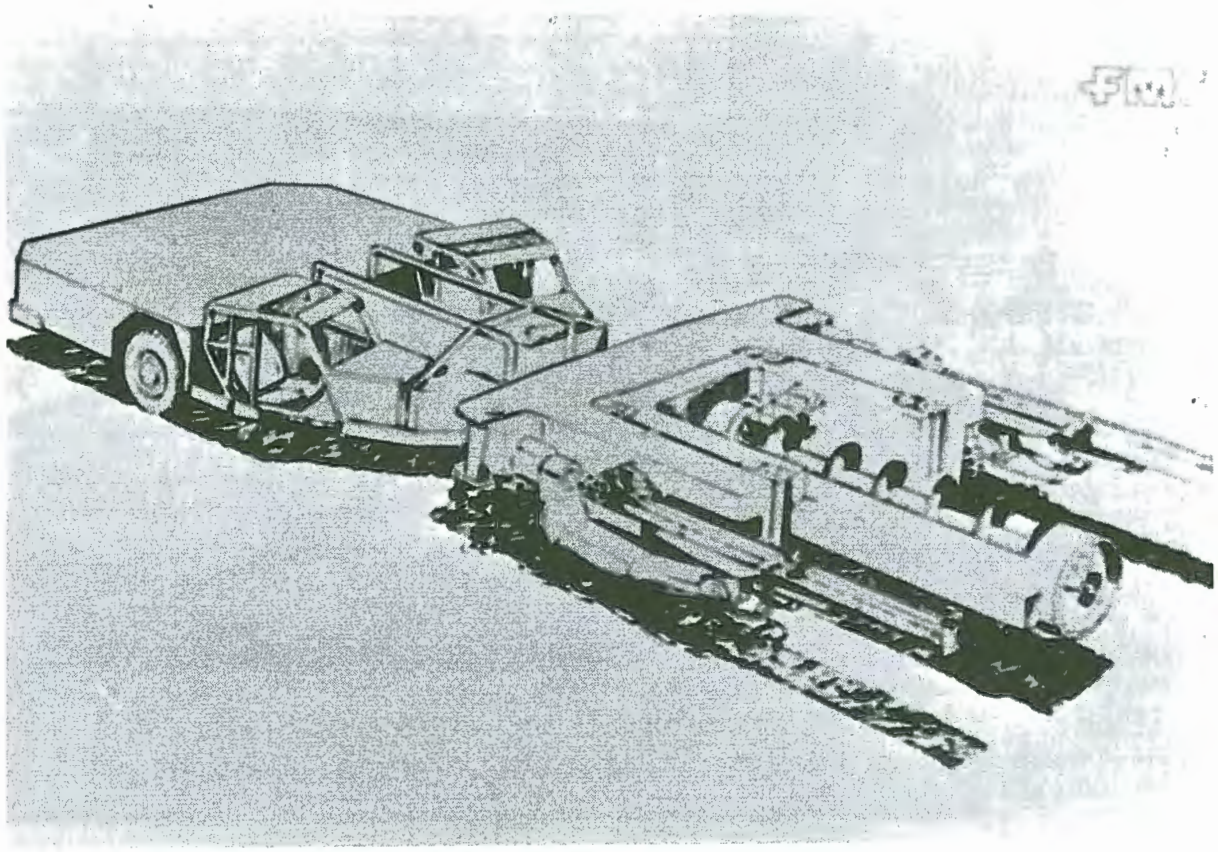

FIGURE 13. Auger cutter with face drills (Bureau of Mines, U. S. Department of the Interior).

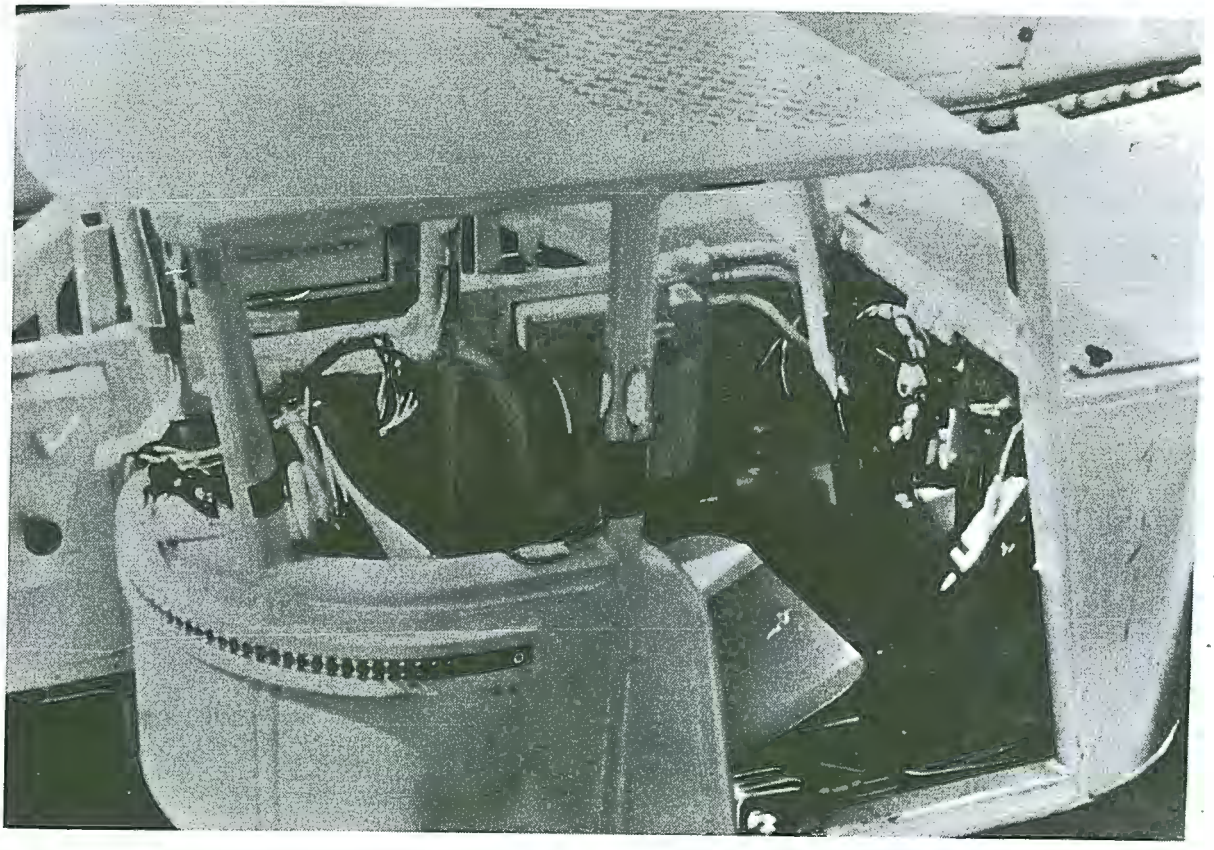

FIGURE 14. Human-engineered cab for four-foot seam face use (Bureau of Mines, U. S. Department of the Interior).

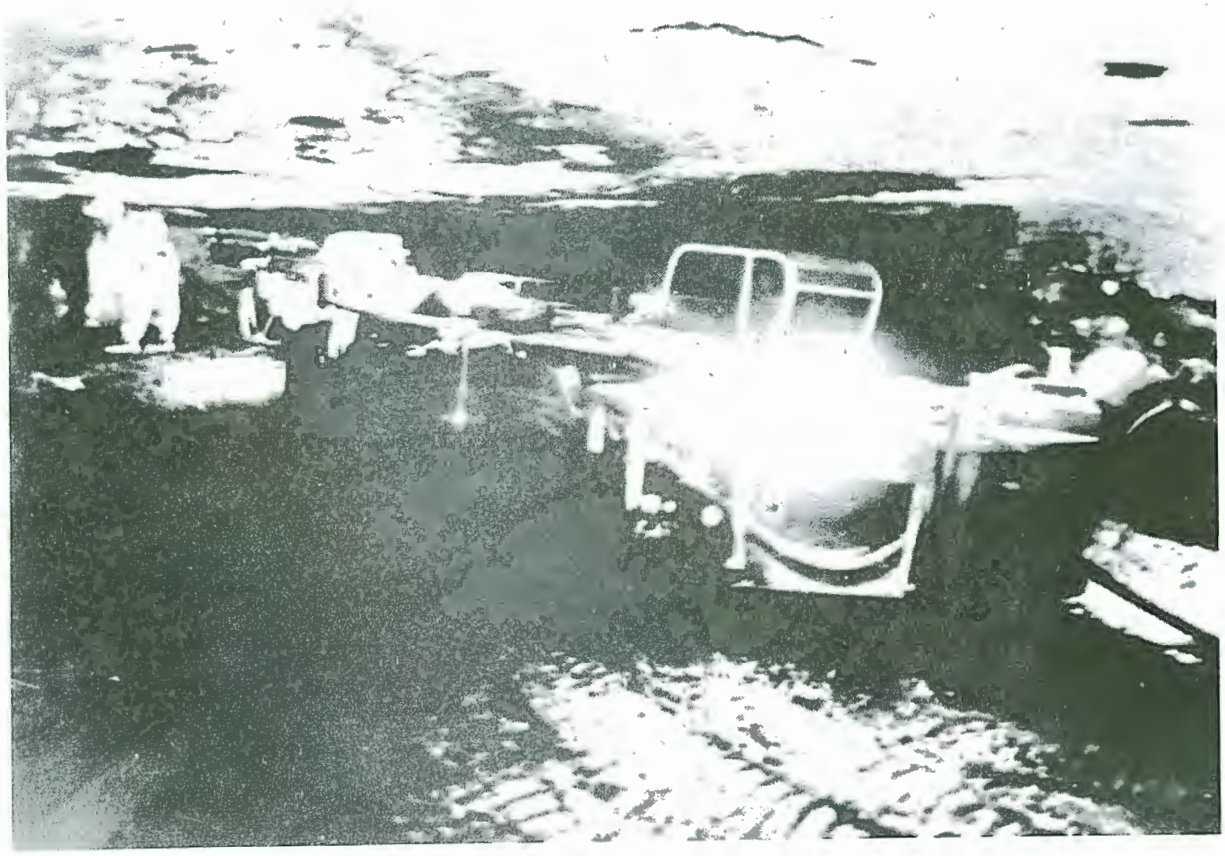

FIGURE 15. Belt feeder station fully illuminated with advance mercury vapor and fluorescent lights (Bureau of Mines, U. S. Department of the Interior).

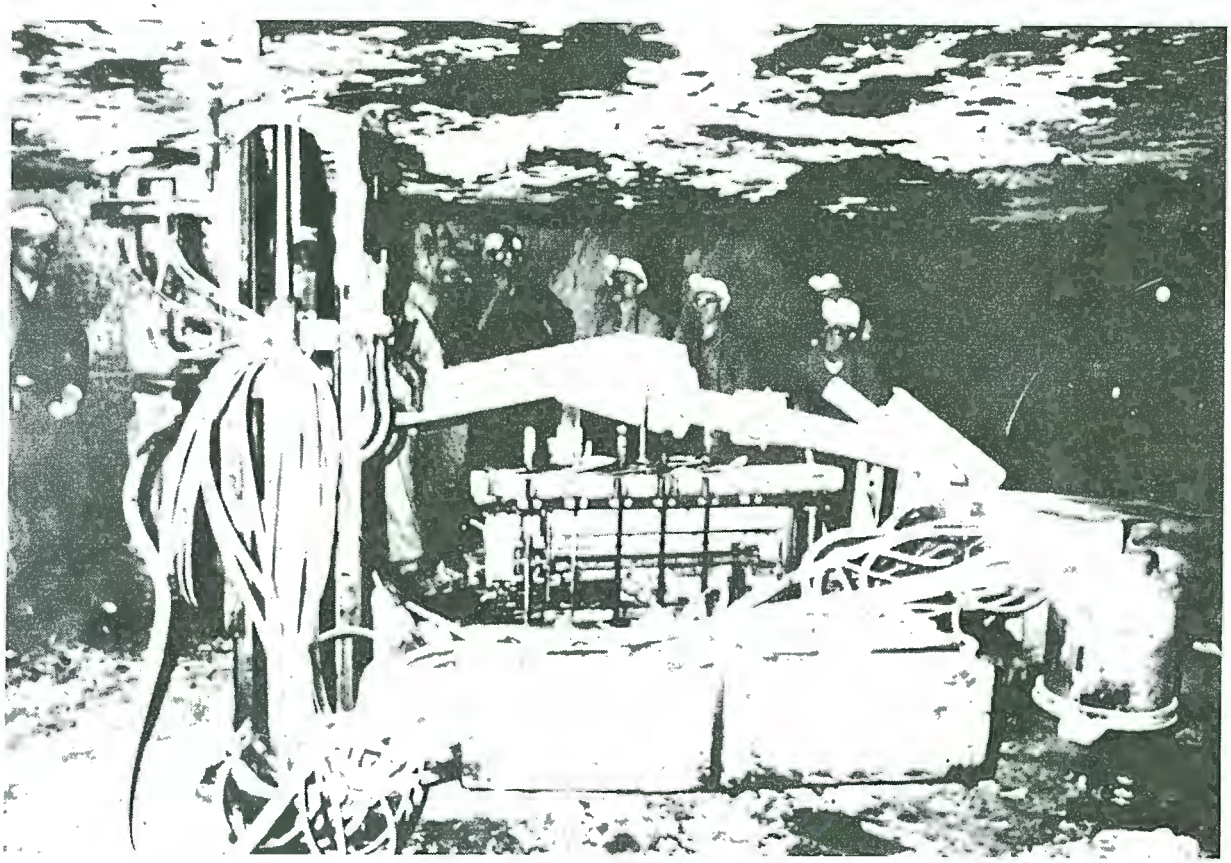

FIGURE 16. Automated roof bolting machine (Bureau of Mines, U. S. Department of the Interior).

The ISMS continuous mining section was demonstrated at Peabody's Mine No. 10, in Pawnee, Illinois. Featured was a miner-bolter that could mine and automatically install a four-bolt pattern in an 18-foot entry with single pass cutting. A continuous belt system from miner to panel belt, and an automated pick-up bolter were the other main components of the system. Ancillary systems included a communications network like that at the Jenny Mine, and the latest innovations in mine lighting.

In follow-up work, four continuous miner manufacturers are now under contract with the Bureau to design a miner-bolter without the limitations of the first model. Ancillary systems are also to be developed to permit truly continuous mining.

However, the success of the ISMS can best be measured by its excellent safety record, and industry's enthusiasm for it. For example, no accidents occurred in the conventional section, compared to 0.15 accidents per 1,000 man-hours in control sections with similar conditions, seam height, and equipment. In the continuous ISMS section, 0.48 minor accidents were reported per 1,000 man-hours, compared to 0.77 accidents of varying severity, including fatalities, per 1,000 man-hours in the control section. A worker attitude survey conducted during the conventional ISMS demonstration disclosed a very positive attitude on the part of the mine labor force towards the ISMS program, its objectives, and equipment. Moreover, industry support on follow-up work has been very encouraging.

Looking ahead to the anticipated long-term benefits of the program, we can reasonably expect that the improved cabs and controls developed in ISMS will be incorporated into future design criteria, and possibly into future mine safety regulations. Even now, several equipment manufacturers are thinking about using ISMS innovations on their equipment. The ISMS demonstration of improved illumination hardware gave many people a preview of new lighting concepts, for which regulations will be promulgated by MESA in October. The ISMS roof bolting concept, representing a first step in solving problems associated with the leading cause of fatalities in underground mines, is now being further examined in our research, and in cooperative studies with engineering and manufacturing companies.

Finally, I'd like to talk briefly about the Bureau's mining systems work aimed at increasing both mine safety and productivity. Promising developments thus far include the operation of improved longwall and shortwall systems.

Performance of longwall mining in the United States has not been outstanding, often because of problems associated with strata control. Because of unfavorable experiences with ordinary longwall chocks in mines in this country, the Bureau has been experimenting with the shield-type supports that are popular in Europe. The supports are supposed to more completely protect operations at the longwall face, and could be used to mine coal seams thicker than those normally mined by longwall methods

using conventional supports. The Bureau is testing these shields (Figure 17) in Kaiser Steel Corporation's York Canyon Mine, in Raton, New Mexico, and both management and miners have been satisfied with their performance so far.

Because of the success of that operation, the Bureau will be testing the shields with the Old Ben Coal Company, in Illinois, which has tried without much success to use the longwall technique at least six times. Roof support design was a particular problem that may be alleviated—if not eliminated—by the use of the shield supports.

The longwall demonstration at Old Ben is funded under the Bureau's Advancing Coal Mining Technology program, which is integrated with our Mine Health and Safety program. A related R & D project, funded solely by Health and Safety money, is the development and testing of a shortwall mining system.

Shortwall mining is a modified longwall technique aimed at increasing coal recovery without extending the coal face to longwall dimensions. Basically, it combines the flexibility of room and pillar mining with the safety and efficiency of the longwall system.

A demonstration and evaluation of the shortwall technique are underway at Beth Elkhorn Corporation's Hendrix No. 22 mine, near Jenkins, Kentucky as shown in Figure 18. Four panels have been mined over a two-year period, and production during that time has been close to 550 tons per production shift. Production could have been even better if a continuous haulage system had been integrated with the continuous miner. So far, safety benefits of the shortwall system have been very encouraging: Roof and rib falls have been considerably reduced; respirable dust control has been simplified because all faceworkers are on the fresh-air side of the major dust source; and machinery accidents have declined.

Coal recovery with shortwall mining is approximately 85 percent, about the same as with more conventional systems at the Hendrix No. 22 mine, but still considerably above the national average.

We anticipate that shortwall mining will be used increasingly in the future to improve pillar recovery, where physical conditions prevent recovery by more conventional methods, and to mine coalbeds penetrated by oil and gas wells, which could prevent longwall mining.

There is a need for more R & D in the human resources area. Man is an integral part of the man-machine system and, unless we realize this, efforts to improve health and safety and productivity will be limited. As I see it, there are two basic "human resources" approaches:

- Human Engineering
- Attitudinal/Motivational/Interactional

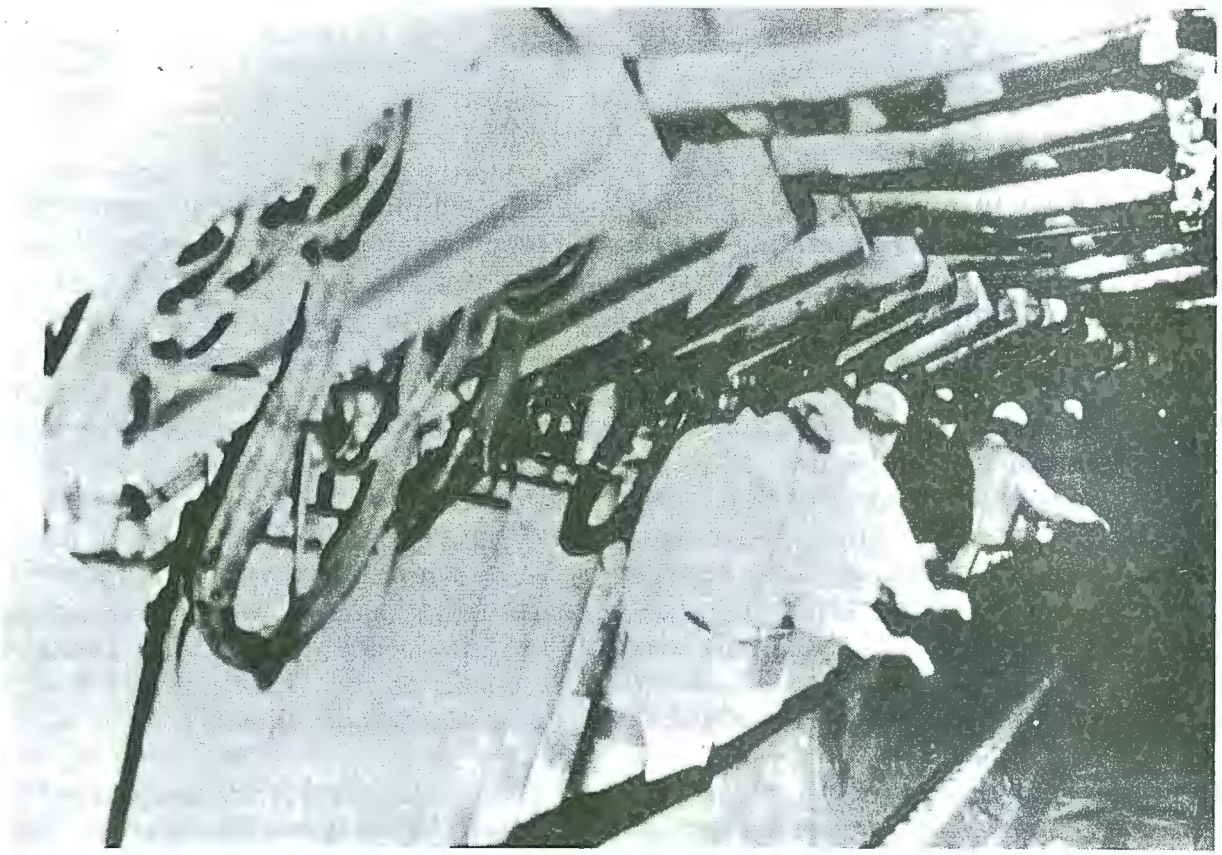

FIGURE 17. Shield-type supports being tested by the Bureau in Kaiser Steel Corporation's York Canyon Mine, in Raton, New Mexico (Bureau of Mines, U. S. Department of the Interior).

FIGURE 18. Shortwall technique at Beth Elkhorn Corporation's Hendrix No. 22 mine, near Jenkins, Kentucky (Bureau of Mines, U. S. Department of the Interior).

The Bureau is taking both approaches, and I personally feel strongly that our efforts in the human resources area must be increased.

Let me describe briefly for you the philosophy that governs the Bureau's mining research program:

- The program embraces all levels of effort, from fundamental research through applied, development work, and into the demonstration phase.
- Our objectives are to improve and evolve existing technology in the near term, and at the same time to develop new technology for the medium and longer terms.
- We contract for research projects where it makes sense to do so, but we also intend to maintain a strong in-house capability, which is essential if we are to effectively monitor the contract effort.
- From the outset we have taken an integrated, systems approach, in which each mining problem is looked at simultaneously from the standpoint of health and safety, environmental compatibility, and production/productivity impact.
- We make every effort to get industry—and by that I mean the entire mining community—involved from the start. We try to use mines as laboratories wherever possible. And so, we use cost-sharing and other kinds of working agreements to parlay government/industry efforts, to promote faster technology transfer, and to catalyze industry into doing more research, development, and demonstration.

By law and by nature MESA is one of the biggest users of Bureau research products, which can play an important role in the standards setting process. Our relationship with MESA has improved greatly in recent months, and we have jointly adopted procedures that facilitate MESA's input and permit considerable give and take on Bureau programs.

Those of you who attended the Coal Show this spring in Detroit saw some results of the Bureau's health and safety research that are now commercially available to mine operators. You saw human-engineered cabs and canopies, superior illumination equipment, longwall shield supports and sophisticated systems of underground communication. Our Technology Transfer group is even now working on ways of speeding additional research developments from the laboratory to the industry. For unless our innovations can make that transition from the laboratory to the working section, we might as well have not spent the public's money. Unless it helps to save lives, and prevent accidents, the work counts for nothing. That is our philosophy now, and I trust it always will be.

Thank you.

August 31 and
September 1-2, 1976

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