Information Circular 8752

Metal Mine Fire Protection Research

Proceedings: Bureau of Mines Technology Transfer Seminar, Tucson, Ariz., March 18, 1977

Compiled by Staff–Mining Research

UNITED STATES DEPARTMENT OF THE INTERIOR
Cecil D. Andrus, Secretary

BUREAU OF MINES

This publication has been cataloged as follows:

Bureau of Mines Technology Transfer Seminar, Tucson, 1977
Metal mine fire protection research : proceedings, Bureau of Mines Technology Transfer Seminar, Tucson, Ariz., March 18, 1977, compiled by Staff-Mining Research. [Washington] : U.S. Dept. of the Interior, Bureau of Mines, 1977.

51 p. : ill. ; 27 cm. (Information circular - Bureau of Mines ; 8752)

1. Mine fires - Prevention and control - Congresses. 2. Mine fires - Prevention and control - Addresses, essays, lectures. I. United States. Bureau of Mines. II. Title. III. Title: Technology Transfer Seminar on Metal Mine Fire Protection. IV. Series: United States. Bureau of Mines. Information circular - Bureau of Mines ; 8752.

TN23.U71 no. 8752 622.06173

U.S. Dept. of the Int. Library

PREFACE

This Information Circular summarizes recent Bureau of Mines research results concerning improved fire protection for our country's open pit and underground metal mines. The papers are only a sample of the Bureau's total effort to improve noncoal mine fire safety, but they delineate the major concerns of the program. Much of the technology discussed is applicable to nonmetal as well as metal mines.

The five technical presentations reproduced herein were made by Bureau personnel at the March 18, 1977, Technology Transfer Seminar on Metal Mine Fire Protection. This meeting was held in conjunction with the 1977 Southwest Safety Congress and Exposition, March 15-17, 1977, at the Tucson Convention Center, Tucson, Ariz.

Those desiring more information on the Bureau's mine fire safety program in general, or information on specific situations, should feel free to contact the appropriate author or the Bureau of Mines Washington office, located at 2401 E Street, N.W., Washington, D.C. 20241.

The Bureau would like to take this opportunity to thank the members of the Southwest Safety Congress, especially William Wood, safety director, Magna Copper Co., San Manuel, Ariz., and the Mining Enforcement and Safety Administration, especially Robert Riley, subdistrict manager, Metal and Nonmetal Mine Inspection, Phoenix, Ariz., for their assistance in arranging for, and contributing to, the Technology Transfer Seminar.

CONTENTS

METAL MINE FIRE PROTECTION RESEARCH

Proceedings: Bureau of Mines Technology Transfer Seminar, Tucson, Ariz., March 18, 1977

Compiled by Staff–Mining Research

ABSTRACT

This Bureau of Mines publication presents five papers given at a Technology Transfer Seminar on Metal Mine Fire Protection Research. Several seminars are held each year to bring the latest results of Bureau conducted and sponsored research to the attention of the mining industry as quickly as possible.

INTRODUCTION

by

David R. Forshey[1]

The objective of the Bureau of Mines metal and nonmetal mine fire protection research program is to improve mine fire safety through developing timely technology and competitively priced, reliable hardware. The design criteria for fire protection hardware are typically developed as a result of contract research, although some basic design work is carried out inhouse. After specific techniques and devices are developed, this laboratory research is followed by inmine tests and demonstrations of prototype systems. Cooperative agreements between the Bureau and equipment manufacturers and/or mining companies are frequently utilized to accelerate the transfer of this new technology to the mining industry in general and also to the Mining Enforcement and Safety Administration (MESA).

Building upon many years of fire protection work developed to address coal mine fire problems, initial Bureau work in the noncoal area involved the development and inmine demonstration of conveyor system fire protection hardware and an automatic fire protection system for large haulage trucks. The details of this work, initiated in the early 1970's, are discussed in the following five papers. Current Bureau metal mine fire research, which is also discussed, includes (1) work in the development and inmine fire testing of mine shaft fire and smoke protection systems, (2) the application of the automatic truck fire protection system's technology to all classes of mobile mining equipment, both underground and surface, and (3) testing of a number of conveyor belting materials in a large fire gallery. The coal mine fire protection research most closely related to our current efforts in the noncoal area includes projects to develop improved fire sensors and suppressants, inhouse studies of flame rate propagation and spontaneous combustion, and a contract to develop a manually activated dry-chemical fire protection system for underground mobile coal mining equipment. The basic studies in flame rate propagation are still active, as is work in evaluating the spontaneous combustion properties of different types of coals.

Future work, some of which has just been initiated, involves (1) the development and inmine fire testing of improved fire protection systems for underground fueling areas, (2) an evaluation of designs for improved underground fire doors, with particular attention to the problems inherent in their application in large excavations, (3) the development and reliability testing of improved underground fire sensors, and (4) work to address the growing spontaneous combustion problem in sulfide ore mines.

Table 1 gives an overview of the Bureau's fiscal year 1977 funding in mine health and safety research. Research on the prevention of mine fires and

[1]Staff engineer, Division of Mining Research--Health and Safety, Bureau of Mines, Washington, D.C.

explosions is $2,800,000 in coal mine research and $900,000 in metal and nonmetal mine research. These funding levels and the associated research programs are developed on the basis of reported fires and of injuries and fatalities resulting from fires; it is recognized that potential for disaster is ever present.

TABLE 1. - Fiscal year 1977 health and safety research funding

(Million dollars)

Subprogram	Coal	Metal and nonmetal	Total
Respirable dust	1.9	0.5	2.4
Noise	.9	.2	1.1
Industrial hygiene	1.5	.4	1.9
Radiation hazards	-	1.0	1.0
Ventilation	-	.3	.3
Fires and explosions prevention	2.8	.9	3.7
Methane control	1.5	-	1.5
Ground control	7.5	1.0	8.5
Industrial-type hazards	8.3	1.1	9.4
Postdisaster survival and rescue	1.4	.2	1.6
Systems engineering	4.4	.2	4.6
Total	30.2	5.8	36.0

As mentioned earlier, one major facet of the Bureau's research program involves cooperative research including (1) demonstrations conducted by Bureau contractors to evaluate the adequacy of design criteria and prototype hardware, and (2) cost-sharing contracts and cooperative agreements between the Bureau and mining companies and/or equipment manufacturers to carry out long-term validation testing of preproduction hardware, systems, and new procedures.

All of these paths lead to technology transfer: to the mining industry in terms of procedures and hardware, to equipment manufacturers in terms of design criteria and hazard assessment, and to MESA in terms of techniques to provide means for compliance with regulations.

Good research results are dependent upon feedback from the users of technology. Technology transfer is a major program of the Bureau; one aspect of technology transfer is covered by questions and answers from seminars such as this one. The development of new MESA standards is not an overriding objective of our work, although this aspect of technology must be considered. Rather, the Bureau tries to develop improved mine safety technology that will be sufficiently cost effective that voluntary acceptance and utilization by the mining industry occurs. Some regulations will always be required; however, we are striving to develop technology in such a way that it improves both mine safety and overall productivity with attendent reductions in insurance and health care expenses.

IMPROVED FIRE PROTECTION SYSTEMS FOR MOBILE MINING EQUIPMENT

by

Guy A. Johnson[1]

ABSTRACT

The Bureau of Mines, through inhouse work and research and development contracts with the FMC Corp., the Ansul Co., and Lease AFEX, Inc., has developed and inmine-tested automatic fire sensing and suppression systems for large mobile mining equipment. This work was undertaken to enhance driver safety, lessen the substantial property damage from fires, and increase the vehicle operator's productivity.

One automatic truck fire protection system protects both the engine compartment and brake grid areas of haulage trucks, while a second system is used in the engine compartment-fuel tank area of a truck. Both systems have redundant fire-sensing capabilities and manual actuation controls. Upon sensing flames and/or heat, the systems suppress the fire with pressurized, B-C class, dry chemical. Both systems are flexible enough in design so that they can be modified for use on other types of mobile mining equipment. Prototypes of both systems have been subjected to long-term, inmine validation testing and actual onvehicle fire tests on 100-ton-capacity trucks at the Pima mine near Tucson, Ariz., and the Erie mine at Hoyt Lakes, Minn. During a 4-month endurance test of the first system at Pima, an accidental flash fire occurred in the engine area of the test truck while it was working in the pit. The prototype system successfully sensed and automatically extinguished the fire with no injury to the driver and very little damage to the truck.

Other systems have also been developed for mobile underground equipment. A third system utilizes a thermal wire to sense a fire and then suppresses it with cartridge-operated, dry-chemical extinguishant. A fourth, less complicated system uses point-type thermal sensors. All systems can be used on both underground and surface noncoal equipment.

DISCUSSION

As mobile open pit mining equipment becomes larger, the danger to operators during fire emergencies is increased because the cabs are farther from the ground. Also, access ladders are usually located next to engine compartments, an area where many vehicle fires occur. Frequently drivers are not immediately aware of fires and escape is difficult owing to the size of the fire when finally detected. In January 1973 a truck driver working in an iron ore mine in Upper Michigan was seriously hurt when he was forced to jump from his truck during a flash fire in the engine compartment. The truck was a 75-ton-capacity model (which is of only moderate size considering the

[1]Mining engineer, Twin Cities Mining Research Center, Bureau of Mines, Twin Cities, Minn.

200-ton-capacity models now available). Although the floor of the cab was only 8-1/2 feet above the ground, the driver fractured both heels and received first and second degree burns. The Bureau of Mines Health and Safety Report (No. 20-00424) concerning this accident stated: "An automatic fire extinguishing system would have prevented personnel injury and minimized property damage." Although the truck was equipped with a manually activated, fixed fire suppression system, the driver did not activate the manual system because of his haste to get out of the vehicle.

To help solve this health and safety problem, and to better protect expensive equipment, the Bureau of Mines initiated a contract research program to develop improved fire protection prototype systems for large mining vehicles. The first contract, awarded to FMC Corp., San Jose, Calif., in June 1972 was completed in April 1974. Further work involved contracts with the Ansul Co., Marinette, Wis., and Lease AFEX, Inc., Raleigh, N.C. This paper discusses the fire protection systems developed under these contracts plus current inhouse work to demonstrate their use.

The objective of the program was to identify the most fire-prone class of surface-mining equipment, and then design and test reliable fire protection systems that could be produced at a reasonable price to solve the problem. Manually activated, fixed (that is, permanently installed), dry-chemical fire protection systems for trucks had been on the market for a few years, but many complaints from mine operators indicated that the systems currently available were inadequate for proper driver and truck protection.

FMC, in its contract work, confirmed that haulage trucks of 100-ton capacity and over represented the greatest fire hazard, and that most vehicle fires resulted from broken hydraulic lines and electrical shorts. Design criteria were then generated for a "dual sensing, automatic with manual override, fire detection and suppression system." The design incorporated both near-infrared and thermal wire sensors to detect fires. The system contained electronic self-checking (fail-safe) features plus a timing sequence to allow the driver to test a suspect fire-warning signal and use his manual suppressant-dispersion switch if he believed the system was malfunctioning. This first system was designed to protect the engine compartment and brake grid areas of a truck with pressurized, B-C class, dry chemical. If the driver did not manually disperse the powder when he saw a fire, or if he was incapacitated, the system would automatically disperse the suppressant before the fire became too large to control. This "automatic, with manual override" electronic control feature is considered preferable to a manually activated system because of the frequent panic situation during a fire emergency. As happened in Michigan, a driver's first thought when a flash fire occurs is usually of getting away from the truck; thus, he may forget to initiate a manually activated type fire protection system. Figure 1 is a schematic of the first automatic truck fire protection system design.

Prototype hardware fabrication and inmine, ontruck demonstration of the effectiveness of this first system were accomplished when it was successfully fire-tested in April 1973 on a 100-ton-capacity truck at the Cyprus-Pima mine, Tucson, Ariz. Fires set in the engine compartment and brake grids of the

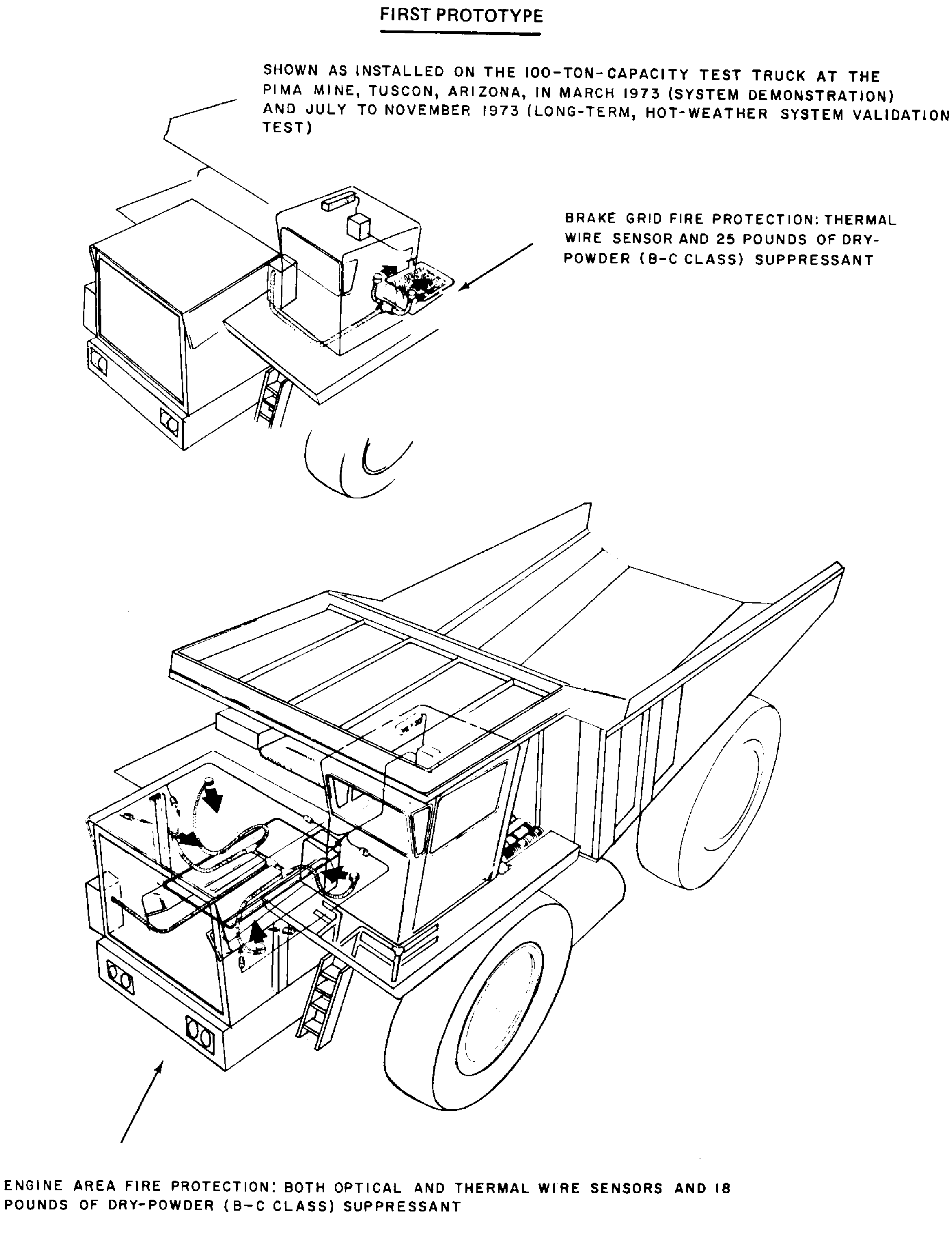

FIGURE 1. - Schematic diagram of the first automatic truck fire protection system design.

truck were successfully sensed by the system and automatically extinguished. The Pima mine truck fire test is shown in figure 2.

The prototype system was then ontruck, inmine tested on the 100-ton-capacity truck at the Cyprus-Pima mine for 4 months. This hot-weather endurance test took place during the summer of 1974. During the test period, an accidental flash fire occurred in the engine compartment of the truck while it was working in the pit. A faulty oil filter seal sprayed oil on the hot engine, and the driver did not manually discharge the system before he left the cab. The system automatically sensed and extinguished the fire with so little damage to the truck that it was back in service within 4 hours. Similar fires in the past have cost from $15,000 to over $40,000 in equipment repairs.

FIGURE 2. - Onsite test of the truck fire suppression system.

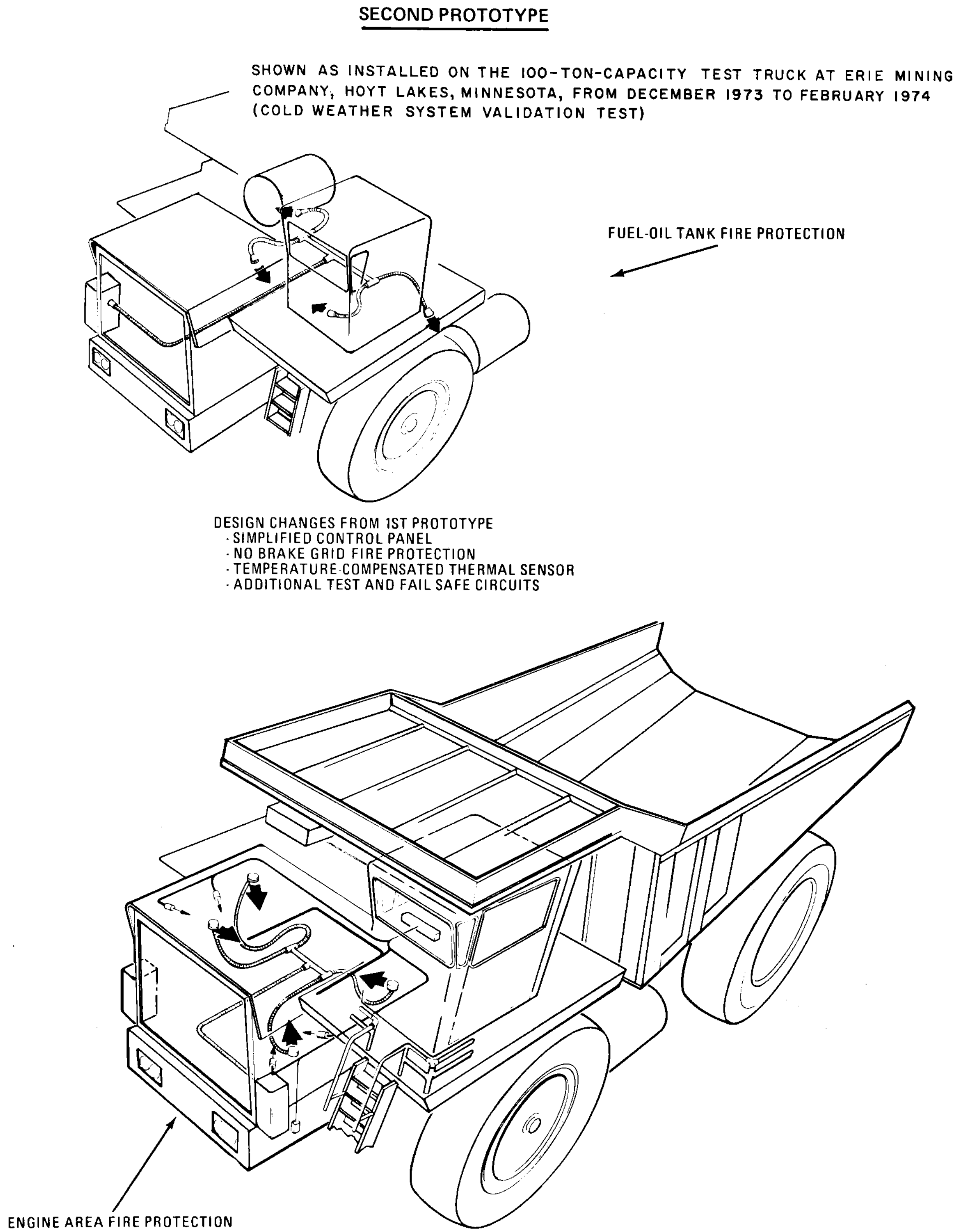

FIGURE 3. - Second prototype truck fire suppression system design.

As a result of the experience gained during the testing at Cyprus-Pima, a second system was designed and fabricated. This second prototype was then subjected to 6 weeks of ontruck, cold weather testing at the Erie Mining Co., Hoyt Lakes, Minn., in the winter of 1974. The second system (1) protects the engine compartment-fuel tank area of a truck rather than the engine compartment-brake grid area, (2) includes an increase from one to two 25-pound-capacity dry-chemical cylinders used for the truck's engine compartment-fuel tank area, and (3) modifies the thermal detection subsystem so it can automatically compensate for changes in outside ambient air temperature, thereby making the modified system more sensitive to fire stimulus.

The second prototype (fig. 3) was successfully subjected to onvehicle fire tests at Erie at the end of 6 weeks of cold weather endurance testing. Figure 4 shows the components of the modified system. Figures 5 and 6 show the lighting of a test fire and its automatic suppression at Erie.

Detailed information on the early development and inmine testing of the FMC-type automatic truck fire protection systems can be acquired from Bureau of Mines Information Circular 8683, "Automatic Fire Protection Systems for

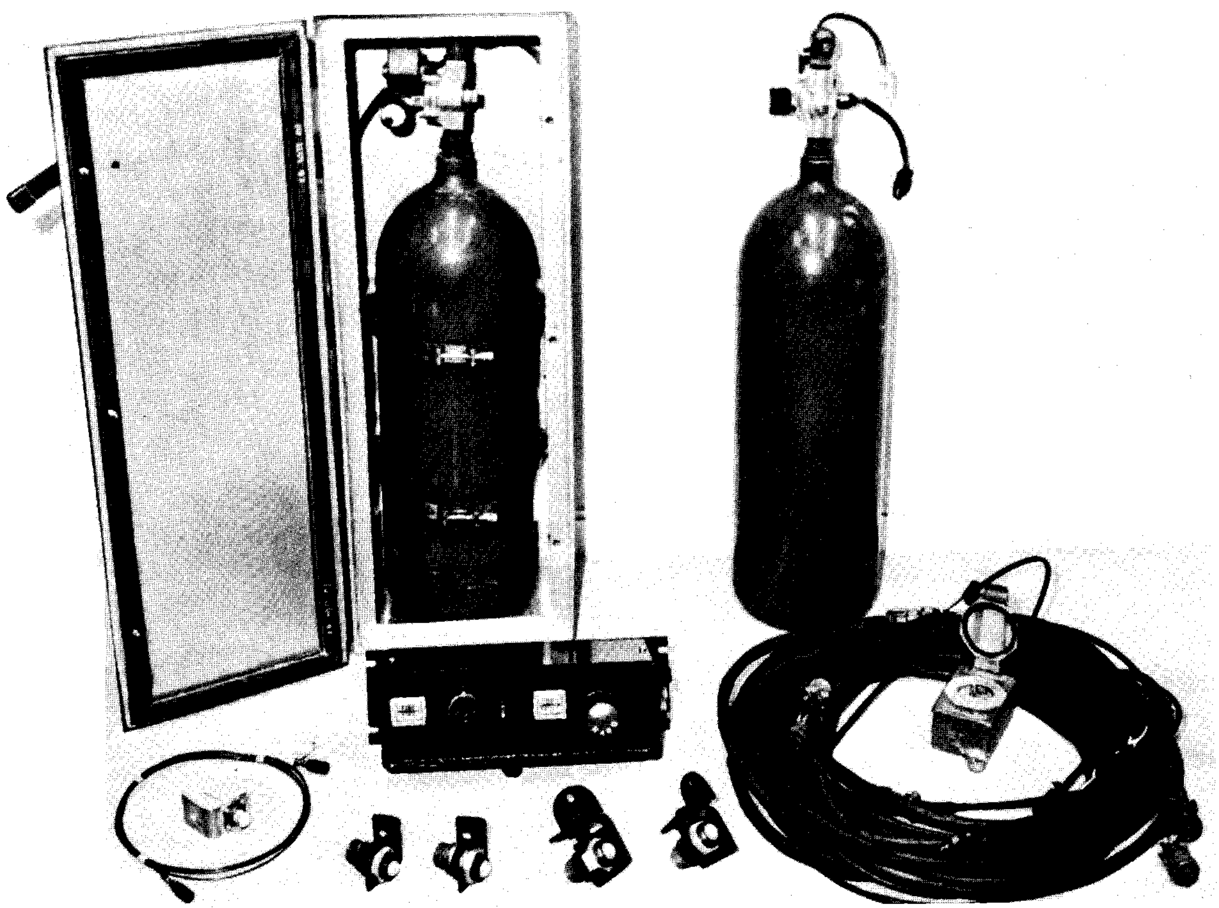

FIGURE 4. - Components used in modified system.

FIGURE 5. - Lighting the fire for system demonstration.

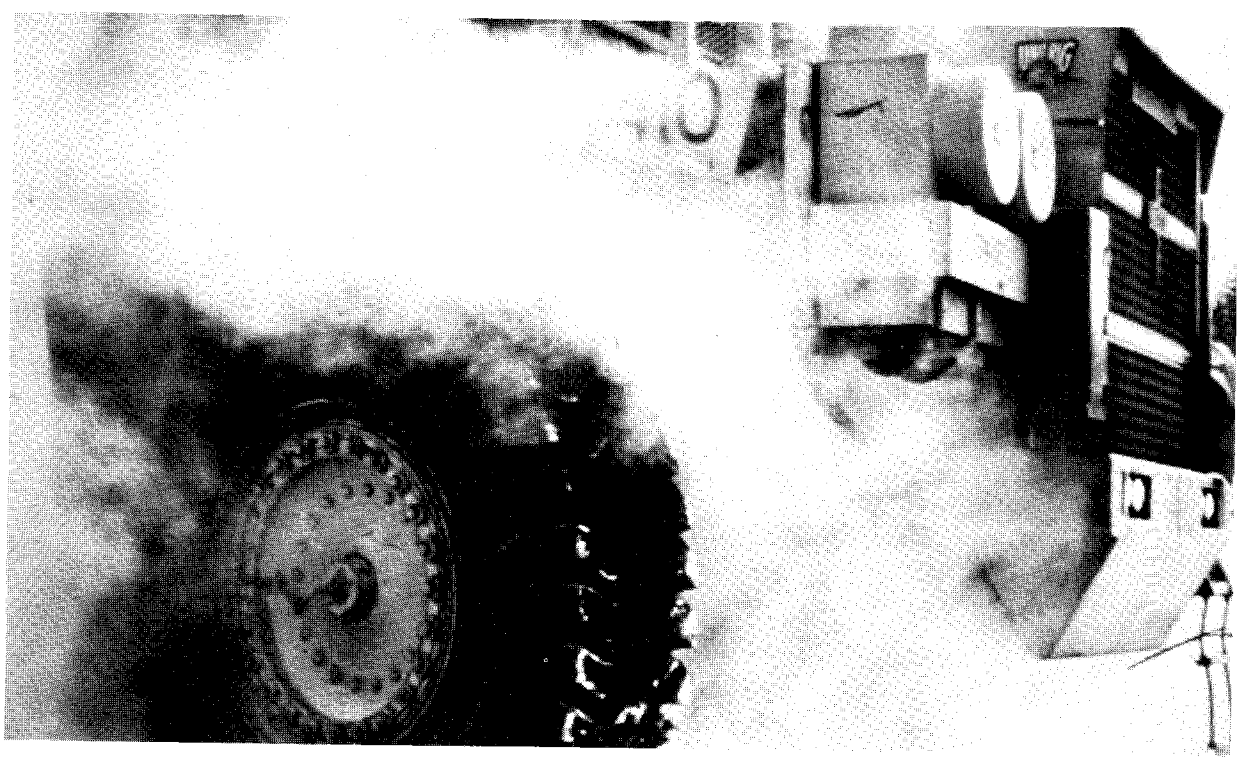

FIGURE 6. - Erie truck fire being automatically extinguished.

Large Haulage Vehicles: Prototype Development and In-Mine Testing," by G. A. Johnson and D. A. Forshey, 1975.[2] Both systems are easy to install and cost about $3,000 to $5,000, which is quite reasonable when compared with the $250,000 and higher cost of today's large ore haulage vehicles.

In 1975 the Bureau decided to expand its fire protection program to include underground vehicles. As a result, the Ansul Co., Marinette, Wis., received a contract to develop and inmine-test prototype systems for such mining equipment. Figure 7 depicts the system Ansul developed. It utilizes a thermal wire to detect fires and cartridge-operated dry chemical to suppress them. The prototype system can also be manually activated. Figure 8 depicts the results of a successful inmine fire test of the prototype hardware that occurred in Hecla Mining Co.'s Lakeshore mine, Casa Grande, Ariz., in the summer of 1976. Current work on this novel piece of fire protection hardware involves long-term, inmine tests of four prototype systems in two different underground mines. Further information concerning this work can be obtained from Ansul's "Phase II Report, Development of an Automatic Fire Protection System for Mobile Underground Metal Mining Equipment," December 2, 1975.[3]

Other Bureau work in the area of improving fire protection for mobile mining equipment involved funding the development of a low-cost, point-type automatic fire protection system for coal augers (fig. 9). This project involved working with Lease AFEX, Inc., Raleigh, N.C., to develop the system and a cooperative test program with the Cedar Coal Co., Cheylan, W. Va., for inmine, long-term testing. This system utilized cartridge-operated, dry-chemical extinguishant and had simplified electronics including four point-type thermal sensors to sense an engine compartment fire. Information concerning this system can be obtained from the contract's final report, "Development and Testing of a Fire Protection System for Coal Augers."[4]

Current work with the AFEX-type system involves its utilization on bulldozers, front-end loaders, and diesel-powered down-hole drills. Information concerning the bulldozer portion of this work will soon be available through AFEX's final report, "Development, Installation, and Testing Services for an Automatic, Point-Type Thermal Sensor, Fire Protection System on a Mining Dozer."

---

[2]Available from Government Printing Office, Washington, D.C., stock number 024-004-01776-7, 80 cents (minimum mail order $1).

[3]BuMines Open File Rept. 81-76, 1975, 151 pp.; available for consultation at the Bureau of Mines libraries in Denver, Colo., Twin Cities, Minn., Bruceton, Pa., Pittsburgh, Pa., and Spokane, Wash., at the Energy Research and Development Administration library in Morgantown, W. Va., and at the National Library of Natural Resources, U.S. Department of the Interior, Washington, D.C.; sold by the National Technical Information Service, Springfield, Va., as PB 254 851/AS, $6.75 paper, $3 microfiche.

[4]BuMines Open File Rept. 25-76, 1975, 13 pp.; available for consulation at the Bureau of Mines libraries in Denver, Colo., Twin Cities, Minn., Pittsburgh, Pa., and Spokane, Wash., at the Energy Research and Development Administration library in Morgantown, W. Va., and at the National Library of Natural Resources, U.S. Department of the Interior, Washington, D.C.; sold by the National Technical Information Service, Springfield, Va., as PB 249 865/AS, $3.50 paper, $3 microfiche.

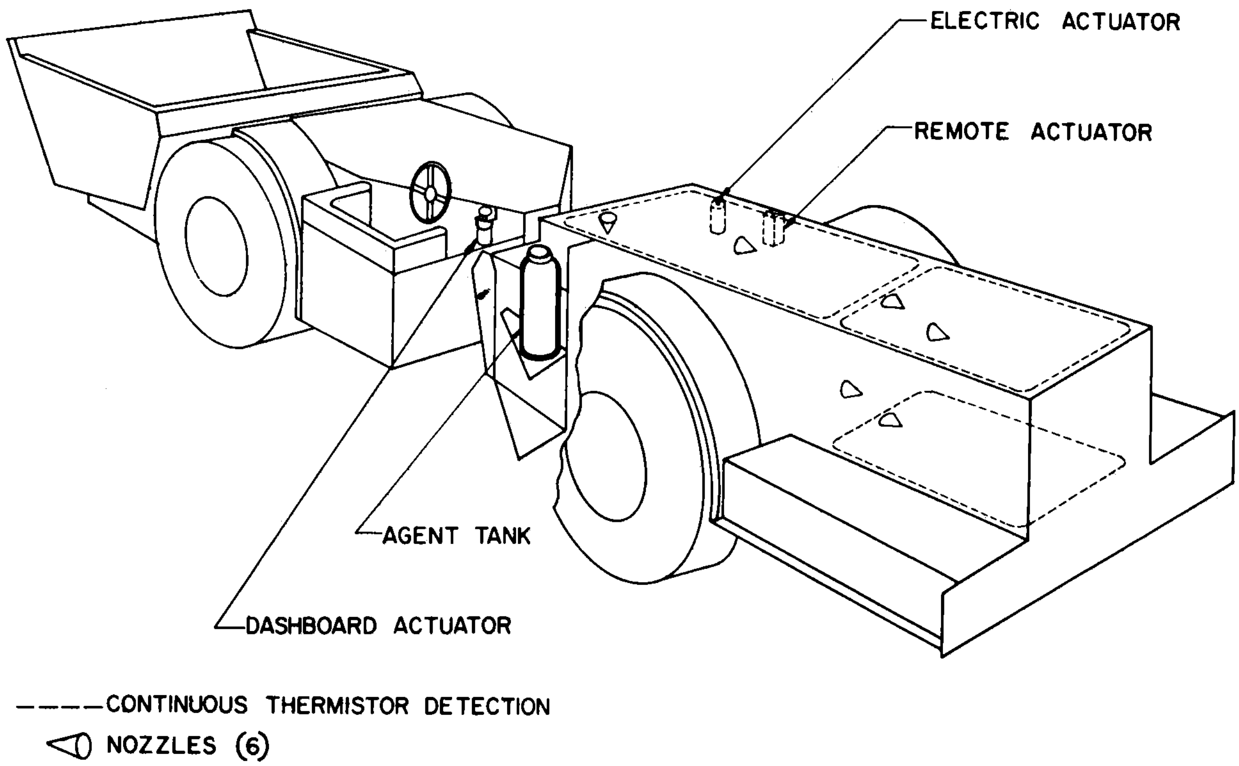

FIGURE 7. - Automatic fire control system installation.

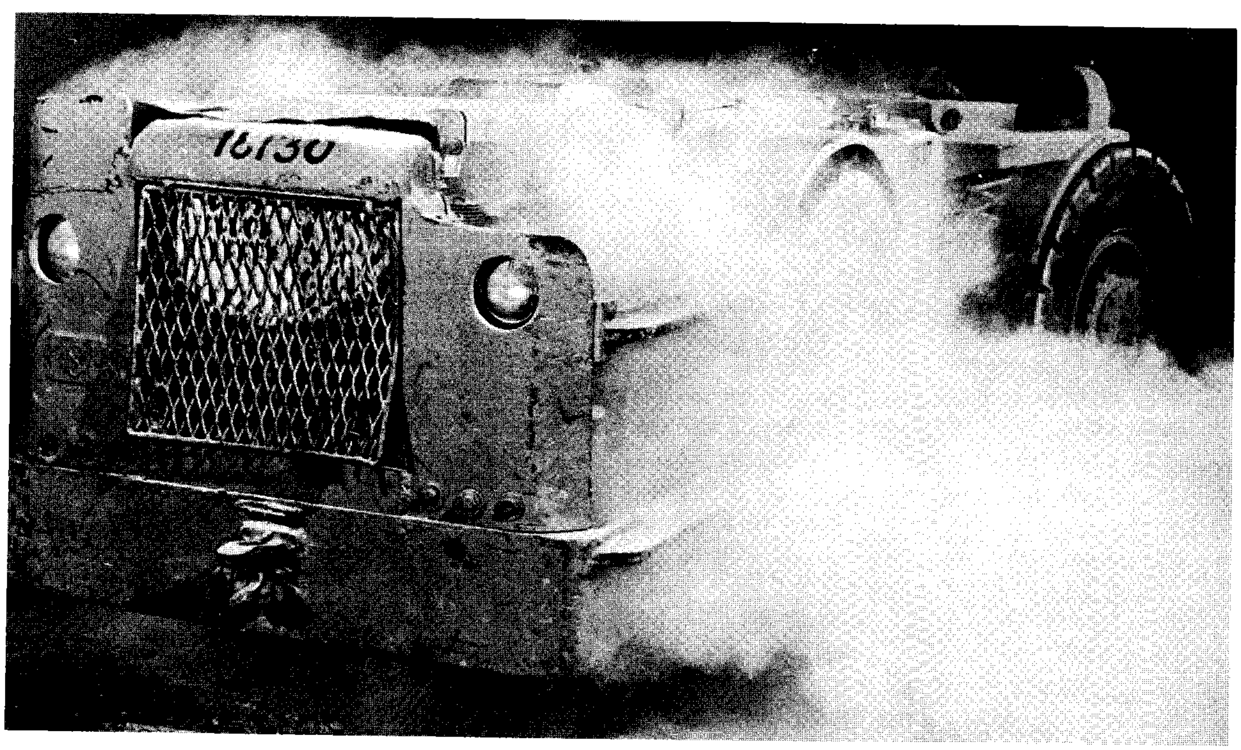

FIGURE 8. - Successful inmine fire test of prototype fire suppression hardware.

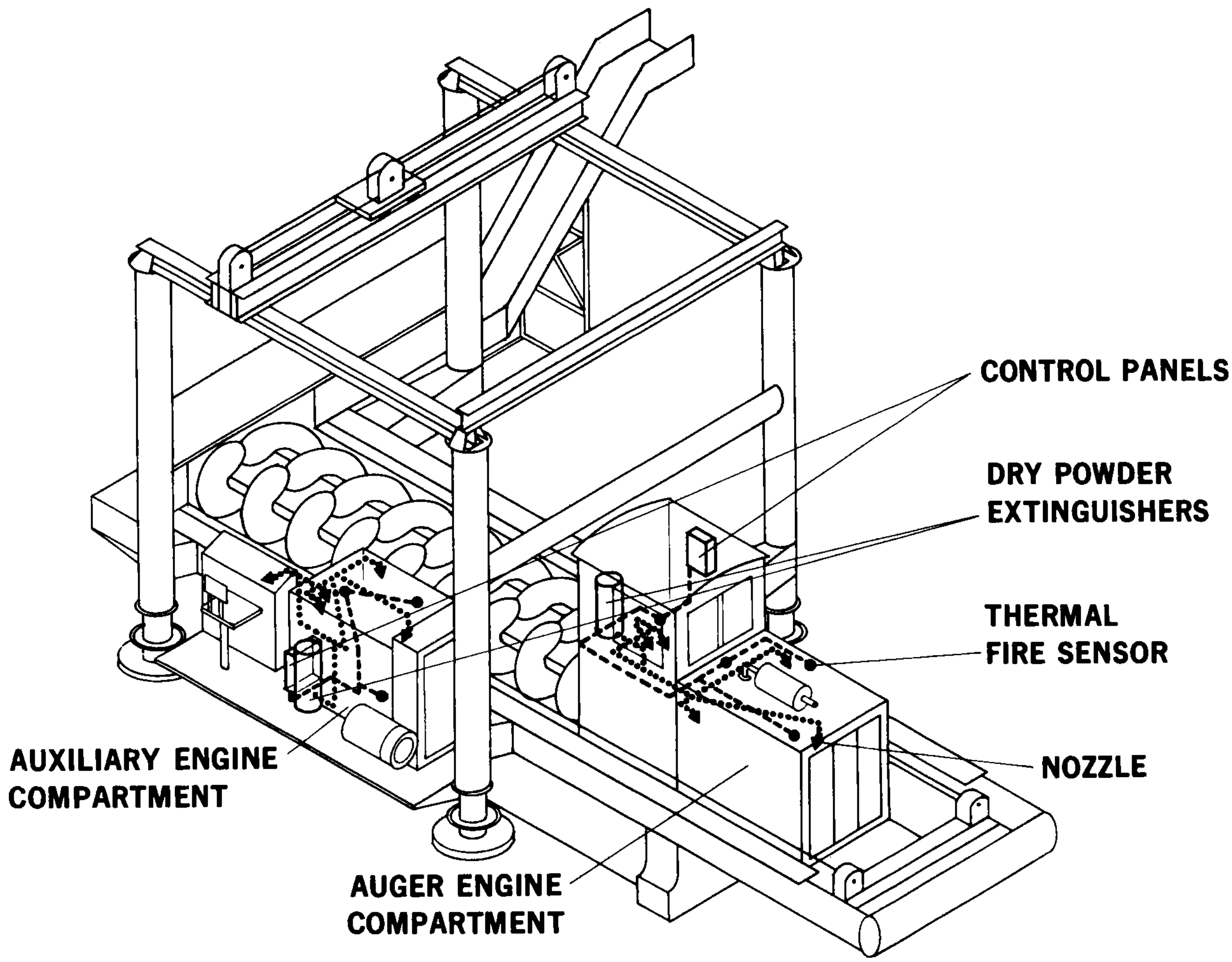

FIGURE 9. - Low-cost automatic fire protection system for coal augers.

FIVE AUTOMATIC FIRE PROTECTION SYSTEMS FOR MOBILE MINING EQUIPMENT: THEIR DESIGN AND INMINE RELIABILITY TESTING

by

Kenneth L. Bickel[1]

ABSTRACT

Since the development of the FMC-type automatic fire protection system for trucks, the mining industry has suggested that additional long-term inmine evaluation of the system be conducted and simplified systems be made available that would be applicable to other types of mobile mining equipment. With that in mind, the Bureau has initiated a project to long-term-test the FMC-type system and four modifications of that system. The goal of this new project is to provide four reliable, cost-effective alternatives to the original prototype system which can be applied to a majority of mobile mining equipment.

DISCUSSION

In June 1972, the Bureau of Mines awarded a research and development contract to the FMC Corp. to develop and inmine-test an automatic fire protection system for large haulage vehicles. This work resulted in the FMC-type fire protection system (fig. 1), which utilized thermal and optical fire sensors, stored pressure cylinders, dry-powder suppression agent, ambient temperature compensation, and logic control which provided automatic with manual override fire protection. This system, which will also be referred to as system 1, was installed and long-term-tested on 100-ton-capacity trucks in the Cyprus-Pima copper mine in Arizona and the Erie taconite mine in northerm Minnesota. The project was completed in 1974.

Since that time, the mining industry has suggested that additional long-term, inmine evaluation of system 1 be conducted and that simplified systems be made available that would be applicable to other types of mobile mining equipment. With that in mind, the Bureau and FMC initiated a contract to long-term-test system 1 and four modifications of that system. The goal of this new project is to verify system 1 design and reliability, and to provide four reliable, cost-effective alternatives to system 1 that can be applied to a majority of mobile mining equipment.

Besides additional testing of system 1, the following four system designs have been fabricated on a production-run basis and are being inmine-tested during this project:

A. System 2 is the existing FMC-type system without optical sensors and ambient temperature compensation (fig. 2). This design eliminates the problem of false alarms from the highly sensitive optical sensors. System 2 costs approximately $1,500 installed and provides very reliable sensing of a fire.

[1]Mining engineer, surface mining, Twin Cities Mining Research Center, Bureau of Mines, Twin Cities, Minn.

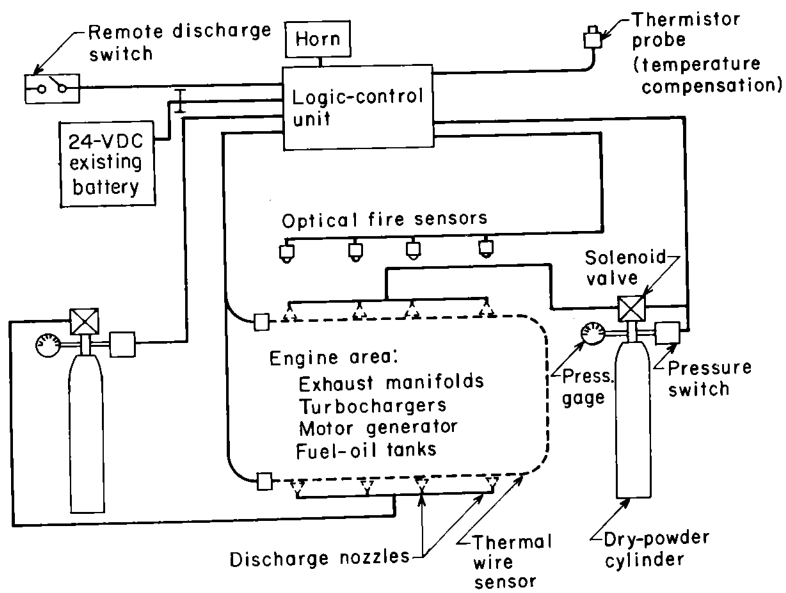

FIGURE 1. - System 1 schematic.

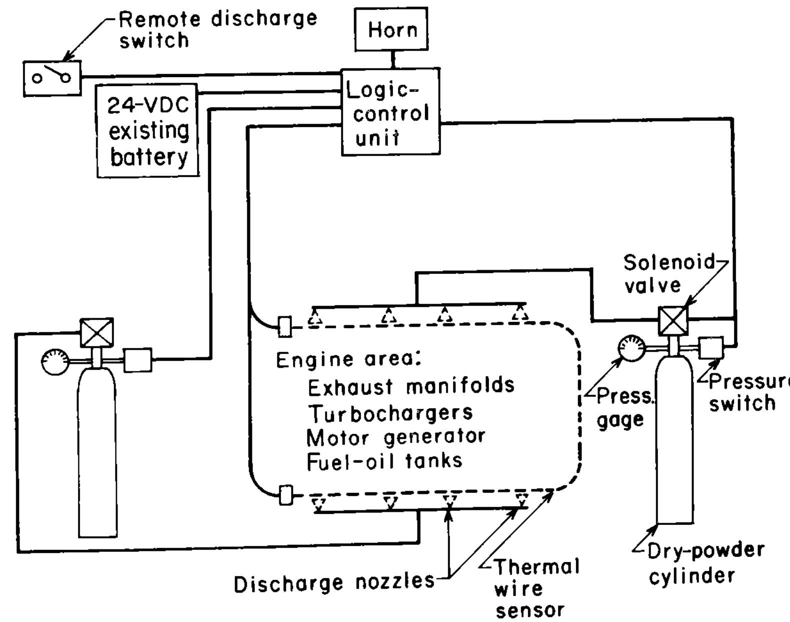

FIGURE 2. - System 2 schematic.

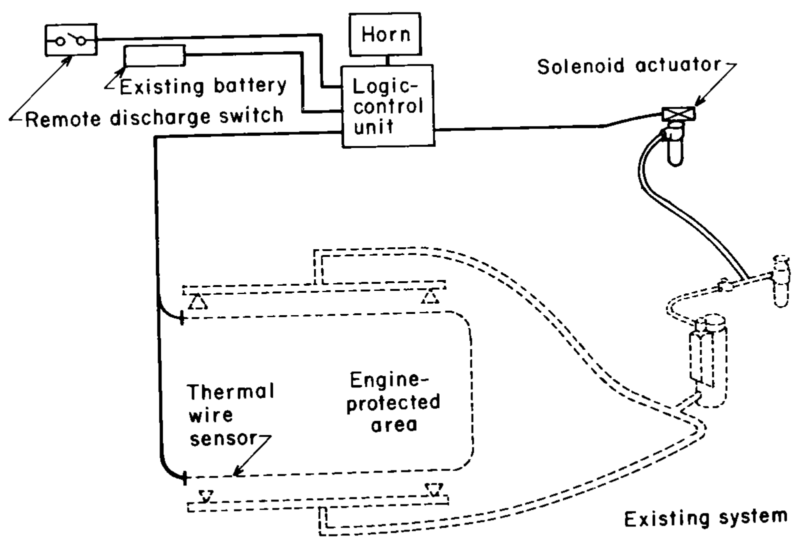

FIGURE 3. - System 3 schematic.

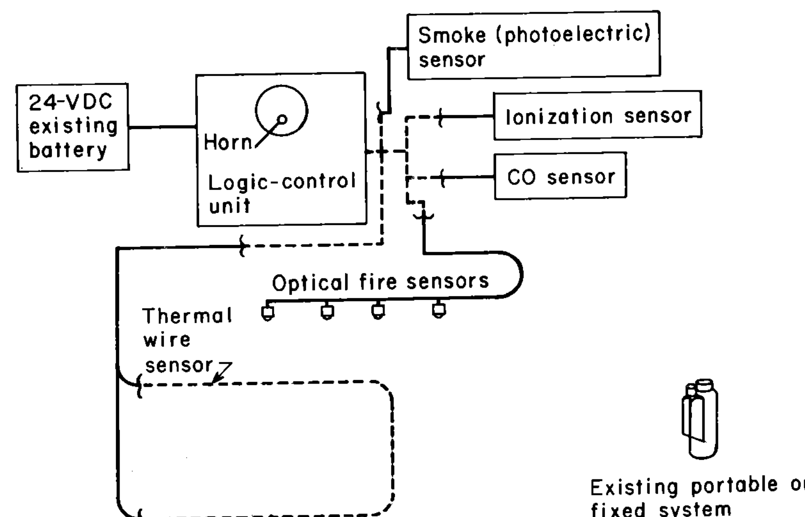

FIGURE 4. - System 4 schematic.

B. System 3 is a system 2 design that is retrofittable to existing fixed, manually activated systems (fig. 3). Many pieces of mining equipment currently have fixed, manually activated systems installed on them. System 3 provides hardware that allows automatic protection, utilizing the fixed system already installed on the vehicle. A new solenoid valve has been designed for automatically actuating the fixed system. This retrofittable hardware costs approximately $800 installed.

C. System 4 is a fire-alarm-only system using one or a combination of sensors that provides visual and audible alarm with no suppressant discharge (fig. 4). System 4 automatically warns the equipment operator that a fire has started, allowing him to stop and turn off the engine before actuating suppressant discharge himself. This system gives the equipment operator more control over his equipment and costs less than an automatically actuated system.

D. System 5 is a self-contained, battery-operated, automatic fire detection system using point source sensors, which is retrofittable to existing fixed, manually activated fire protection systems (fig. 5). If an electrical fire were to occur on a piece of equipment with an FMC-type system installed on it, the automatic portion of the fire protection system would be rendered unusable. Because it has its own power source, system 5 will still work if such a fire should occur. Also, system 5 utilizes low-cost, highly reliable point source heat sensors to sense the fire.

Table 1 shows the types of equipment on which the five systems are installed. A total of eight systems have been installed for up to 12 months in two different mines; although neither mine is a metal mine, results should be applicable in metal mines. At the end of the testing period, the systems will be demonstrated using simulated fire tests.

TABLE 1. - Fire protection systems and mine equipment

Mine name	System 1 (FMC/USBM)	System 2 (without optics)	System 3 (automated manual system)	System 4 (alarm only)	System 5 (self-contained automated and manual system)
Diamond Crystal salt (underground), New Iberia, La.	-	-	Euclid R35 truck, Galion 125 A crane.	-	Goodman 2500 cutter, Cat 988 LHD.
Jim Bridger coal (surface), Rock Springs, Wyo.	Wabco 120 truck.	Cat 992 end loader.	Wabco 120 truck.	M8200 dragline.	-

The Bureau's objectives in undertaking this work are twofold: (1) To show that reliable, low-cost automatic fire detection and suppression systems are available that utilize "off-the-shelf" hardware, and (2) to provide a body of technology for the mining industry and the Mining Enforcement and Safety

Administration to review before deciding what type of fire protection system should be installed on various types of mining equipment.

Information on the FMC-type system can be obtained from two FMC Corp. reports: "Improved Sensors and Fire Control Systems for Mining Equipment,"[2] and "Truck Fire Protection System Validation. Final Report. System Modification and Validation Testing of Fire Protection Systems for Mine Haulage Trucks."[3] Information on the current project may be obtained by contacting Kenneth L. Bickel at the Bureau of Mines Twin Cities Mining Research Center, Twin Cities, Minn. (612-725-4579).

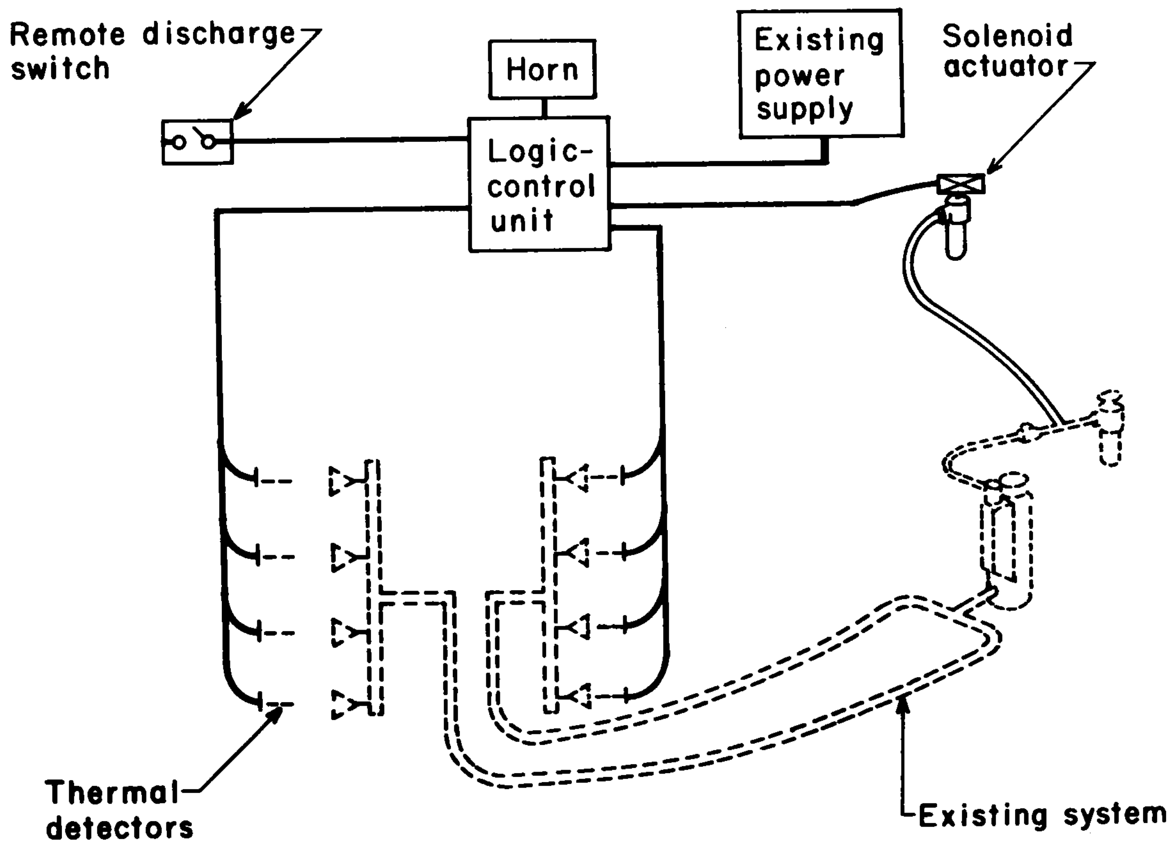

FIGURE 5. - System 5 schematic.

[2]BuMines Open File Rept. 25(2)-74, 1973, 178 pp.; available for consultation at the Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Spokane, Wash., and Denver, Colo., and at the National Library of Natural Resources, U.S. Department of the Interior, Washington, D.C.; sold by the National Technical Information Service, Springfield, Va., as PB 232 406/AS, $7.50 paper, $3 microfiche.

[3]BuMines Open File Rept. 33-74, 1974, 170 pp.; available for consultation at the Bureau of Mines libraries in Denver, Colo., Pittsburgh, Pa., Spokane, Wash., Morgantown, W. Va., and Twin Cities, Minn., and at the National Library of Natural Resources, U.S. Department of the Interior, Washington, D.C.; sold by the National Technical Information Service, Springfield, Va., as PB 234 577/AS, $6.75 paper, $3 microfiche.

FIRE SUPPRESSANTS FOR MOBILE MINING EQUIPMENT

by

William H. Pomroy[1]

ABSTRACT

The first step in selecting a fire protection system for a specific application is the choice of a fire suppressant agent. Each of the five common suppressants--dry chemical, water, CO_2, foam, and halogenated agents--has capabilities and limitations that affect its usefulness in different situations. In response to varying mine equipment fire protection needs, the Bureau of Mines has developed a number of novel fire protection systems. This paper discusses four such systems that involve the use of dry chemical on large front-end loaders, the use of water in underground mine shafts and shaft stations, firefighting foam used in conjunction with dry chemical in underground fuel storage and transfer areas, and Halon 1301 used in conjunction with dry chemical in surface blasthole drills.

DISCUSSION

Effective fire protection systems are an essential component of modern mining equipment. A properly installed and maintained system will provide a safe working environment for the operator, protect valuable mining equipment against costly fire damage, and insure against mine production losses resulting from damaged or destroyed equipment. A number of options are available to mine safety personnel who must specify a particular fire protection system for a specific application (Is a hand portable adequate or should a fixed system be installed? Should it be manually activated or automatic? and so forth), but the most fundamental decision that must be made regards the type of fire suppressant agent to be used. The five common fire suppressants are (1) dry chemical, (2) water, (3) CO_2, (4) foam, and (5) Halon. Each has specific capabilities and limitations that affect its usefulness in different situations. The Bureau of Mines, in its continuing effort to improve metal and nonmetal mine fire protection technology, has developed a number of novel mine equipment applications for these suppressants, utilizing specially designed hardware that best takes advantage of their unique attributes. This paper discusses four applications involving dry chemical, water, foam, and Halon.

Fire protection on large front-end loaders is especially important because the operator cab is 10 to 12 feet off the ground. During a fire emergency the operator is faced with a dilemma: if he jumps, he's sure to be hurt, but if he crawls down the ladder, he's exposing himself to the articulation area of the machine, a prime fire hazard zone.

[1]Mining engineer, surface mining, Twin Cities Mining Research Center, Bureau of Mines, Twin Cities, Minn.

To help protect the operators of these machines, the Bureau of Mines contracted with the Lease AFEX, Inc., Raleigh, N.C., in June 1976, to develop a rugged, reliable, cost-effective automatic fire protection system for large front-end loaders. Our contractor fabricated the required hardware for installation on a Clark 675 front-end loader operating in the Kellerman mine near Tuscaloosa, Ala. This 24-cubic-yard machine is powered by twin 700-hp Cummins diesels. The installed fire protection systems used dry chemical as the extinguishing agent. Dry chemical is an excellent suppressant for flammable fluid and electrical fires as well as for fires involving ordinary combustibles. In addition, its use will not adversely affect vehicle components.

Four individual suppression systems were installed (fig. 1). When discharged, they dumped a total of 112 pounds of dry chemical. Two systems protect the engine area, and one each protects the transmission area and the front-end hydraulics. Fourteen point-type thermal sensors are located at strategic hazard areas on the machine. The sensors are connected in series so that when any one sensor detects the presence of a fire, all four suppression systems are discharged. This is done to prevent a small fire from spreading to unaffected parts of the machine.

The installation took about 5 man-days and required only simple hand tools. Following installation, our contractor tested the system by lighting a fire under one of the sensors. The system responded in a few seconds with complete agent discharge in about 15 seconds. Excellent powder coverage was

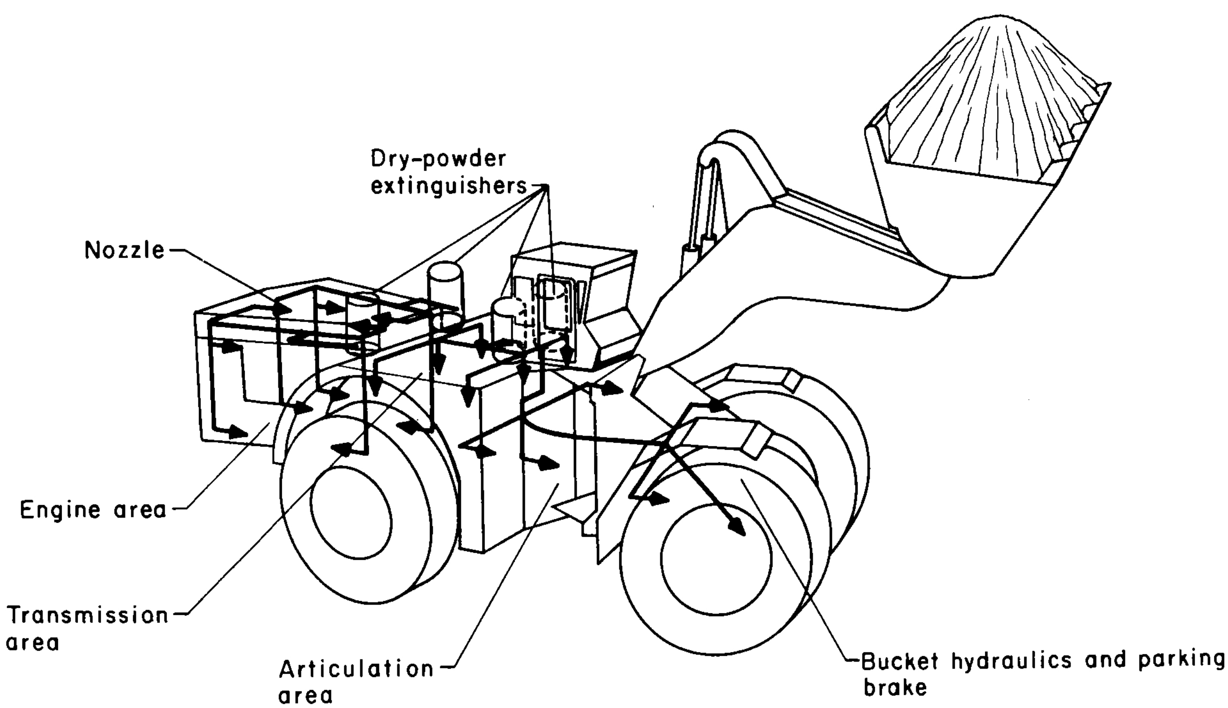

FIGURE 1. - Automatic fire protection system for large front-end loaders.

achieved in all hazard areas. This system is commercially available and can be installed by the dealer or by mine personnel for $3,000 to $4,000.

As MESA examines the use of dry-chemical fire suppressants on mine equipment, one of their concerns is the toxicity of the powder and of the powder's thermal decomposition products. To help give MESA some answers, the Bureau contracted with MSA Research, Evans City, Pa., in March 1976, to install two manually activated dry-chemical fire protection systems on a piece of metal or nonmetal mining equipment, and then determine the health effects of using the systems to extinguish onvehicle fires. MSA bought two commercially available systems and installed them on a Cat 988 front-end loader operating in the Fletcher mine near Viburnum, Mo. Both a pressurized and a nonpressurized system were installed on the loader for comparative purposes; however, throughout the test program, no significant operational differences were observed between the two systems. The two systems were installed to protect the machine's engine area, parking brake, and articulation area (fig. 2). After about 4 months of operation, the two systems were fire-tested. Fire pans about 18 by 4 by 4 inches were welded to the frame between the engine and rear tire. The pans were filled with a diesel fuel-naphtha mixture and ignited. The fire was allowed to burn about 1 minute before the fire suppression system was manually discharged. During the fire and discharge, air samples were collected on and near the machine to determine the operator's exposure to harmful substances. Although certain toxic compounds were generated by the discharge (ammonia and phosphoric acid), the sampling instruments did not measure concentrations high enough to present an immediate hazard to mine personnel.

Water is the most commonly used fire suppressant for underground mines. It is cheap and readily available, and is an effective suppressant for most fires. But many times during a fire emergency, mine personnel are not able to reach manual hose lines because of smoke or heat, and fusible link-type

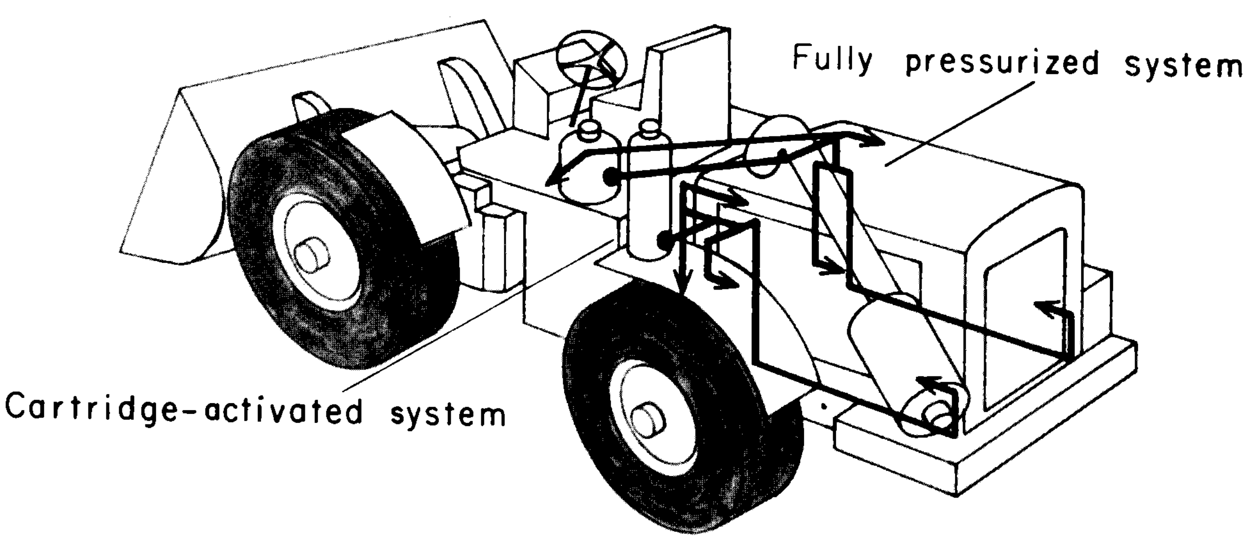

FIGURE 2. - Manually activated fixed fire protection system for underground mining equipment.

nozzles in sprinkler systems are apt to corrode shut. To solve these problems, the Bureau contracted with the FMC Corp., San Jose, Calif., to develop a mine shaft fire and smoke protection system for underground metal and nonmetal mines.

Among the many parts of this system is a water sprinkler system. But rather than using fusible link-type nozzles, it uses an open-nozzle, dry-pipe system regulated by a solenoid-operated water valve. This valve can be open and shut at the valve site or at any remote area, including the surface. (NOTE.--This system is discussed in more detail in the next paper.)

Although water is a good general purpose suppressant, certain types of fires should not be approached with water. One of these is a fire involving flammable fluids like diesel fuel or hydraulic oil. With the increased use of diesel equipment in underground mines, the risk of a fire involving these fuels is greatly increased. To deal with this growing problem, the Bureau of Mines issued a contract to the Ansul Co., Marinette, Wis., to develop and inmine-test a fire protection system for underground fuel storage and transfer areas.

As a first step in the development of a prototype system, the contractor generated a set of safe design criteria for fueling areas that will help reduce the chances of fire starting in the first place. These criteria require that bulk storage of flammable fluids be maintained on the surface and that fuel be piped underground to a smaller underground storage area separated by a fire wall from the actual fuel transfer area.

In engineering the fire protection system, it was found that no single fire suppressant agent offered the fast-acting, reliable response necessary to deal effectively with an underground class B fire. Therefore, a twin-agent system was selected. This system rapidly extinguishes the fire with dry chemical and secures the fuel against reignition with aqueous film-forming foam (AFFF). Separate systems protect the fuel storage area (fig. 3) and fuel transfer area (fig. 4). The fire is sensed with ultraviolet-type optical flame detectors for millisecond response to fire conditions.

The final system to be discussed is also a combined-agent system. It was designed to protect large enclosed blasthole drills. These drills present complex fire protection problems. The machinery house and operator cab areas contain high-voltage electrical apparatus so an electrically conductive agent like water or foam cannot be used safely. These areas also contain delicate electrical switching gear that would be damaged by the residual deposits left by dry chemical, rendering that agent unsuitable as well. These areas are completely enclosed, however, so a gas-type agent like CO_2 or Halon 1301 that does not have the aforementioned shortcomings could be used effectively. Because of the toxicity of CO_2, Halon 1301 was used. (The transformer room is not adequately enclosed so Halon cannot be used effectively in that area, but since the transformer room does not house delicate electrical switching gear, dry chemical can be used in that area without causing adverse after-effects.) Thus, an effective fire protection system for large enclosed blast-hole drills must utilize both Halon and dry chemical (fig. 5).

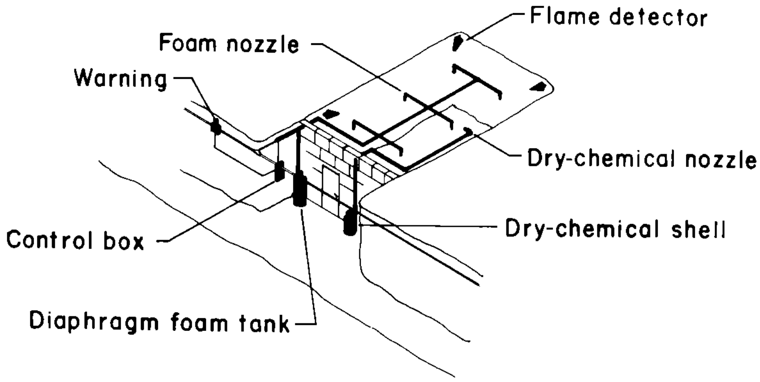

FIGURE 3. - Underground fuel storage area fire protection.

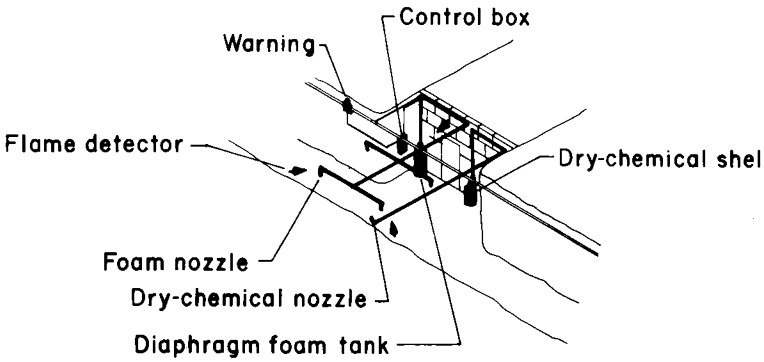

FIGURE 4. - Underground fuel transfer area fire protection.

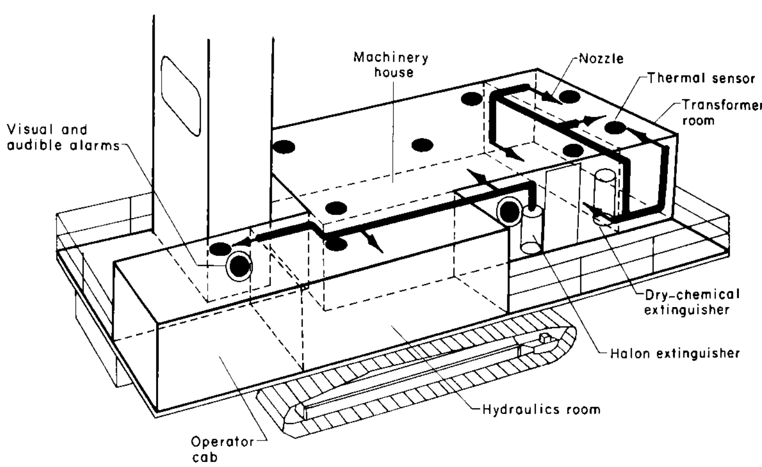

FIGURE 5. - Automatic Halon-dry chemical fire protection system for large blasthole drills.

In June 1976, the Bureau contracted with the Lease AFEX, Inc., to install and inmine-test a system based on our conceptual design. The hardware was assembled and installed on a BE 61R drill operating in the Ayrshire mine near Evansville, Ind.

Both the Halon system and the dry-chemical system are automatically activated with manual override. The Halon system has point-type thermal sensors located in the cab, hydraulic room, and machinery house.

When a temperature of 300° F reaches any sensor, the system automatically begins an actuation sequence. First, a warning bell sounds and the machine is immediately shut down. After a 40-second delay, a horn sounds, and the Halon is discharged. The 40-second delay is necessary to allow time for the fans to stop completely to avoid blowing the Halon gas out of the machine. The Halon gas is discharged through three nozzles, one located in each area. The machine can be restarted only when a manual reset switch on the operator console is tripped. After the installation, we discharged the system twice to test agent concentrations. We achieved 6 to 7 percent in all three areas, which is well within National Fire Protection Association guidelines.

The dry-chemical system operates independently of the Halon system. It also uses 300° F point-type thermal sensors. When the activation temperature is reached, the dry chemical is automatically discharged through four nozzles directly onto the transformers. This system is currently undergoing long-term endurance testing. In a similar effort, we have contracted with the Ansul Co. to design and test systems for blasthole drills as well as for power shovels and draglines.

To sum up our work in improving metal and nonmetal fire technology, fixed dry-chemical systems are recommended for mobile equipment. For large enclosed surface equipment, Halon 1301 is recommended, with dry chemical, foam, and CO_2 used for certain specific local applications. For underground areas, water, foam, and dry chemical are best; however, Halon 1301 or CO_2 can be used for small, normally unoccupied, enclosed areas.

INMINE EVALUATION OF IMPROVED UNDERGROUND FIRE PROTECTION EQUIPMENT

by

Guy A. Johnson[1]

ABSTRACT

In May 1974, the Bureau of Mines let a metal and nonmetal health and safety contract to FMC Corp., San Jose, Calif., to (1) evaluate the mine shaft fire and smoke hazard problem and (2) develop and demonstrate low-cost, reliable mine shaft fire and smoke protection systems. This hardware was to be flexible in design so that (with modifications) it would be applicable to the majority of noncoal shafts and shaft stations, especially for deep mines.

After the definition of the underground metal and nonmetal mine fire and smoke problems, which was accomplished by extensive inmine examination of the hazard, and analysis of the qualitative information available, the design criteria for the first prototype system were defined in the winter of 1974-75. The system involved thermal and smoke-type fire detectors, plus remotely controlled smoke doors and sprinklers. Fire testing of the prototype hardware was conducted in March 1975 in a shaft and shaft station mockup built at FMC's facilities. An inmine demonstration of the system (involving the successful sensing and remote extinguishment of an actual fire) took place in April 1975. The inmine fire testing was conducted in the Silver Summit shaft near Wallace, Idaho. Long-term, inmine validation tests of an improved ("second generation") system and cost-effectiveness evaluations of optional designs were then initiated. This work was completed in the summer of 1976 and involved a second inmine fire test, which took place at Union Carbide's Pine Creek mine, Bishop, Calif.

This paper outlines the steps taken by FMC and the Bureau to define the underground noncoal mine fire and smoke hazard problem, and then to design and inmine-test prototype hardware for a system that is better than the shaft-collar water ring system now commonly used.

INTRODUCTION

As metal and nonmetal mines become deeper, larger, and more mechanized, the fire danger increases because of the increased combustibles loading in the mines and the restricted miner egress. This fact was unfortunately illustrated in May 1972 by the Sunshine mine fire at Wallace, Idaho, in the Coeur d'Alene lead-zinc-silver mining district, in which 91 miners lost their lives. Figure 1 depicts an earlier mine fire that occurred in Nevada.

[1]Mining engineer, Twin Cities Mining Research Center, Bureau of Mines, Twin Cities, Minn.

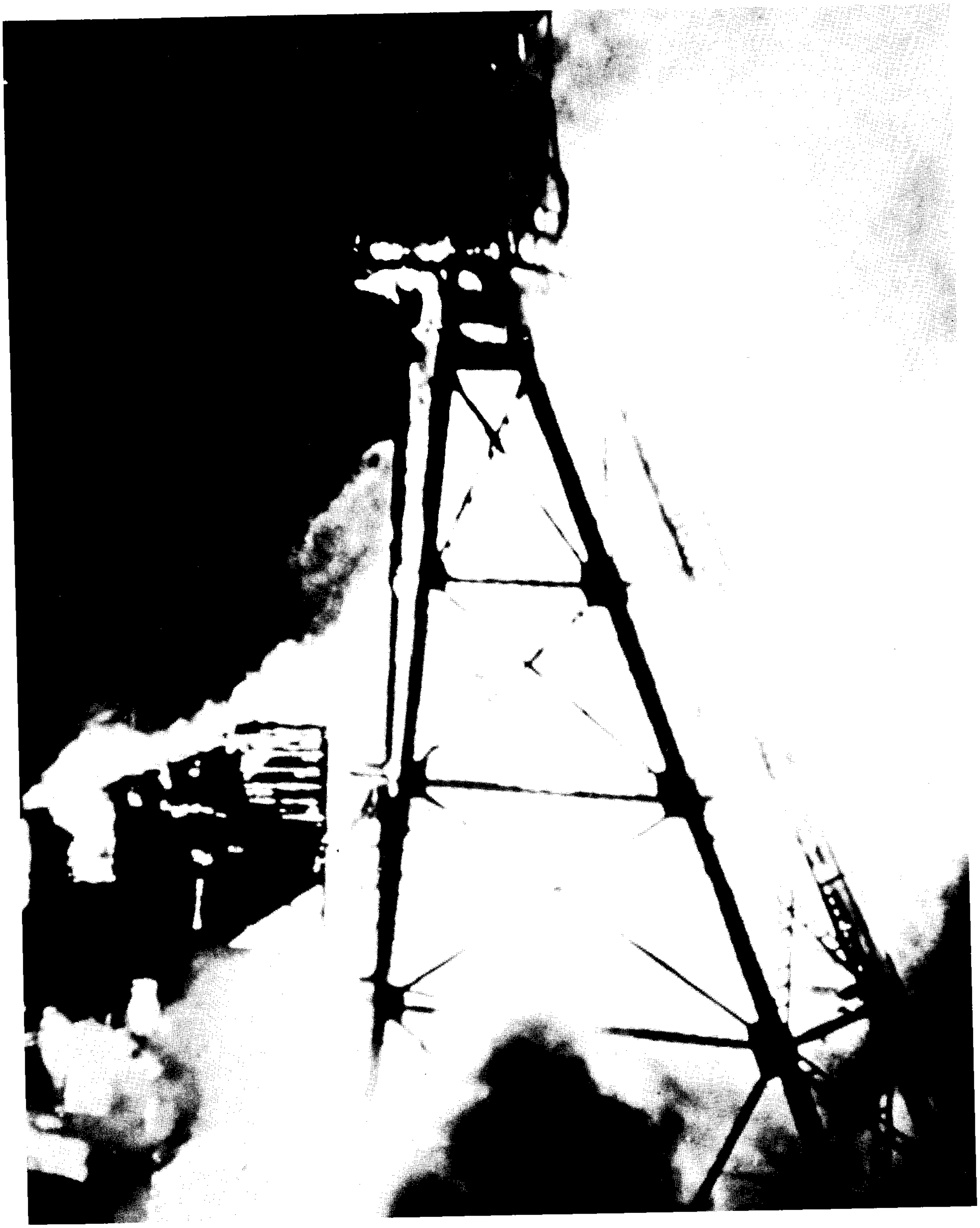

FIGURE 1. - Shaft fire in the 1940's in Nevada.

To help solve this health and safety problem and to better protect the production capability of our Nation's mines, the Bureau of Mines proposed development of a mine shaft fire and smoke protection system for metal and nonmetal mines through contract research. The methodology for the hardware development and inmine testing was to follow that used in the Bureau's successful effort to develop automatic fire protection systems for large mobile mining equipment.

FMC Corp., San Jose, Calif., was awarded a contract (H0242016) in May 1974 to (1) evaluate noncoal mine fire and smoke hazard problems and (2) develop and demonstrate a reliable mine shaft fire and smoke control system. This system was to be flexible in design so that with modifications it would be applicable to the majority of metal and nonmetal mine shafts and adjoining shaft stations. Following the system hardware inmine fire test at the Silver Summit shaft near Wallace, Idaho, the contract was extended for long-term, inmine validation testing and detailed evaluation of the cost effectiveness of the system's hardware.

DEFINITION OF THE FIRE HAZARD

Electrical shorts and welding and torch cutting are the chief causes of underground noncoal mine fires. Other causes are spontaneous combustion and friction. As mines become deeper, ventilation systems tend to become more complex; thus the spontaneous combustion hazard will probably increase. The Bureau has taken this into consideration in its planning for future research on improved fire protection systems. Improved fueling-area fire protection is also being delineated by the Bureau.

Smoke control is an important requirement of the system because air contamination by smoke, toxic products, etc., from an underground fire is very dangerous. Most miners die from inhaling toxic gases produced from combustion rather than from being burned to death.

SYSTEM DESIGN AND MOCKUP TESTING

As a result of the fire and smoke problem analysis portion of the contract, the design concept for a mine shaft fire and smoke protection system was developed (fig. 2). The system utilizes thermal, carbon monoxide, and ionized-particle smoke detectors, plus remotely controlled smoke doors and sprinklers. The system protects both the shaft and shaft station areas of a mine. The system's surface control unit receives underground fire warning signals via multiplexed electronics sent through two separate twisted-pair wire routings. The system's underground control units are then activated from the surface to warn the miners in the shaft station area. A stench system would also be activated by surface personnel to warn other miners.

The sprinklers and doors can be opened or closed from either their local control unit or the master control unit on the surface. Fire warning horns and lights and mine evacuation signals at the underground units can also be controlled from the surface control unit. Automatic sprinkler

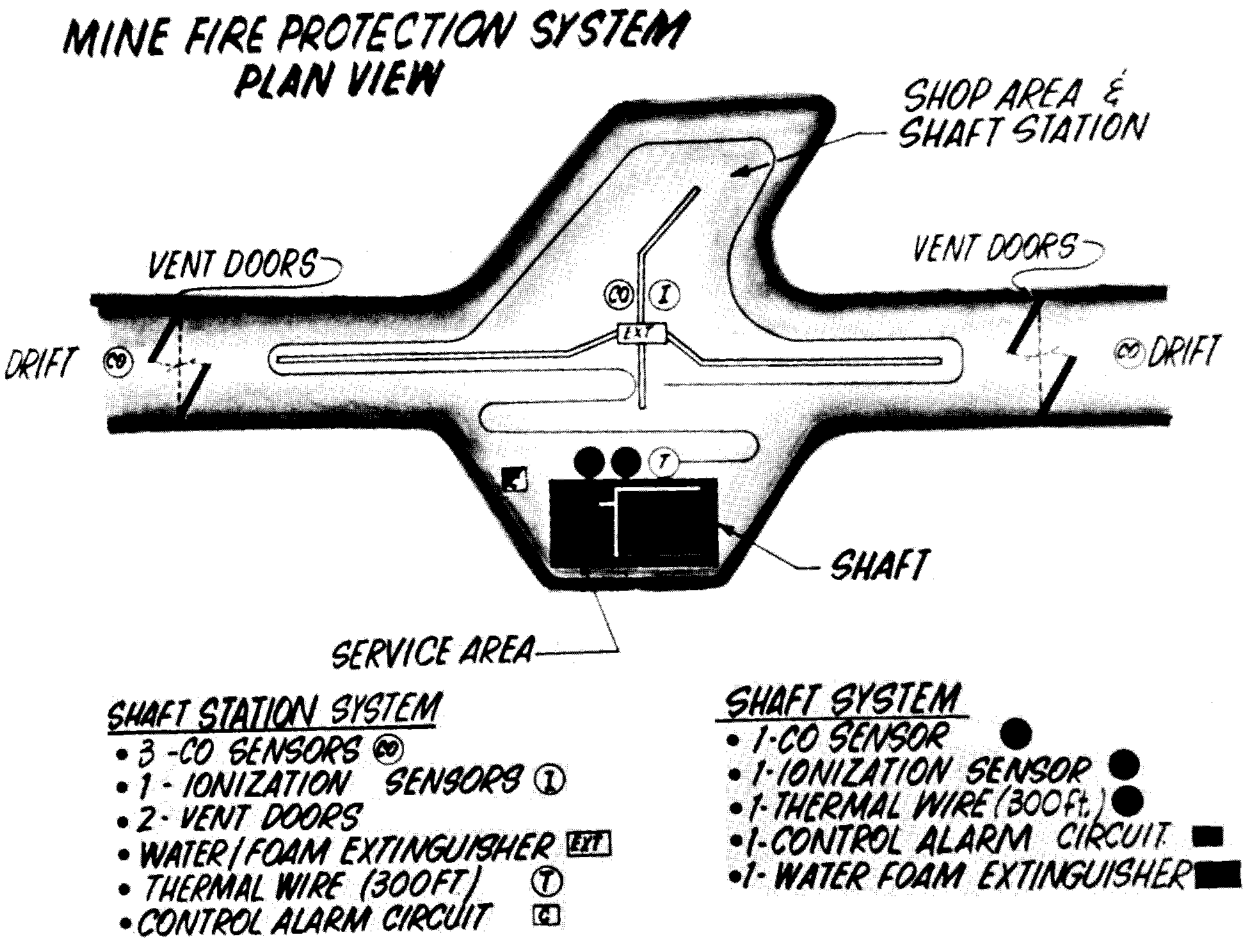

FIGURE 2. - System design concept.

actuation is currrently not a feature of the system, but such a design alternative could be easily added if a user wanted it.

A shaft and shaft station mockup (fig. 3) was built at FMC's plant in San Jose, and system component tests were conducted during the winter of 1975. Figure 4 depicts possible smoke sensors to be used in the shaft system. Mockup testing was highlighted March 20, 1975, when the system's hardware was demonstrated to Bureau, MESA, and industry representatives with an actual fire test in the mockup.

Figure 5 depicts the system's surface control unit. Figure 6 is the underground control unit. Figures 7 and 8 show the "modularized" electronics in both control boxes. Figure 9 shows the fire sensors utilized by the system.

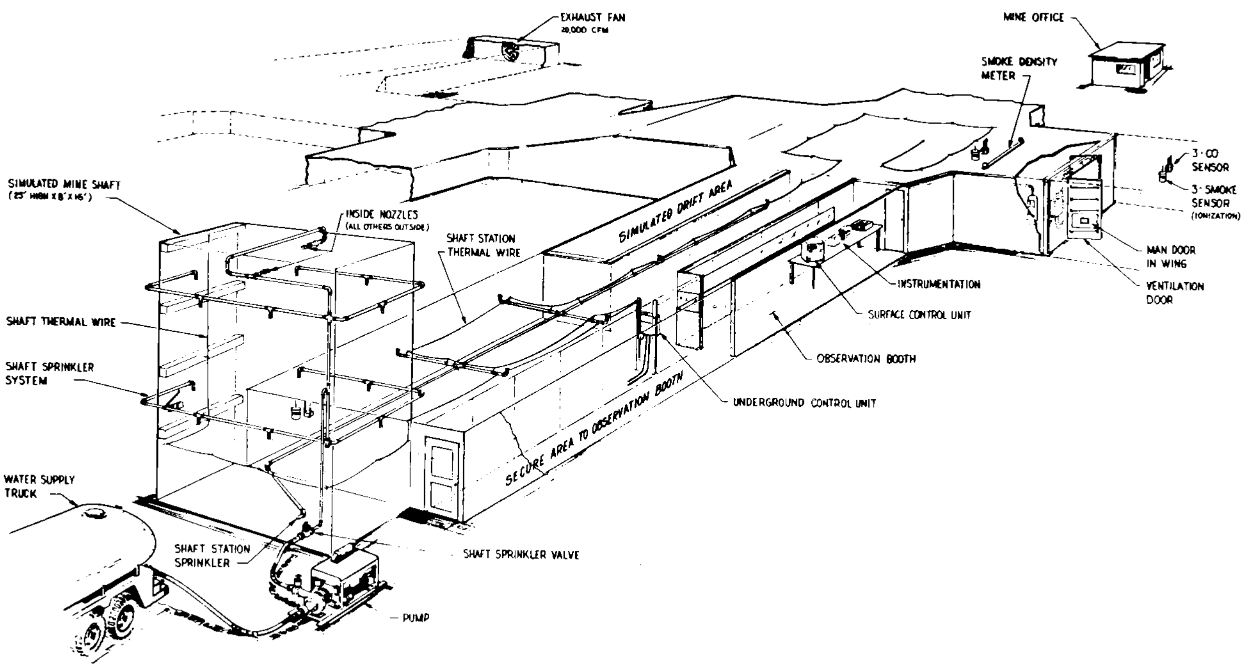

FIGURE 3. - Shaft and shaft station mockup.

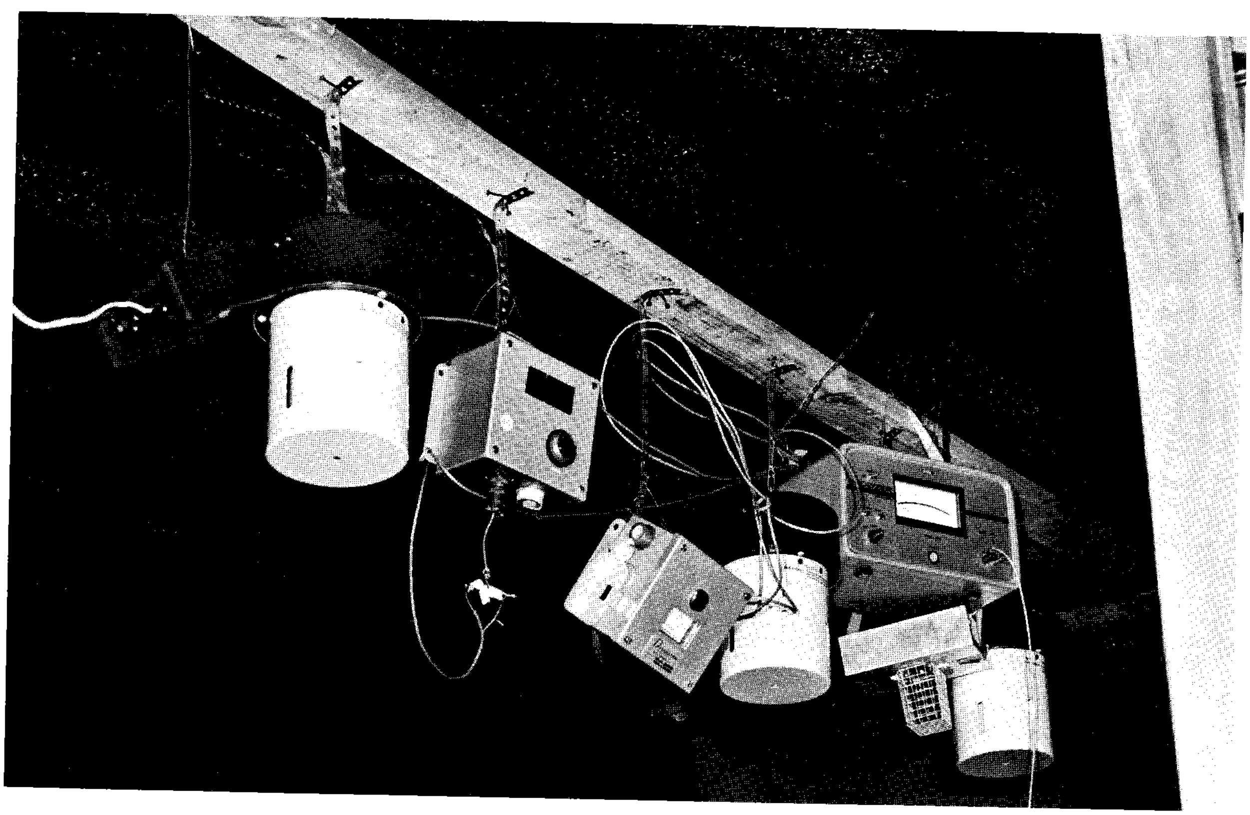

FIGURE 4. - Sensors tested for use in shaft fire system.

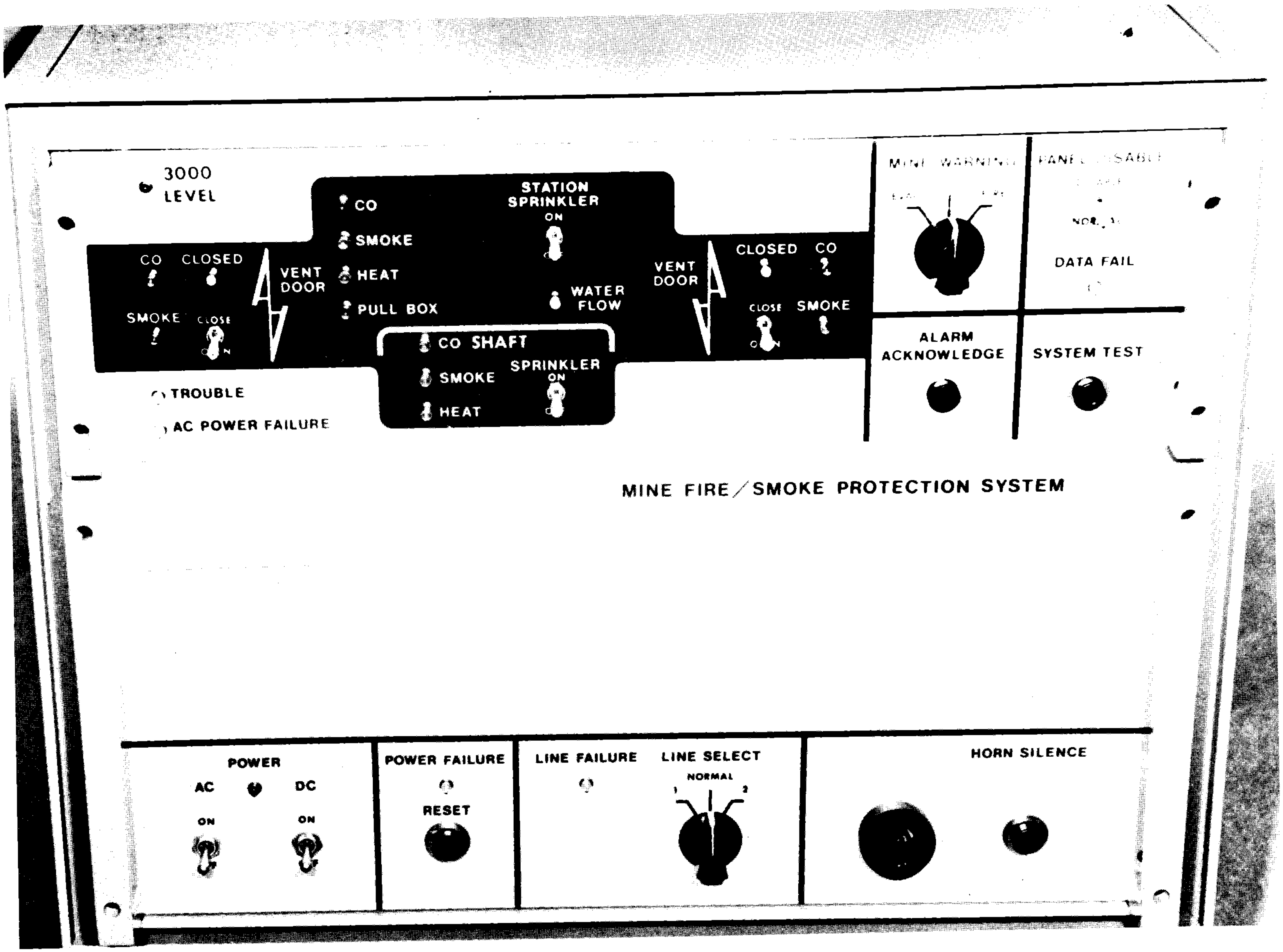

FIGURE 5. - Surface control unit.

FIGURE 6. - Underground control unit.

FIGURE 7. - Mine shaft fire and smoke protection system, surface control unit.

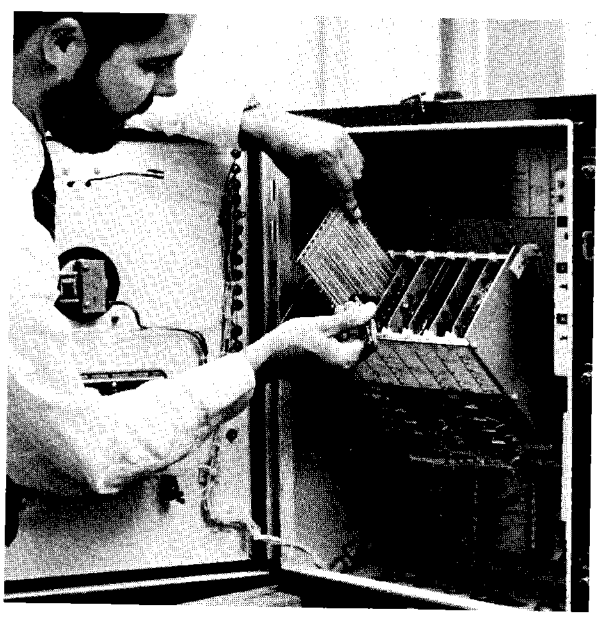

FIGURE 8. - Underground control unit interior.

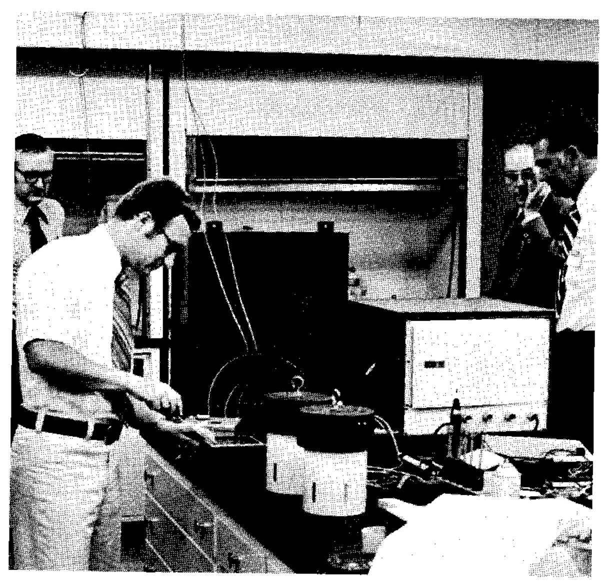

FIGURE 9. - Becon Mk II smoke sensors and CO fire detectors.

INMINE FIRE TESTING

After the mockup testing, the final design for the first mine shaft fire and smoke protection system prototype was developed. Figure 10 is a schematic of this system as it was to be installed in the 3000 level of Consolidated Silver Corp.'s Silver Summit shaft near Wallace, Idaho. The Hecla Mining Co. operates the facility. To maintain timeliness of this preliminary test of the first-generation hardware, the north drift sprinklers and smoke door and the bottom half of the shaft sprinklers were not installed.

The first inmine testing of the system took place at Silver Summit in April 1975. The hardware was successfully demonstrated to Bureau, MESA, and Hecla personnel by actual inmine fire testing; figures 11 through 16 depict the inmine fire test.

Followup work was then conducted to (1) reinstall the mine shaft fire and smoke protection prototype system in two underground locations for long-term reliability testing, and (2) conduct cost-effectiveness evaluations of optional system designs and uses. In this program a second-generation system was tested at Union Carbide's Pine Creek mine, Bishop, Calif., in the summer of 1976 (fig. 17). This followup helped to analyze the viability of the system and demonstrate how it can be modified for other underground fire protection situations.

Volume 1 of FMC's final report, "Mine Shaft Fire and Smoke Protection System--Design and Demonstration," is now available.[2] The followup work will produce a "Mine Shaft Fire and Smoke Protection System Selection and User Manual" in 1977.

[2] BuMines Open File Rept. 24-77, 1975, 407 pp.; available for consultation at the Bureau of Mines libraries in Denver, Colo., Twin Cities, Minn., Bruceton, Pa., Pittsburgh, Pa., and Spokane, Wash., at the Energy Research and Development Administration library in Morgantown, W. Va., and at the National Library of Natural Resources, U.S. Department of the Interior, Washington, D.C.; sold by the National Technical Information Service, Springfield, Va., as PB 263 577/AS, $11 paper, $3 microfiche.

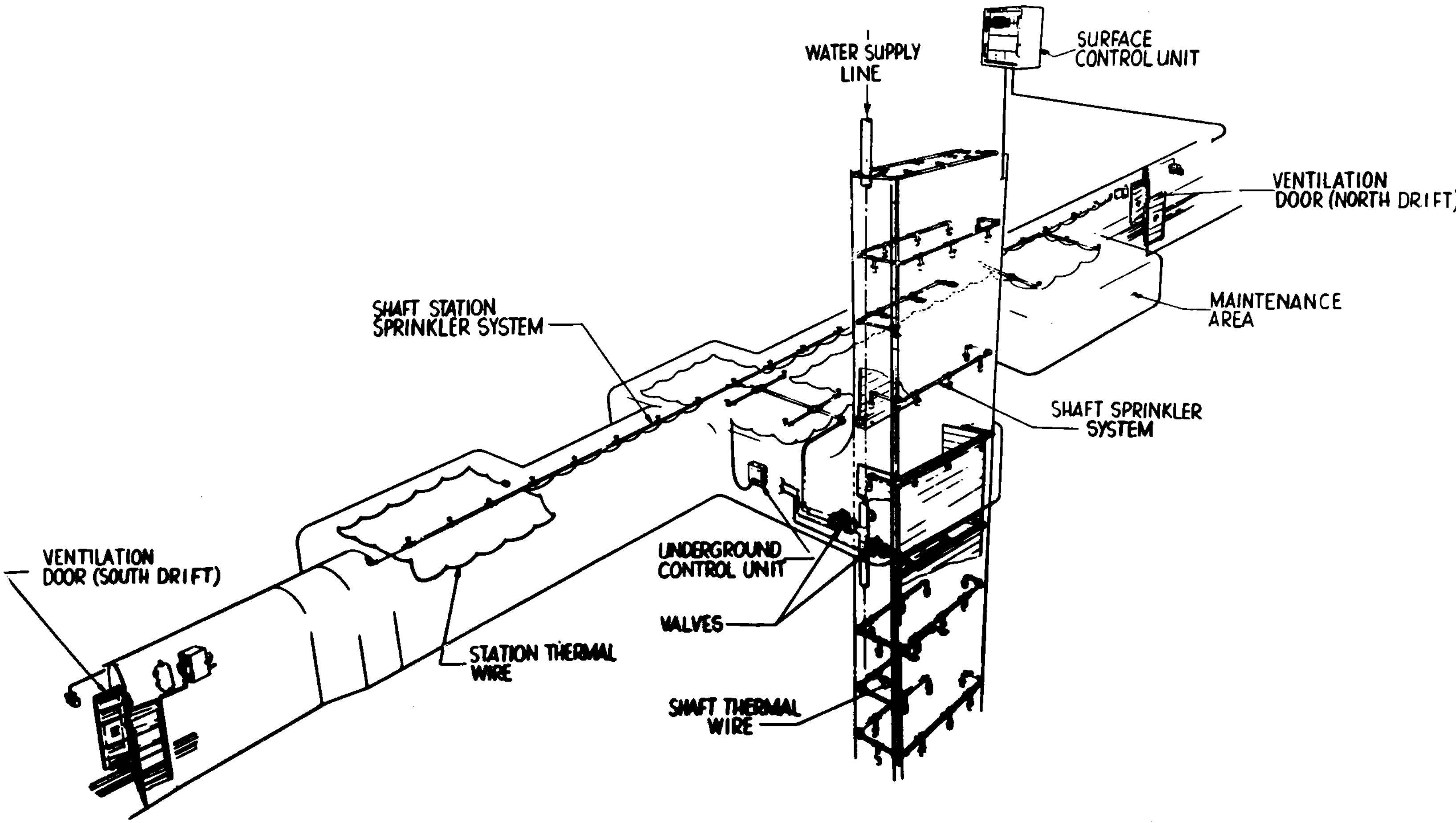

FIGURE 10. - Design of the system.

FIGURE 11. - Lighting the underground fire test.

FIGURE 12. - Fire test burning.

FIGURE 13. - Smoke from the inmine fire test.

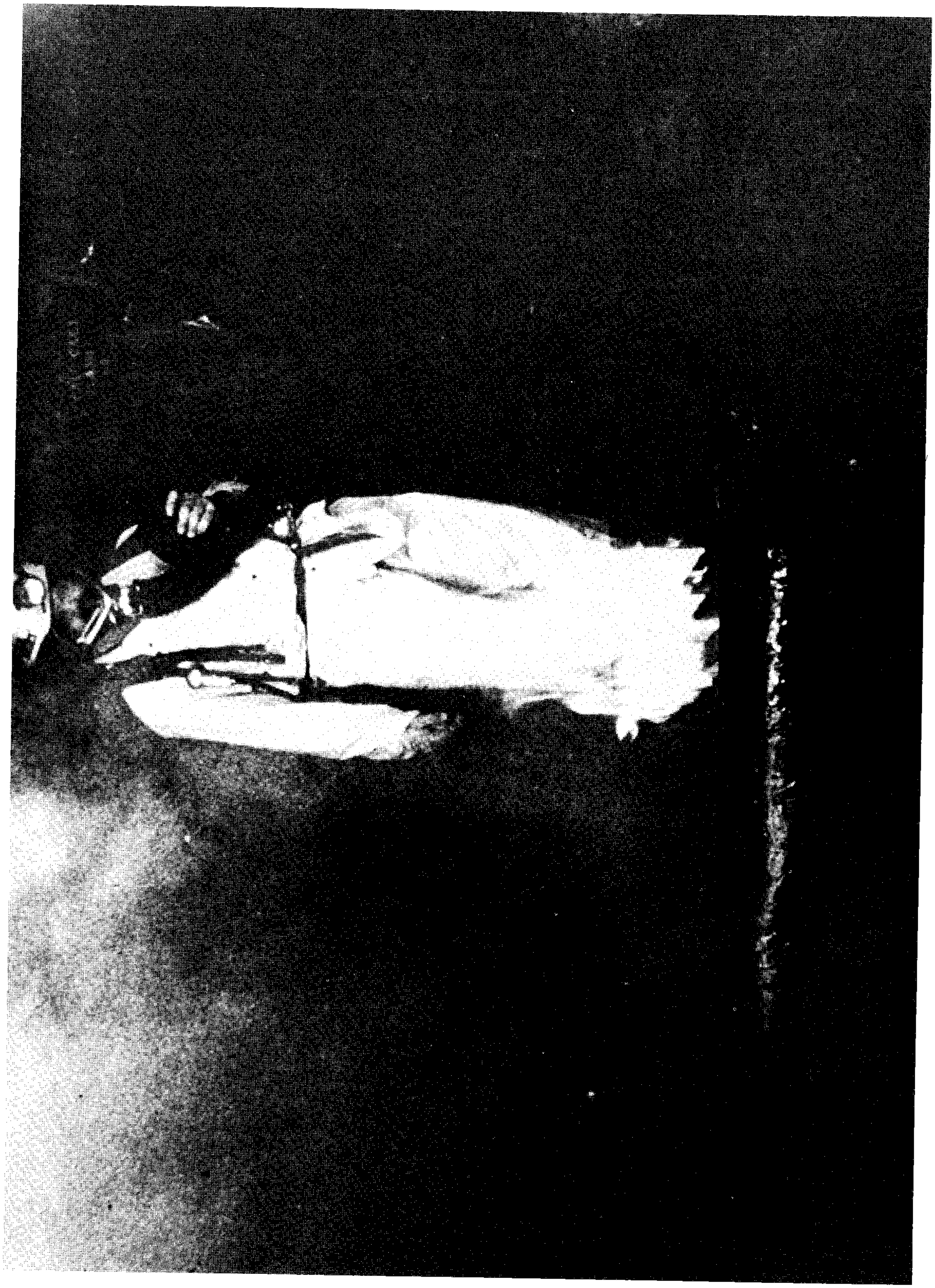

FIGURE 14. - Flames from the test.

FIGURE 15. - Fire being extinguished by the remotely controlled sprinkler system.

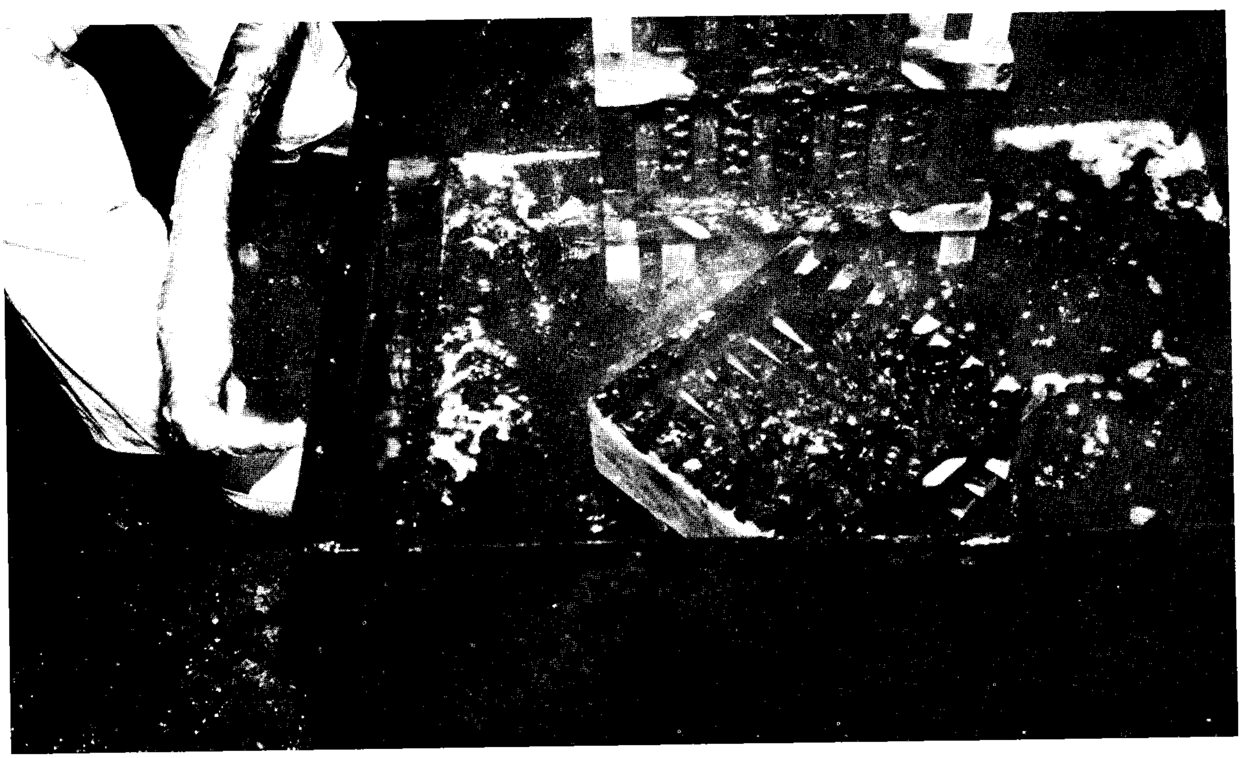

FIGURE 16. - Underground fire successfully extinguished.

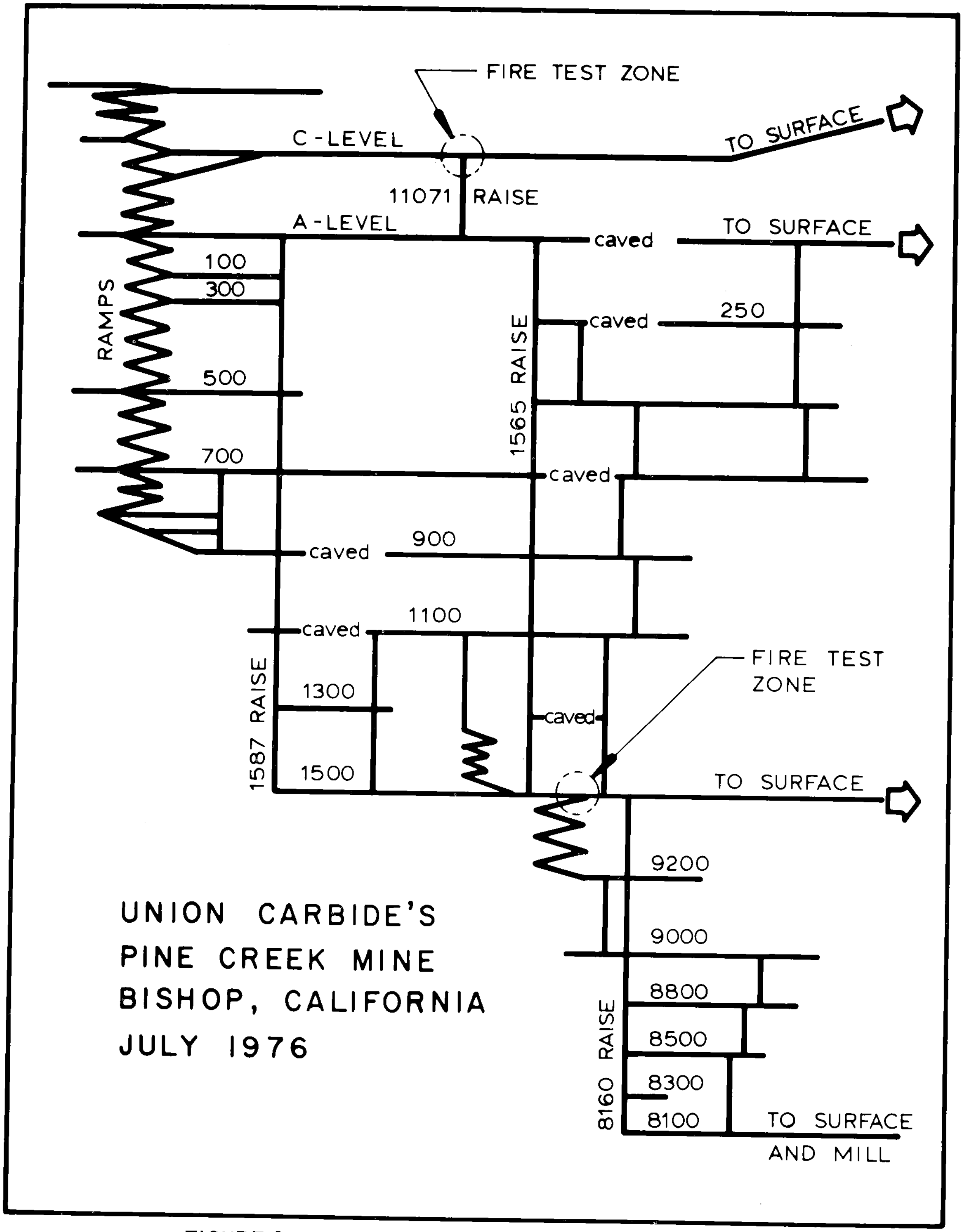

FIGURE 17. - Installation of the second-generation system.

ADVANTAGES AND COST OF THE SYSTEM

The mine shaft fire and smoke protection system has a very fast response to fire situations. Also, having sprinklers in the shaft and shaft station areas is much more effective in extinguishing fires than the commonly used shaft-collar water ring. The cost of the system is estimated to be $10,000 to $40,000 per shaft station level, depending on the sophistication desired in the system. This is a large investment, but compared with the millions of dollars a shaft can cost and the increased protection provided the miner, the system is a significant contribution to the improved safety of underground mines.

SUMMARY

This project involved efforts by FMC and the Bureau to define the mine shaft fire and smoke hazard problem, and then to design, fabricate, and inmine-test prototype hardware for a system that better protects miners and the mine than the shaft-collar rings now commonly used. The resulting mine shaft fire and smoke protection system involve both thermal and smoke detectors, remotely controlled smoke doors at the shaft station, and remotely controlled sprinklers. The system was successfully demonstrated by actual fire tests in the Silver Summit shaft near Wallace, Idaho, in the spring of 1975, and in Union Carbide's Pine Creek mine, Bishop, Calif., in the summer of 1976. Long-term, inmine testing of alternative system designs showed that the system is a reasonably priced, reliable piece of improved mining health and safety hardware.

FIRE PROTECTION FOR MINE CONVEYORS

by

Joseph M. Kuchta[1]

ABSTRACT

This report briefly summarizes fire protection requirements for coal mine conveyor belts and some pertinent Bureau inhouse and contract research in which conveyor belts and fire suppression systems were evaluated under moderately large or full-scale fire conditions.

INTRODUCTION

Conveyor belt fires are usually caused by excessive frictional heating in belt head areas and can present a serious hazard in the confined environment of an underground mine, depending upon what safety measures have or have not been implemented. Such measures include the use of "approved" fire-resistant belts and fire protection systems, as required for underground coal mines by the Code of Federal Regulations--Title 30, Sections 75.1101 and 75.1108 (Schedule 2G); similar requirements for metal and nonmetal mines have not been adopted to date. Any dependable fire protection system should provide adequate means of fire detection, extinguishant dispersion, and fire extinguishment. To avoid misleading results because of scaling effects, such systems should be evaluated under conditions that simulate a realistic fire environment.

FIRE RESISTANCE OF CONVEYOR BELTS

Fire resistance is a relative measure of the ability of a material to resist ignition and the spread of flame and can be expected to vary with such physical variables as material dimensions, space dimensions, ignitor heat flux, air velocity, and burning orientation. The ventilation conditions in conveyor belt haulageways are generally neutral; actual airflow requirements will depend upon how much methane is being released. In the Federal Schedule 2G test, the fire resistance of coal mine conveyor belts is determined under laboratory-scale conditions; 1/2- by 6-inch specimens are ignited in a 21-inch cubical chamber with a bunsen burner flame, and the duration of flame or glowing combustion is noted at an air velocity of 300 ft/min. Current research is underway to update this test method because the fire resistance requirements are not sufficiently conservative, as shown below by data from larger scale testing.

[1]Supervisory research chemist, Pittsburgh Mining and Safety Research Center, Bureau of Mines, Pittsburgh, Pa.

BUREAU LARGE-SCALE FIRE TESTS

Fire-resistant-type conveyor belts include those made with neoprene, polyvinyl chloride (PVC), styrene butadiene (SER), and combinations with natural rubber. Their carcass is generally made of nylon, rayon, cotton, or a combination of these fabrics and can be the determining flammability factor in the case of used belts.

Results of a 1967 Bureau investigation[2] are indicative of how much the fire resistance of conveyor belts can vary in small-scale and large-scale fire tests under different ignition conditions. Table 1 summarizes some of the flame propagation data obtained in a 4-foot-diameter gallery with four conveyor belts, three of which were fire resistant by the Schedule 2G test; belt width was 2-1/2 or 3-1/2 feet in most trials. These moderately large-scale data show that even "approved" PVC and neoprene belts can ignite and propagate flame when exposed to flame under certain heating and ventilating conditions. Here, flame propagation was attained when the flame ignition source (4,200 Btu/min) was supplemented with a thermal radiation source (~1,300 Btu/min) and the airflow was increased from "zero" to 200 ft/min, above which the flow effect was small. Neoprene belts were the most difficult to ignite, but their propagation rates did not differ greatly from those for PVC belting, ≤3.5 ft/min; highest rates occurred with the non-fire-resistant rubber, particularly when the carcass was removed. Such variables as belt preheating, belt width, and coal dust and grease accumulations generally increase the fire hazard. The ability of these belt materials to sustain flame propagation was also demonstrated in full-scale fire tests in the Bureau's Experimental Mine.

TABLE 1. - Fire resistance of conveyor belts in 4-foot-diameter gallery under various airflow and ignition conditions[1]

(Belt dimensions--15 by ≤3-1/2 feet)

Air velocity, ft/min	Flame propagation rate, ft/min[2]			
	Rubber	Neoprene[3]	Neoprene[3] impregnated	PVC[3] impregnated
PREHEATING PLUS PROPANE BURNERS (4,200 BTU/MIN) PLUS RADIANT HEATER (~1,300 BTU/MIN)				
~0	NP	NP	NP	NP
200	7.6	2.1	3.5	3.5
500	9.8	1.8	2.1	2.7
PROPANE BURNER (4,200 BTU/MIN) PLUS RADIANT HEATER (~1,300 BTU/MIN)				
~0	NP	NP	NP	NP
200	4.0	1.1	3.0	3.2
500	5.6	1.2	3.3	2.0
PROPANE BURNERS (4,200 BTU/MIN)				
~0	NP	NP	NP	NP
200	NP	NP	NP	NP
500	NP	NP	NP	NP

[1]BuMines data from reference cited in footnote 2.
[2]NP indicates no propagation.
[3]Fire resistant according to Schedule 2G.

---

[2]Mitchell, D. W., E. M. Murphy, A. F. Smith, and S. F. Pollack. Fire Hazard of Conveyor Belts. BuMines RI 7053, 1967, 14 pp.

WALTER KIDDE LARGE-SCALE FIRE TESTS

Results of a recently completed Bureau contract[3] with Walter Kidde & Co. provide further evidence of the inadequacy of laboratory-scale fire tests. In this work, full-scale fire and suppression tests were conducted in a 6- by 15- by 175-foot simulated belt haulageway using a flame source (3,500 Btu/min) and radiation source (~8,500 Btu/min) for igniting the belts; the fire suppression tests are described in the next section of this report. Figure 1 is a line diagram of the experimental setup used in these tests.

The results of this contract study confirmed many of the trends observed in the Bureau's inhouse work, including the greater ease of ignition with belt preheating and great effect of flow conditions. Table 2[4] lists flame propagation rates that were calculated from the reported data of this work for 10 of the conveyor belts evaluated. Again, it is seen that some Schedule 2G "approved" belts sustained propagation in large-scale fires under moderately high flow conditions. Of particular interest are the data for the new PVC-3 belt, which gave the highest propagation rates of all the belts tested. This material had propagation rates of 5 and 6.5 ft/min at air velocities of 125 and 350 ft/min, respectively, compared with only 0.8 ft/min at neutral airflow; these were obtained with a mineral oil coating. As noted

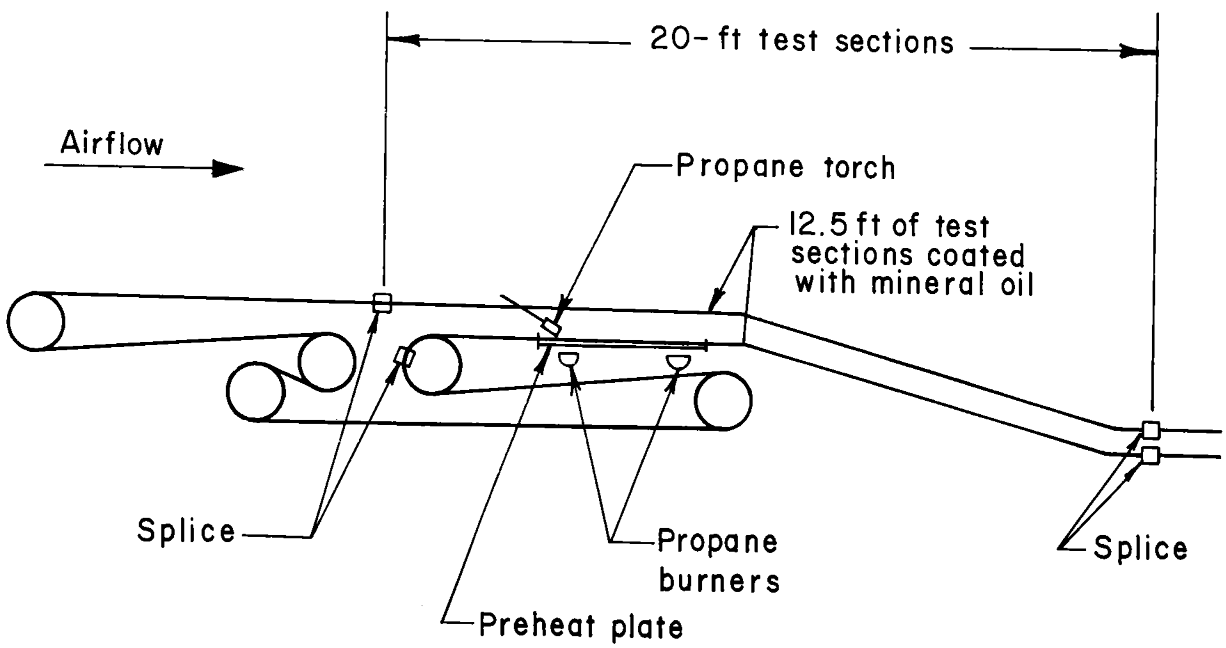

FIGURE 1. - Schematic of Walter Kidde test gallery setup for conveyor belt fires.

[3]Warner, B. L. Suppression of Fires on Underground Coal Mine Conveyor Belts. Walter Kidde & Co., Inc., BuMines Contract H0122086, Final Report, Sept. 13, 1974, 79 pp.

[4]Specific trade names are given in this report to facilitate understanding and do not imply endorsement by the Bureau of Mines.

in table 2, flame propagation is generally enhanced by belt coatings of mineral oil and/or coal dust; however, coal dust itself tends to retard ignition. Also, new belts appeared to give higher propagation rates than used belts of the same make, but belt thickness was not the same in all such comparisons.

TABLE 2. - Fire resistance of conveyor belts in 6- by 15- by 175-foot gallery at various conditions[1]

(Belt dimensions--20 by 2-1/2 feet; total ignitor heat input--11,500 Btu/min)

Belt material	Flame propagation rate, ft/min[2]		
	125 ft/min airflow	200 ft/min airflow	≥350 ft/min airflow
Fire-resistant belts[3];			
Neoprene-1 (used), B. F. Goodrich, Caricoal	-	-	NP
Neoprene-2 (used), Acme Hamilton, Pyroprene	-	NP (0.15)	NP
Rubber (used), Republic Rubber	-	- (NP)	-
SBR-1 (new), Bridgestone, Nycon	-	0.4	-
SBR-2 (new), Goodyear, Glide 220	(0.25)	0.6	-
PVC-1 (new), B. F. Goodrich, Koroseal	(1.8), 0.8	0.65	-
PVC-2 (used), B. F. Goodrich, Koroseal	(0.25)	NP (0.6)	-
PVC-3 (new), Scandura, Gold Line	(5.0)	0.9	(6.5)
PVC-4 (used), Scandura, Gold Line	(0.4)	-	-
Non-fire-resistant belt; rubber (new), B. F. Goodrich, Medium Longlife	(1.4), 1.9	-	-

\- indicates no data.

[1]Calculated from data of reference cited in footnote 3.

[2]NP indicates no propagation; values in parentheses obtained with mineral oil and/or coal dust on belts.

[3]Fire resistant according to Schedule 2G.

The PVC-3 belt material produced the most intense fires in the gallery full-scale tests. As shown by the temperature profiles in figure 2, the maximum roof temperatures exceeded 1,000° F and these occurred near the area of ignition where the initial 5 feet of belt was preheated. With a mineral oil coating, the PVC-3 belt fires propagated over the entire belt test section (20 feet) in as little as 3 minutes after ignition with a 350-ft/min airflow, and within 25 minutes with the neutral flow condition. Although the fires are spread more rapidly with increasing air velocity, one can expect ignition itself to be increasingly more difficult because of flame instability and convective heat loss.

Schedule 2G results for conveyor belts are less conservative than those from large-scale fire tests because the laboratory-scale method utilizes marginal heat source conditions for ignition and the belt dimensions are not optimum for sustaining flame propagation. Furthermore, the specified air ventilation rate (300 ft/min) for the small-scale fires can result in

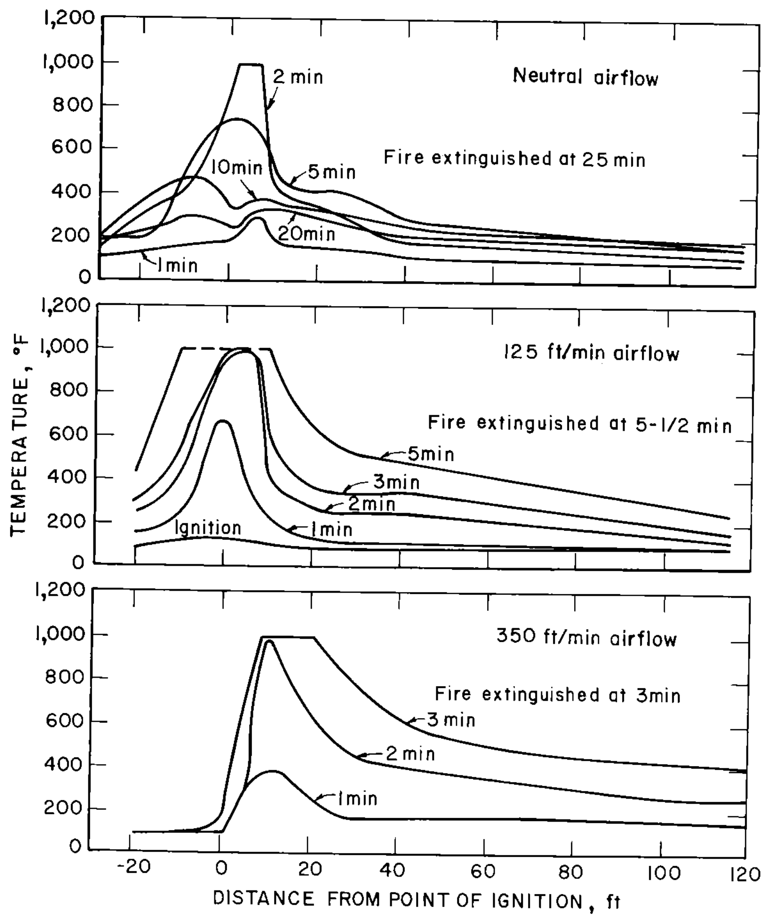

FIGURE 2. - Gallery roof temperature profiles for PVC-3 conveyor belt fires under three flow conditions.

flame "blowout" in some cases. Such deficiencies, as well as the lack of quantitative fire resistance ratings, need to be rectified to make the approval test more reliable and useful.

SUPPRESSION OF CONVEYOR BELT FIRES

Present coal mining regulations (CFR-75.1101) require that suitable automatic fire-extinguishing systems be installed at main and secondary belt-conveyor drives and provide protection over a belt distance of at least 50 feet. The requirements specified for an automatic water sprinkler or deluge-type system include an application rate of not less than 0.25 gal/min/ft^2 on the upper surface of the top belt, adequate coverage between top and bottom belts, a maximum spacing of 8 feet for spray nozzles or sprinklers along branch lines, and a sufficient water supply to provide a 10-minute flow. Foam and dry-powder chemical systems may also be used if they can provide the minimum fire protection requirements defined in the above regulations. The foam-generating system must be able to produce and deliver the required amounts of foam within 5 minutes, provide full envelopment of the belt head areas and adjacent belting up to 50 feet, and maintain the water or foam flow for at least 25 minutes. Each dry-powder system that is required must contain a minimum of 125 pounds of multipurpose dry powder and be capable of discharging all the powder within 1 minute. Only extinguishing agents that would not create a serious toxic hazard to the miner are acceptable. As a backup system, waterlines are required along the entire length of the conveyor belts with fire hose outlets at 300-foot intervals and with a capability of discharging 50 gallons of water per minute at 50-psig nozzle pressure. Where applicable, the regulations incorporate National Fire Protection Association recommendations for the installation of fire control components; namely, those approved by the Underwriter's Laboratories or Factory Mutual Research Corp.

The mining regulations for conveyor belt fire suppression systems are necessarily based upon simulated full-scale studies and practical experience. An evaluation of the existing regulations for water sprinkler, high-expansion foam, and multipurpose dry-powder systems was conducted under the Walter Kidde contract sponsored by the Bureau; fire detection systems were also evaluated and are discussed later. Water deluge systems were not evaluated since the criteria for water sprinkler systems would also apply to them. The experiments were conducted in the previously described fire test gallery using the same simulated belt haulageway (fig. 1) and ignitor conditions as in the fire resistance tests; air velocity was 125 or 350 ft/min in most trials. The test fires were produced by burning the polyvinyl chloride (PVC-3) or non-fire-resistant rubber belting listed in table 2.

AUTOMATIC WATER SPRINKLERS

The sprinkler system in the gallery consisted of a 2-inch main at the roof with 1/2-inch branches which were fitted with sprinkler heads and spaced at intervals of 8, 10, 12, and 15 feet over the conveyor belt. Each sprinkler head was equipped with a fusible link that was actuated at 165°, 212°, or 280° F. Figures 3 and 4 show a typical conveyor belt fire before and shortly after actuation of the sprinkler system with 10-foot spacing of the sprinkler heads; here the air velocity was 350 ft/min and extinguishment occurred within approximately 15 minutes. Sprinkler spacing appears to be one of the most critical variables in determining the system effectiveness.

Test results indicated that a single overhead branch line with 1/2-inch-orifice sprinklers located on 10-foot centers and with actuation temperatures between 200° and 300° F can be adequate for suppressing conveyor belt fires in most situations; also, the residual water pressure may be as low as 10 psig. An exception to these results is observed at high air velocities (350 ft/min),which tend to delay sprinkler actuation because of the cooling effect. To cover such situations, it appears that the actuation temperature should be no higher than 225° F or the sprinkler spacing should be no greater than 8 feet, the maximum distance specified in the present regulations. The lowest practical actuation temperature should be used since it is more difficult to extinguish fully developed fires.

In these experiments, the fires were controlled with a spray application rate of 0.72 gal/min/ft^2 on the top surface of a 30-inch-wide belt. This rate would correspond to 0.36 gal/min/ft^2 for a 60-inch-wide belt, which meets the minimum spray requirement ($\geq$0.25 gal/min/ft^2) in the mining regulations for the upper surface of a top belt. Although only overhead sprinkler heads appeared to be necessary in these tests, previous Bureau work[5] demonstrated the need for sprinklers between belts, which are therefore also required in existing regulations.

Automatic sprinkler systems are advantageous because of economy, reliability, good suppression capability, moderate water requirements, and minimum maintenance requirements. Also, they are not dependent upon a separate

---

[5]Work cited in footnote 2.

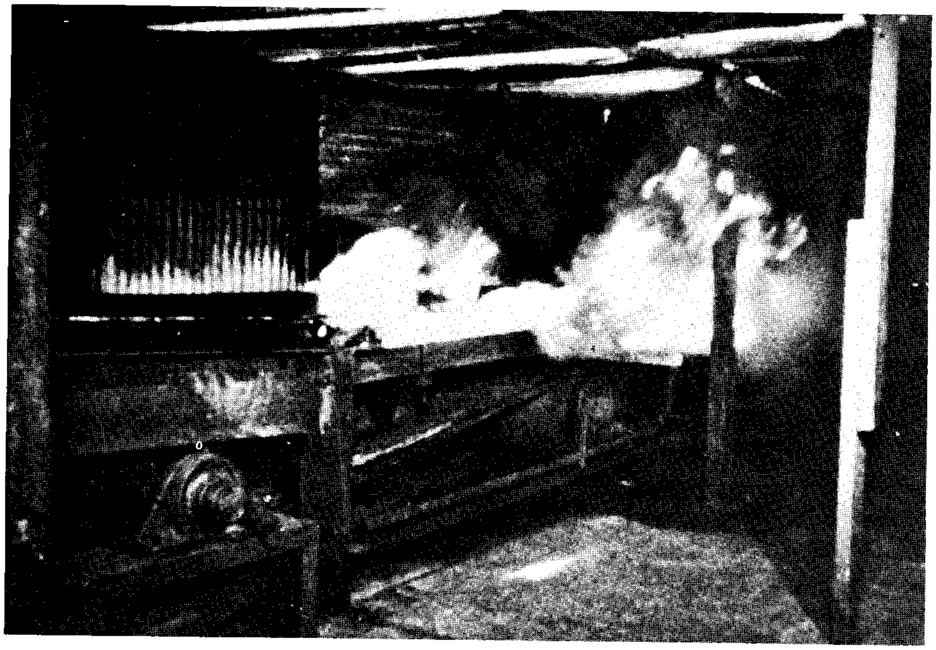

FIGURE 3. - PVC-3 conveyor belt fire prior to actuation of automatic sprinkler system (air velocity—350 ft/min).

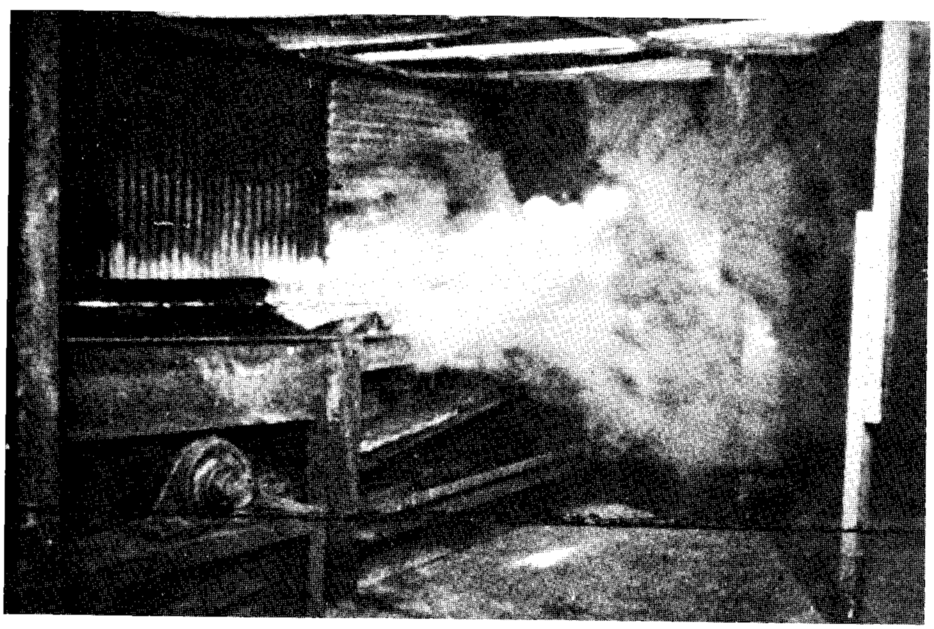

FIGURE 4. - Action of automatic sprinkler system in PVC-3 conveyor belt fire at 350-ft/min air velocity.

detection system, and the independent actuation of each sprinkler head provides a safeguard against the failure of a given sprinkler. Their primary disadvantage is that they are not practical at freezing temperatures.

HIGH-EXPANSION FOAM

A foam generator with a rated capacity of 5,000 ft^3/min was used to produce high-expansion foam (~1000:1) for the fire suppression tests (fig. 5). The unit was located on the air intake side and was capable of filling approximately 50 feet of the simulated haulageway (6 by 15 feet) within 1 minute. Actuation time for the foam system was generally set for 2 minutes after ignition.

High-expansion foam is highly effective for extinguishing belt-head fires, as evidenced by its performance in the present tests where the fires were rapidly quenched after they became enveloped by the foam. A foam generation rate of 10 ft/min in a belt haulageway appears to be sufficient for extinguishment of such fires, although the effect of preburn time was not evaluated;

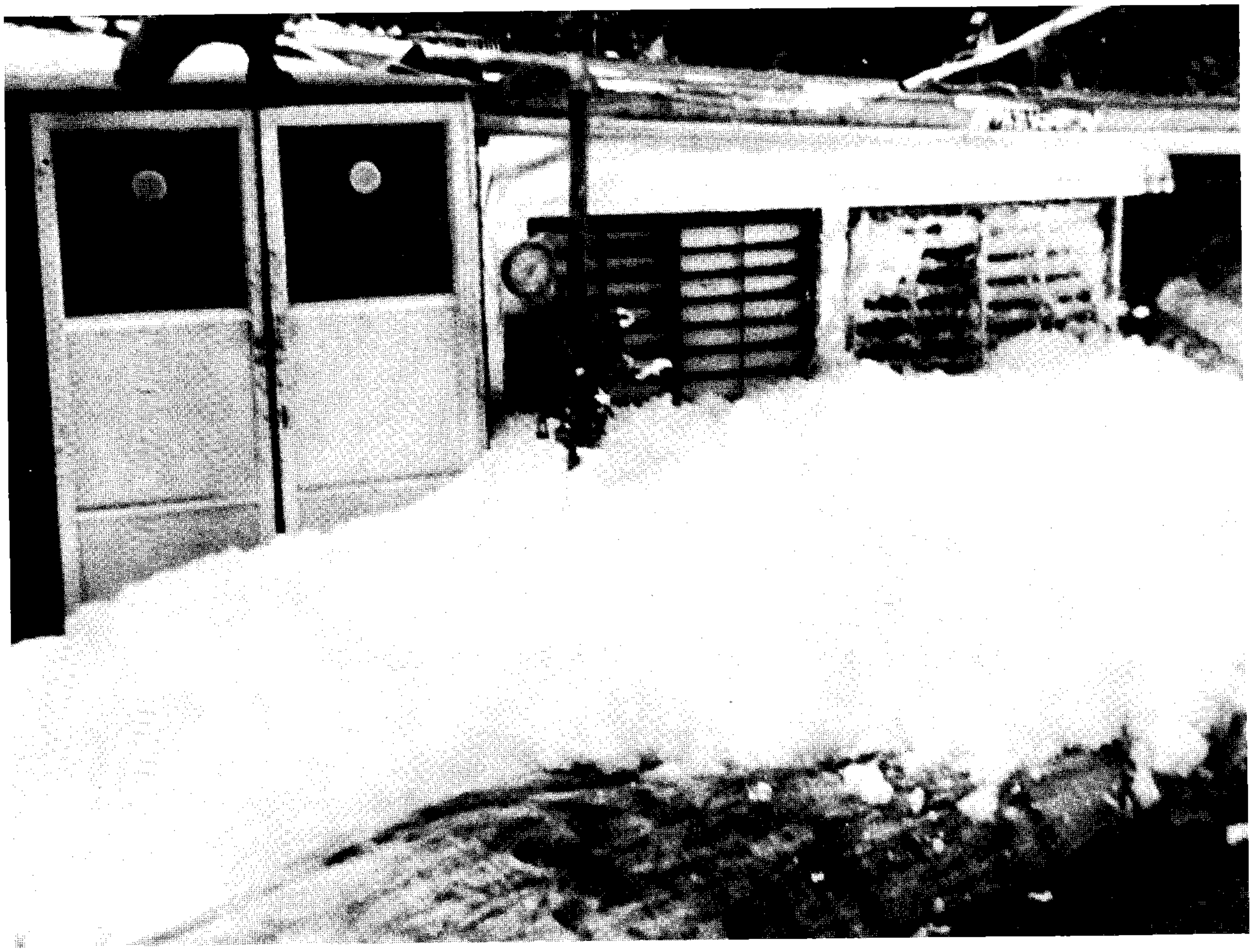

FIGURE 5. - High-expansion foam overflowing from test gallery.

adequate protection seems to be possible with as little as 50 to 100 gallons of water. Since higher rates than 10 ft/min are readily achieved, the regulation requirement of enveloping 50 feet of conveyor belting within 5 minutes is not unreasonable. Also, if the 25-minute operation requirement is satisfied, this provides increased belt coverage and greater assurance of extinguishment.

The main advantages of the foam system are rapid fire suppression and low water requirements. The disadvantages include slow delivery rate, increased maintenance requirements, and potential development of gaps at the roof of the haulageway because of ventilation restrictions, particularly at high air velocities (350 ft/min).

MULTIPURPOSE DRY POWDER

The dry-powder system utilized an ABC multipurpose powder (monoammonium phosphate) that was contained in a 150-pound extinguisher pressurized to 350 psig. The system provided coverage for 50 feet and consisted of branches on either side of the belt drive and takeup sections (fig. 1) and along one side of adjacent belting beyond the takeup assembly. Nozzles were arranged to provide a powder discharge onto the top surface of the top belt and between the top and bottom belt layers. To simulate worst-case conditions, the belt fire was allowed to progress until a belt layer had burned through and separated. Figures 6 and 7 show a belt test fire before and shortly after actuation of the extinquishing system with 50 pounds of powder and an air velocity of 350 ft/min.

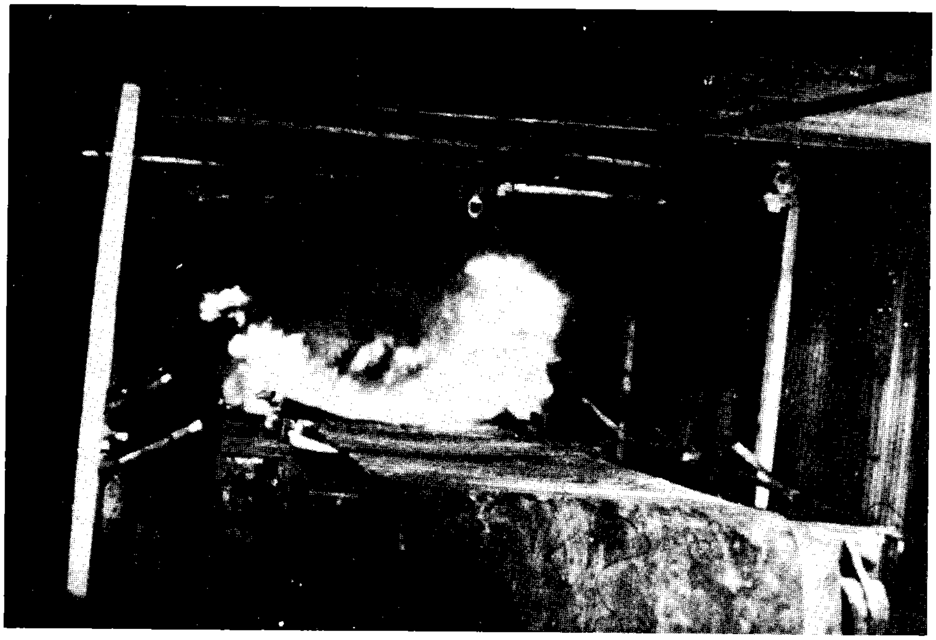

FIGURE 6. - PVC-3 conveyor belt fire prior to actuation of multipurpose dry powder (ABC) extinguishing system (air velocity—350 ft/min).

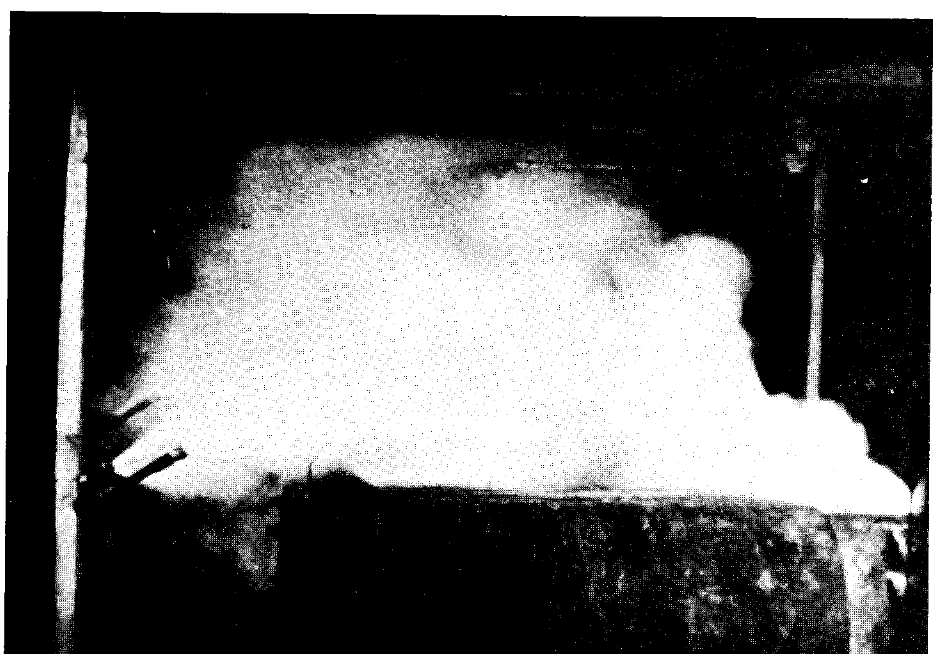

FIGURE 7. - Action of dry powder (ABC) extinguishing system in PVC-3 conveyor belt fire at 350-ft/min air velocity.

As with high-expansion foam, extinguishment with the dry-powder system is rapid. Generally, extinguishment occurred within the discharge time, which was less than 1 minute as required by regulation. The most important design consideration is powder distribution to insure adequate belt surface coverage. All belt fires, except those involving decking on the conveyors, were extinguished with 75 pounds of powder or less, indicating that the currently specified requirements in the regulations are satisfactory. Each dry-powder system should be individually designed to provide the proper dispersion and distribution of agent along the conveyor belt system and to overcome any limitations due to shielding by decking, conveyor structure members, or other obstacles.

The advantages of the dry-powder system are primarily its suppression effectiveness and capability for low-temperature applications. Its disadvantages include powder distribution problems, increased maintenance requirements, and potential reignitions because of little cooling capability.

FIRE DETECTION SYSTEMS

Regulations (CFR-75.1103) require that a fire sensor system be installed on each coal mine belt conveyor that will stop the belt drive and provide an automatic warning, both audible and visual, when a belt fire occurs. Point temperature rise sensors are one recommended type; they must be installed at the beginning and end of each belt flight, at the belt drive, and in maximum increments of 125 feet along each belt flight (50 feet where the ventilation rate is >100 ft/min). Sensors responding to ultraviolet (UV) and infrared (IR) radiation, smoke, combustion product gases, or other indications of fire may also be used if they are spaced at proper intervals and provide protection equivalent to that of thermal point-type sensors. Where applicable, appropriate measures must be taken to protect against loss of effectiveness due to dust, dirt, or moisture.

Of the various types of fire detectors examined in the Walter Kidde program, the thermal point and thermal continuous types were found to be most suitable for the mine conveyor belt application. Most are adequately sensitive for early fire detection and sufficiently durable to withstand the mine environment; also, they are relatively economical and simple to use. For belt fires with temperature histories as shown in figure 2, detection by the thermal point-type sensors can be expected to occur within 2 to 4 minutes; the models having a rating in the 135° to 160° F range appeared to be adequate for detector spacings up to 60 feet. The thermal continuous-type sensors are somewhat more sensitive and can be suitable at higher temperature ratings for signaling an alarm.

Products-of-combustion-type detectors are less practical than the thermal type because of their vulnerability to dust. Both ionization and photoelectric types displayed high sensitivity to early fire products but did not perform reliably in dust-laden air such as that possible from rock-dusting operations. Smoke or combustion products from areas other than the belt haulageways could also lead to false actuations of the extinguishing system with these detectors; the same limitation applies to carbon monoxide detectors.

Spacings requirements for such detectors would necessarily depend upon the ventilation rate and the time within which the detector should operate.

Optical-type detectors also have rapid response capability, but their effective range appears to be too limited for the conveyor belt application. The normal settings of most UV and IR detectors would limit their use to about 20 feet, and this assumes no gross dust obscuration or shielding by any obstacles. Furthermore, the detectors must be insensitive to extraneous light sources, and the costs may be prohibitive.

CURRENT FIRE RESEARCH ON CONVEYOR BELTS

Because of the inadequacies of the Schedule 2B fire resistance test, the Bureau recently initiated research to assist MESA in updating this approval test for conveyor belts. As a part of this effort, full-scale fire tests are being conducted with various conveyor belts in a fire test gallery that was constructed for the Bureau by the Factory Mutual Research Corp.[6] Results from this test program are intended to provide necessary design data for developing a reliable, laboratory-scale fire resistance test.

Figure 8 is a photograph of the fire test gallery, which is T-shaped with each section measuring 8 by 8 by 150 feet and with part of one section having a 12-1/2° slope. The test belts are mounted on a conveyor-belt-type frame and ignited to simulate various mine fire conditions by varying the belt width, air velocity, burning angle, preheating time, ignitor heat flux, and coal dust-grease or oil accumulation. Both fire-resistant and non-fire-resistant belts are being investigated. Their fire resistance will be determined from measurements of flame spread rates, propagation distances, gallery temperatures, and the heat flux at various stations. Based upon the full-scale fire data, a laboratory-scale flame-spread-type apparatus will be designed to provide realistic fire resistance ratings for conveyor belts which can be correlated with mine fire situations. The test method is being designed to provide quantitative ratings and to discriminate between poorly, moderately, and highly fire-resistant materials. The Bureau is conducting the laboratory-scale study under an inhouse project (7B3) of its Fires and Explosions Group at Bruceton.

The toxic products formed by conveyor belts are also to be determined in the full-scale fire tests. This will include such gaseous products as HCl, NO_x, CO, and CO_2. These data will be compared to those obtained in laboratory-scale studies under an ongoing contract with Ultrasystems.[7]

[6] Factory Mutual Research Corp. Gallery Testing Related to Mine Timber Fires. BuMines Contract H0252085, 1975.

[7] Paciorek, K. L., R. H. Kratzer, J. Kaufman, and J. H. Nakahara. Coal Mine Combustion Products Identification and Analysis. Ultrasystems, Inc. BuMines Contract H0133004, Annual Reports, August 1973, 146 pp.; August 1975, 152 pp.

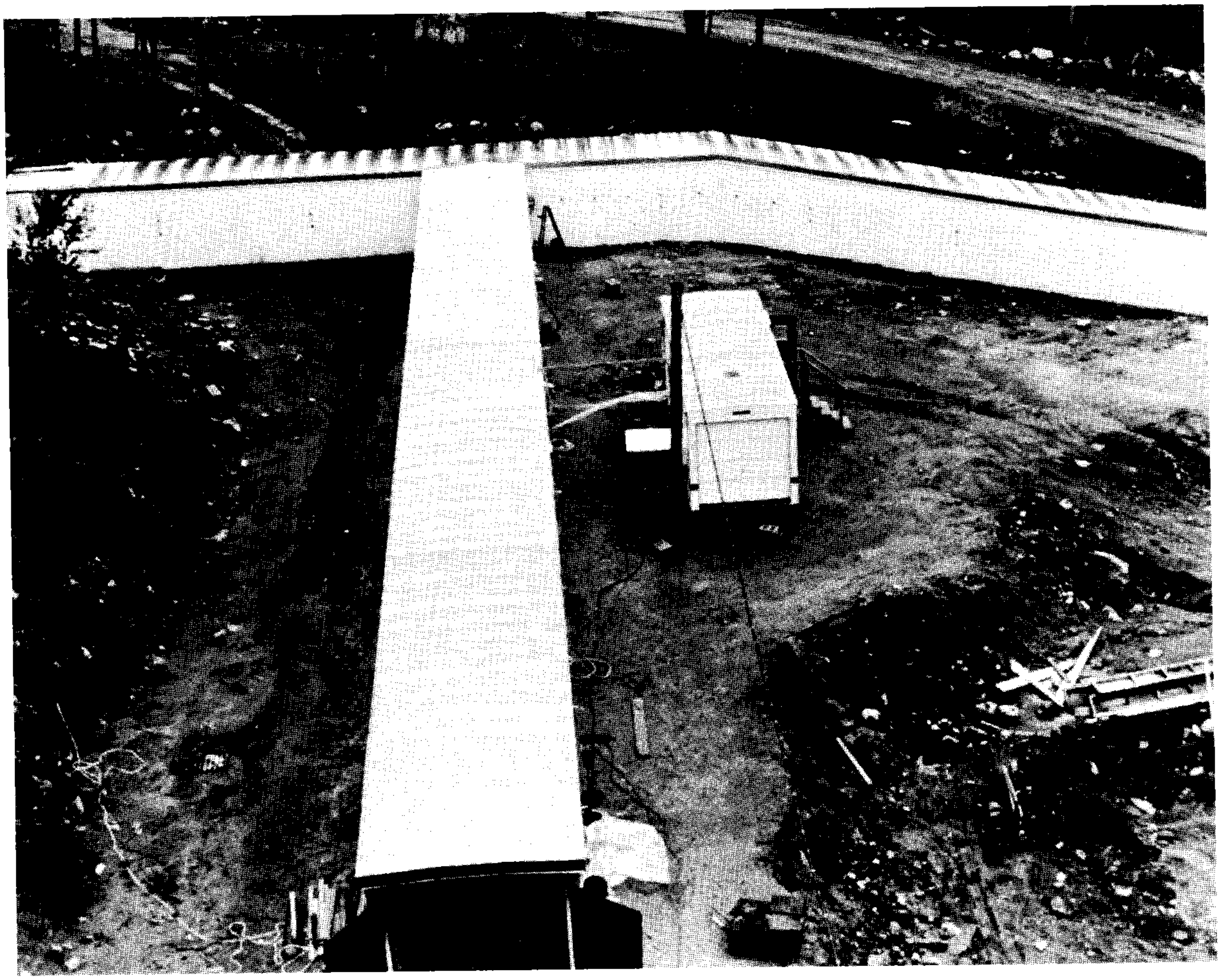

FIGURE 8. - New fire test gallery at Factory Mutual Research Corp. test site.

U.S. GOVERNMENT PRINTING OFFICE: 1977-703-001/95

INT.-BU.OF MINES,PGH.,PA. 22412