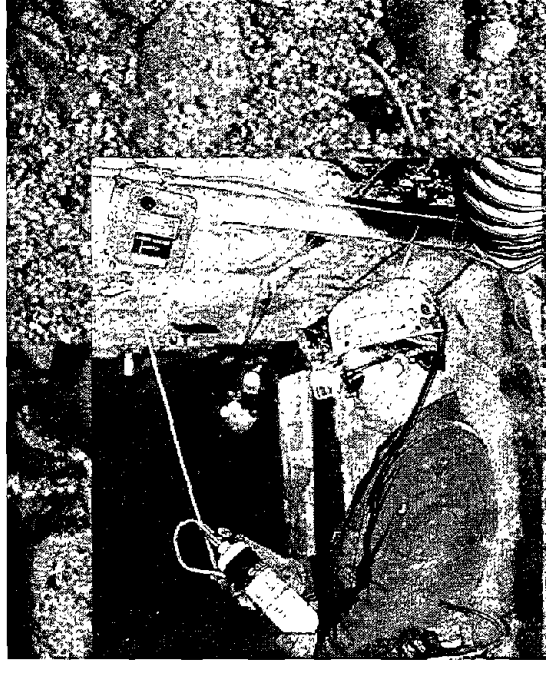
From Concept to Customer:

Technology Transfer at the U.S. Bureau of Mines



Cover: U.S. Bureau of Mines researchers investigate many facets of mining and minerals processing. Among the resulting technologies are ways to make better use of mineral wastes, such as the residue from an industrial furnace, which is shown as the background of the cover design.

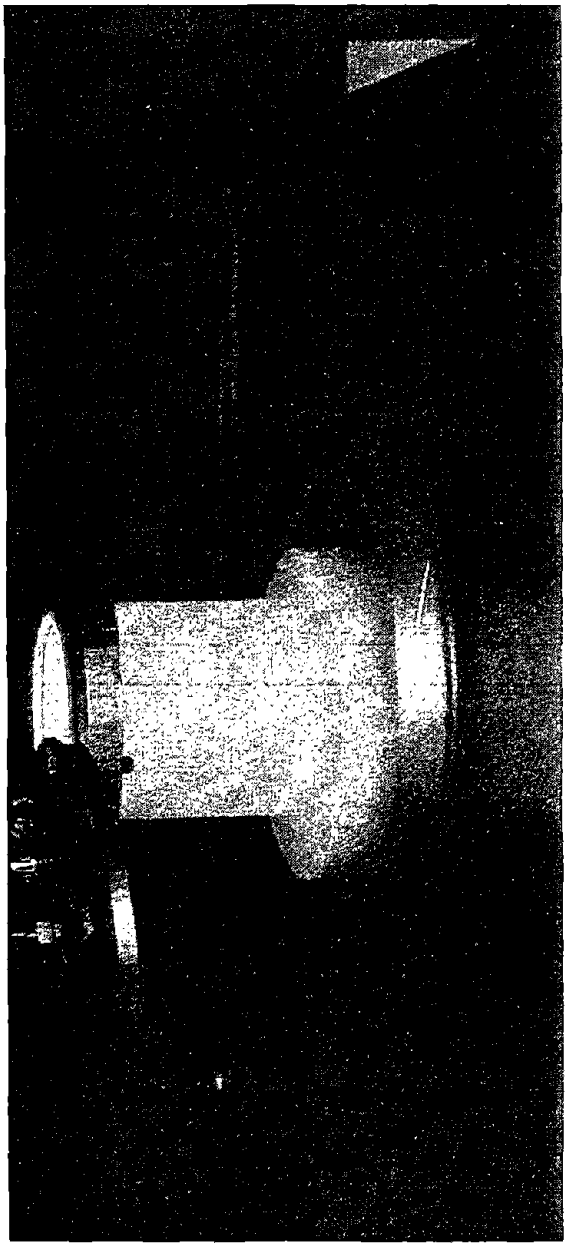
From Concept to Customer:

Technology Transfer at the U.S. Bureau of Mines

Compiled and edited by Marie R. Barrett
Office of Technology Transfer

U.S. DEPARTMENT OF THE INTERIOR
U.S. BUREAU OF MINES

In laboratories, mines, and processing plants, U.S. Bureau of Mines scientists and engineers explore ways to turn ideas into realities. From their ideas have come exciting results that can have tremendous benefits for our Nation's economy and well-being.



Innovative concepts in mine safety, rock fragmentation, minerals processing, waste cleanup, recovery of metals from wastes, economics, and other fields have resulted in products and processes that are now being used by industry, Government, and others.

What is Technology Transfer?

USBM researchers have come up with new and effective ways to--

— make mining safer and more productive,

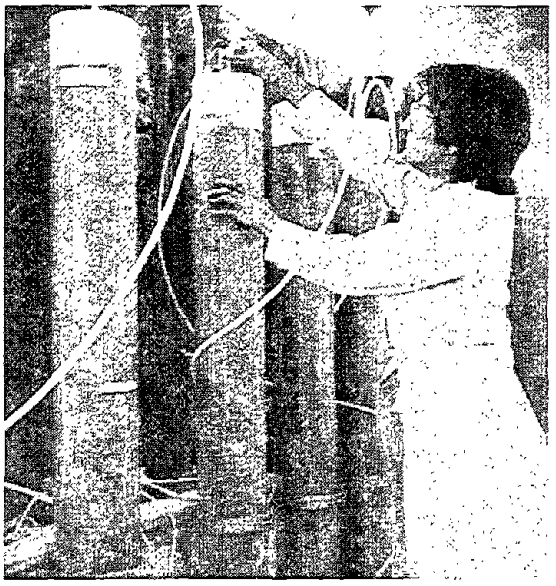
— make better use of domestic resources,

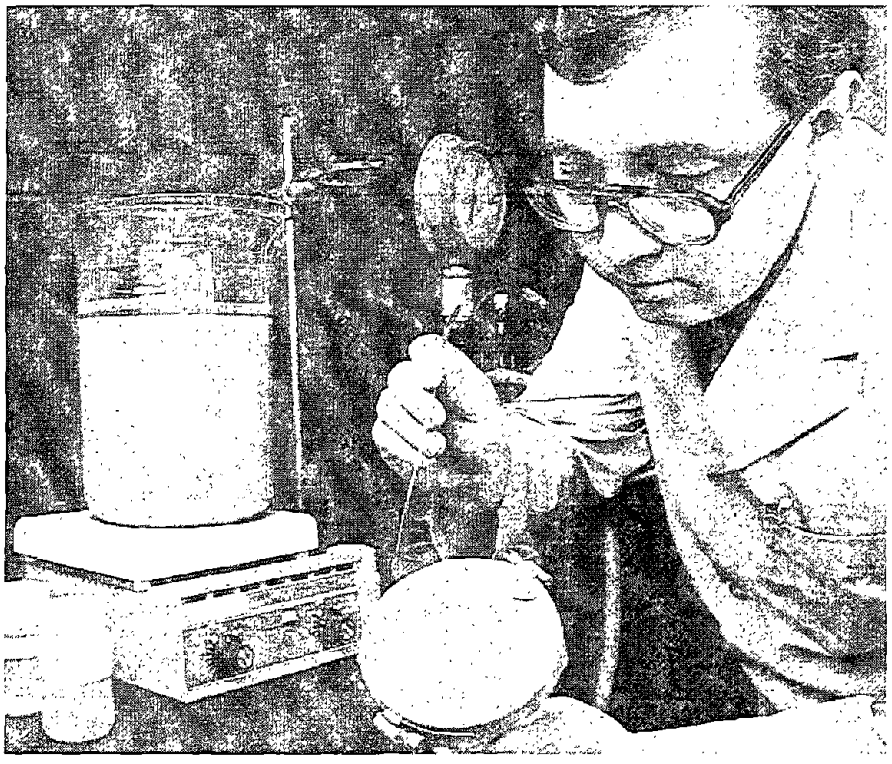
—recover valuable minerals from industrial waste,

— clean up or prevent pollution from mining and minerals processing.

But even the best ideas won't make a difference until they're put to use. The next step is to get these proven concepts for innovative products and processes into the hands of the Bureau's customers. Getting the results of the research out to the customer is the process of technology transfer.

The Federal Technology Transfer Act of 1986 makes technology transfer a responsibility of all Federal laboratory scientists and engineers. The act encourages cooperative work, provides for licensing of patents to commercial companies, and rewards Federal inventors and innovators.





How is Technology Transferred?

The USBM actively promotes the transfer of its information and research results to its customers. Those customers include members of the mining and minerals industry, other Government agencies, universities, and other institutions. With the passage of the 1986 act, the Bureau's technology transfer program put additional emphasis on marketing to industry and encouraging commercialization of USBM technology.

One of the most effective ways of getting ideas out of the Bureau's labs and into the real world is through cooperative efforts—

Cooperative research and development agreements with industry. These agreements provide the opportunity for private industry to collaborate with the USBM early in the research cycle. The USBM can test its new technology in actual operating mines and plant facilities, and industry operators can see the technology in real-life situations, which keeps the research on track. At the end of the cooperative effort, the industrial collaborator may commercialize the technology.

Partnerships with other Government agencies. The USBM works with Federal agencies such as the Department of Defense and the Mine Safety and Health Administration, as well as with State and local governments. Many of these agreements involve the use of USBM information and expertise to solve specific problems, such as cleaning up acid mine drainage in National Forests or closing up abandoned mines in National Parks.

Agreements with universities and other organizations. Cooperative agreements with universities allow the sharing of personnel, facilities, and equipment in conducting specific research, which can provide both parties with resources not otherwise available. Agreements with other organizations often make use of USBM

technical assistance in activities outside the area of mining and minerals, for example, the preservation and restoration of historic buildings.

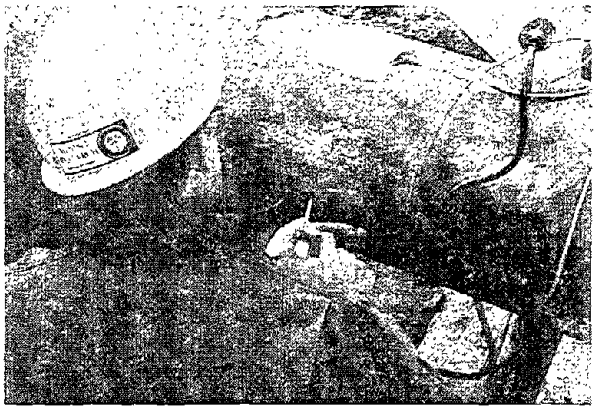
Other technology transfer tools include—

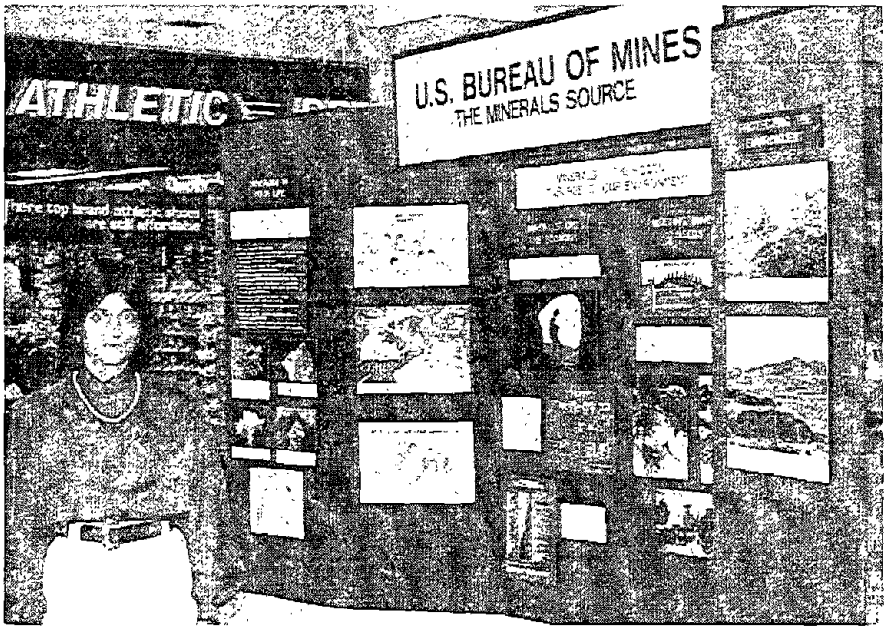
Technology Transfer Projects program. This program, a new approach to marketing, was begun in 1991. The USBM identifies especially promising research projects or developments and designs marketing plans and provides seed money to help encourage their commercialization. Researchers are given the opportunity to demonstrate their products and processes in pilot plants and to meet with industry personnel, with a view toward stimulating interest in cooperative agreements or in eventually commercializing the technology.

Patent licensing. Over the past 10 years, almost 100 USBM-developed products and processes have been granted patents. Private companies that are interested in commercializing and marketing these technologies can obtain patent rights or exclusive licenses.

Publications. The USBM publishes two newsletters that promote its technology transfer. They describe developing and mature technologies, encourage cooperative efforts, and announce patent licensing opportunities. The USBM also advertises for cooperative work and patent licensing through special publications and through notices in business and trade journals.

Exhibits and meetings. The USBM demonstrates its research and information products at major conferences, trade shows, seminars, and open industry briefings. These activities reach a large audience; they're aimed at increasing customer awareness of what the USBM has to offer and encouraging potential cooperators, including those outside the traditional minerals industry.



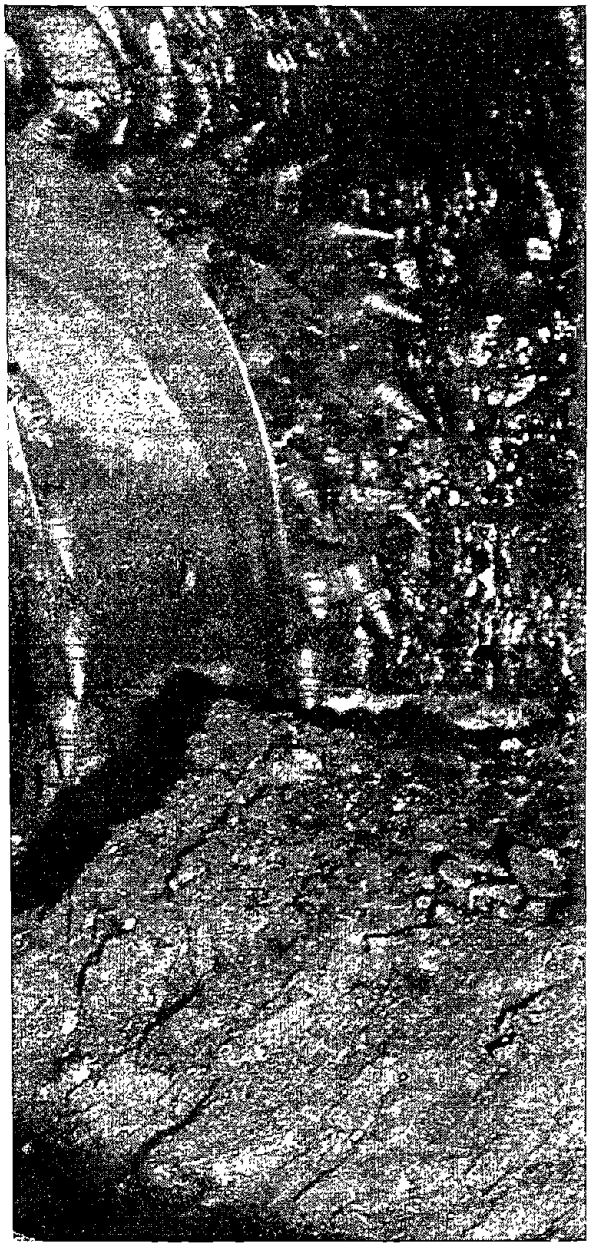


R&D 100 Awards. Each year, the USBM submits several of its new technologies to Research and Development Magazine as candidates for the R&D 100 Awards. These awards, which recognize the 100 most technologically significant new products of the year, are coveted prizes in the scientific community. Thousands of entries are submitted each year, from all over the world. The USBM is among the top 20 organizations in the number of R&D 100 Awards received since the beginning of the competition in 1963, in the company of such giants in R&D as General Electric, Westinghouse, and NASA. The publicity attached to this worldwide recognition adds to the visibility and marketability of the Bureau's products.

The USBM technology transfer program maintains a headquarters office in Washington, D.C., and personnel in USBM centers around the country: the Center for Health and Safety, Pittsburgh, Pennsylvania; the Center for Materials Partnerships, Albany, Oregon; the Center for Pollution Prevention and Control, Salt Lake City, Utah; and the Center for Environmental Remediation, Minneapolis, Minnesota.

Hundreds of USBM-developed technologies have been transferred to industry, to others in the private sector, and to other Government agencies. Following is a sampling of some recent products and processes that have gone from being a concept in the mind of a USBM researcher to a useful tool in the hands of a customer.

Mining remains a highly dangerous occupation, but some of the dangers can be reduced if people are removed from the most hazardous locations. USBM technologies include a sensing system that can take the place of a human miner at the coal face and a roof support system that is set up by remote control.



The USBM has also developed, patented, and licensed to industry devices that will provide warnings in case of danger and life support in case of disaster.

Coal Interface Detection (CID) System

The USBM is developing computer-assisted mining as a way to improve mine safety, as well as productivity. Automation will let mine workers run machinery from a safe control center, instead of in the coal-extraction area, the most hazardous area in a mine.

However, moving humans away from the coal face means that the mining machine operator can no longer see or feel where the coal ends and the rock begins, making it harder to keep the cutting head in the coal seam. If rock is mined along with the coal, the costs of processing and cleaning the coal go up. In addition, mining into the rock can jeopardize mine roof control.

The CID system takes the place of the human operator's senses at the coal face. It uses a radar sensor to penetrate and measure the thickness of coal between the cutter head of the continuous mining machine and the shale above the coal and to detect the interface between the coal and adjoining rock.

With this information, the system guides a prototype computer-assisted mining machine and keeps the machine in the coal seam. More precise cutting means cleaner coal with less waste, greater productivity, and greater safety because the stability of the mine roof is not compromised. Without such a sensor, remote operation of mining equipment would not be possible.

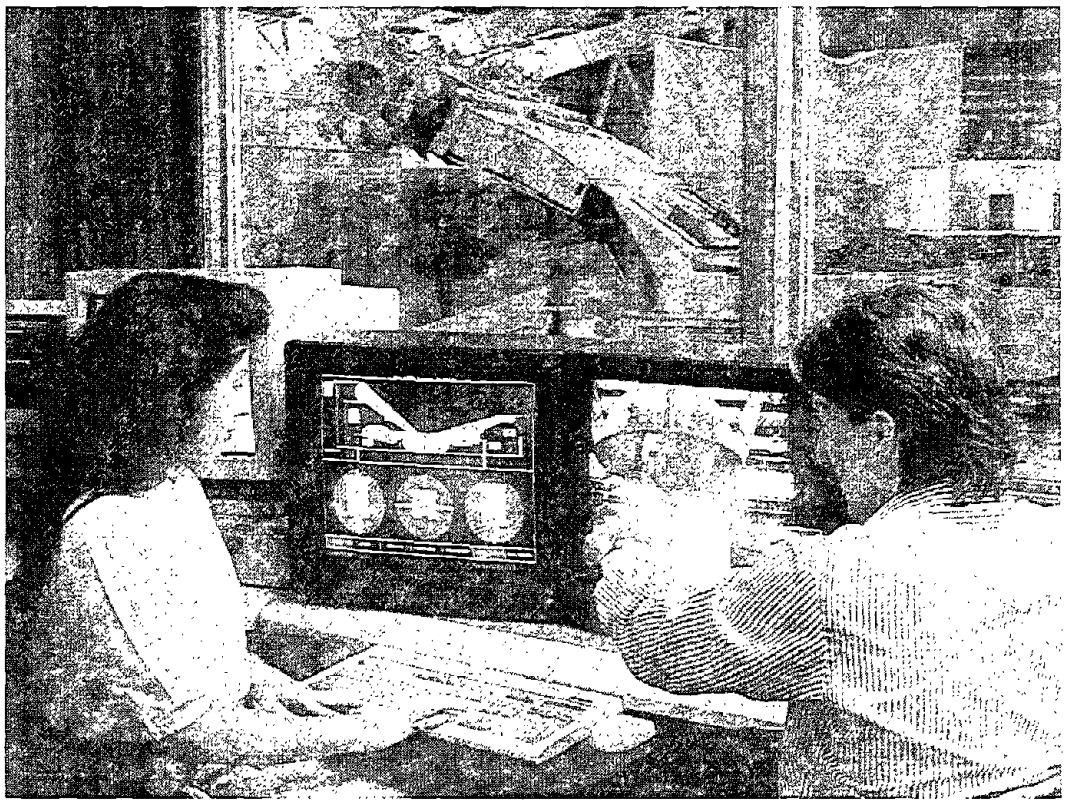
The radar sensor won an R&D 100 Award in 1992 as one of that year's most significant new products. A prototype CID system was tested under actual operating conditions, and a demonstration was given to representatives of industry, government, and academia at an open industry briefing in 1992.

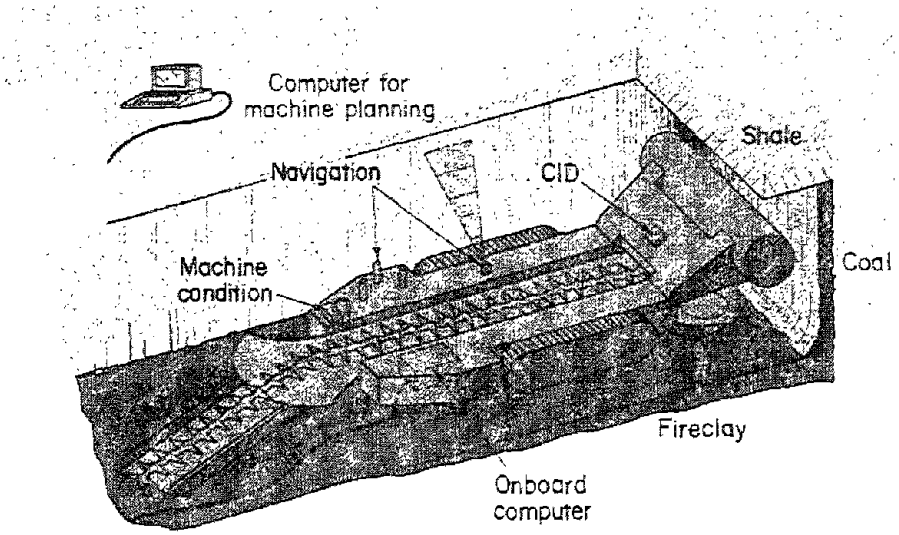
In addition to its use in computer-assisted coal mining, the interface detection system has other applications in locating underground features and as a survey tool. It can detect hazardous conditions such as fractures and voids in underground areas, and it can be used in minerals exploration and extraction to measure the thickness of rock formations. The system can measure the thickness of concrete or asphalt paving, can locate reinforcement rods in concrete structures, and can detect and measure tunnels.

One nonmining application is in archaeological exploration. USBM scientists are using the ground-penetrating radar equipment to assist archaeologists exploring the site of a prehistoric whaling village and other ancient settlements in Alaska. The use of radar to locate artifacts minimizes the need for costly, time-consuming excavations. This work is funded by a grant from the National Science Foundation and is being done in partnership with universities, private businesses, other Interior Department agencies, and the North Slope Borough (Alaska) Commission on History, Language, and Culture.

The radar sensor technology is also being evaluated by the Department of Defense and the Department of Energy for other nonmining applications, such as locating buried ordnance or nuclear waste.

Researchers use computers to control a mining machine from a safe location, as part of the USBM program to reduce the exposure of workers to some of the worst mining hazards.



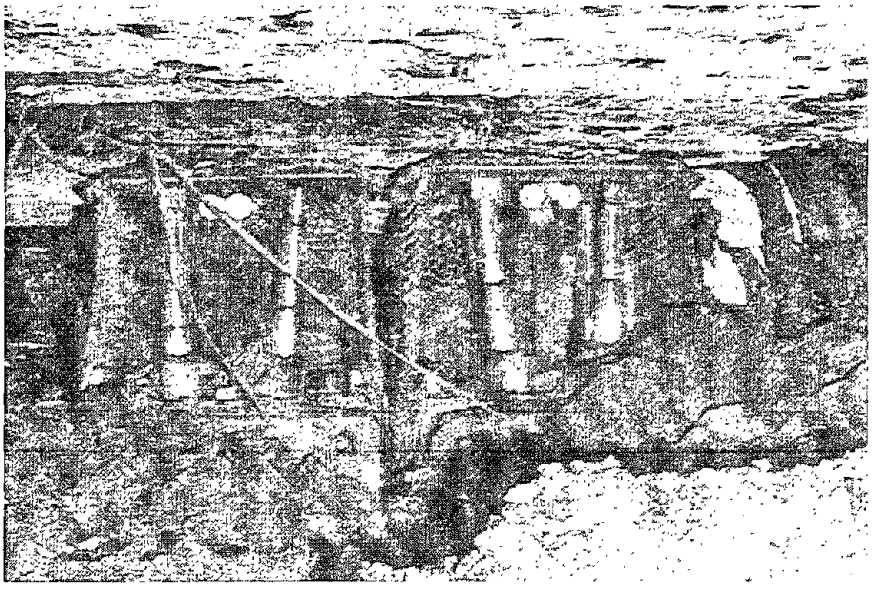


The CID sensor measures coal thickness and detects the interface between coal and rock, critical factors in computer guidance of a mining machine. The sensor has found a number of other applications as well, locating a variety of underground features, both natural and manmade.

Mobile Roof Support to Increase Mine Safety

During the extraction of coal pillars in retreat mining, the mine roof must be supported by supplemental supports such as posts to keep it from caving unpredictably. Supplemental support posts are set manually by miners working in an area that is dangerous because the roof could cave in prematurely. A number of accidents have occurred during the preparation and installation of such posts.

The USBM mobile roof support system eliminates the need for workers to install other types of support. To provide support, the machine is set against the mine roof. The system is positioned, set, and moved through the use of radio remote controls, so that there is no need for miners to go into dangerous areas during pillar extraction. Use of this system has significantly improved safety and increased production.



Mobile roof support systems in operation underground.

The mobile roof support system was described in a USBM newsletter in 1985. A cooperative agreement with a major coal producer followed, in which the system was tested for 1 year in a Utah coal mine. The success of the system led to its commercialization and its use in U.S. coalfields.

Mobile roof supports are currently being manufactured by J.H. Fletcher and Co., Huntington, West Virginia, and Voest-Alpine Mining and Tunneling Corp., Pittsburgh, Pennsylvania. The Long-Airdox Co. has also designed and patented a mobile roof support system and will start fabricating the machines this year.

Under a memorandum of agreement, the mobile roof support technology has been adopted by the Department of Energy for use in underground salt deposits at the Waste Isolation Pilot Plant (WIPP) site, used for storing nuclear waste.

The USBM is currently working with industry and with the Mine Safety and Health Administration to assess other applications of mobile roof support. Field trials are planned to test the potential use of the roof support system in longwall head gates and tail gates.

A Proximity Warning System for Remotely Operated Equipment

Remote control of heavy mining equipment such as continuous miners provides advantages to the mining operation in terms of health and safety. Workers remain behind the equipment and a distance away from the coal face, the most hazardous location in the mine.

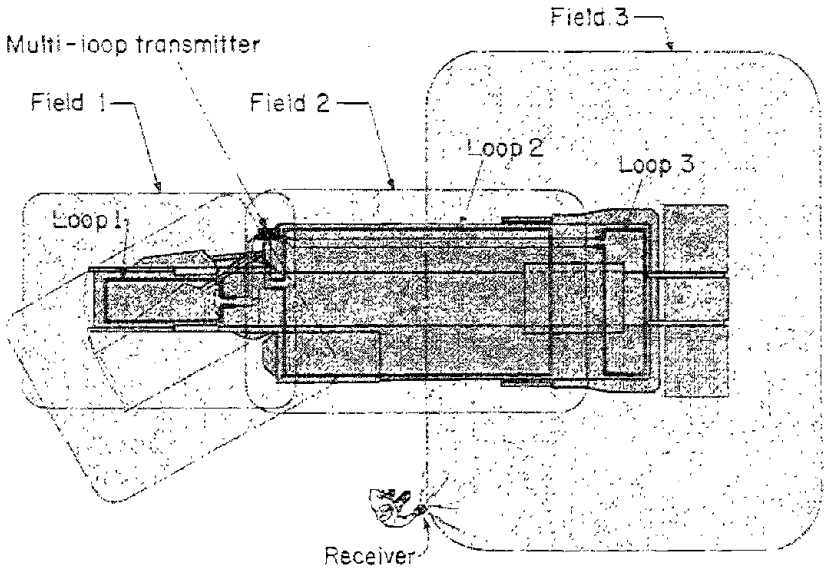
At the same time, however, operators and their helpers are still working in the same general area as the remotely operated equipment. Working too close to such equipment is dangerous and could even be fatal.

The hazardous area signaling and ranging device (HASARD) is a warning system that detects the presence of a person in hazardous areas around mining equipment. The system includes a transmitter on the mining machine and a small receiver on the worker. If the worker comes within range of the transmitter's field, the receiver lights up and sounds an alarm. The receiver can also be connected to the operator control panel to automatically shut down the machine if the worker gets too close and is in danger of being injured.

Operator remotely controls a continuous mining machine.

HASARD can be modified to meet different applications. It could be used with heavy equipment and machinery in other industries, including construction.

The proximity warning system was developed under a cooperative agreement with a mining company, Joy Technologies, Inc., Franklin, Pennsylvania. The USBM and Joy are in the process of making further improvements to the system, which should lead to a commercial product.



Transmitter sets up fields of protection around the mining machine. The worker's receiver lights up and sounds an alarm if the worker comes too close to the machine.

The New "Miners' Canary": An Emergency Warning System

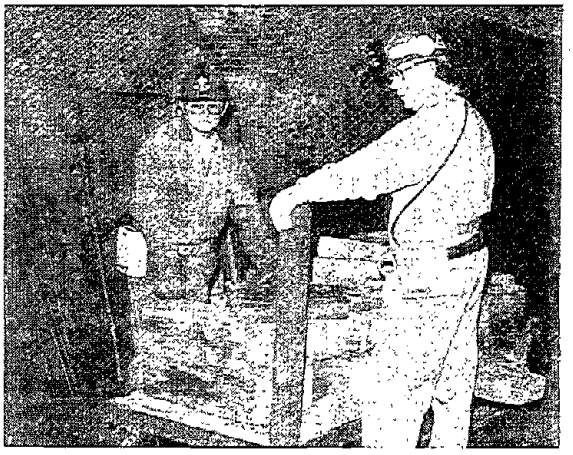
In underground mining, small groups of miners are scattered over miles of workings, without the ability to communicate with each other or with workers on the surface. This inability to communicate can be inefficient and annoying at times, but it becomes critical in the event of a mine fire or other emergency. Workers must be notified of an emergency immediately so they can quickly evacuate the mine or take other action.

Currently, miners are warned of fires by means of stench systems (an odoriferous chemical is released into the mine ventilation system), audible or visible alarms, telephones, and messengers. None of these systems have been satisfactory, since they are often slow and unreliable and limited in the areas they can cover.

The "Canary" system is an altogether new approach to mine communications and fire warning, and it fills a long-standing need. Canary is a wireless communications system that can reach individual miners or all miners instantaneously and simultaneously.

The system uses a transmitter on the surface or underground to send an ultralow-frequency electromagnetic signal through the earth to miniature receivers built into the cap lamp battery cases worn by miners on their belts. When a signal is received, the cap lamp blinks and a buzzer sounds, alerting the miner to an incoming message. The message appears on an LED display on the top of the battery case. Vehicle dashboard-mounted units are also available.

A miniature receiver is built into the cap lamp battery case. An incoming message appears on an LED display on the top of the case.



The Canary system provides a way to communicate with miners underground wherever they are located

Like the miners' canaries used in years past, the Canary system can warn miners about dangers such as methane gas accumulations. But it can also transmit routine information about mining operations from the surface to miners below.

This message system could also have applications in the tunneling and construction industries. It might be used for communications and remote control of systems and equipment in tunnels, sewers, or similar underground structures.

The ultralow-frequency through-the-earth communications system was described in a USBM newsletter in 1988. Development of the system, including exhaustive field testing, was done in conjunction with two companies, and the system was demonstrated under a cooperative agreement with an active underground mine.

The innovative Canary system won an R&D 100 Award in 1993, and it is now being marketed commercially by VLF Magnetic Systems Inc.

Lightweight Breathing Apparatus for Mine Rescue

Fires and explosions in underground mines are two of the most feared hazards mine workers face. Following a fire or explosion, the atmosphere inside the mine can become toxic. A miner's only escape route may be through oxygen-deficient and smoke-filled tunnels.

Federal regulations require that every person in an underground coal mine have a respiratory protective device, called a self-contained self-rescuer, that can provide breathable air for 1 hour in case of emergency. Most self-rescuer breathing devices have been large and heavy, making them awkward for miners to wear or carry while working. The devices have usually been stored near the work area instead. However, in an emergency, even seconds are important, and the time needed to reach the stored self-rescuers could be critical.

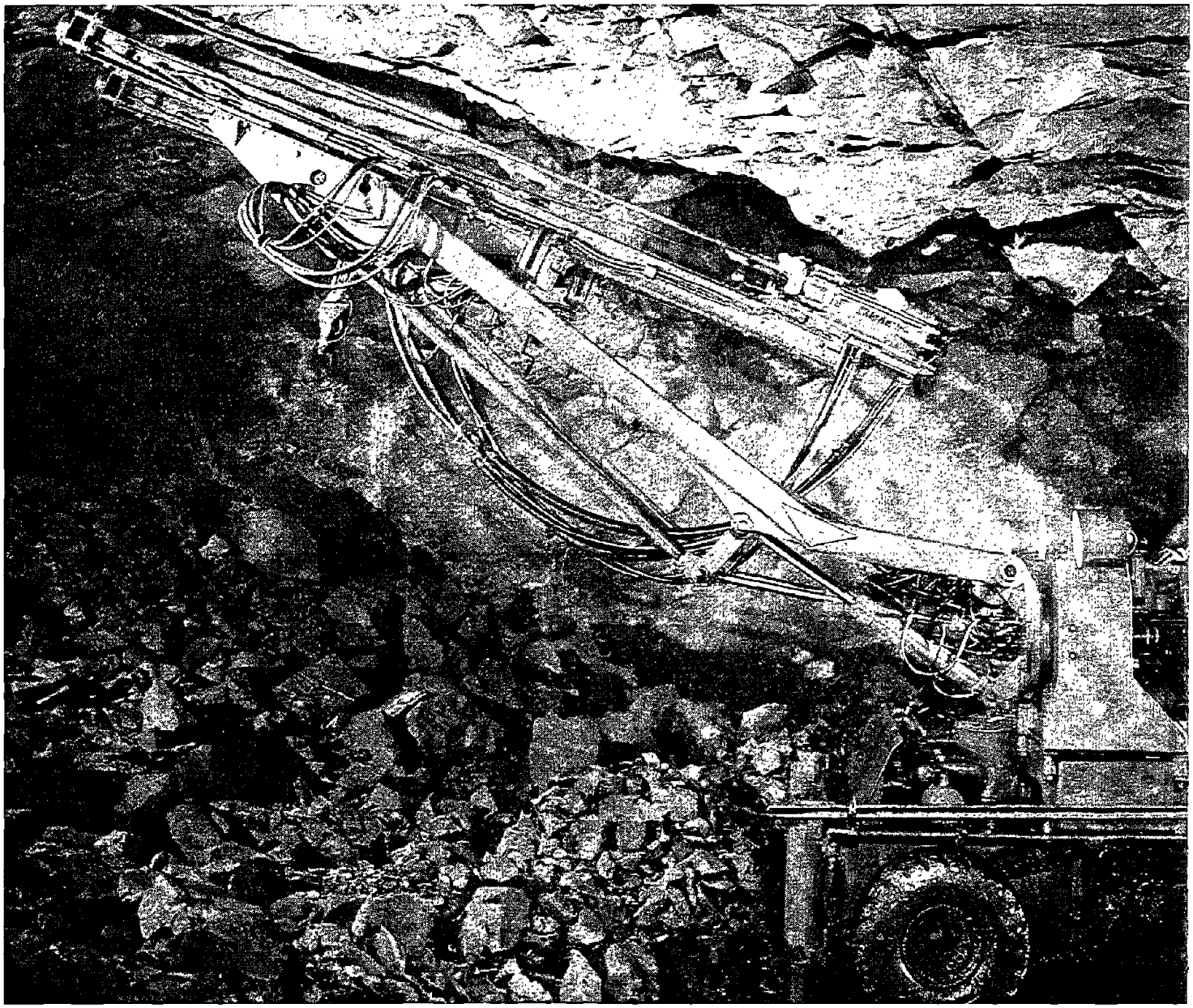
The USBM's self-contained self-rescuer, called the SR-100, provides the respiratory protection needed, in a small and lightweight package. The closed-circuit breathing apparatus supplies oxygen and isolates the wearer's lungs from contaminated air. The package is about half the size and weight of existing devices, which makes it easy to carry on a miner's belt, yet it provides the required hour's supply of air. It is also easy for a miner to use, supplying emergency respiratory protection in seconds, a lifesaving advantage in a situation where seconds matter.

This new self-rescuer also has potential as a rescue device in other industrial environments that may deal with toxic gas situations, such as tunneling and utilities construction projects.

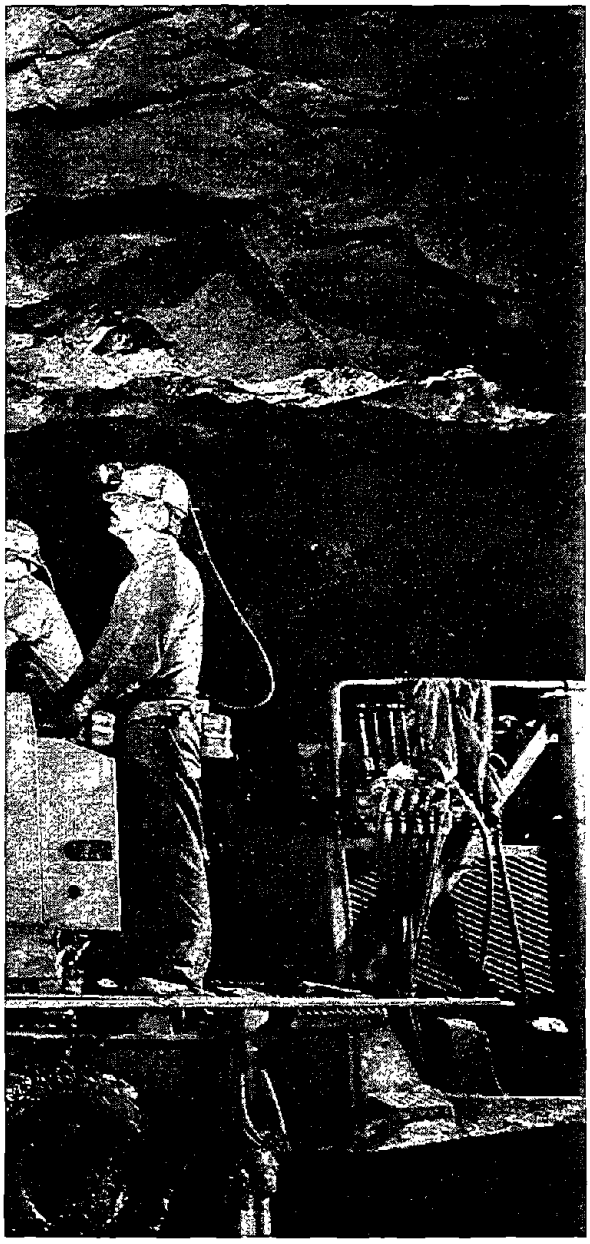
The SR-100 was developed under an agreement with an equipment manufacturer. Miners throughout the Nation's coal fields were trained to put on the self-rescuer, and they were asked to carry it while working, over a period of 1 to 2 months. Their observations on both facets of use were carefully considered before the self-rescuer was placed into commercial production.

The self-rescuer provides respiratory protection in a small package.

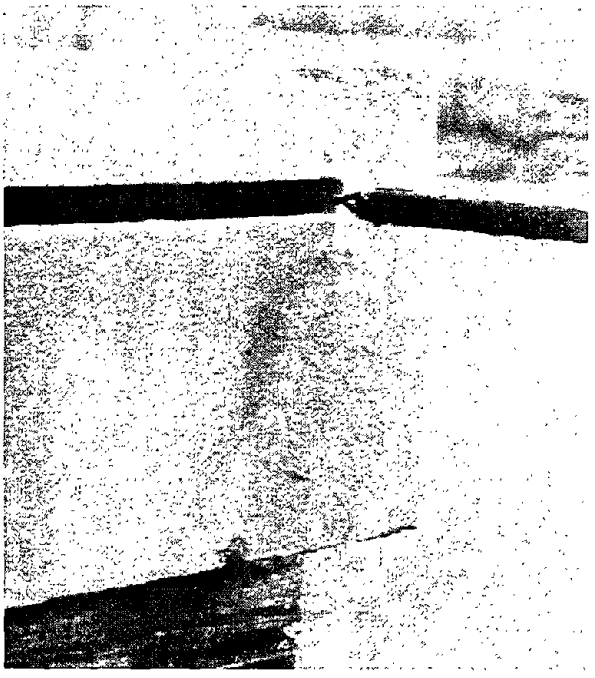
In 1989, the SR-100 was approved by both the National Institute for Occupational Safety and Health and the Mine Safety and Health Administration. The SR-100 won an R&D 100 Award in 1991 as one of the best technological developments of the year. The device is now being marketed by CSE Corp., Monroeville, Pennsylvania.



Breaking rock is the most basic element in mining. USBM researchers have designed, patented, and licensed to manufacturers a number of innovations in rock drilling and fragmentation, including improved drills, bits, and explosive charges. In addition, the USBM has developed guidelines to minimize the impact of blasting on areas around surface mines.



Abrasive Water-Jet Rock Drill



Slot, about 2.5 centimeters (1 inch) wide, cut into limestone with an abrasive jet drill

Drills with powerful water jets can be used for rock bolting and other mining or construction applications. These drills have a number of advantages over rotary or percussive rock drills, including portability and the ability to collar, or start, a hole at any angle.

One disadvantage of water-jet drills is that they require extremely high pressures to drill hard rock. This disadvantage can be overcome by incorporating abrasives such as sand into the cutting jet. The addition of abrasives enhances the cutting ability of the jet so that relatively modest pressures can be used to cut very hard rock.

Abrasive water jets are in common use in industrial cutting of hard materials, but before now they have not been used to drill deep holes or to cut deep slots (kerfs) in hard materials.

There are many engineering applications for which deep drilling or slotting hard rock is desirable. These include rock bolting, drilling for blasting, cutting slots in reinforced concrete, preventing overbreak in blasting, and isolating ore from waste rock for selective mining.

The USBM has developed an abrasive water-jet rock drill and slot cutter that incorporates several novel design features, including a collimator, a jet diverter, and a low-pressure swivel.

The collimator, a pipe attached downstream of the nozzle, enables the high-velocity abrasive jet to retain its cutting ability more than about 2 meters (6 feet) from the nozzle. The abrasives are added to the water jet downstream of the nozzle so that the nozzle is not damaged.

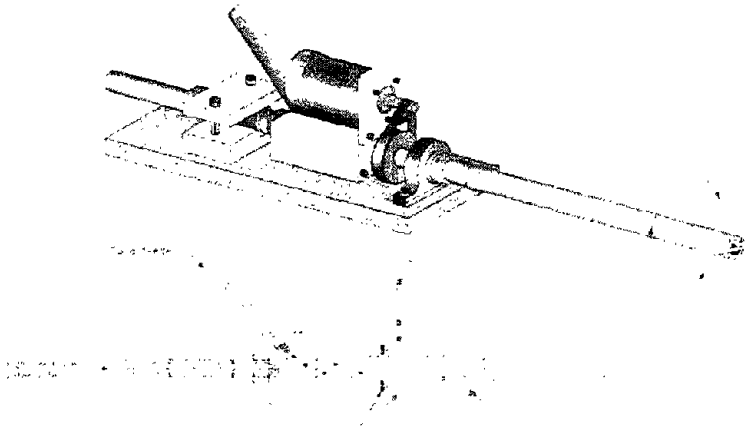
Jet diverters, plates placed at the exit of the collimating pipe, permit the jet to cut a wide enough clearance so that the pipe can follow the jet into the cut.

The swivel, which rotates the collimating pipe at 500 rpm, is also placed downstream of the nozzle, so that it doesn't require sealing against high pressure. The swivel is clamped on the outside of the pipe so that it is not in contact with the high-velocity abrasive slurry and thus escapes wear.

This drill can cut through hard rocks with moderate-pressure water jets. In addition to drilling holes, the drill can cut deep and narrow kerfs, collar a hole at any angle, drill through rubble, and chamber or enlarge holes.

The abrasive water-jet drill and slot cutter also has civil engineering applications, such as drilling or slotting reinforced concrete in highway bridges so that they can be retrofitted with earthquake protection.

The USBM has patented this novel drill and transferred the technology to industry. The drill was publicized in a 1987 USBM newsletter and granted a patent the same year. Funds provided under the Technology Transfer Project program enabled the researchers to demonstrate the potential of this drill to industry. In 1993, Aqua-Dyne of Houston, Texas, was granted an exclusive patent license to manufacture and sell the drill.



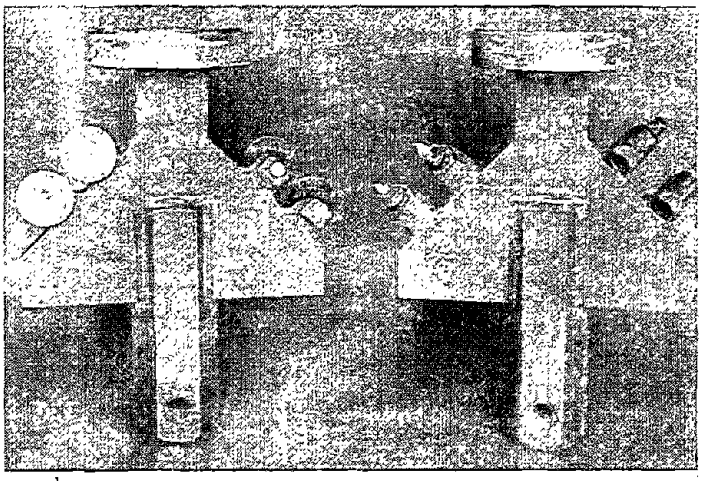
Abrasive water-jet drill.

Concave Bit for Faster and More Effective Cutting

Many mechanical excavators, such as continuous mining machines, roadheaders, shearers, and plows, use cone-shaped bits for cutting. The conical bit is inexpensive and useful in cutting a wide variety of materials, but it requires large forces to operate effectively and is relatively energy intensive. These characteristics affect the overall cost and productivity of the excavators using it.

The USBM has developed a cutting bit with a different shape that works better: a circular cutter with a concave face that outperforms standard conical bits in coal and soft rock.

In controlled comparison tests, the cutting rate of the concave bit was two or more times faster than the rate of conical bits at the same thrust, and the concave bit required only 60% of the energy required for conical bits to cut the same volume of rock. The concave bit also dramatically reduced the amount of airborne dust generated.

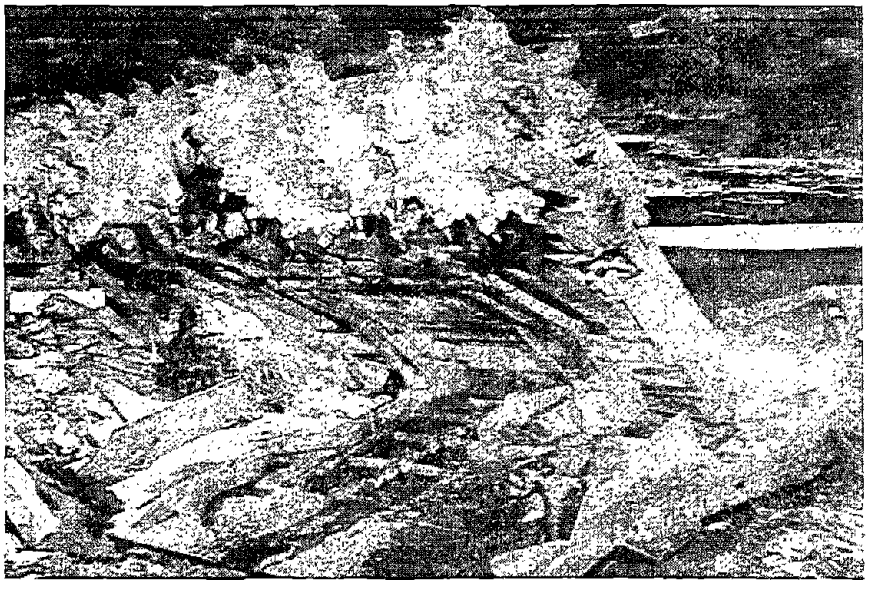


The reamer on the left is equipped with the new circular concave-face bits; the reamer on the right has conical bits.

These bits can replace conventional conical bits on all mechanical excavators, such as continuous mining machines and trenchers, enabling these machines to cut faster, with less force and less energy consumption.

The concave bit cutter device and method were patented in 1992. As part of the Technology Transfer Project program, funds were provided so that USBM researchers could demonstrate this new kind of bit.

An exclusive royalty-bearing license has been grated to Kennametal Inc., of Latrobe, Pennsylvania. Kennametal is now manufacturing the concave bit for use on trenching machines and eventually other cutting equipment. Royalties from the sales are used by the USBM to further technology transfer of other research.



With the Bureau's new conical bit, mining machines such as these can be more productive while using less energy.

Sheathed Permissible Explosive Charge

Explosive charges are used to break up large rocks in mines. In the past, regulations required that charges in underground mines be placed in holes drilled into the rock. Open or unconfined blasting—that is, firing an explosive on a rock surface instead of in a borehole—was prohibited. There was a danger that an unconfined charge would ignite methane gas or coal dust in the mine atmosphere, which could result in a massive, minewide explosion.

But if the danger of such an ignition is eliminated so that open blasting can be used, there are advantages for both safety and production. Unconfined blasting can help to reduce mine hazards by breaking up loose roof rock or piles of fallen rock. And because no holes are drilled, unconfined blasting is quicker and more efficient than confined blasting, so production downtime is less.

The Bureau's sheathed explosive charge is a nonincendive charge that can be safely fired, unconfined, in a gassy or dusty mine atmosphere. The charge is covered with a layer of flame-inhibiting material such as damp salt, and is enclosed in a cloth-reinforced latex rubber housing.

When the explosive is fired, the salt disperses in a fine cloud and acts as a flame retardant, which prevents ignition of coal dust or methane in the mine atmosphere. The rubber housing allows flexibility in placing the charge, and gives the charge durability so that it can withstand rough handling.

The sheathed charge can be safely fired in underground mines without blastholes or packing, and it effectively breaks rock such as the large stones that can jam the feeder-breaker or pan conveyor on longwalls and stop production.

The Mine Safety and Health Administration has developed a test protocol for the approval of sheathed explosive charges as permissible explosives and has published regulations governing their use.

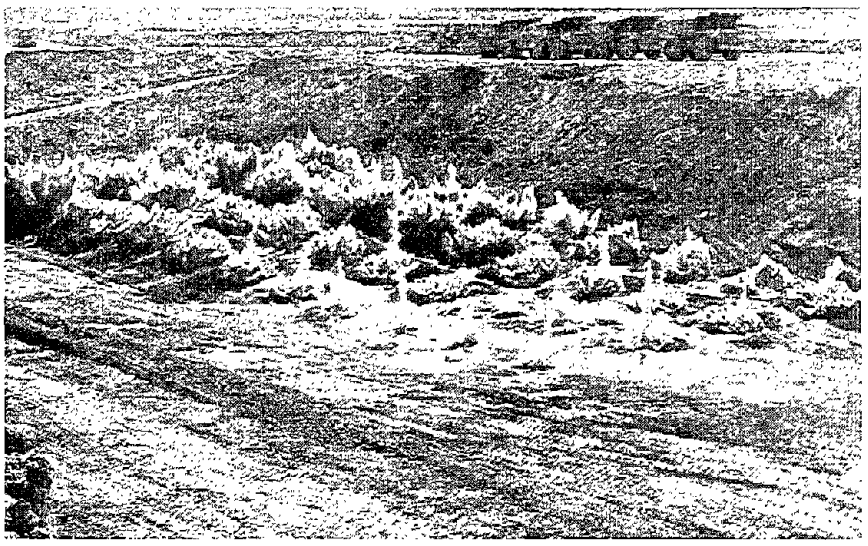
The sheathed charge was a 1982 winner of an R&D 100 Award as one of the year's 100 most innovative technologies. It was further publicized in a USBM newsletter in 1983, patented in 1985, and successfully tested under cooperative agreements with mining companies. USBM researchers also held a number of demonstrations of unconfined blasting with the charge at the Bureau's Lake Lynn Laboratory in the late 1980's.

In 1990, an exclusive license to produce this charge was granted to Austin Powder Co., Cleveland, Ohio. Royalties from sales are used by the USBM to further advance technology transfer activities. In 1994, the inventor of the sheathed charge was recognized as Inventor of the Year by the Pittsburgh Intellectual Law Association.

Below: In an underground mine, workers place two sheathed explosive charges on a large boulder that has been impeding mining progress.

Right: The boulder is safely and effectively broken up by the charges, without the danger of a coal dust or methane gas ignition and without excessive downtime.

Guidelines for Safer Blasting



Control of blast vibrations begins with the design practices of the mine or quarry. This photograph shows time sequencing of individual blastholes to maximize fragmentation and control vibration. In the design shown, the charges are being ignited from left to right; the holes closest to the camera are just going off.

The effect of blasting vibrations on structures has long been a problem for the surface mining industry. These vibrations can damage residences and other property near the blasting site, causing cracking of walls and foundations. In addition, the people living in the nearby residences may have to put up with wall rattling, noise, and airblasts.

In the late 1970's, there were no adequate guidelines on how to avoid blasting damage. The explosives industry and State regulatory agencies asked the USBM to develop guidelines for safe blasting, based on field research.

The blasting guidelines produced by the USBM are based on extensive research of residences and other structures that were subjected to high levels of ground vibration from actual production blasts at surface mines. New observations by USBM researchers were combined with the results of nine previous studies on blasting impacts in the United States, Canada, and Europe.

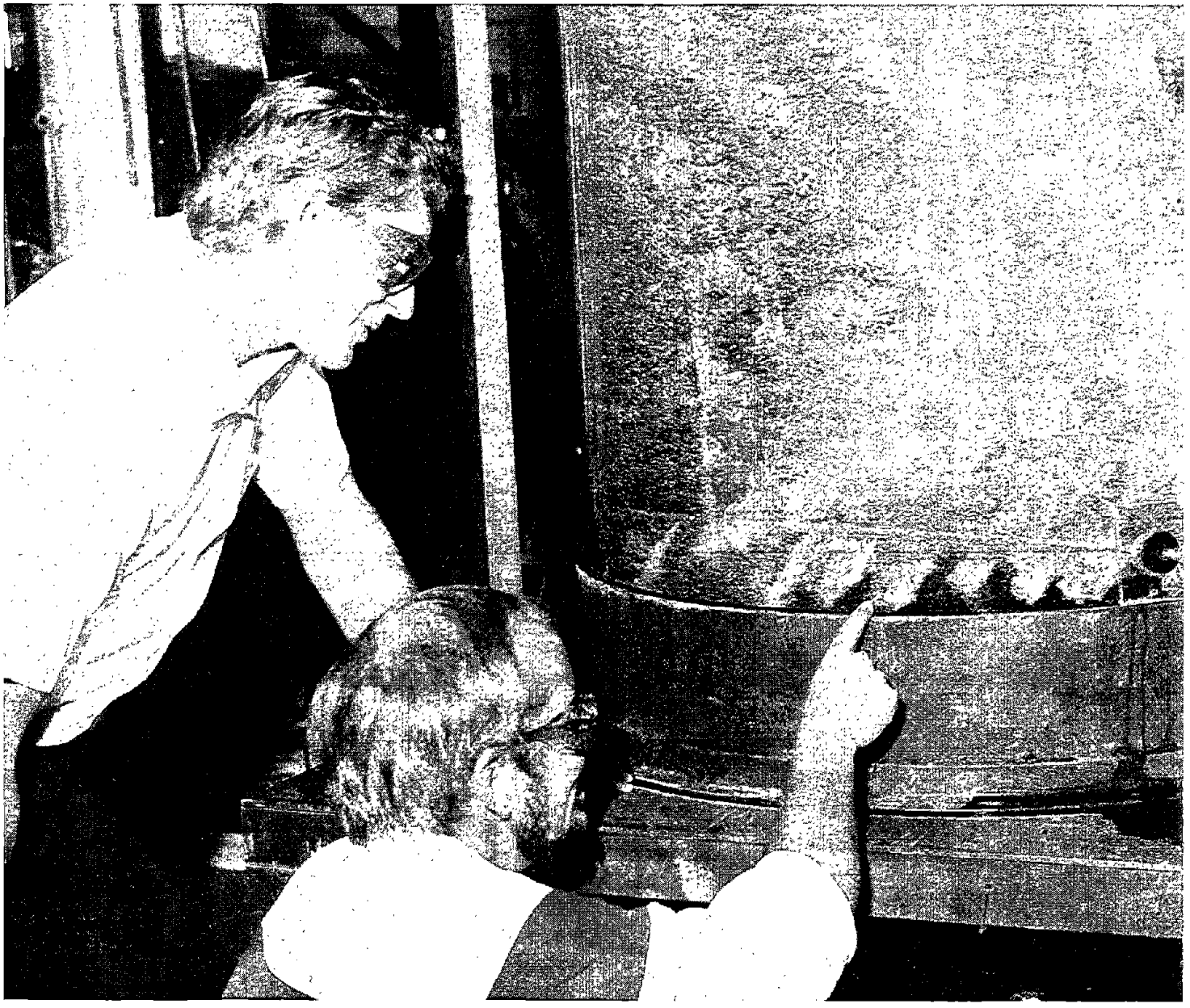
The resulting guidelines give safe levels of ground vibration and airblast, and appropriate analysis and measurement techniques. These recommendations allow the development of good and safe blasting practices, and their use eliminates the possibility of damage from surface mine blasting to nearby structures.

The results of the blasting studies were published in a number of USBM Reports of Investigations in the 1980's and 1990's. A newsletter in 1990 highlighted the earlier studies. The information has been adopted and used by mine operators, explosives suppliers, manufacturers of monitoring equipment, and seismographic consultants.

The USBM guidelines are also used by regulatory agencies at all levels of government, including the U.S. Office of Surface Mining Reclamation and Enforcement. These agencies are responsible for controls and preventive measures when blasting takes place near populated areas.

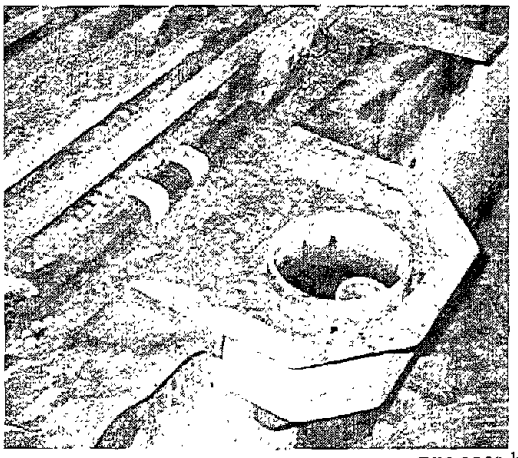
Followup studies by the USBM have examined the risks of blasting near pressurized transmission pipelines, water pipes, wells, and telephone cables. The guidelines that have been developed provide for both maximum resource recovery and safe blasting.

Recently, the USBM studied blasting effects on pressurized transmission pipelines near an active surface coal mine.



New ways of processing minerals are replacing old ways, in part to make better use of domestic resources such as low-grade ores. The USBM, with industry cooperation, has contributed to these new technologies by providing ways to reduce energy consumption and costs and to better control process operations.

Alternative Anode Reaction for Improved Electrowinning of Copper



Industrial copper electrowinning cell. Plastic balls and a surfactant (some of the surfactant foam is visible in the photograph) are used to help control acid misting.

Copper is produced by the traditional method of smelting or by the newer method of electrowinning, a process that uses electricity to extract a metal from solution and deposit it on an electrode. Electrowinning of copper has grown steadily in the United States since the mid 1980's, in part because it can be used to recover copper from low-grade domestic ores.

However, there are two problems with the present process because the electrochemical reaction at the anode involves the breakdown of water, with the production of oxygen bubbles. These bubbles rise to the surface and break, producing a fine acid mist in the air above the electrowinning cells, which can endanger the health of workers in the area. Additionally, the breakdown of water is energy intensive and therefore costly.

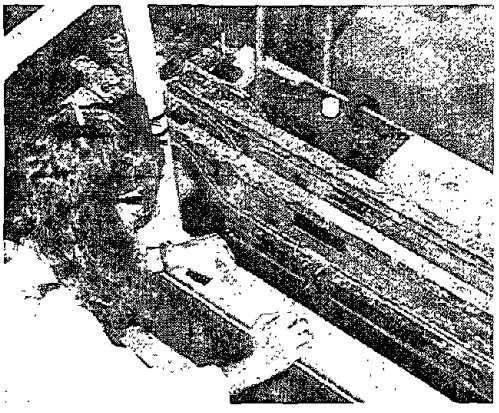
USBM scientists are investigating a new anode reaction that provides a solution to both acid misting and high energy costs. The alternative anode reaction does not involve water and so eliminates oxygen bubble formation and acid misting.

In addition, the alternative reaction decreases energy consumption by decreasing cell voltage. The low-voltage reaction can reduce the energy needed in copper electrowinning by 50%.

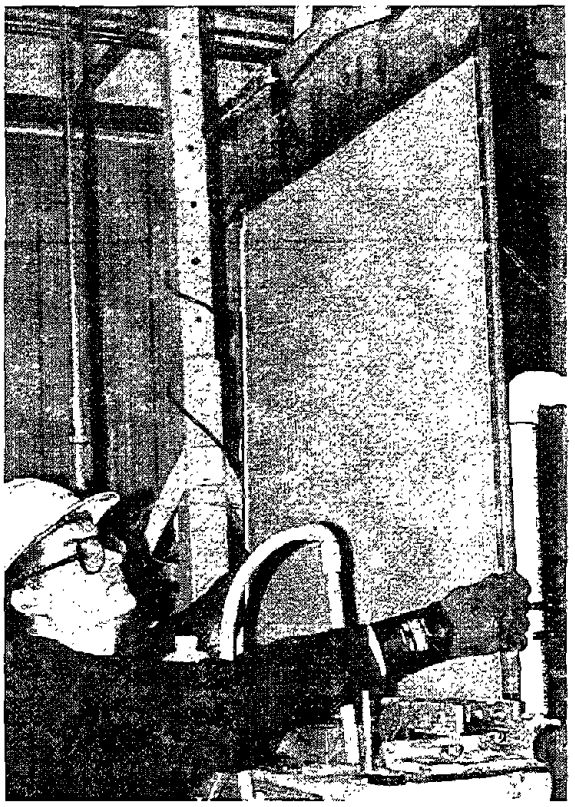
This change in copper electrowinning should make it safer for the workers and should help U.S. companies to save energy, cut production costs, and compete more effectively in world markets.

Initially, the USBM had a cooperative agreement with Magma Copper Co., San Manuel, Arizona, and Cyprus Sierrita Corp., Tempe, Arizona, to determine the feasibility of using the alternative anode reaction.

Now four companies are cooperating with the USBM in full-scale tests of the technology, representing both manufacturers and users. The manufacturers are Eltech International Corp., Chardon, Ohio, and Prosep Technologies Inc., Pickering, Ontario; the users of the new technology are Magma Copper Co. and Cyprus Miami Mining Corp., Claypool, Arizona.

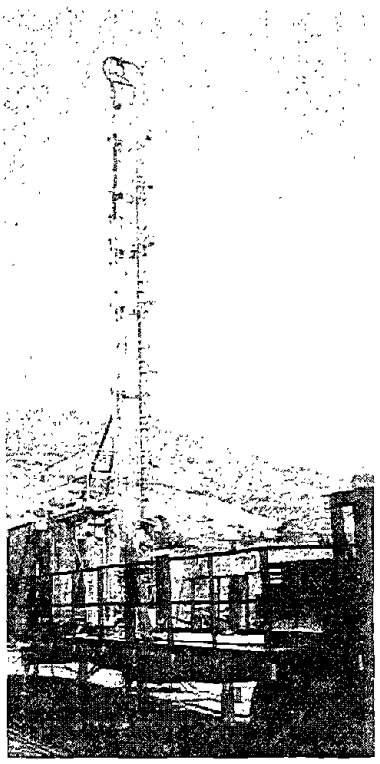


Top view of pilot copper electrowinning cell. No plastic balls or surfactants are needed since there is no acid misting.



Copper deposit produced in USBM pilot electrowinning cell using the new process.

Bubble Generator for Improved Mineral Separation



The mobile column flotation unit has been used to demonstrate USBM technology to industry.

Flotation is a widely used method of separating valuable minerals from low-grade ore. In this process, air bubbles within an ore slurry attach to the fine mineral particles and float them to the surface.

Flotation in tall columns rather than conventional flotation cells is relatively new. The advantages of column flotation include energy efficiency and better control of operating conditions such as fluid flow, making the process more selective and efficient and providing a better product at a lower cost. The USBM played a pioneering role in developing column flotation in the early 1980's and in transferring the technology to industry.

An important influence on performance in column flotation is the way in which the air bubbles are generated. Conventional sparger systems provide only limited control of bubble size and rate; in addition, when conventional spargers require maintenance, the whole column must be shut down, reducing productivity.

The USBM's air bubble generator and gas sparger provides a low-maintenance, reliable way to aerate the flotation column. The unit is a pressurized chamber attached to the outside of the column, in which air and water are mixed. The mechanism that injects the pressurized mixture as bubbles into the flotation column also controls bubble size. This allows for a much wider range of bubble sizes, which can be controlled and optimized for each mineral separation application. Also, because the bubble generator is an external component, maintenance can be performed on the unit without shutting down the entire column.

The improved bubble generator and gas sparger system was described in a USBM newsletter in 1987, and the device was patented in 1988. The patent was licensed to Control International in 1989 and subsequently to Pyramid Resources in 1991; both companies are located in Salt Lake City, Utah. The companies are now marketing the bubble generator unit as well as other column flotation technologies.

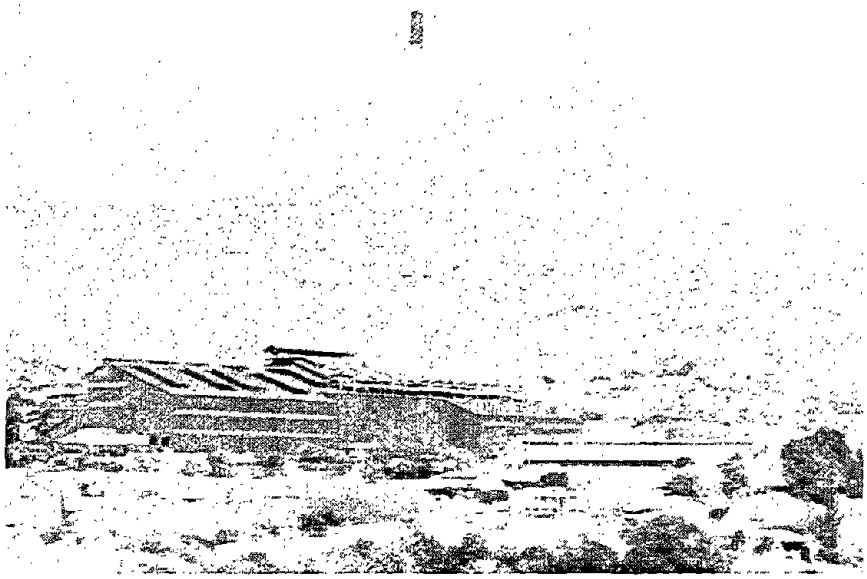
In column flotation, air bubbles attach to mineral particles and float them to the surface. With the USBM's bubble generator the size of the bubbles can be controlled to optimize mineral separation.

Commercialization has resulted in installations of the bubble generator and associated technologies in at least 50 mines in the United States, Canada, and around the world.

The USBM plans to combine its recent flotation technologies into a single pilot-plant system, integrating the bubble generator and other column flotation developments with USBM advances in process control, on-line sensors, and a new rapid flotation device. This system, at a commercial flotation plant in the Western United States, will demonstrate the whole range of USBM innovations to improve flotation technology.

USBM scientists haven't yet found a way to spin straw into gold, as in the fairy tale, but they have found ways to recover other valuable metals and materials from a variety of common wastes. With industry cooperation, the USBM has developed waste recycling technologies that can provide a domestic source for valuable materials while eliminating disposal problems.

Recovering Copper from Smelter Flue Dust



Copper smelter. The flue dust may contain substantial amounts of copper, which could be recycled, but it also contains materials that can contaminate the environment.

Flue dust is one of the wastes generated during copper smelting and refining. This dust may contain substantial amounts of recyclable copper, but it also contains materials such as arsenic, cadmium, and bismuth that can contaminate the environment or interfere with the refining process. Disposal or recycle of such waste is a problem.

The USBM treatment for copper smelter flue dust recovers copper and separates out arsenic and other contaminants for environmentally safe disposal. The process, which includes acid-leaching and precipitation, can extract more than 90% of the copper from the dust, producing copper-rich solutions or solid copper sulfides that are suitable for recycle to the smelter.

The treatment can also include a neutralization phase to remove bismuth, a contaminant that is detrimental to the refining process.

USBM researchers have worked cooperatively with a major copper producer to integrate the technique into the $880 million modernization of its copper smelter. The flue dust treatment should enable the company to recover an estimated 30 tons of copper annually, uncontaminated by bismuth or other components. This major change in the smelter eliminates a costly problem for the company.

Continuous leaching of copper flue dust.

Recovering Graphite from Steelmaking Waste

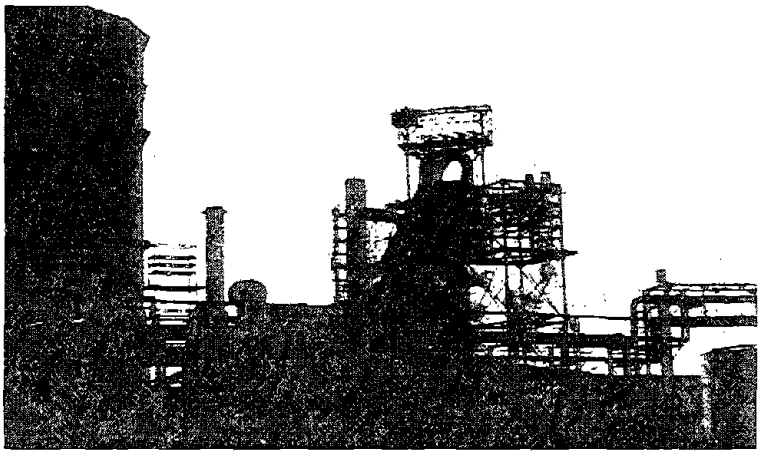
Graphite is used in a wide range of industrial and consumer products, from brake linings to the common pencil. However, the availability of this mineral is diminishing and its cost is rising. The United States is totally dependent on foreign sources for natural flake graphite.

Meanwhile, a graphite waste called kish has been considered a nuisance waste and buried in landfills. This waste is produced by the steel industry, the largest user of graphite. The steel industry uses graphite in such things as crucibles and refractories, and steelmaking produces kish, a mix of graphite, iron, and slag. Kish is a potential resource for enough graphite to meet U.S. demand several times over.

The USBM process can produce high-quality graphite from kish. The process includes screening, sizing, and leaching of the kish. The product is large-flake graphite, which appears equal to or better than natural graphite in a wide variety of uses.

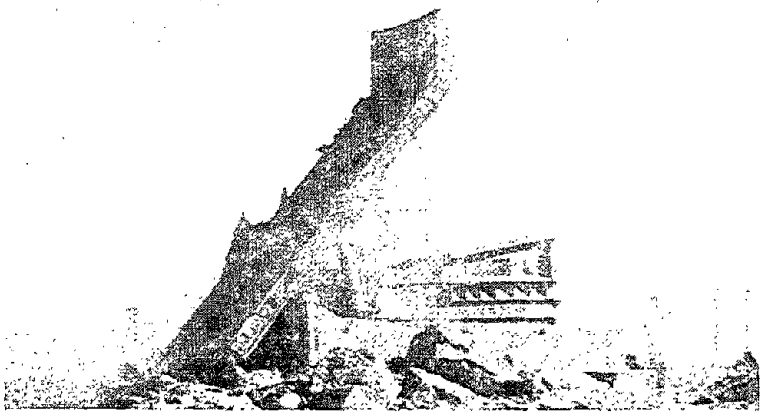
The graphite-from-kish process won a prestigious R&D 100 Award as one of the most important new technologies in 1992, and it was further publicized in a USBM newsletter in 1993. Commercial testing was performed under a cooperative agreement in which Inland Steel, East Chicago, Indiana, constructed and operated a pilot plant, and Asbury Graphite Mills, Inc., Asbury, New Jersey, tested and marketed bricks made from the recovered graphite.

If costs can be lowered so that production is profitable, this process could provide a stable domestic supply of graphite with consistent quality, while reducing the volume of waste disposed of in landfills by the steel industry.



Blast furnace at steel plant.

Kish pit. Kish skimmed from molten iron is dumped here before final disposal as landfill.

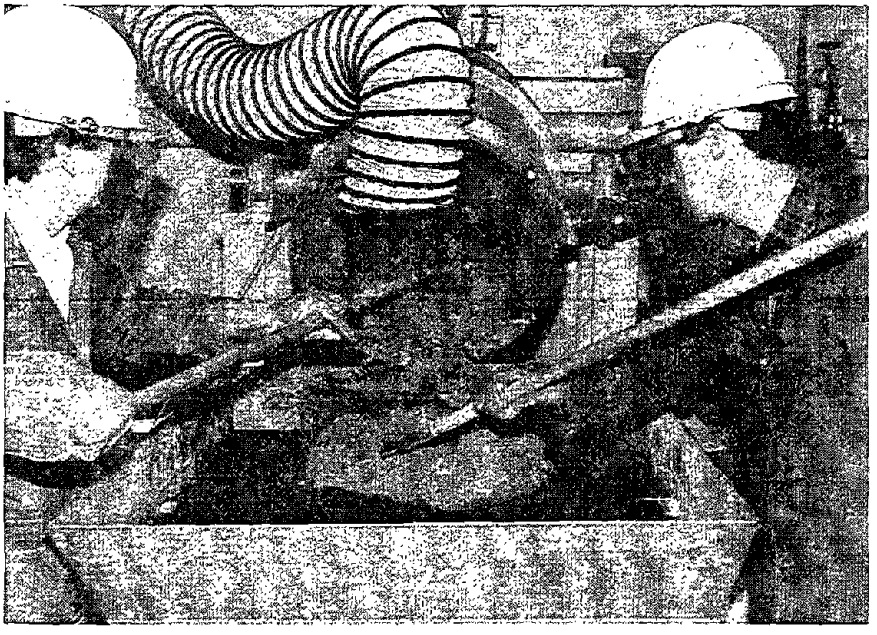


Screening large lumps of iron from kish. The iron is returned to the blast furnace.

Recovering Platinum-Group Metals from Catalytic Converters

The United States depends on imports for most of its platinum-group metals (PGM), the metals platinum, palladium, and rhodium. However, there is a domestic resource for substantial amounts of these metals: used automotive catalytic converters. About 1 million troy ounces of PGM annually go into the manufacture of catalytic converter components in the United States.

Catalytic converters are used in automobiles to convert automotive exhaust into environmentally harmless vapors. About half of the used catalytic converters in this country are collected rather than junked. But most of those are exported to Japan or Europe for processing because there has been no cost-effective way to process them domestically.



Researchers empty a pilot plant autoclave containing leached catalysts.

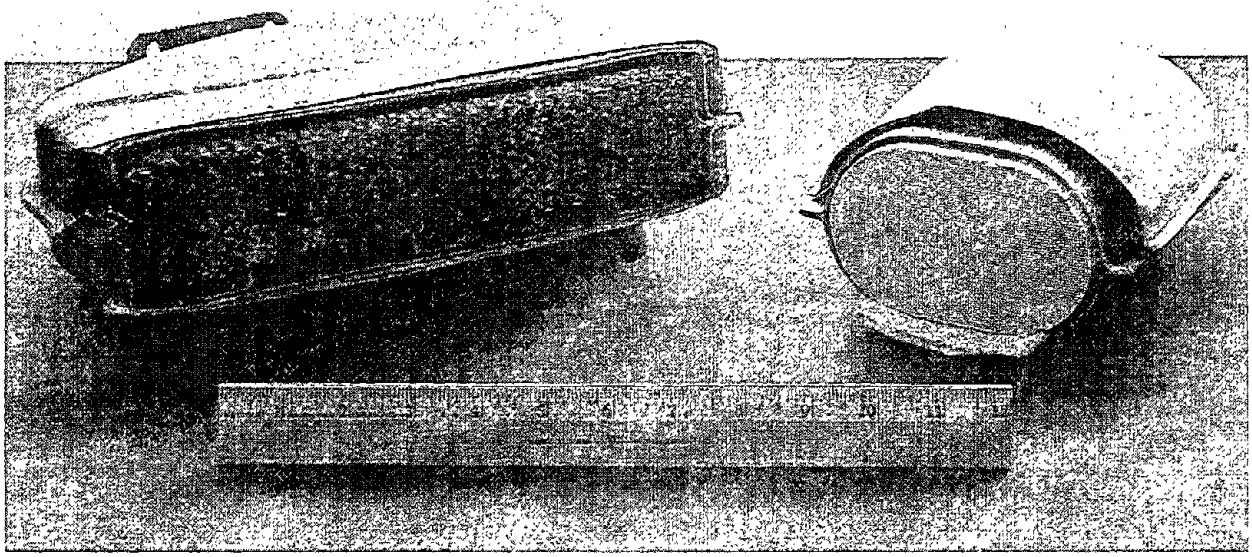
The Bureau's high-temperature process uses cyanide to selectively dissolve PGM from used automobile catalytic converters and recover a metal concentrate. The process can recover up to 90% of the PGM, and the concentrate is an excellent feed for a refinery. The cyanide is totally destroyed, so the wastes are nonhazardous.

The system is simpler, more effective, and less expensive than other current technology. This process for recovering PGM, which can be done economically on a small scale, should increase the percentage of catalytic converters being collected and encourage domestic processing. Automobile manufacturers are interested especially in recycling rhodium, which is very expensive to mine.

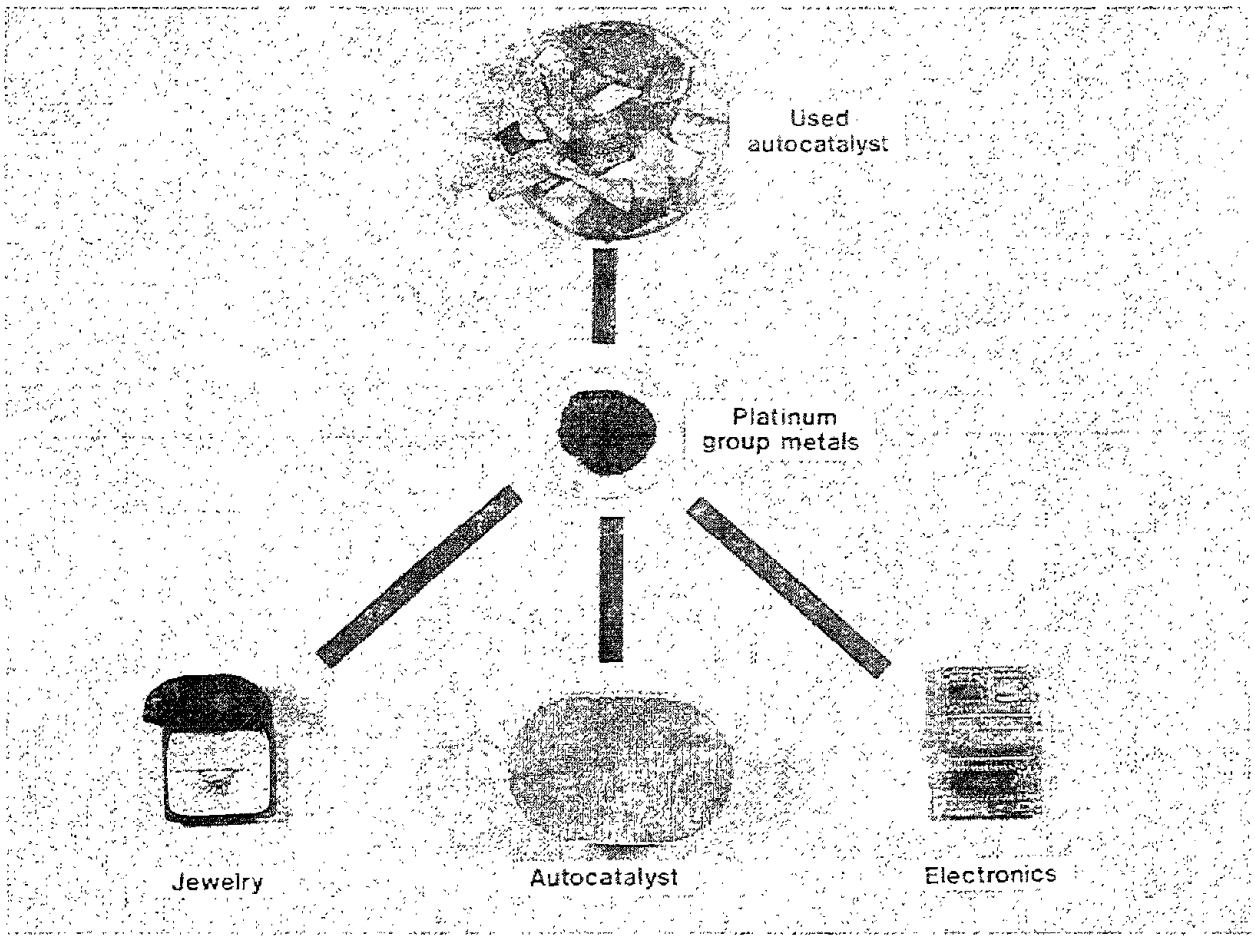
The high-temperature cyanide process was publicized in a USBM newsletter in 1992 and was granted a patent the same year. Initially, three companies cooperated in cost-sharing a pilot test: Two companies provided catalyst material, and one evaluated the concentrate.

A patent license is being negotiated, which would provide technical support from USBM scientists to help implement the technology to process catalytic converters domestically and to recover the PGM.

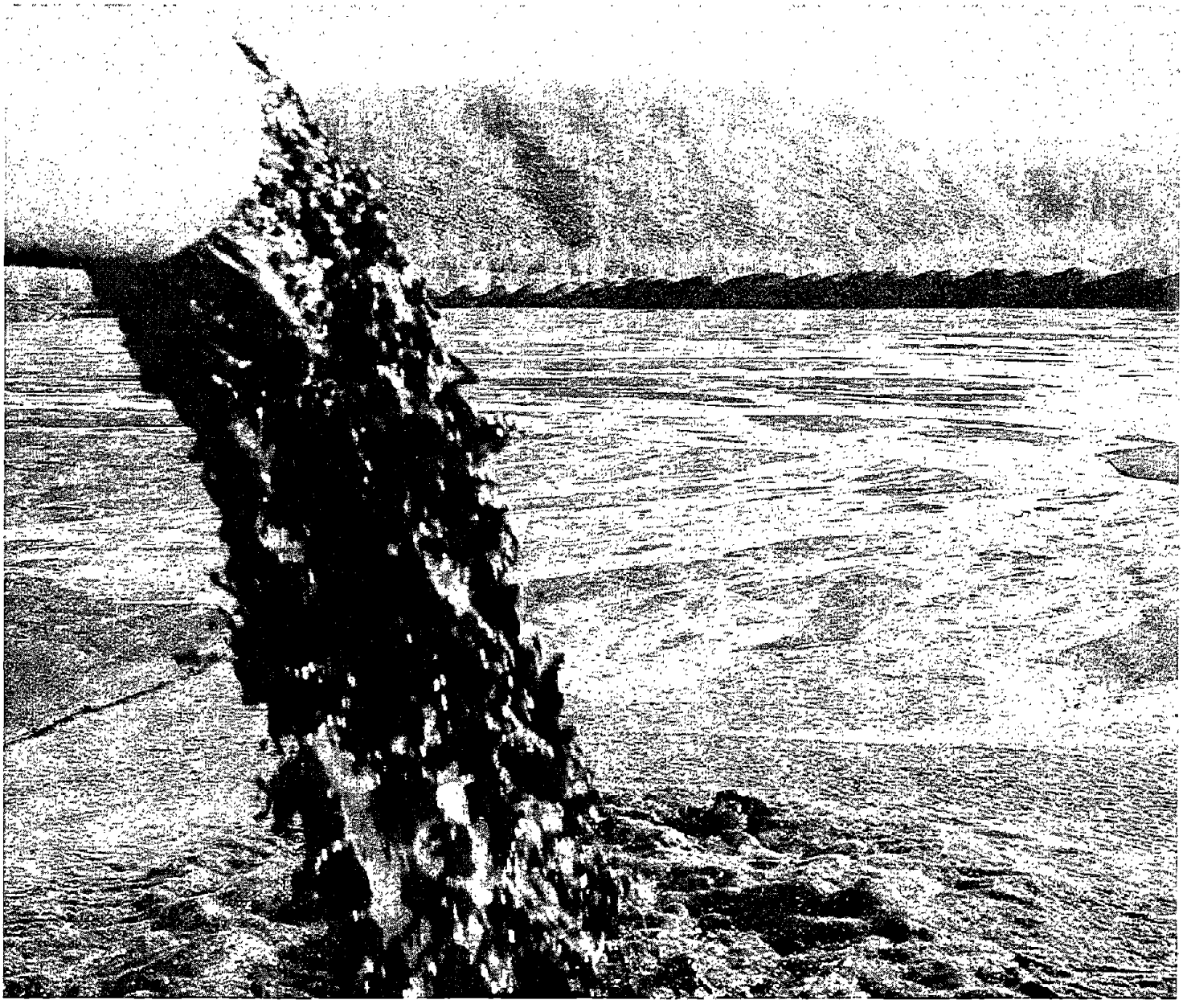
The USBM is now exploring the possibility of cooperative work with the petroleum industry to recover PGM from petroleum refining catalysts.



Automobile catalytic converters such as these are often junked, although they contain useful materials.



The metals recovered in this process can be recycled for a number of uses, including production of more catalytic converters.



Plastic beads and a way to make clumps of clay are among a range of USBM technologies that can help the Nation manage its industrial and municipal wastes. These technologies have been patented and commercialized. Still under development and testing is a process that traps toxic metals in a furnace slag, so that they have no chance to affect the environment.

Waste Water Cleanup with Metal-Removing Beads

Both active and abandoned mining and mineral processing operations discharge water that contains toxic metals. The toxic metals kill fish and plants, contaminate drinking water supplies, and make streams unfit for recreational use.

Thousands of such sites exist on U.S. Forest Service land and other public lands. Conventional treatment for these waste waters often fails to completely remove the toxic metals and produces hazardous sludge that is difficult to dispose of.

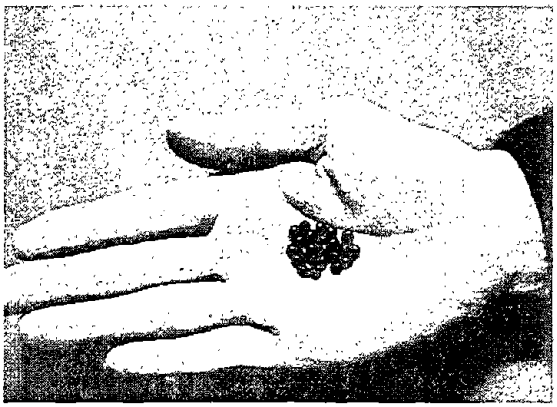
USBM-developed polymer beads are a low-cost answer to the problem. The porous plastic beads contain inexpensive biological material such as peat moss that can remove metal contaminants from water, including hazardous cadmium, lead, and mercury. Waters treated by the beads meet or exceed National Drinking Water Standards.

The beads can be used over and over because the adsorption process is reversible. The metals can be stripped off the beads and often recovered as useful products, so there is no hazardous waste.

The beads are easy to fabricate and can be used in existing waste water treatment equipment. Extensive field tests have shown that the beads remove the last traces of metals from many different types of waters for long periods of time. They continue to work effectively in wet or cold weather.

The metal-removing beads won an R&D 100 Award in 1990 as one of the year's most innovative developments.

Waste waters containing toxic metals limit the use of scenic recreation areas, such as this site in central Colorado.



These small plastic beads remove toxic metals from water and can be used over and over again.

The beads received additional publicity in a USBM newsletter article, which resulted in over 4,500 requests for more information. Three companies were granted patent licenses in 1992, and technical support was provided by USBM scientists as the companies began production.

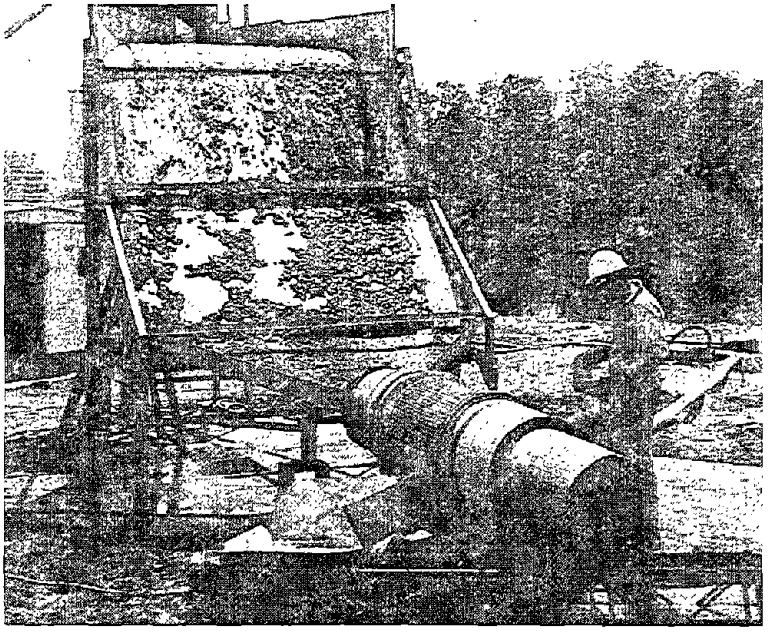
Two companies are currently marketing the beads: Harrison Western Environmental Services, Inc., Denver, Colorado, and ATA Technologies Corp., Cleveland, Ohio. ATA Technologies is a small business that was created as a result of the development of this new technology.

A full-scale treatment system using the beads has been installed at the Asarco Globe plant in Denver to remove several toxic metals from waters at the site.

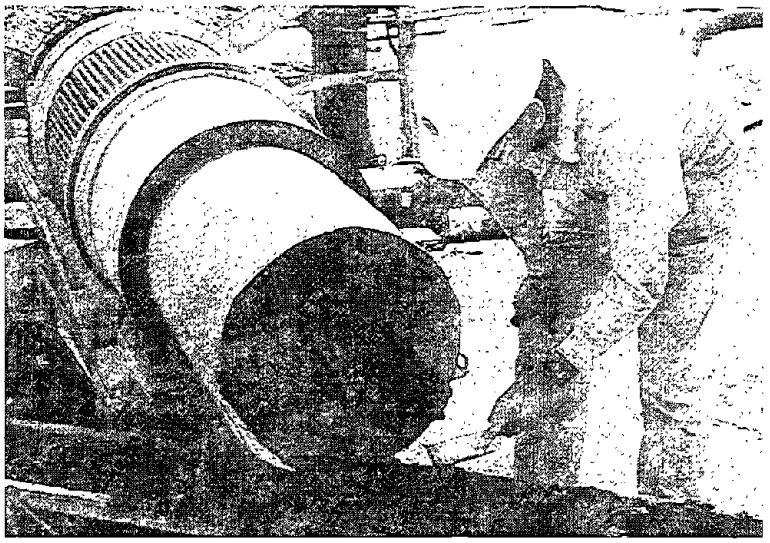
Other commercial applications are likely in the near future, including removal of metals from waters in municipal waste water treatment plants and concentration of copper in processing solutions to enhance recovery and minimize waste.

Dewatering Process for Mineral Waste Slurries

Minerals separation by hydrometallurgical treatment produces a waste slurry of water and fine particles. The particles settle out very slowly, which makes the waste difficult to dewater and difficult to handle and dispose of. Even when waste is dewatered, it will often be turned back into a muddy slurry by rain or water from other sources.



A demonstration unit in Kentucky. Much of the water is removed from muddy coal-clay wastes as the flocs move down a screen.



Dewatered waste such as this can be safely placed in a holding pond, where it will continue to dry out.

The USBM developed a technique to remove the water from problem coal-clay wastes and other fine mineral wastes. The method includes flocculation, a chemical process that uses a reagent to bring fine particles together, causing them to coalesce into clumps. The researchers found that a nontoxic polymer of polyethylene oxide (PEO) would cause clay particles to clump together and settle out of the water. For other wastes, such as those generated by crushed stone operations, a variety of polyacrylamide polymers have been used successfully.

The clumps or flocs that result are dewatered on screens, and the water can be recycled to the processing facility. The partially dewatered material continues to lose water when placed in a holding pond, becoming solid enough to support mobile equipment. It can also be mixed with coarse waste and stacked. In either case, disposal of the material is environmentally sound.

Two USBM newsletters, in 1985 and 1986, described the PEO flocculation process and spurred interest in this dewatering technique for coal and mineral wastes containing clay. Through cooperative agreements, USBM researchers demonstrated the technique to industry personnel in various parts of the country, using different kinds of wastes: phosphate wastes in Florida, coal-clay wastes in Alabama and Kentucky, mica wastes in North Carolina, effluent from gold placer mining in Alaska, and more recently, wastes from crushed stone operations in Alabama and Virginia.

The process was patented in 1992, and two companies were granted patent licenses. One of them, Ensite, Inc., in Kennesaw, Georgia, builds flocculation units and uses them to clean up waste from both mineral processing and nonmineral hazardous waste sites.

Vitrification of Waste Materials in an Electric Arc Furnace

Inside the furnace, organics are consumed and inorganic wastes are melted by the three electrodes into nontoxic, potentially useful products.

A wide variety of wastes are generated by mines, mineral processing operations, manufacturing industries, and municipal waste combustion facilities. These wastes or combustion residues often contain toxic heavy metals that can contaminate the environment when the waste or residue is buried in landfills.

Vitrification prevents heavy metals in wastes from entering the environment. In the furnace process, heavy metals become incorporated into a molten slag product and are thereby stabilized.

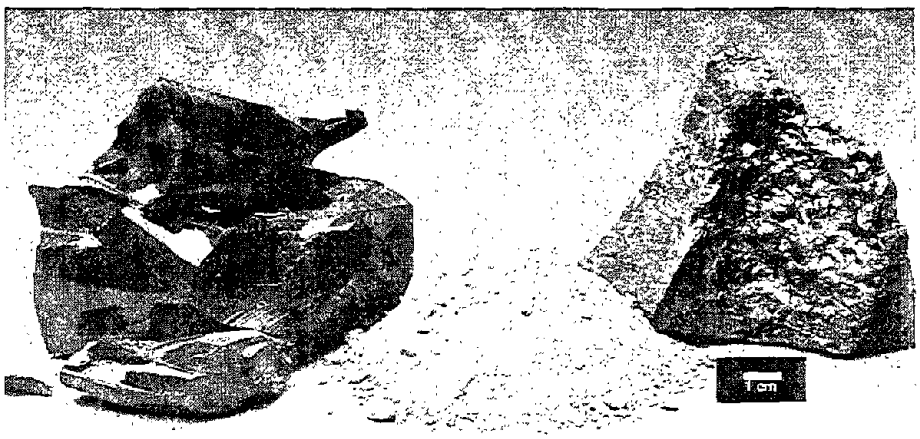
A number of commercial vitrification processes are available that use high-tech, proprietary furnaces. USBM researchers are demonstrating that standard electric arc furnaces can be used to vitrify a variety of wastes at lower costs. These processes would eliminate or significantly reduce the need for land disposal of many of these wastes and would provide opportunities for recycling the vitrified materials produced.

The USBM has demonstrated this technology under a number of cooperative agreements, including the initial agreement with the American Society of Mechanical Engineers for constructing a versatile sealed furnace system and testing it on residues from five municipal waste combustion facilities.

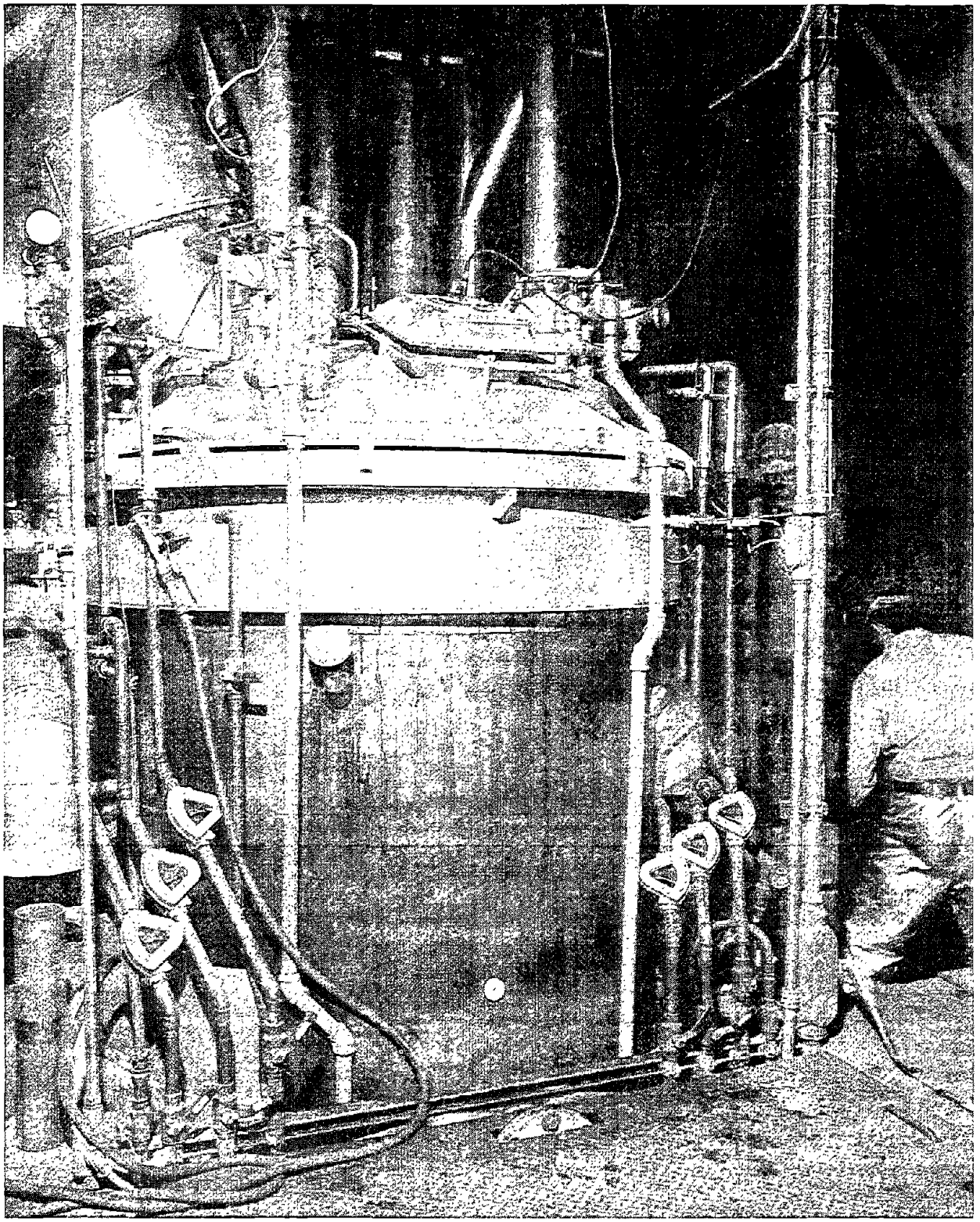
Under an interagency agreement with the Department of Energy's Idaho National Engineering Laboratory, the USBM has demonstrated that simulated radioactive wastes can be vitrified.

The USBM is also evaluating waste samples from an electric utility in California that is planning to construct a waste-to-energy facility to burn refuse-derived fuel. Because of the State's stringent requirement that no hazardous materials leave the utility site, vitrification of the residues is planned.

Two USBM publications and numerous other articles and reports have described the electric arc furnace research. This work is providing the waste industry with information necessary for designing commercial furnaces and for product evaluation with regard to heavy metal stabilization. The comprehensive, unbiased data being generated are sought by both industry and regulatory agencies.

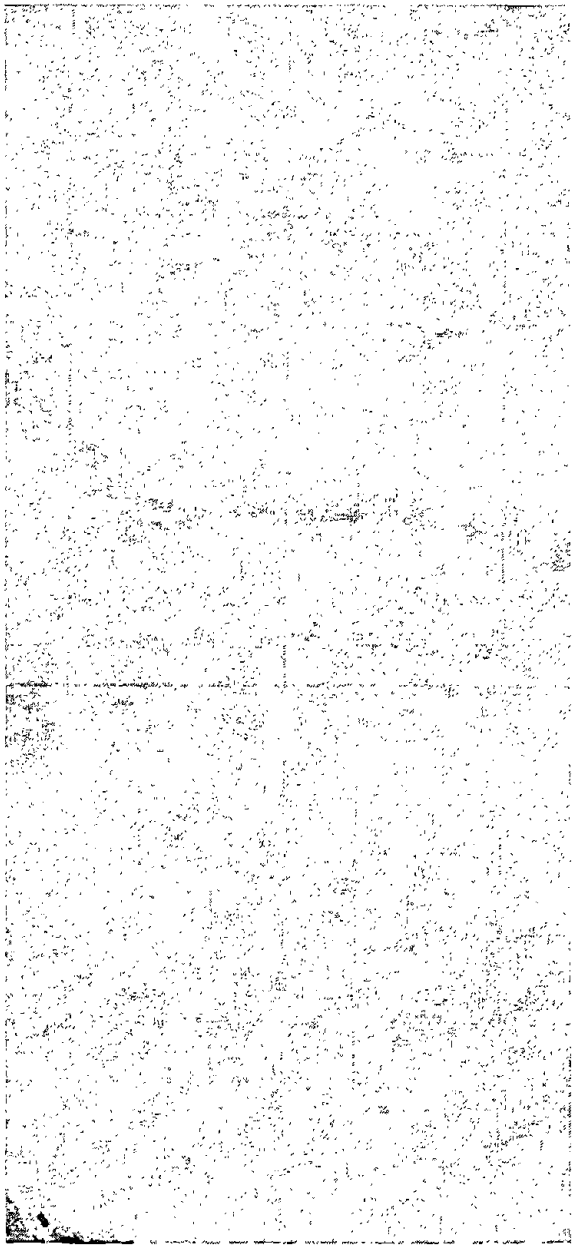


Technologies were demonstrated whereby waste feed material, shown in the center, could be melted into either of two final, environmentally safe forms suitable for reuse.



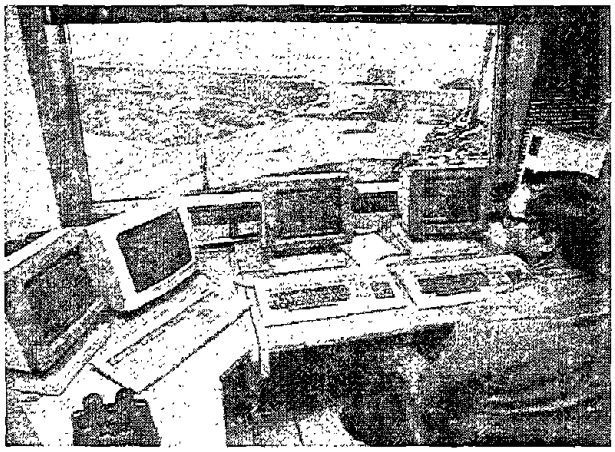
Exterior of the Bureau's generic three-phase, electric arc furnace, capable of continuously treating up to 1 ton per hour as demonstrated for test periods of 100 hours on a variety of waste materials.

One of the tasks of the USBM is to identify, measure, and classify domestic mineral resources by evaluating the economics of mineral recovery operations. Bureau analysts have developed computer programs to aid those evaluations by considering costs from exploration through treatment of processing wastes.



And the benefits of Bureau research extend beyond the mining and minerals industry. USBM expertise has played a role in restoring historic buildings, making the Nation's parks safer, and improving the armor used on U.S. Army vehicles.

Computerized Engineering and Economic Evaluations



USBM computer programs help to estimate the costs of running a mining operation.

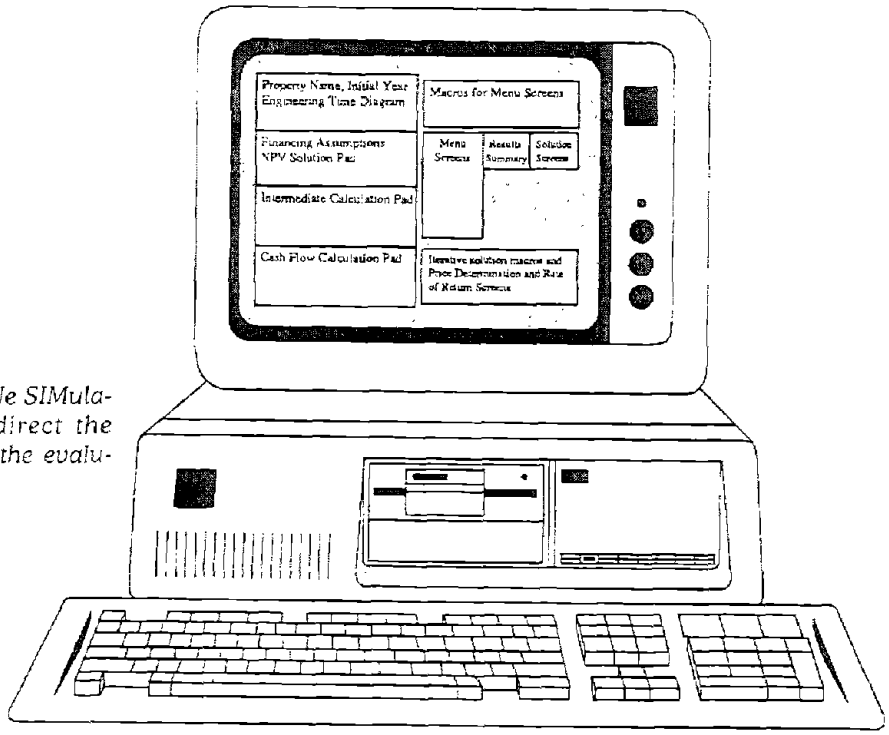
The USBM evaluates the economics of mineral recovery operations, using variables such as exploration, reserve tonnage, ore grade, mine plans, infrastructure, supplies, labor, and financial and tax conditions to estimate the cost of production.

The USBM has developed several computer programs to facilitate its evaluation methodology. Computerized models provide quick, convenient, and documented economic evaluations and cost estimates. The user inputs values and variables, and can select and adjust processes to reflect a particular mineral occurrence or operation.

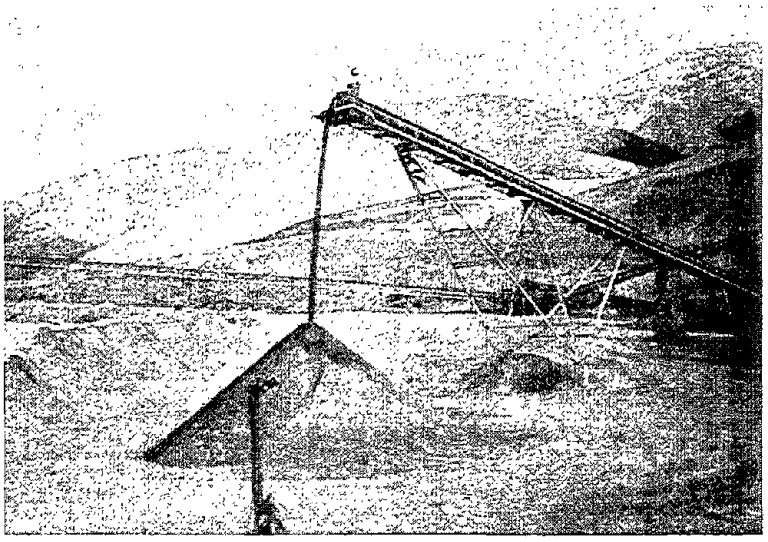
The mine simulator program (MINSIM) applies a discounted-cash-flow rate of return to estimate the economics of a mineral recovery operation over its entire life, from exploration to return on capital. It uses site-specific engineering and economic data from the USBM's Minerals Availability database, as well as information entered by the user. It can assess both existing and proposed operations.

The cost estimating system (CES) calculates capital and operating costs for mining and mineral beneficiation operations including surface and underground mines and mineral processing facilities. It produces cost estimates for individual unit processes that constitute a mineral operation, including development, environmental assessments, and waste treatment. Costs are based on available geologic data, the mine plan, supply and labor costs, and engineering judgment.

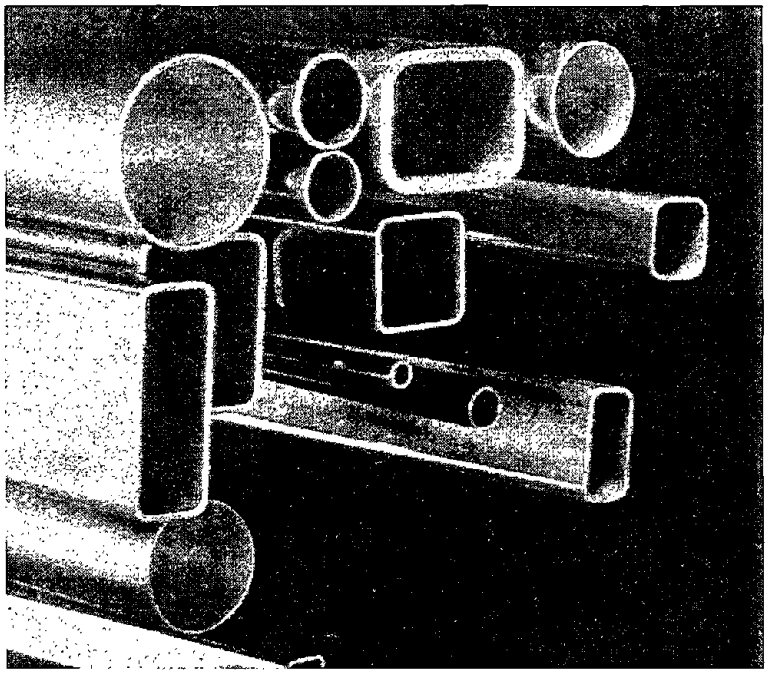
These and other computerized engineering and economic evaluation systems for mining and mineral processing operations have been in



MINSIM (MINe SIMulator) menus direct the user through the evaluation process.



Crushed gold ore is stockpiled for further processing. The CES program estimates costs of each process in a mineral operation.



Minerals and the materials produced from them are basic to the Nation's economy. USBM economic studies help to ensure that our mineral supply is adequate and dependable.

continuous development for over 20 years. In the 1980's, the USBM Minerals Availability program used the systems to estimate the availability of 34 commodities.

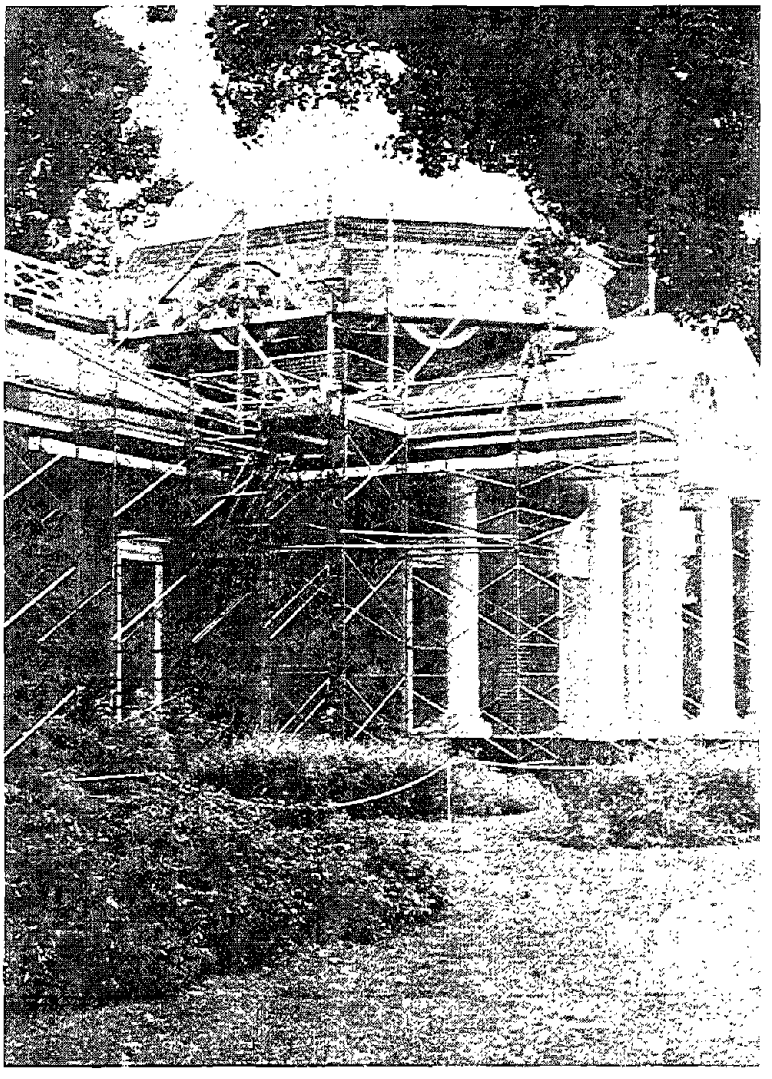
Both USBM analysts and others in organizations such as the Congressional Budget Office and the General Accounting Office applied system results to evaluate the effect of policy alternatives such as royalties on mining operations on Federal land. Under an agreement with the Bureau of Indian Affairs, USBM analysts used these computer programs to evaluate mineral resources and to estimate costs of environmental remediation on Indian land.

USBM workshops, training programs, and demonstrations that focus on the costing methodologies using these systems have been presented to interested parties in industry, government, and academia, both domestic and international, over a number of years. Training has been provided to Bureau of Land Management personnel and to Regional Resource Officers of the State Department. Training has also been tailored to meet the needs of USBM-equivalent agencies in other countries, including Russia, China, Poland, and Hungary.

Demonstrations of the products are often featured at mineral industry conventions, such as the International Geologic Congress, the annual AIME and SME conventions, and the McKelvey Forum, sponsored by the U.S. Geological Survey.

All Minerals Availability computer products are or will be available to the public. MINSIM is currently available with extensive documentation in two versions that can be used on DOS-based personal computers. The CES has recently been substantially revised, and the revised version will soon be available.

Monticello Roof Restoration



A view of Monticello at the beginning of roof restoration. An atmospheric corrosion model developed jointly by the USBM and the EPA predicts a 60-year life for the tin plate on the new roof.

USBM scientists helped to ensure that the newly restored roof on Thomas Jefferson's home will last for at least 60 years. Jefferson's estate, Monticello, is located on a mountain near Charlottesville, Virginia. The residence has been maintained as a national shrine by the Thomas Jefferson Memorial Foundation since 1926. In the recent restoration of the roof, completed in 1993, the Foundation decided to replicate the appearance of the tin-plated iron shingles used by Jefferson in 1824 by using tin-plated stainless steel shingles.

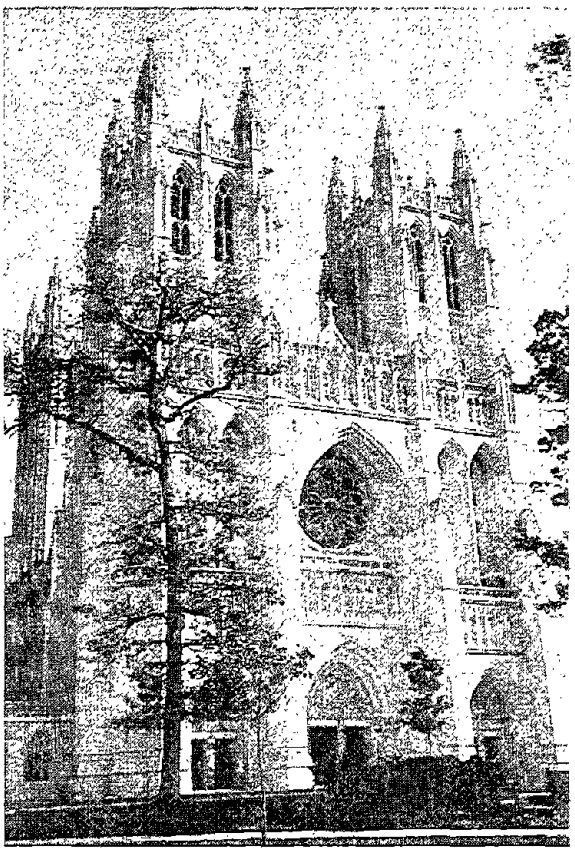
The Bureau's expertise in corrosion work was called on to determine how thick the tin plate should be to ensure a long life for the new roof. USBM scientists estimated the long-term corrosion rate of tin plate and the impact of pollutants such as acid rain. They computed the tin plate thickness required using local environmental conditions and an atmospheric corrosion model that had been developed jointly by the USBM and the Environmental Protection Agency (EPA) as part of the National Acid Precipitation Assessment Program.

Monitoring Stresses at the National Cathedral

The USBM is also helping in the preservation and restoration of the historical National Cathedral in Washington, D.C. The cathedral was envisioned in Pierre L'Enfant's original plans for the city, although it was not begun until 1893. Major stonework was completed almost 100 years later, in 1989, and even today stone carvers continue to work on the building.

Preserving this national treasure requires monitoring, maintenance, repair, and restoration as the years go by. The Cathedral Foundation, charged with that task, has asked for assistance from the USBM to determine the movement and settlement of the building in the next few years so that officials can plan and prioritize future restoration projects. The USBM was contacted because of its expertise in the area of stress and subsidence monitoring.

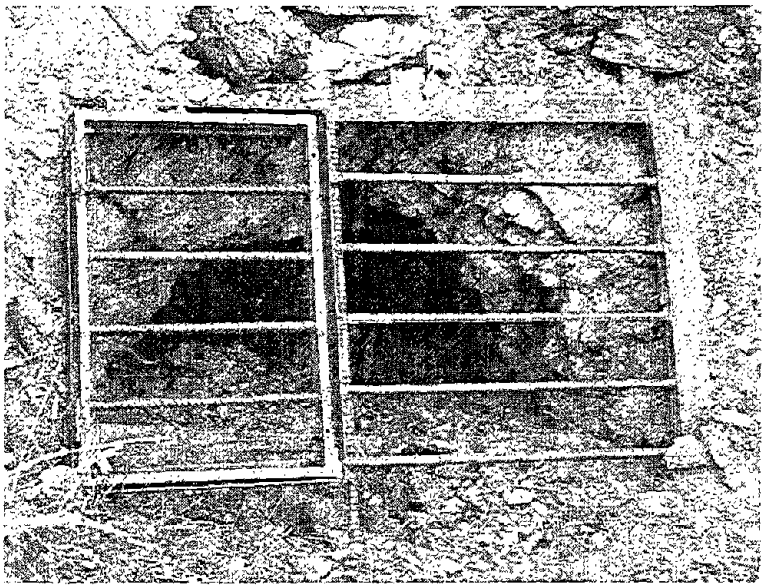
Under a memorandum of agreement with the Cathedral Foundation, Bureau personnel designed and installed and now operate the monitoring system. Data will be collected for a year, to incorporate seasonal effects, and then Bureau staff will analyze and interpret the data to provide Cathedral officials with a sound basis for repair and restoration decisions.



Washington National Cathedral, west towers. The USBM is monitoring settlement of the building to provide information for future preservation or restoration efforts.

Installing a tiltmeter to measure changes in the tilt of the cathedral towers.

Mine Closure Guidelines



A bat gate, a steel grate about 1.2 by 1.8 meters (4 by 6 feet), is cemented or bolted into the rock at a mine portal. The gate allows bats to enter the abandoned mine while preventing human access.

The National Park Service asked the USBM for guidance on ways to close up abandoned mines located in National Parks. The openings to these mines need to be sealed off so that people using the parks can't enter the old mines accidentally or intentionally. Abandoned mines are dangerous because of the potential of rock collapse.

However, in many cases, the mines cannot be closed completely or permanently. Some abandoned mines shelter bats and other wildlife, and so they must have small openings to provide access and ventilation for the animals. In addition, some closures need to be temporary so that the mines could be opened again for geological study or further mining.

USBM engineers responded to the National Park Service request by compiling information and technical drawings on various types of mine closures to meet different situations. Field guides were prepared to help Park Service personnel determine the most appropriate type of closure and how the closure should be constructed. A brief description of 11 techniques was also published in a 1994 USBM newsletter to reach a wider audience.

Expendable Pattern Casting of Steel Armorplate

Through an interagency agreement with the U.S. Army, Tank and Automotive Command (TACOM), the USBM used a new steel-casting process to develop supplementary armor for the Bradley Fighting Vehicle and the M1A1 tank. The armor, battle tested in the 1991 Gulf War, proved to be lighter, ballistically superior, and less expensive than conventional armor.

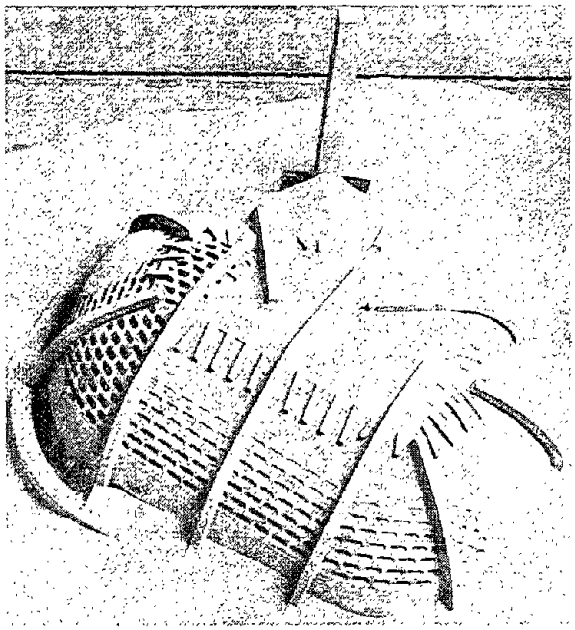
The process used to make the prototype armor is known as expendable or evaporative pattern casting, a technique for sand-casting metal. A pattern or mold of the piece to be cast is constructed of a material such as expanded polystyrene that vaporizes easily. The pattern is placed in sand, which is compacted around it. Molten metal is poured into the pattern, which vaporizes, allowing the metal to fill the place of the pattern in its exact configuration.

This technique has been used for over 30 years for aluminum and nonferrous alloys, but it was considered technically impossible for making complex castings from metals like steel. Molten steel is much hotter than molten aluminum, and the pattern begins to vaporize before the steel completely fills the voids, causing collapses in the mold and loss of detailed features.

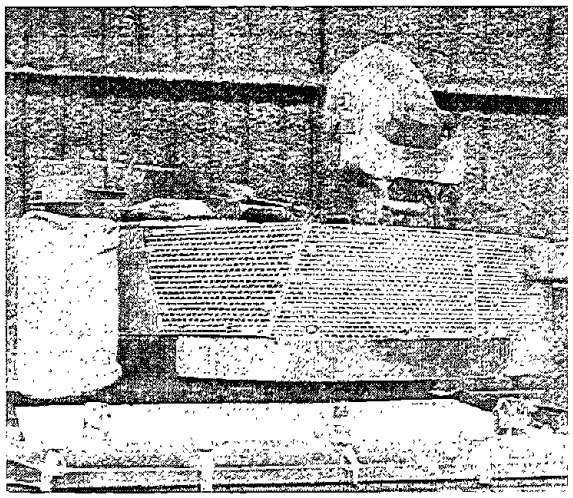
The USBM developed a method of evaporative pattern casting for steel alloys that overcomes these problems, so that large and complex shapes such as armorplates can be cast. Collapse of the mold is prevented by enhancing the flow of the molten steel to all sections of the mold and by providing ways to keep the pattern rigid so that critical dimensions and specific contours are maintained throughout the process.

This process accommodates complex designs while producing an excellent surface finish with less scrap. It offers the foundry industry an inexpensive means of producing high-quality steel casts to demanding specifications.

TACOM's contractors are setting up production facilities based on this technique to retrofit various Army vehicles. Interest in the steel-casting method has also been shown by shipping companies. The method was patented in 1993.



Polystyrene mold of prototype hatch in flask with sand.



Cast steel armor made by expendable pattern casting protects rear of turret on Bradley Fighting Vehicle.

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Additional information on USBM research and technologies can be found in the following publications, available from the Office of Technology Transfer (phone: 202-501-9323; fax: 202-501-9957).

Innovative Technology. 1992. Highlights new products and processes from a range of programs in the USBM.

Mine Safety and Health Research: Achievements of the U.S. Bureau of Mines. 1993. Covers health and safety research from 1970 through 1990.

FY 1994 Annual Research Report. 1995. Reviews USBM research accomplishments of the past fiscal year.

U.S. Bureau of Mines Cooperative Research Opportunities. 1995. Provides summaries of developing technologies that are ready for cooperative research with industry.

Technology News, Technology Transfer Update. USBM newsletters that promote technology transfer. These newsletters are available in paper copies or on the Internet.

Special Publication 09-94. Gives information on USBM publications on the Internet.