MINE RESCUE AND RECOVERY:
WHAT WORKS AND WHAT DOESN'T WORK

by

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ABSTRACT

During the past ten years the mining industry has experienced several mine fires and explosions. In some of these cases, Mine Rescue Teams were deployed to perform search and rescue operations. In all of the cases, recovery operations of some degree were required.

This paper examines the major fires and explosions that have taken place in the United States during the past ten years with respect to the techniques and technologies that were employed to deal with the emergency situations. Techniques that have been successful and those that have been unsuccessful are summarized and recommendations are made for improvements in future rescue and recovery operations.

INTRODUCTION

In May of 1991 a member of Congress appearing before the Subcommittee on Interior Appropriations stated the following in his testimony: "Last October a mine fire erupted at the XYZ Coal Company (name changed) facility in ... Pennsylvania. Fortunately, no one was seriously injured; however, due to the extent of the fire, it was necessary to seal all of the mine openings, thus putting 350 hourly and salaried workers out of a job ... The costs associated with a mine fire are enormous. The loss of mining equipment and infrastructure alone for XYZ Coal exceeds $25 Million. In addition, current recovery of certain coal reserves in not possible, and this loss is estimated at $6 Million. Furthermore, the combined cost of fighting the fire and employee severance pay was nearly $4 Million. Finally, every month that passes while the mine is idle, requires a $700,000 outlay, which will soon deplete the cash resources of XYZ."

This statement dramatically drives home the point that mine fires and explosions can have a devastating affect on industry, labor, and the associated communities. Luckily, no lives were lost at this incident--we have not been so fortunate at others.

By law, every operator of an underground mine must assure the availability of a mine rescue capability for the purposes of emergency rescue and recovery. While Mine Rescue Teams have commonly been associated with mining for more than 70 years, today many mines are also developing quick-response fire-brigades specifically for fire-fighting situations.

Where emergency managers previously had only limited resources to apply to emergency situations, today they now have a cadre of techniques and technologies to employ in mine rescue and recovery operations.

During the period January, 1982 through December, 1992 there have been more than 100 fires in United States coal mines. There have been 19 major mine fires, 17 explosions, and 5 associated sealing/unsealing operations. This paper reviews the techniques and technologies that were employed to deal with mine rescue and recovery operations, and evaluates the relative success of these various methods in achieving their desired results.

FIRE-FIGHTING OPERATIONS

Most fires are the direct result of a chemical reaction between a fuel (such as coal, wood, gas, grease, etc.) and the oxygen in the mine atmosphere. In all cases, three well-known elements must be present simultaneously for the fire to occur: 1) fuel, oxygen, and heat. This is commonly known as the “fire triangle”. To extinguish a fire, it is necessary to remove at least one element, or side, of the triangle.

Fighting a fire with water removes heat. Smothering the fire with a noncombustible material, such as rock dust, or sealing off the fire area removes oxygen. Loading out material or spraying water on combustible material ahead of the fire removes fuel. Dry chemical extinguishers are used to chemically inhibit the oxidation of the fuel source.

The National Fire Protection Association (NFPA) classifies fires into four classes: A, B, C and D. Class A fires involve combustible materials such as wood, plastic, paper, and cloth. They are best extinguished by cooling with water or by blanketing with certain dry chemicals. Class B fires involve flammable or combustible liquids such as gasoline, diesel fuel, kerosene, and grease. They are best extinguished by excluding air or by special chemicals that affect the burning reactions.

Class C fires are electrical fires. They are best extinguished by nonconducting agents such as carbon dioxide and certain dry chemicals. Class D fires involve combustible metals such as magnesium, titanium, zirconium, sodium, and potassium. Special techniques and extinguishers have been developed to put out these fires.

A discussion of the most common fire-fighting methods follows:

DIRECT ATTACK

Once a mine fire has been discovered, three basic methods of defense can be used to fight the fire: 1) dry chemical extinguishers, 2) rock dust, and 3) water. Dry chemical extinguishers are applied to inactivate the intermediate products of combustion, thus decreasing the combustion rate and, hopefully, extinguishing the fire. They are useful on Class A, B, and C fires.

Rock dust is prevalent in many areas of most mines. It is used to smother the fire, or eliminate oxygen from the fire triangle. It can be used on Class A, B and C fires. It is usually applied by hand or shovel directly on the fire. Rock dust machines; however, should never be used when a fire is involved. Since these machines use air to disperse the rock dust, this could potentially fan the fire and increase its intensity.

Water is directly applied on the fire and is often placed into the path of oncoming flames. This is performed by Fire Brigades or Mine Rescue Teams to cool the air flowing from the fire and to decrease the production of tars and gases produced by the fire. Water is effective on Class A fires. Two sources of water are often used by teams to fight fires: a) water lines, and b) fire cars.

Water lines are required to be run to working sections that mine over 300 tons per shift when portable fire fighting equipment is not available. Federal regulations require such lines to be extended to each section loading point and to be equipped with enough fire hose to reach each working face.

Fire cars usually are equipped with a water tank, a pump, and hose. Some, more elaborate, cars may also be equipped with large chemical extinguishers, hand tools, brattice cloth, rock dust, or low expansion foam.

Low expansion foam is produced by introducing a foam agent into the water delivery system and run through a specially designed foam nozzle. Such foam extinguishes the fire by both smothering and cooling it. Low expansion foam is very wet and heavy, and does not move down an entry as well as high expansion foam.

DIRECT ATTACK--APPLICATIONS

It is difficult to determine how often Direct Attack methods have been, utilized, or how effective this method has been due to the fact that mine fires that last for less than 30 minutes are not reported to MSHA. However, it is obvious that the quicker such fire fighting resources are applied, the more effective Direct Attack techniques will be. This strategy will only be effective if fire fighting equipment is well maintained, routinely tested, and if people are well trained in using such equipment.

A perfect example of how things can go wrong is described in this excerpt from an MSHA report of a recent mine fire fighting operation involving a belt drive and conveyor system:

“When the fire was discovered, it was described as being within the belt drive installation in the vicinity of the drive rollers. Visibility was good at that time, and the fire had not reached the roof, which was about two feet above the top belt. The shift foreman stated in his interview that 'I could see some flames around the belt drive, and I knew right then it was a fire, but at that time I didn't think it was something that couldn't be put out. The flames there, they looked like something your hit with a fire extinguisher and that was it.' Miners initially tried to extinguish the fire using all available fire extinguishers from underground areas, including the two fire stations... [the] Shift Foreman, observed a fire hose and nozzle attached to the fire tap at the belt drive. He began pulling on the fire hose and found it to be wedged under the belt drive unit. He tried every means possible to remove the hose, but had to eventually cut the hose. This left a short piece of hose, without a nozzle, for use in fire fighting. He sent miners to...get additional hose to extend up the belt entry. [The] shop mechanic observed that water was not being discharged from the water deluge spray nozzles. The control valve handle was missing so [he] used a wrench to turn the valve stem to the "on" position. Water began to flow from the spray nozzles, but by this time the fire had spread inby the take up, and to leave the water from the spray nozzles running would serve no purpose...[the Shift Foreman] reentered the belt entry and assisted miners in moving a 150-pound fire extinguisher through the equipment doors to alongside the belt drive, but it did not work...he found that the fire had spread inby to the belt take up, and was burning out of control. He realized the safety of the miners inby was in jeopardy. He...called...to evacuate the mine; however, by this time, evacuation procedures had been started."

Foam generators were put into service to combat the fire; however, this was done to no avail. One foam generator, while in operation, was even totally engulfed by the fire. This mine, eventually, was permanently sealed. One of the conclusions of the MSHA report was "the lack of adequate fire protection and fire fighting equipment contributed to the severity of the accident [and eventual loss of the mine]."

At another mine fire, a fire was put under control by fire extinguishers and water only to rekindle again while fire-fighters waited for fire-cars to arrive with more water and fire extinguishers. The fire cars were delayed because the electric power supplying the section they were located in was cut-off. This mine also had to be permanently sealed.

Experts who teach mine fire fighting have performed audits of the fire fighting capabilities at several mines. They have found fire hoses that have dry-rotted or which have multiple holes, fire-hose couplings that don't fit, inadequate water supplies, nozzles and couplings that have melted during fire fighting operations, fire extinguishers that do not work, and a host of other problems that indicate that many mines are ill-prepared for "the big one". Even worse, however, is the fact that many mines aren't even prepared for the "little one".

INDIRECT ATTACK

High expansion foam has been used on many occasions to similarly cool and smother mine fires. This type of foam, however, has some advantages over direct water sprays and low expansion foam in some instances where brigades or teams cannot get close enough to the fire due to high heat, high humidity, or impaired visibility.

High expansion foam is made by mixing water, air, and a foam concentrate or detergent in a foam generator. This type of foam can be forced or ducted close to fire areas, thus covering the distances that teams are prohibited from attaining. Fire fighters have used high expansion foam commonly at a distance of 500 feet and, in some instances, up to 1500 feet.

INDIRECT ATTACK - APPLICATIONS

High expansion foam has not extinguished any mine fires; however, in several instances these types of foam generators have enabled miners to re-approach a fire that had chased them back too far for Direct Attack by water. It is useful on Class A and B fires.

SEALING OPERATIONS

When direct or common indirect methods fail, mine sealing operations must be conducted. Three generally known techniques are: 1) in-mine seals, 2) surface sealing, and 3) remote sealing.

IN-MINE SEALS

Traditionally, these are seals strategically placed along entries to cutoff the air to the fire. There are two general categories of seals: temporary and permanent. Temporary seals are often put up before permanent seals are erected in order to seal off a fire area as quickly as possible. Usually permanent seals are then constructed outby the temporary seals to seal off the fire area more effectively.

Temporary seals are built to be fairly airtight. They are usually constructed of brattice cloth, concrete blocks, or wood, and sometimes sprayed with material such as Rigiseal for reinforcement. Permanent seals are built to be much stronger and more airtight than temporary seals. They are notched into the roof, ribs, and floor to make them as sturdy as possible, so that they can better withstand the force of a potential explosion (minimally 20 psi).

SEALING OPERATIONS--APPLICATIONS

The use of sealing operations underground has been highly successful in many instances where miners have had the time to identify the extent of the fire and develop a strategy for isolating the fire area. Often this process has saved mines from having to be sealed at the surface--a costly, time consuming alternative.

During the past ten years research has been conducted to develop innovative stoppings that can be quickly deployed and constructed. The parachute stopping and inflatable stopping are two of such projects that have shown some promise. Parachute stoppings can, theoretically, be used as a check curtain, however these have not been used in practice. Inflatable stoppings, which are inflated with air underground, or deployed through a borehole from the surface, have also been experimented with, mainly by the Bureau of Mines; however, unless they are stockpiled, they are not readily available, and, again, have not been used in practice.

SURFACE SEALING

Surface sealing involves effectively sealing all openings into the mine. Shafts, slopes, drifts, boreholes and outcroppings should be sealed as best as possible. However, it can be said that this method has been applied very successfully in several instances. By successfully, I refer to the fact that several mines were able to be unsealed and put back in operation. Of course, in all cases, this involved several months of down time, temporary or permanent layoffs of personnel, and an enormous drain on financial resources. In two instances, over the last 20 years, mines have had to remain sealed for over a year until rescue teams could re-enter, recover the mine, and conduct a thorough investigation. These mines eventually were put back into production.

REMOTE SEALING

Remote sealing involves the injection of flyash, slurry, concrete, or other mixtures into mine passages from the surface to attempt to isolate the fire area.

REMOTE SEALING--APPLICATIONS

During the last ten years, and extending over the last 20 years, there have several attempts to utilize remote sealing techniques. These attempts, for the most part have been non-productive. The process, while looking good in theory, is belabored by multiple problems in practice. First, inaccuracies in the correlation between underground and surface mine maps introduces a considerable problem since remote sealing often involves drilling multiple boreholes at critical locations within the mine. If mine maps are inaccurate, holes are often drilled in the wrong locations, too close to ribs when the center of the entry is the target, missing intersections, and many times, into coal pillars.

Even if surveying can be performed accurately, the drilling abilities of various drilling contractors is highly variable. I have seen drillers who are highly accurate (the exception) to drillers who have been off the mark by over 50 feet, horizontally, in 1000 feet of vertical drilling.

Another problem involved with remote sealing is the delivery system and obtaining the proper material for the specific application being considered. Fly ash comes in varying degrees of moisture content. Without prior experimentation at a specific mine, the proper moisture content is difficult to determine. Other material and aggregates have been experimented with; however, often the material that is most available is used. Obviously this is not a very scientific application. The next consideration deals with what to use as the mixing agent for delivery. Air cannot be used if a mine fire or explosion situation would be aggravated. Thus, nitrogen or some other inert gas must be used. This can be extremely costly endeavor.

Even if we can assure accurate surveying and drilling, the proper material and mixing agent, the most insurmountable problem is accurately determining how well the seal has been installed, what portion of the entry has been sealed, and the integrity of the seal. A partial seal can cause severe problems if a mine is re-ventilated and an increase of fire intensity or even a mine explosion results. TV and sonar probes, in the past, have been unable to determine the degree of sealing that has been established by remote sealing methods.

INERT GAS TECHNIQUES

Inert gas techniques includes the injection of an inert substance, usually nitrogen or carbon dioxide, into a sealed area. This is done to reduce the oxygen content of the mine atmosphere and subsequently reduce the degree of fire intensity or reduce the risk of explosions.

INERT GAS TECHNIQUES--APPLICATIONS

The use of inert gas techniques is VERY COSTLY. Millions of gallons of inert gas have been used in attempts to control or put out mine fires. These millions of gallons have cost mining companies millions of dollars. At one mine fire in particular, a company spent over a million dollars a day just to pump inert gas into a mine. This mine, eventually was permanently sealed.

There have been no major mine fires in the United States that have been extinguished using inert gas. There have been several instances, however, where inert gas has been used to successfully control fires, or reduce the risk of explosion, while underground seals or other operations have taken place--in other words, to buy time. On the other hand, in one instance, the introduction of nitrogen caused methane to be redistributed and directed to a mine fire causing multiple explosions to occur underground during the injection process.

The Polish government has reported some success in utilizing a jet engine to produce inert gas and extinguish mine fires. This success, however, is mainly limited to single entry mines. Thus, the concept has been researched and determined to not be applicable to most U.S. mines.

FLOODING THE MINE

The final method of indirect fire-fighting is by flooding the sealed fire area or the entire mine with water. This usually is done as a last resort because it makes recovery of the mine more difficult. Sometimes, underground seals can be built to form retaining dams, and thus isolate a fire area.

FLOODING THE MINE--APPLICATIONS

Flooding the mine requires the ability to determine 1) the extent and location of the fire, 2) highly accurate surveys including elevations, and 3) vast amounts of water and a competent delivery system. Determining the extent and the location of a mine fire can be extremely difficult to impossible at times. Accurate surveys must help engineers determine the location of in-mine water retaining seals or the location of pumps for de-watering the mine. The quantity of water is a major factor. Mining companies have re-routed small rivers and streams, trucked water to emergency sites, and developed elaborate systems of pipes and pumps to bring water to the site.

At one mine, water retaining seals were successfully built underground and water was pumped from the surface. After three months, when gas analyses showed a “safe” atmosphere, the water was pumped out and the mine re-ventilated only to have the fire rekindle. Eventually the burning coal was physically loaded out and hauled away to allow the mine to go back into production.

At another mine, over 8 million gallons of water were pumped down a borehole to no avail. The mine was permanently sealed.

EXPLOSIONS

Explosions are similar to fires in that all three elements of the “fire triangle” must be present for an explosion to occur: fuel, oxygen, and heat (ignition). The fuel for an explosion can be an explosive mixture of gas, a sufficient concentration of coal dust, or a combination of both. The source of ignition is commonly sparks, an electric arc, an open flame, or a misuse of explosives.

Once an explosion has occurred, there is always the potential for further explosions due to the fact that once the ventilation system is damaged from the first explosion, methane can accumulate and be ignited by fires or other ignition sources. Coal dust stirred up by the first explosion can propagate further explosions.

RECOVERY TECHNIQUES

The major objectives of mine recovery techniques are 1) to remove potential dangers to recovery teams, and 2) to facilitate the rehabilitation of the mine and to get it back into operation as soon as possible after a mine fire, explosion, inundation, or similar event. Depending on the extent of damages and other conditions, recovery operations can range from a few days to over a year, if extensive sealing and monitoring had to take place.

Until ventilation is reestablished in the affected areas, apparatus crews will be needed to assess conditions, rebuild stoppings, and, where necessary, clear debris, pump water, and stabilize the roof and ribs. Once ventilation has been restored and fresh air advanced, non-apparatus crews can take over the rehabilitation and cleanup effort.

RE-ESTABLISHING VENTILATION AFTER A MINE FIRE OR EXPLOSION

In a fire area that has not been sealed, the process of re-establishing ventilation involves simply assessing the damage and making the necessary repair to restore normal ventilation.

In a fire area that has been sealed, unsealing operations must be planned and implemented, the damage must be assessed, and repairs and rebuilding of the ventilation system is necessary.

If an area has been damaged by an explosion, an extensive amount of construction is usually needed to restore ventilation. Stoppings, overcasts, water, electric and air lines, are among the things that may have to be either repaired or replaced.

UNSEALING AN AREA AFTER A FIRE OR EXPLOSION

Unsealing an area after a fire or an explosion requires careful planning and experienced teams to implement the plan. Opening seals prematurely (although often very tempting) can cause a re-ignition of the fire or set off an explosion. Normally a recovery plan is developed by company mine officials and approved by MSHA and the State regulatory agency. Union review of such plans is often granted by courtesy.

The major factors governing the decision of when to unseal a mine area are:

a) The analysis of mine gases taken from behind seals. This information is often obtained from borehole samples or sampling lines placed behind seals.

b) The trend analysis of gas samples.

c) The extent and intensity of the fire at the time of sealing.

d) The characteristics of the burning material and the surrounding strata.

e) The tightness of seals.

f) The effect of changing barometric pressure on the enclosed area.

g) The temperature and temperature trend.

h) The location of the fire with respect to ventilation.

i) Potential ignition sources.

Prior to unsealing a mine area three considerations should be made:

1) Oxygen or combustible content behind seal should be low enough to make an explosion impossible.

2) Carbon monoxide should be very low.

3) Area behind the seal has sufficient cooling time.

4) Trending indices/ratios indicate favorable conditions.

METHODS OF UNSEALING MINE AREAS

There are two basic methods that can be used for unsealing and reventilating mine areas: progressive ventilation and direct ventilation. Progressive ventilation is the re-ventilation of a sealed area in successive blocks by means of air locks. Direct ventilation is the re-ventilation of the entire sealed area at one time.

Progressive ventilation is the most common method of unsealing fire areas, and the only type of re-ventilation that should be used following a mine explosion. The advantage of progressive ventilation is that gas conditions can be carefully controlled, and the operation can be temporarily stopped if hazardous conditions develop. The disadvantage of progressive ventilation is that it is a very time consuming process.

Direct ventilation is accomplished more quickly than with progressive ventilation; however, gas conditions are less controlled. Before using direct ventilation there should be conclusive evidence that all fires have been extinguished, and no explosive mixtures or ignition sources exist in the mine.

NEW TECHNOLOGIES

GAS CHROMATOGRAPHS AND CONTINUOUS MONITORING EQUIPMENT

All mine emergency operations involving mine fires or explosions require a great deal of gas analyses to be performed. While hand-held instruments are the main source of information about gas levels underground, certain conditions, such as low oxygen levels or contaminants that may poison sensors, may can cause instruments to read erroneously. For this reason it is essential to take bottled gas samples underground for analysis on the surface. Bottle samples at surface sampling locations (usually boreholes and fans) should also be performed to verify hand-held instrument readings and continuous sampling results.

MSHA has developed a mobile laboratory capability that can do on-site gas analyses for decision-making purposes. The new laboratory has an on-board robot that aids in multiple gas chromatograph analyses. Experienced personnel assure that analyses are conducted within the guidelines that have been established for quality control.

In addition to the mobile laboratory, MSHA has infrared and other special analyzers that can continuously monitor CO, CO_2, CH_4, and O_2. This is important information that is normally obtained from fans, boreholes, shafts, and behind seals. Computer programs have been developed to perform trend analyses to aid the decision-making process.

AIRBORNE THERMAL INFRARED (TIR) IMAGERY

Infrared technology dates back to the burn of the century. It was first developed primarily for military use; however, today, aside from military applications, it is also commonly used for performing electrical and mechanical inspections of equipment and buildings and in energy audits to determine the effectiveness of insulation.

TIR can be useful for observing areas over a mine fire. “Hot spots” or other critical leakage points may be able to be detected using this technology. This can potentially be a great benefit to mine sealing operations.

Previously, the use of TIR systems was limited mostly to early morning fly-overs. This was necessary due to the fact that operation of the equipment was affected by the sun’s radiative effects on the ground which interfered with the readouts (contrasting light and dark visual representations).

Recently, a new, highly refined infrared camera has been developed and put into operation. The Forward Looking Infrared (FLIR) provides an extremely high resolution and a jitter-free quality. Best of all, operations are no longer limited to the morning hours. Mounted under a helicopter, the system can be used at distances of 500-1000 feet above the ground and at speeds of 35-40 knots. This is a significant improvement over past TIR technology, a technology that has yet to be exploited by the mining industry.

INNOVATIVE STOPPINGS

As mentioned earlier, innovative stoppings such as the parachute stopping and the inflatable stopping are currently being evaluated. There is a need in mine search and rescue for a reliable, quickly deployed, cost effective stopping. Such stoppings should be deploy able both in the mine and from the surface through boreholes.

DE-GASING PUMPS

At two recent mine emergencies involving explosions, Mine Rescue Teams were halted in their operations when a considerable amount of methane was encountered that could not be controlled with underground ventilation techniques. In both of these cases a small diameter borehole (6-8 inches) was drilled from the surface into the mine. At the surface a high-capacity gas pump (3500 cfm) was installed to de-gas the affected area of the mine. In both cases this method was effective in draining the methane sufficiently to allow the Mine Rescue Teams to re-enter and complete their work. This technique may become standard practice in the future.

ROBOTS

While it may seem like science fiction, the use of robots for search and rescue and recovery operations has been under consideration for the last 20 years. Technology had not previously progressed to develop a permissible robot that could operate in the hostile environment resulting from mine fires and explosions; however, now it seems feasible that such a device can be built for exploration, sampling, and even performing some limited recovery work, such as building temporary stoppings, if sufficient interest is shown and research funding can be made available.

MINE RESCUE TEAMS AND FIRE BRIGADES

Aside from the rescue of persons from under roof falls, there are no records of Mine Rescue Teams having rescued any trapped miners, during the last ten years, following major fires or mine explosions. Rescue teams have mainly been utilized to fight fires, build stoppings and seals, and recover mines. Fire Brigades are also becoming more prevalent and are being continuously trained at MSHA's National Mine Health and Safety Academy in Beckley, West Virginia.

While there have been few opportunities to rescue trapped miners, usually because miners that are involved in fires and explosions either get out of the mine on their own, or have become fatalities, Mine Rescue Teams have mainly become involved in the business of rescuing mines. The National Mine Rescue Association has recently identified two major problems that we all should be aware of. These problems relate to the future availability and liability coverage of a mine rescue operation.

First, there is the question as to whether or not there will be enough trained Mine Rescue Teams. Statistics indicate that the number of trained Mine Rescue Teams is dwindling. This is mainly due to the high number of mine closings. Since the work force is smaller, there are fewer volunteers for mine rescue work. Due to the fact that there are fewer volunteers and that mine rescue costs are concurrently rising, some operators can not afford to sponsor their own teams. Furthermore, while several teams may call themselves Mine Rescue Teams, and may even compete in mine rescue contests, it has been noted that not all teams may comply with 30 CFR, Part 49 requirements for Mine Rescue Teams. Thus, the ability, training and readiness of some teams may be called into question.

The second questions is that of liability coverage. When outside Mine Rescue Teams are brought onto a mine property to begin rescue operations, some very important issues are beginning to be raised. Companies are looking at these issues: 1) who bears the actual costs of the guest Mine Rescue Teams? 2) who makes the decisions when multiply teams from different mines or agencies are involved? 3) how should risk and compensation for loss be shared, especially if a team member is injured or loses his/her life?

These same two problems discussed above also apply to Fire Brigades that come from other mines. How do we know how well other Fire Brigades are trained and how is the issue of liability to be treated?

A case in point is an incident that occurred at a recent mine fire: after a ventilation change was made while 14 Mine Rescue Teams were fighting the mine fire, an ignition of unknown origin occurred, causing injuries to seven team members. All seven were transported to a hospital where it was determined that some had suffered second and third degree burns. All persons underground were evacuated and the operator decided to seal the mine openings from the surface. The liability issues relating to this incident are still being debated.

MEO EQUIPMENT

While Mine Rescue Teams have had no opportunities to rescue trapped miners resulting from fires and explosions, the same has been true of the surface rescue and recovery team, Mine Emergency Operations (MEO), within MSHA. The primary mission of MEO was the maintenance, deployment, and operation of the Seismic Location System for trapped miners. The MEO Seismic Location System, although put into use several times, has not contributed to the rescue of trapped miners since it was developed in the early 1970's. Also, since this capability was very costly to maintain, MEO was disbanded in January, 1991 and most equipment was transferred to the Federal Emergency Management Agency (FEMA) for use in Urban Search and Rescue.

The MEO equipment transferred to FEMA included the large seismic location system, portable seismic detection systems, the TV probe system and various pieces of support equipment. Other MEO equipment was distributed throughout MSHA. Although FEMA has no experience in mine search and rescue, it has informally agreed to make this equipment available to MSHA for mine emergencies. This commitment was tested for the first time in December, 1992 when it was deployed to a mine explosion near Norton, Virginia and tests were conducted to search for 8 persons who were not accounted for. Sadly, as in other episodes in the past, all miners who were unaccounted for had been killed as a direct result of the explosion.

SUMMARY AND CONCLUSIONS

In summary, I have briefly reviewed the major techniques and technologies that are currently available to combat mine fires and explosions, which have been employed during the last ten years in actual mine emergency operations. Direct Attack methods are the most effective if sufficient resources are applied immediately. This includes the use of good, well maintained equipment and personnel that are regularly trained, ideally with “hands-on” training. Indirect Attack methods have no proven to be very effective in extinguishing mine fires, but can cool some fires sufficiently to allow rescue teams and Fire Brigades to get close enough to use Direct Attack methods.

In-mine sealing and surface sealing have been effective; however these methods usually are only applied when Direct Attack methods fail. These methods can be extremely costly and time consuming.

New technologies, especially the use of gas CHROMATOGRAPHS and continuous sampling techniques, are now routinely being used. Other, more exotic technologies, such as airborne infrared imaging and innovative, quick erected seals such as the inflatable stoppings, show some promise for applications in the future, but there is no substitute for the abilities and commitment of trained Mine Rescue Teams and Fire Brigades. They are the best we have, but will they be there in the future if we need them?

What can we do now to be better prepared to deal with mine emergency operations? First, all mine operators should regularly conduct a mine emergency preparedness audit and correct all deficiencies discovered. Second, we should support the creation of in-company mine fire fighting teams such as Fire Brigades. This is our first resource for Direct Attack. Third, we should all work together to develop a viable mutual aid package that can be used between mines, between states, and even between countries (considering Canada). Finally, Labor, Industry, and Government representatives should regularly participate in Mine Emergency Response Development (MERD) training be better prepared for mine emergency operations.