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MARCH 1983

DEMONSTRATION OF A MINE SHAFT FIRE AND SMOKE PROTECTION SYSTEM FOR COAL MINES

Contract H0100017
ESD Corporation

OFR 1985-116

BUREAU OF MINES
UNITED STATES DEPARTMENT OF THE INTERIOR

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16. Abstract (Limit: 200 words)

The goal of this 44-month contract was to increase the safety of workers in underground coal mines by developing and in-mine testing a low-cost, available, and flexible fire safety system to reduce the spread of fire and contaminated air in or near mine shafts. The contract detailed information on the magnitude of the hazard, industry acceptance of remote data acquisition systems, and alternative fire safety systems to meet four different mine profiles. A complete fire reporting system was designed, installed, and in-mine tested at a midwest underground coal mine from April 1980 to March 1983. The surface-located master control unit provided analog displays of real time sensor data and a printer graph-record of the last 24 hours of activity. Fire warning sensors included ionization particle sensors, electrochemical cell carbon monoxide (CO) analyzers, a solid state CO analyzer, and continuous heat sensitive wire sensors. Multiplex telemetry of data occurred on existing telephone lines and wireless radios from shafts up to a 5-mile distance. Four fire conditions occurred during in-mine testing that demonstrated the system's effectiveness. Evaluation of converting the system to meet MSHA approval is included.

17. Document Analysis a. Descriptors

Underground coal mining, fire protection systems, fire and smoke sensors, mine-wide monitoring system, multiplex telemetry, computer memory and display

b. Identifiers/Open-Ended Terms

Ionization fire sensor, electrochemical cell, metal-oxide semiconductor (Taguchi)

c. COSATI Field/Group

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FOREWORD

This report was prepared by ESD Corporation, San Jose, California, under U.S. Department of the Interior Bureau of Mines Contract H0100017. The contract was initiated under the Mining Health and Safety Technology Program. It was administered under the technical direction of the Twin Cities Research Center with Mr. Steven Sampson acting as Technical Project Officer. Ms. Janice Johnson was the contract administrator for the Bureau of Mines. This report is a summary of the work recently completed as a part of this contract during the period December 1979 through March 1983. This report was submitted by the author in March 1983.

Sincere thanks are extended to the many persons who participated in the investigation, data collection, system design, hardware supply, testing, and documentation throughout the contract.

Special recognition is extended to the mine companies which allowed visits and provided information regarding their operations, fire sensor performance, sensor maintenance, and underground-to-surface telephone and data transmission systems. The Peabody Coal Company and personnel at the Number 10 mine are especially thanked for their interest, assistance, and cooperation during in-mine testing and demonstrations. Our thanks go to Mine Manager Mr. Robert Danko and his competent staff, including Peter Vallar, Thomas Herman, Charles Crawford, Clete Harris, Alan Perks, Gary Smothers, and many others who contributed throughout the program. Thanks also to the support services of MSHA in Pittsburgh, Pennsylvania; Vincennes, Indiana; Benton and Hillsboro, Illinois; and to the Illinois Department of Mines and Minerals in Springfield. Sensor and installation review by MSHA inspectors Paris Webb and Jerry Collier is very much appreciated.

The still and motion photography during the in-mine demonstration was enthusiastically and professionally performed by Mr. James Siemens of WANO-TV, Decatur, to whom much of the photographic documentation is indebted.

The management of Aquatrol Corporation in St. Paul, Minnesota, and the technical expertise of Mr. William Cross, development engineer, are also recognized for excellent performance during data analysis, design, fabrication, installation and support of the surface control station and remote sending units.

Although the mine shaft fire and smoke protection system for coal mines was conceived and developed for laboratory and in-mine testing under USBM Contract H0100017 and several unique features are included that are not available in the general mining industry, no subject invention claims are being made by ESD. By definition, subject invention means any invention, discovery, improvement, or development (whether or not patentable) made in the performance of the experimental, developmental, or research work under this contract. Certain patent rights exist with several vendor-supplied components of the system.

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EXECUTIVE SUMMARY

INTRODUCTION

This final report presents a summary of activities performed under Bureau of Mines Contract H0100017, Demonstration of a Mine Shaft Fire and Smoke Protection System for Coal Mines. The objectives of the 44-month, four-phase program were to evaluate the underground coal mine shaft/shaft-station fire and smoke hazard, develop performance requirements for a prototype system to reduce this hazard, and demonstrate the prototype mine shaft fire and smoke protection system applicable to a majority of coal mine shafts, including inclines, especially in deep mines.

Complete documentation of the program consisted of three phase reports; a final report; a detailed, reproducible drawing package; MSHA variance; FCC license; radiation licenses from the NRC and California; 16mm movies of mine demonstrations; 35mm slides; photographs; a Selection and Use Manual; and a guide for potential users who wish to modify components for MSHA approval. The Selection and Use Manual, also published as a separate document, is a guide for the selection and proper use of a reliable, low-cost, coal shaft fire and smoke protection system. It also informs the reader of how a USBM prototype system will sense an impending hazard, issue a warning, and easily identify the location and magnitude of the alarm. Reader understanding will be enhanced with the use of small line illustrations to further describe the text material.

SUMMARY

Program efforts began in December 1979. Hardware development and mine installation and testing were concentrated in late 1980, with final demonstration tests performed in the first quarter of 1981. The program was extended from June 1981 to allow for in-mine evaluation and added equipment review for MSHA approval. Contract efforts were concluded in July 1983. The program was divided into four phases, culminating in an underground coal mine demonstration of a prototype system:

- Phase I, Data Handling Plan Development (December 1979) (1 month)

  Goals, tasks, data sources, and general plans for conducting the program were outlined.

  A subcontract with Aquatrol Corporation was prepared, and the cost-sharing agreement with the test mine was established. Procedures to obtain licenses to import and use the Becon smoke sensor having 5 millicuries of krypton 85 were initiated with the California Health Department for use at ESD Corporation and with the Nuclear Regulatory Agency for use in Illinois, where the test mine was located.

- Phase II, Data Acquisition, Data Analysis, and Design Concept Development (January - March 1980) (3 months)

  Data was gathered and analyzed from literature, agencies, and vendors, and from mine visits. During these 14 visits, different mine profiles and conditions were evaluated, as well as data transmission and collection systems using remote telemetry and decision criteria used by mines for selecting data collection systems, including fire safety components. Fire and safety hazard zones are shown in Figure 1. Agencies, contractors, and/or vendors with mutual interests in fire safety provided information regarding fire and smoke sensors, types of telemetry systems, permissibility requirements, radiation safety, and existing systems in the mining industry. Optimum, recommended, and alternate systems were established. Figure 2 is a sketch of Alternate I, the recommended mine shaft fire and smoke protection system.

- Phase III, Design, Fabrication, and Factory Testing (April 1980 - July 1980) (4 months)

  Detail design, assembly, and factory testing were performed. Agreements were drawn with the participating mine, Peabody Mine Number 10 in Pawnee, Illinois. Factory demonstrations were conducted at Aquatrol Corporation in late July 1980, also attended by Peabody Mine Manager, safety personnel, and electricians, who offered constructive suggestions and comments.

- Phase IV, Cost-Sharing Field Demonstration, Permissibility Study, and Final Report Preparation (August 1980 - July 1983) (36 months)

  The system was installed at Peabody Number 10 Mine, and approvals from the Federal Communications Commission, Nuclear Regulatory Commission and MSHA were finalized. During the installation period, mine personnel were trained to monitor and operate the system. Sensor reliability was demonstrated, operating and maintenance characteristics were evaluated, modification requirements for MSHA approval were evaluated, and final documentation was prepared. Components of the installed system are shown in Figure 3. A final demonstration took place after 6-1/2 months of operation. This demonstration was documented on film, slides, and photographs.

  Long-term in-mine testing demonstrated the system's effectiveness and mine personnel capability to properly operate and document events during an alarm condition. The following four major events occurred during in-mine testing:

  - Carbon Monoxide In Intake Air

    Exhaust fumes from a truck parked near the slope intake air caused the CO analyzer to alarm. Repeated alarms and investigation by the hoist operator confirmed the condition and cause. Intermittent parking of trucks near the slope collar was not considered a deterrent to health and safety, but was an example of mine intake air being effectively monitored.

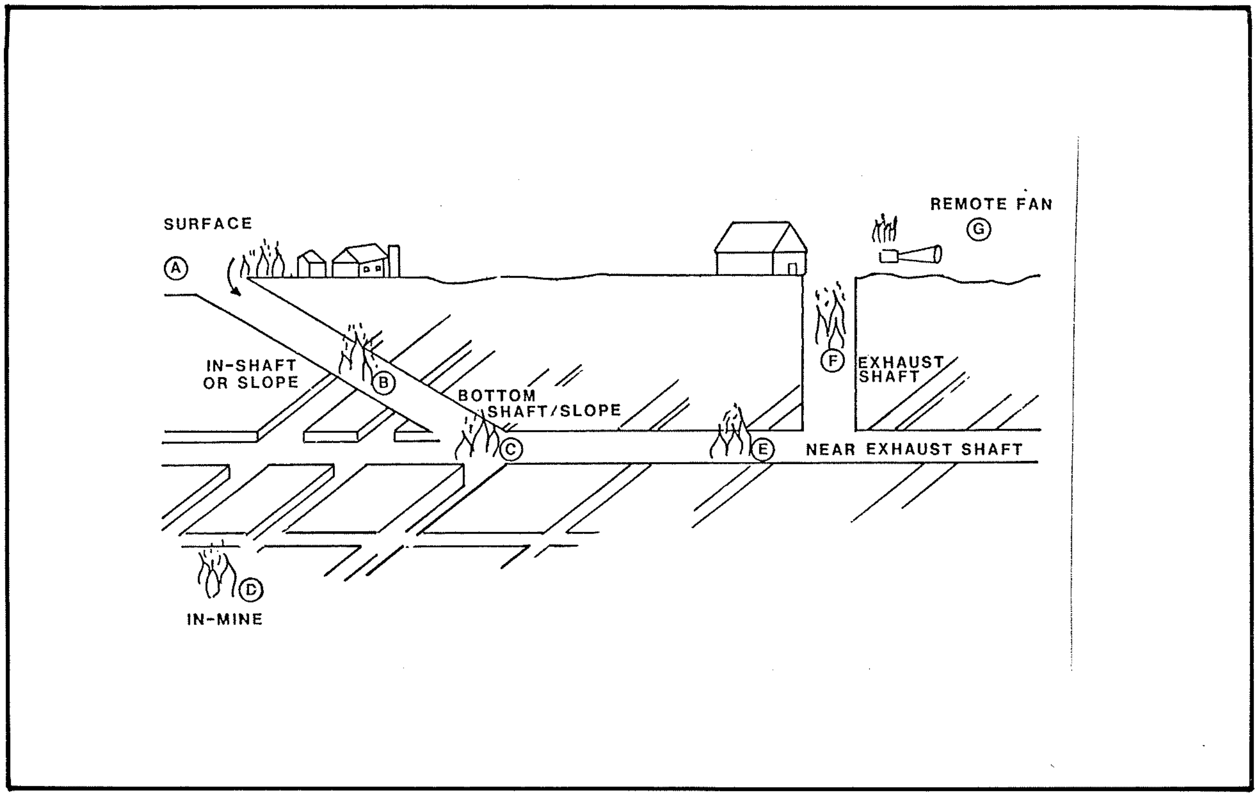

Figure 1 FIRE AND SMOKE HAZARD ZONES

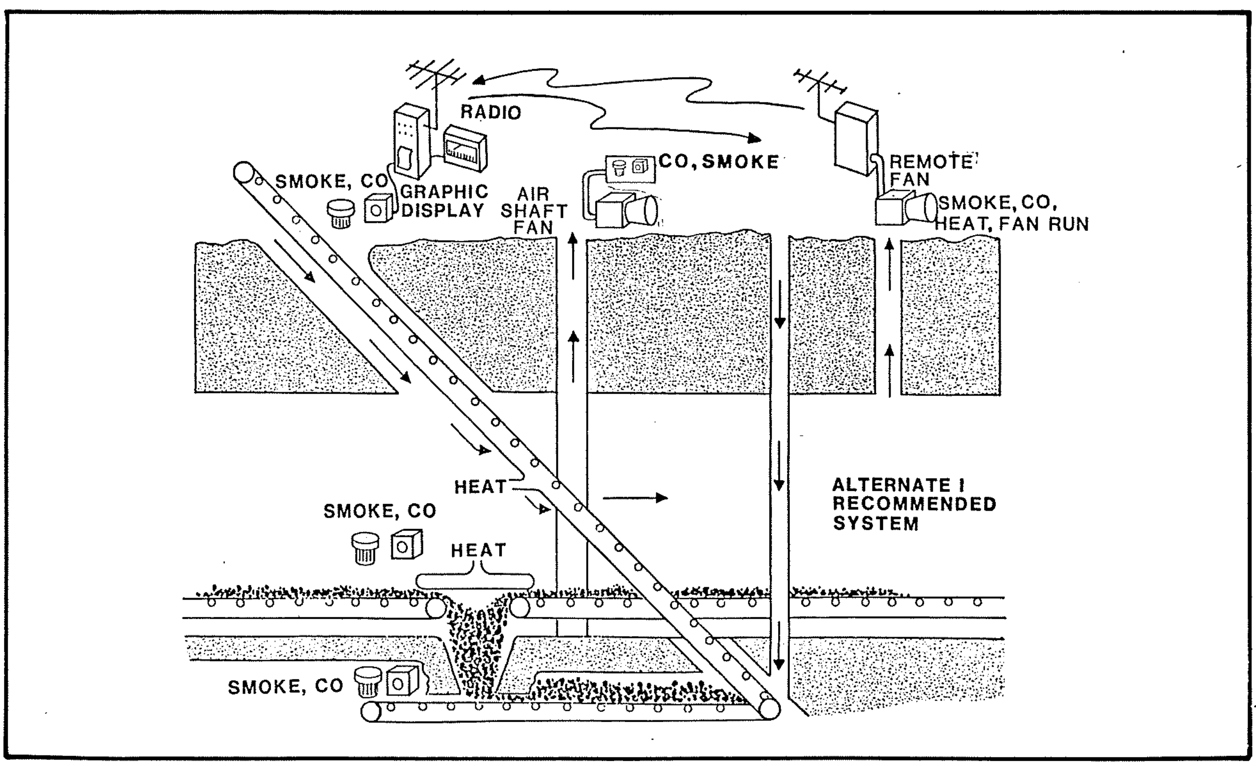

Figure 2 ALTERNATE I - GENERAL ARRANGEMENT SKETCH

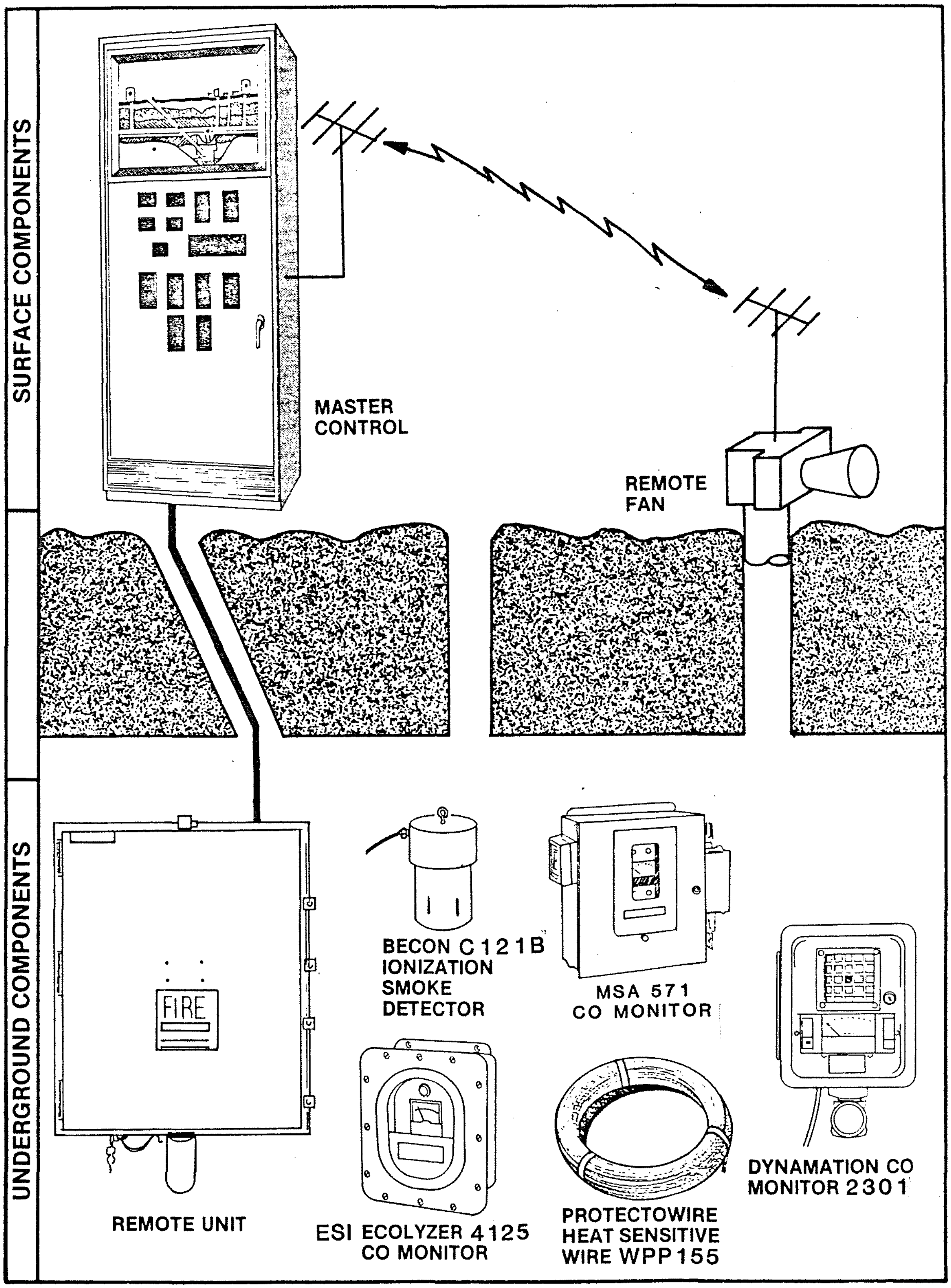

Figure 3 MAJOR COMPONENTS OF A COAL MINE SHAFT FIRE AND SMOKE PROTECTION SYSTEM

- Overheated Motor

  A 150-horsepower, belt-drive motor overheated, causing smoke to alarm the Becon particle sensor in the hopper-top area. Although the motor was 15 crosscuts away, smoke particles consistently caused alarms which the hoist operator reported to the mine superintendent, who investigated and found the smoking motor.

- Heating Coal Pile

  Residual coal remaining in the hopper during the coal strike in May 1981 became sufficiently self-heated to alarm the Becon particle sensor. Although local underground power was occasionally off, the Becon has telemetry line power and remained on during the strike. The hoist operator observed the continuous increase in concentration and notified personnel who removed the heating pile.

- Mine Fire

  A smoldering fire from a worked-out section of the mine was undetected by the mine shaft fire and smoke protection system, although the exhaust was vented over a Becon and CO analyzer. Mine air was routed to the sensors through a flame arrestor protected draw-tube leading from the exhaust-fan housing to the sensor assemblies. The draw-tube was blocked with condensed water, and the contaminated air did not reach the sensors.

CONCLUSIONS

The following are some of the major conclusions drawn from the four-phase program:

- o Many underground coal mines have shafts and inclines which would impair personnel evacuation efforts in the event of fire or smoke contamination, especially if the shafts and inclines become blocked or partially blocked.

- o Accident and injury data indicates that a relatively low percentage (5 percent) of the underground coal mine fires occur in the shafts, slopes, or drifts, but fires in other mine areas nearby have the potential to contaminate the normal personnel entry and egress path of the shaft, slope, or drift.

- o The fire and smoke conditions that have occurred in or caused contamination of the mine shaft have accounted for a significant number (14 percent) of injuries or deaths in underground coal mines from 1950 to 1977.

- o Carbon monoxide and particle analysis (ionization) sensors are leading candidates for use in an early warning mine shaft fire and smoke protection system.

- o A thermal wire sensor and a CO_2 sensor could complement the CO and particle sensors. These have not, however, responded as quickly and do not possess as low maintenance and accurate stability as would be desired.

- o Graphic displays are easily interpreted and are found in various degrees of complexity in mines having central control stations.

- o Mine ventilation was changed during in-mine testing, necesssitating new mounting locations of sensors and revised graphic displays.

- o Radio telemetry, in lieu of 5 to 8 miles of interconnecting hardwired telemetry, was added and proved reliable.

- o Although the system program logic provided adjustment of the automatic printing of the cycle of events, the excessive paper accumulation and required service appeared not to warrant continuous automatic printing.

- o Memory retention of events and the "on-demand" print capabilities of the controls system were effectively utilized.

- o Mine management and personnel were cooperative in installing and maintaining test components.

- o Contractor on-site attendance for directing or implementing activities for system component installation aided the contract progress.

- o Mine personnel familiar with the system operation used various sensor alarm conditions to locate several fire occurrences and sources of smoke or carbon monoxide.

- o Smoke candles used in the final demonstration proved effective for stimulating all sensors. Use of these candles in areas of very low ventilation should be avoided, however. Recognition of smoke contamination when using the candles in high air flow, such as exhaust fan areas, did not provide good signal levels of the fire and smoke sensors.

- o Considerable effort was required of the filmmaker to transport and set up cameras and lighting equipment.

RECOMMENDATIONS

The following are some of the major recommendations that relate to the previous contract conclusions.

- o Some type of remote air monitoring device to indicate air quality entering or passing a major shaft, incline, or bore hole of underground coal mines is recommended for mines with the proper profile.

- o Leading candidate fire and smoke sensors for use in mine shafts are those which possess high stability, accurate signal levels, and low maintenance. This contract defines the Protectowire WPP155 heat sensitive wire and the Becon C121B particle sensor as possessing most but not all of the criteria.

- o Thermal wire sensors are an inexpensive addition to complement the primary fire and smoke sensors, but require a long time to react. They are thus not recommended for further testing with the system.

- The fire and smoke protection system must be of flexible design, allowing for the addition of sensors or other modifications as the mine changes or as system components change.

- We recommend continued evaluation of diffusion-type CO analyzers to eliminate the high maintenance and cost associated with analyzers having mechanical pumps.

- A visual presentation of the mine map should be provided, with visible indicators at sensor locations so that personnel can readily observe and identify their activities.

- Radio interconnection with supporting logic controls is recommended for monitoring devices at distant (above 5 miles) locations.

- Contractor on-site attendance should be continued to maintain and upgrade systems being tested by the Bureau of Mines.

- Mine and agency personnel should be familiarized with the system operation. Their interest in using the system capabilities should be monitored.

- We recommend that personnel be provided to assist filmmakers in carrying cameras and lights during underground filmmaking.

- Smoke contamination from test candles should be avoided in low ventilated areas. Sensors in extremely high air flow areas should be either shielded or relocated when performing smoke candle tests.

- Mining safety procedures and management guidelines must be observed during all mine activities. Documentation, photographs, and film must be submitted for approval prior to release.

- Mine management should be assisted in processing MSHA variances and approval forms through the Federal Communications and Nuclear Regulatory Commissions when necessary.

I. INTRODUCTION AND SUMMARY

1.1 INTRODUCTION

This report presents activities, results, and conclusions of a 44 month effort under Bureau of Mines Contract H0100017, Demonstration of a Mine Shaft Fire and Smoke Protection System for Coal Mines. The objectives were (1) to evaluate the underground coal mine shaft/shaft-station fire and smoke hazard, (2) to develop performance requirements for a prototype system to reduce this hazard with reasonably priced, reliable hardware, and (3) to demonstrate (via a cost-sharing, in-mine demonstration) the prototype mine shaft fire and smoke protection system that will be applicable to a majority of coal mine shafts, including inclines, especially in deep mines.

Program efforts began in December 1979 and will continue through July 1983. Four no-cost extensions were granted for completion of documentation and in anticipation of new budgets to extend the scope of work. Analysis of modifications necessary for permissibility approvals is included in Phase IV.

Figure 4 is a detailed plan of the program schedule and work breakdown. Performance was divided into four phases, culminating in an underground coal mine demonstration of a prototype system. Section III, Technical Discussion, presents detailed discussion of work performed during the individual program phases:

- Phase I, Data Handling Plan Development (December 1979) (1 month)
- Phase II, Data Acquisition, Data Analysis, and Design Concept Development (January - March 1980) (3 months)
- Phase III, Design, Fabrication, and Factory Testing (April - July 1980) (4 months)
- Phase IV, Cost-Sharing Field Demonstration, Permissibility Study, and Final Report Preparation (August 1980 - July 1983) (36 months).

Aquatrol Corporation of St. Paul, Minnesota, provided subcontract services to research, design, build, test, and support the telemetry and control system that was demonstrated in this program.

Other system suppliers were previously reviewed as candidates to perform the above subcontracted services. Aquatrol was selected because of its single business activity in providing hardwired and radio telemetry systems to municipal water facilities. Also, Aquatrol standard components were within the anticipated system design scheme and costs, and the management and technical personnel exhibited qualifications and interest. An additional major factor was Aquatrol's mine-proven equipment installation in an operating underground mine.[1]

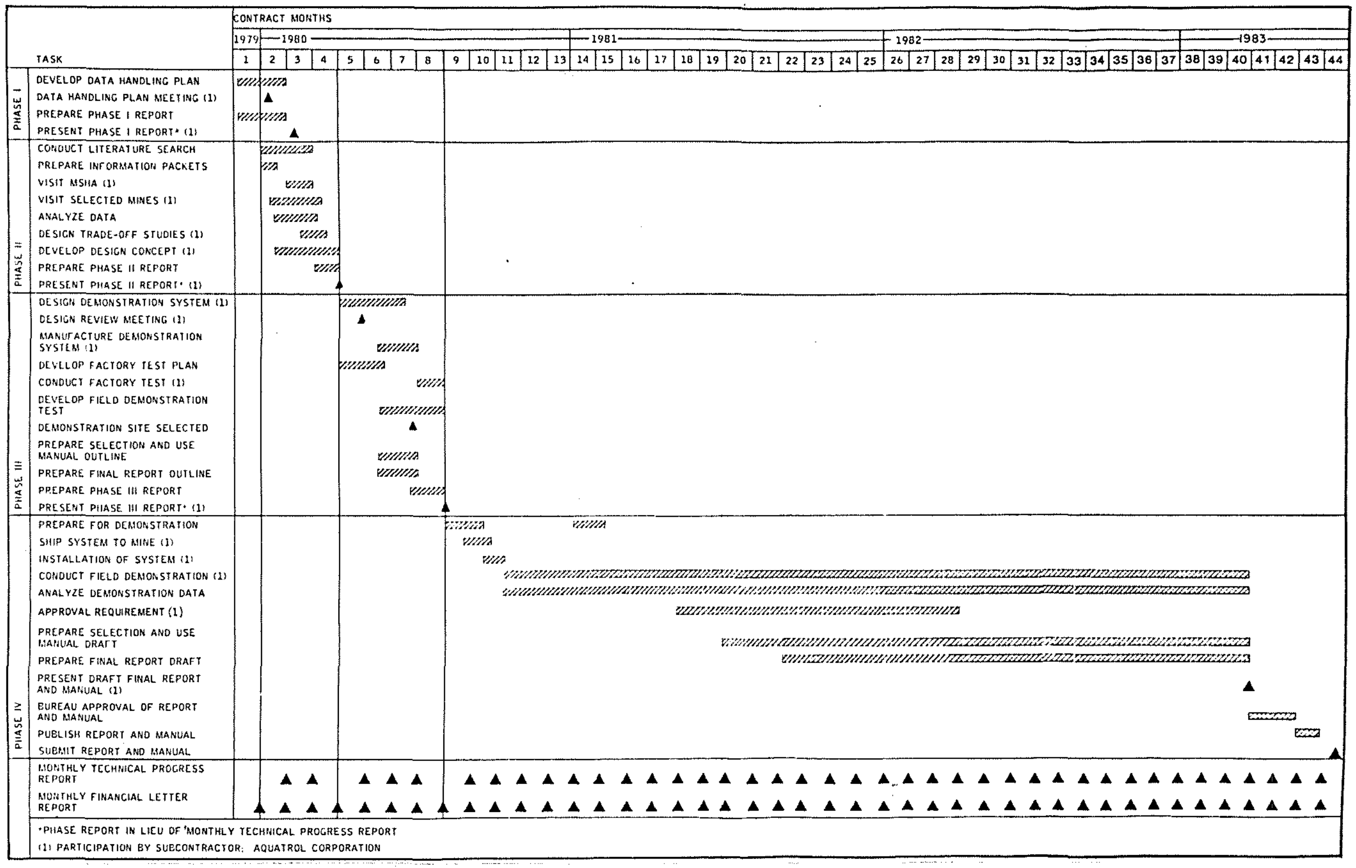

Figure 4 PROGRAM PLAN AND SCHEDULE

Complete documentation of the program consisted of three phase reports; a final report; a detailed, reproducible drawing package; MSHA variance; FCC license; radiation licenses from the NRC and California; 16mm movies of mine demonstrations; 35mm slides; photographs; a Selection and Use Manual; and a guide for potential users who wish to modify components for MSHA approval. The Selection and Use Manual included as Subsection 4.2 of this report is a guide for the selection and proper use of a reliable, low-cost, coal shaft fire and smoke protection system.

1.2 SUMMARY

The 1-month Phase I effort outlined the goals, tasks, data sources, and general plans for conducting the program. A subcontract with Aquatrol Corporation was prepared, and the cost-sharing agreement with the test mine was established. Procedures to obtain licenses to import and use the Becon smoke sensor having 5 millicuries of krypton 85 were initiated with the California Health Department and the Nuclear Regulatory Commission for the Illinois area. Licenses were issued during mid-1980 to import and use this sensor at the coal mine.

Phase II work was concentrated during three months, and considerable data was accumulated from literature, agencies, or vendors, and from fourteen mine visits. Data analysis determined the following:

- Literature indicates that 146,000 or 64 percent of the nation's 221,000 coal miners work in underground mines and that 70,000 or 48 percent of underground coal miners are in mines having shafts and/or slopes.[2]
- Mines with adits or drifts and without shafts and slopes employ 76,000 or 52 percent of underground workers.[2]
- Of the 1,014 underground coal mine fires (other than those which were explosion-related) from 1950 through 1977, 44 occurred in shafts and slopes and accounted for 37 deaths and injuries.[3]
- Mine fires resulting in death or injury are three times more likely to occur in the shaft or slope areas.[3]
- Data indicates 28 injuries or deaths per 100 fires.[3]
- Direct losses due to fires involving deaths and injuries, excluding equipment and capital investment, total \$3.4 million annually.[4]

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1 Jackson, Dan. FMC Mine Adopts Monitoring System. Coal Age, v. 84, No. 1, 1979, pp. 124-125.

2 Keystone Coal Industry Manual, 1979.

3 Allen Corporation of America, "An Annotated Bibliography of Coal Mine Fire Reports," Bureau of Mines Contract J0275008, 1979.

4 FMC Corporation, "Accident Cost Indicator Model to Estimate Costs to Industry and Society from Work-Related Injuries and Deaths in Underground Coal Mining," Bureau of Mines Contract J0255031, 1976.

Eighteen agencies, contractors, and/or vendors with mutual interests in fire safety provided related information about fire and smoke sensors, different types of telemetry systems, permissibility requirements, radiation safety, and existing systems in the mining industry. The following items were determined:

- Particle smoke sensors are common in deep South African gold mines and are being developed by the USBM.

- Other particle or cloud chamber sensing devices, such as residential, commercial, or aerospace applications, are either not physically or not economically suited for mine use.

- Tube-bundle systems do not offer the speed of response and flexibility of an electric data reporting and control system. Mine commitment for maintaining the system and keeping it operational is important.

- Permissibility is a factor when components are in return air, but considerable time is required for approvals.

- Electrochemical cell carbon monoxide gas analyzers are considered reliable for CO and are used in many mines, but mechanical pumps require unwanted maintenance. MSA, Energetic Science, and General Electric have or are working towards development of a diffusion collection electrochemical cell CO analyzer without a pump.

- Radiation licensing consists of processing various forms and keeping records. The 150-microcurie source of the USBM submicron particulate sensor and the 5-millicurie source of the Becon submicron particulate sensor are above the exempt limits and currently require licensing.

Fourteen mines were visited to evaluate (1) different mine profiles and conditions, (2) data transmission and collection systems using remote telemetry, and (3) the decision criteria used by mines for selecting data collection systems, including fire safety components. The following items were established:

- Conveyor belt monitoring systems and a variety of heat sensors were commonly found to be high-maintenance items subject to false alarms.

- Mine management will commit funds to safety systems if those systems can be combined with other production-oriented data analysis or recording systems.

- Ten mines had electronic reporting systems, but these were designed primarily for production rather than safety reporting. Application of fire and smoke sensors was planned.

- Two mines invested over $250,000 in remote data collection equipment, and five others expended over $100,000.

- o Two tube-bundle systems were observed; one was production oriented, and one was a USBM safety system lacking effective mine-management commitments to maintain an operational system.

- o Graphic panels or displays quickly interpret alarm situations, whereas coded printouts and chart recorders retain historical data requiring analysis. Application of easily interpreted displays and graphics was encouraged.

- o Methane control, ventilation recording, and belt-fire systems are important for production and conformance to laws. Most gas analysis is performed by portable electronic devices or color-stain tubes.

- o Carbon monoxide is the recognized gas of interest for fire detection, and one of the 14 mines had MSHA approval to use belt air at the face when an approved CO analyzer was installed.

- o Shaft construction materials were primarily concrete and steel, while inclines often had wood support structures.

- o Assurance of clean intake air was endorsed industry-wide, but fixed electronic monitors to detect contaminated intake air were found in only two of fourteen mine locations, one of which was not functioning.

- o Technology transfer is slow, due in part to the absence of long-term, successful safety test programs in production mines.

Table 1 compares four mine profiles with four different system concepts of mine shaft fire and smoke protection systems. Each system varies in size and component selection, depending on the mine profile and safety requirements. The recommended system uses heat, gas, and particle sensors in three remote locations. Data is transmitted by a combination of underground frequency shift key transmitters and surface radio signals to a central station (Figure 5). The microprocessor-controlled central station is designed to be monitored by hoist operators who can observe mine graphic displays and analog values from sensors. All data received or transmitted is recorded on an easy-to-read printout ledger (Figure 6). The previous 24-hour records can be automatically graphed, by operator command, from the program memory.

Detail design, assembly, and factory testing was accomplished during the 4-month Phase III efforts.

Ten analog and fifteen on/off digital signals are received at the surface control station from three remote units. The remote units receive and transmit signals from and to a variety of sensors or switch devices.

Table 1 MINE SHAFT FIRE AND SMOKE PROTECTION SYSTEM CONCEPTS (Sheet 1 of 2)

Underground Mine Profile	Mine conditions and system concepts			
	Optimum Recommended System	Alternate I Recommended System	Alternate II	Alternate III
	Large mine with many needs for larger system	Readily available hardware	Reduced mine profile and needs	Minimum mine profile and system
I. Conditions				
• Size and depth	Large-deep	Large-shallow	Medium-shallow	Small-shallow
• Entry type, construction and quantity	Distant shafts-slopes, some wood	Distant shafts-slopes, some wood	Multiple shafts	Drift and slope
• Fire history	Biannual event	Annual event	Every other year	Every 2 to 4 years
• Age and estimated close date	15 years old; 30 years remain	20 years old; 20 years remain	20 years old; 10 years remain	10 years old; 5 years remain
• Underground work force	>600	300 to 600	150 to 300	<150
• Workplace location from shaft	3 to 5 miles	3 to 5 miles	1 to 3 miles	Less than 1 mile
• Inactive time	4 days	4 days	7 days	7 days
• Instrumentation labor	Readily available	Limited	Limited	None
• Remote equipment (fan, shafts, shops)	Fans, pumps, power stations, shops	Fans, pumps, power stations, shops	Fans only	Fans only
• Bleeder panels	Yes	Yes	Yes	No
• Combustibles in shafts or slopes	Shaft guides, lubricants, materials, supports	Shaft guides, lubricants, materials, supports	Guides, posts, lubricants	Roof support materials
• Combustibles in other locations	Support timber, maintenance and storage areas, coal, lubricants, conveyor	Support timber, maintenance and storage areas, coal, lubricants, conveyor	Support timber, conveyor, lubricants, coal, storage	Support timber, storage, lubricants, coal, conveyor
• Type haulage	Rail and belt	Rail and belt	Rail and belt	Rail and belt
II. Fire Protected Areas (Figure 4-1)				
Zone A - Surface area Shops, offices, collar, fuel	Yes	Yes	Yes	No
Zone B - Shaft/slope Guides, posts, timbers, haulage	Yes	Yes	Yes	Yes
Zone C - Bottom Transformer/power stations, shops, lunchroom	Yes	Partial	Partial	Partial
Zone D - In mine Haulage, face equipment, power stations, shops	Partial	Partial	No	No
Zone E - Near exhaust Power stations, shops, storage	Yes	No	No	No
Zone F - Exhaust shaft Guides, posts, timbers, haulage	Yes	No	No	No
Zone G - Other Remote fans, hoppers, scales	Fans and hoppers	Fans and hoppers	No	No

Table 1 MINE SHAFT FIRE AND SMOKE PROTECTION SYSTEM CONCEPTS (Sheet 2 of 2)

Underground Mine Profile	Mine conditions and system concepts			
	Optimum Recommended System	Alternate I Recommended System	Alternate II	Alternate III
	Large mine with many needs for larger system	Readily available hardware	Reduced mine profile and needs	Minimum mine profile and system
III. Area Fire Protection	Zones	Zones	Zones	Zones
1. Sensors				
• Radiation (optical)	A (vehicle fuel area)	None	None	None
• Smoke/gas/particles	A, C, E, G	A, C, G	A, C	C
• Thermal	B, C, E, F, G (hopper)	B, C, G	B, C	B, C
• Run-stop, on-off, open-close	B (transformer), G (fans), doors, CO_2- air flow	G (fan)	–	–
2. Barriers				
• FR coatings	A, B, C	B (option)	No	No
• Doors	A, C	A, C, (option)	C, (option)	No
3. Extinguishing (optional)				
• Water sprays	A, B, C, D, and hoppers	B, C, D	B, C, conveyors	Conveyors
• Foam	A-portable, C, D	A-portable, conveyors	A-portable	No
• Gas (fixed or portable)	Electrical only	Electrical only	Electrical only	Electrical only
4. Alarms				
• Audible (phone-gong)	Surface and underground	Surface and location	Surface	Surface
• Visual (lights)	Event and location	Event and location	Event and location	Event only
IV. Control System				
• Remote units (expandable to 98 total)	4 multiplex, 2 radio	3 multiplex, 1 radio	2 multiplex	1 multiplex
• Readout-display	CRT, graphic panel, printer, graph of analogs (PPM), 24-hour record	Graphic panel, printer, graph of analogs (PPM), 24-hour record	Printer, volts convert to PPM	Digital readout of present analog data only in volts
• Manual versus automatic	CRT lightpen, keyboard entry, manual alarm, door, extinguisher, regulator activate	Setpoint changes logged, manual alarms, locations graphed	Setpoint changes logged, locations numbered, manual alarms	Thumbwheel setpoints, manual alarms
V. Cost (Estimate)				
• Purchase	\$80,000 to \$120,000	\$60,000 to \$100,000	\$45,000 to \$70,000	\$35,000 to \$50,000
• Install	3 to 5 man months	1 to 2 man months	3/4 to 1½ man months	½ to 1 man month
• Annual operating	\$7,000 to \$9,000	\$3,000 to \$5,000	\$2,000 to \$4,000	\$1,500 to \$2,500

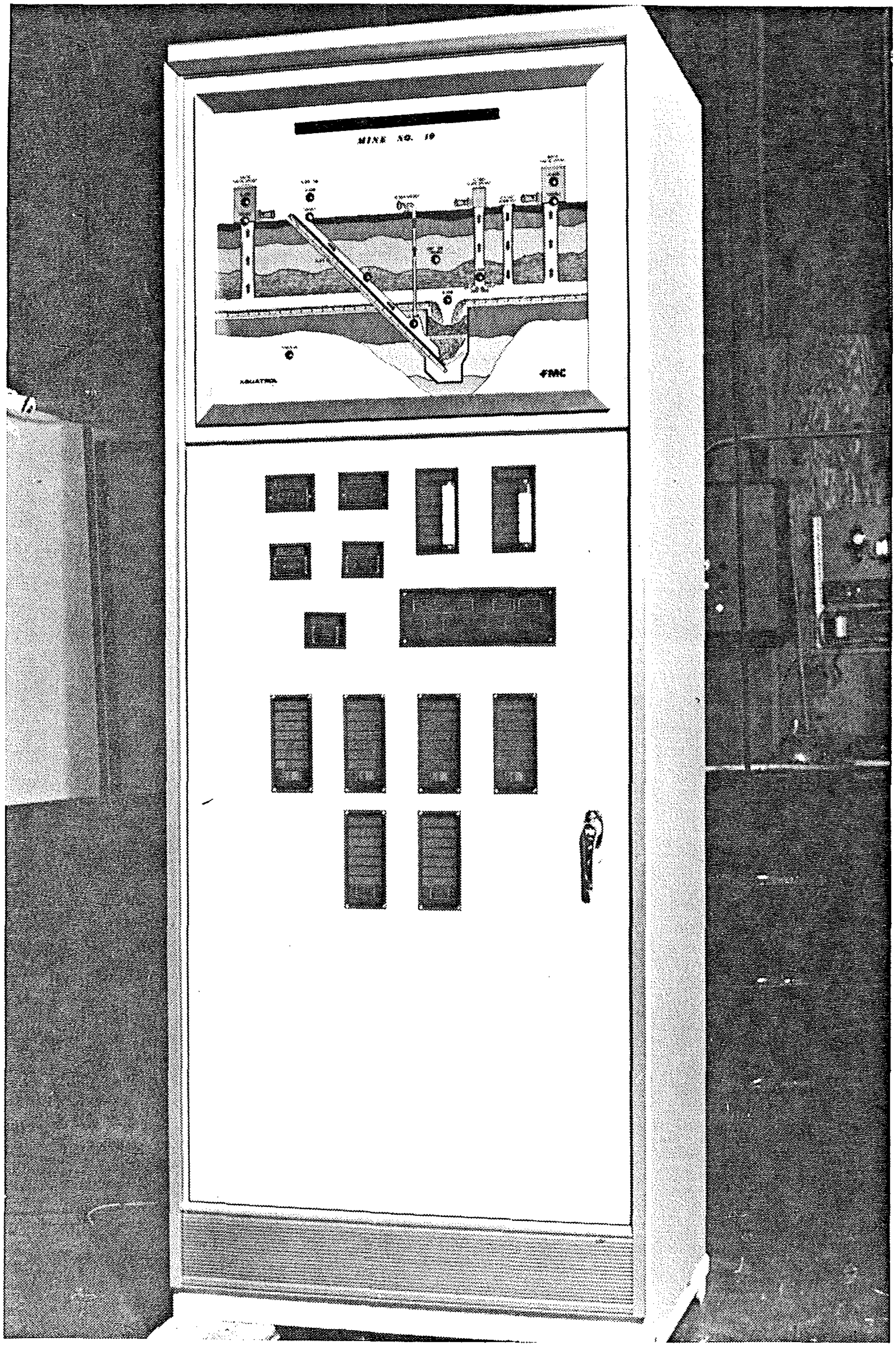


Figure 5 MASTER CONTROL UNIT EXTERIOR VIEW

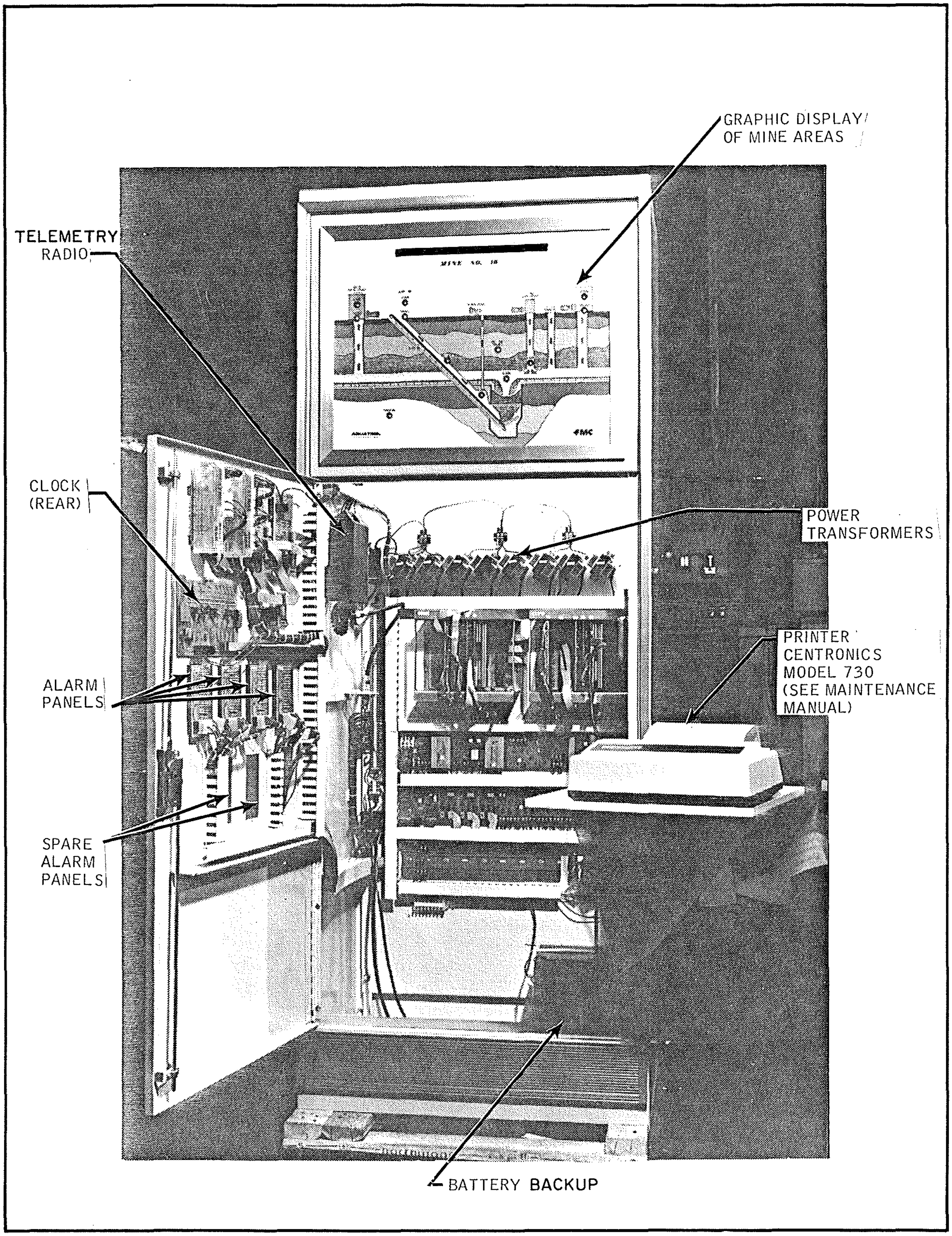


Figure 6 MASTER CONTROL UNIT INTERIOR VIEW

Mine areas where CO gas, smoke, and temperature are being monitored are in an intake slope, an intake borehole, a hopper top, and at two exhaust shafts. One exhaust shaft is 5 miles from the master control unit, where all data is multiplexed and transmitted via radio.

Anticipated future expansion prompted the supplier, Aquatrol Corporation, to program and graphically represent a fourth remote unit at an upcast south shaft. Since this area was 6 miles from the central station, it would also transmit and receive data via radio.

Fire and smoke sensors initially used were three different CO analyzers: one with electrochemical cell with pump; one with electrochemical cell without pump; and one metal oxide semiconductor CO analyzer. A Becon particle smoke sensor and heat-sensitive wire were also used in each location.

Factory demonstrations were conducted at Aquatrol Corporation in late July 1980 to conclude Phase III activities. Attendance by the Peabody mine management, safety personnel, and electricians allowed them to contribute by offering constructive suggestions and comments. One unscheduled CO condition that occurred during laboratory testing provided a realistic example of ease of alarm interpretation and system control.

Phase IV was a 36-month effort starting in August 1980 to install the system at Peabody No. 10 mine, demonstrate the sensor reliability, evaluate and demonstrate operating and maintenance characteristics, review requirements for MSHA approval, and prepare final documentation.

Peabody mine contributed 210 man-hours plus various support items and wire during the 2-week installation period of August 18-29.

State and Federal agencies participated in reviews of the surface-located, but unapproved, sensors that monitored return air from exhaust shafts via a flame arrestor protected draw-tube concept. Temperature and moisture conditions of the area quickly resulted in blocked or frozen tubes and inoperative sensors. An approval condition of MSHA acceptance of the draw-tube monitoring concept was for ESD to process nonapproved sensors for permissibility testing. This process is part of the continuation work effort.

During the installation period, mine electrical maintenance personnel, supervisors, and hoist operators were trained to monitor and operate the system. Each remote station location was provided with a brief instruction sheet describing the components (see Appendix A), and a complete operator's manual was prepared to describe all components in detail.

Highlights of the in-mine testing were as follows:

- o Hoist operators quickly became familiar with the system controls. All operators followed procedures requiring that they note unusual events and check the source if possible.

- o Mechanical pumps on electrochemical cell CO analyzers failed often, as did the cells, when in poor environments.

- Sensor alarm levels differ, depending on the location and background; e.g., the particle sensors located in the hopper-top alarm regularly when floor dusts are discharged from the belt.

- Voltage transients during mine radio transmissions caused spikes and unwanted alarms. A brief time-delay would solve the situation, but corrections by the manufacturer are encouraged.

- After early computer program deficiencies, the data recording portions of the control system functioned well, but the sequenced automatic printout features still need review.

- The memorized graph is a function of the automatic printout and should print the maximum concentration during a time period rather than the signal level at the particular sequence time.

Four major events occurred during mine testing that demonstrated (a) the system effectiveness and capabilities and (b) the ability of mine personnel to properly operate and document events during an alarm condition:

- <u>Carbon Monoxide In Intake Air</u>

  Exhaust fumes from a truck parked near the slope intake air caused the CO analyzer to alarm. Repeated alarms and investigation by the hoist operator confirmed the condition and cause. Intermittent parking of trucks near the slope collar was not considered a deterrent to health and safety, but was an example of mine intake air being effectively monitored.

- <u>Overheated Motor</u>

  A 150-horsepower belt-drive motor overheated, causing smoke to alarm the Becon particle sensor in the hopper-top area. Although the motor was fifteen crosscuts away, smoke particles consistently caused alarms which the hoist operator reported to the mine superintendent, who investigated and found the smoking motor.

- <u>Heating Coal Pile</u>

  Residual coal remaining in the hopper during the coal strike in May 1981 became sufficiently self-heated to alarm the Becon particle sensor. Although local underground power was occasionally off, the Becon has telemetry line power and remained on during the strike. The hoist operator observed the continuous increase in concentration and notified personnel who removed the heating pile.

- <u>Mine Fire</u>

  A smoldering fire from a worked-out section of the mine was undetected by the mine shaft fire and smoke protection system, although the exhaust was vented over a Becon and CO analyzer. Mine air was routed to the sensors through a flame arrestor protected draw-tube leading from the exhaust-fan housing to the sensor assemblies. The draw-tube was blocked with condensed water, and the contaminated air did not reach the sensors.

ESD participated during in-mine testing and component evaluation until July 1983. During the final demonstration in March 1981, smoke candles and other artificial fire stimuli allowed each sensor to respond. Each of the 10 analog signals and 15 digital signals was successfully transmitted and displayed on the graphic panel of the surface control unit. Sensor identification, area, sensor value, and alarm/no alarm condition were memorized in the system memory and/or printed by the system printer. Test movie footage, slides, and other photo documentation was provided via a subcontract to a camera operator from a local news agency.

Addition of radio-remote sensors to a sixth location (remote shaft) was proposed, as were other improvement changes, over the months following the final demonstration.

Premature failures of mechanical pumps, radio interference of the diffusion collection CO analyzer, relocation of sensors monitoring return air via draw-tubes into return air underground, control logic improvements, failure of A/D converter cards, and the need for established particle values of the Becon sensor remain as highlights for future work.

Mine management expressed strong interest in continuing the cooperative test program and stressed that efficient monitoring required the sensors to be underground and often in return air. Two of the five test areas of the mine shaft fire and smoke protection were sampling return air via draw tubes that were often plugged and inoperative.

An evaluation effort was made to determine the changes required for making the total system MSHA approved. Although other types of sensors or sensors of different manufacturers may be already MSHA approved and appear more feasible for use in the tested system, they lack in-mine evaluation within this contract. The evaluation described the flow of tasks required, what agencies perform specific work, and the detail changes necessary to limit the electrical current of existing components to be within safe guidelines for MSHA approval. Several sample documents are also included for starting the approval process.

II. CONCLUSIONS AND RECOMMENDATIONS

2.1 CONCLUSIONS

The following conclusions, grouped according to program phase, have been drawn from the results of the 44 month program.

The 1-month Phase I effort allowed the contractors, subcontractors, Bureau of Mines personnel, MSHA personnel, and other interested parties to schedule the scope of work, assign personnel, plan budgets, prepare trips, select data sources, and update prices and delivery dates of major items anticipated for purchase. This period was also used to contact the proper nuclear radiation agencies regarding license requirements for the ionization smoke sensors. It was concluded that this initial program phase was a valuable time for accomplishing the above activities and getting the program off to an orderly start.

The 3-month Phase II data acquisition effort yielded several conclusions, as follows:

- Significant numbers of underground coal mines have shafts and inclines which would impair personnel evacuation efforts in the event of fire or smoke contamination, especially if the shafts and inclines become blocked or partially blocked.

- Workers can often walk out of drift or slope mines, but shaft mines rely on a ladder or the main cage. This limited evacuation capability is especially significant, because data indicates that shaft mines typically have a larger work force than do drift mines.[2]

- Many underground coal mines do not regularly check the quality of intake air. Shaft or intake air heaters and other facilities near the collar could, due to malfunction and fire, cause contaminated air to enter the mine.

- The presence of equipment repair shops, transformer stations, storage areas, and lunch rooms near the shaft and slope bottoms provides a potential for fire and smoke. Although these areas are usually frequented by personnel during shifts, there are occasional periods of hours and even days when no persons are available to sense and take action in a fire situation.

- Accident and injury data indicates that a relatively low percentage (5 percent) of the underground coal mine fires occur in the shafts or slopes, but fires in other mine areas nearby have the potential to contaminate the normal entry and egress path of the shaft, slope, or drift.[3]

- The fire and smoke conditions that have occurred in, or caused contamination of, the mine shaft have accounted for a significant number (14 percent) of injuries or deaths.[4]

- MSHA classified and approved sensors presently exist, and more sensors are being developed, that can check the quality of intake air as well as air that may enter the shaft bottom area from within the mine.

- Carbon monoxide and particle analysis (ionization) sensors are leading candidates for use in an early warning mine shaft fire and smoke detection system.

- MSHA-approved electrochemical cell CO analyzers by Energetic Science Industries (ESI) are installed to allow the use of belt air for face ventilation. These, along with the new diffusion CO analyzer (electrochemical cell) by Mine Safety Appliance (MSA), should prove viable shaft air sensors.

- A particle analyzer, thermal wire sensor, and perhaps a CO_2 sensor, could complement the CO analyzers, as would a TGS combustible gas sensor.

- Automatic or remote range changing of the CO analyzer (0 to 500 ppm vs. 0 to 50 ppm) would be desired in a mine sensing system. Any reduction in the required mine maintenance will enhance acceptance, and a 6-month or longer maintenance-free system is desirable.

- Graphic displays are easily interpreted and are found in mines having central control stations.

- Real-time data acquisition allows observers to relate conditions with better accuracy.

- Tube-bundle systems have not gained wide acceptance in the U.S. because of high maintenance and poor system reliability. The mining industry in England is supplementing tube bundles with fixed sensors at underground locations to accelerate gas analysis response time.

- Considerations against the use of tube-bundle systems include particle decay, gas absorption, high initial cost, maintenance demands, and inability of the system to perform tasks other than gas sensing (i.e., no air flow, temperatures, humidity, dust, etc., sensing).

The 4-month Phase III effort accomplished the design, construction, and factory testing of the approved Alternate I Mine Shaft Fire and Smoke Protection System for Coal Mines. Conclusions drawn from Phase III activities are as follows:

- System changes occurred throughout the concept and assembly stages, and during in-mine testing, for a variety of reasons. Delivery of new vendor items under development cannot be relied upon.

- Mine ventilation was changed during testing, necessitating new mounting locations of sensors and revised graphic displays.

- Radio telemetry, in lieu of long hardwired telemetry, was added for reliability.

- Vendors supported deliveries of original or substitute materials in order to meet the factory demonstration schedule.

- Importing and licensing Becon smoke detectors requires time and a budget to match the application.

- Interconnection of the variety of electronic components and tests for their proper operation consumed valuable time during the final days prior to the factory demonstration.

- The factory demonstration was an equipment display and brief example of the system operation for the Bureau of Mines and mine operators to review. Observa- tions of each component by the mine personnel prior to installation was well accepted and prompted several design improvement suggestions.

- Mine management was opposed to draw-tube monitoring of return air at the exhaust fan, but agreed to allow the Bureau of Mines in-mine testing if concurrent efforts would gain MSHA approval for placing the sensors underground.

- Graphic displays of large mines are often reduced or compressed to near-illegible proportions to fit the hardware package. The 11-mile distance from north to south mine areas, shaft diagrams, and system elements are often represented pictorially rather than shown at true scale.

Conclusions drawn from the 36 month Phase IV effort are as follows:

- Carbon monoxide and particle analysis (ionization) sensors are leading candidates for use in an early warning mine shaft fire and smoke protection system.

- A particle analyzer, thermal wire sensor, and perhaps a CO_2 sensor could complement the CO analyzers.

- Mine ventilation was changed during testing, necesssitating new mounting locations of sensors and revised graphic displays.

- Mine management and personnel were cooperative in installing and maintaining test components.

- Contractor on-site attendance for directing or implementing activities for system component installation aided the contract progress.

- Mine personnel familiar with the system operation used various sensor alarm conditions to locate several fire occurrences or sources of carbon monoxide and smoke.

- Smoke candles used in the final demonstration proved effective for stimulating all sensors. Use of these candles in areas of very low ventilation should be avoided, however. Recognition of smoke contamination when using the candles in high air flow, such as exhaust fan areas, did not provide good signal levels of the fire and smoke sensors.

- Considerable effort was required of the filmmaker to transport and set up cameras and lighting equipment.

- Continuous monitoring of return mine air via flame arrestor protected draw-tubes extending into surface-located exhaust fan shrouds resulted in significant added maintenance. Water condensation and freezing occurred often, and a mine fire was undetected when the draw tube was blocked.

- MSHA variances to use draw tubes for sampling return mine air were attained with relative ease, but continued use of the marginally acceptable system and the need for variance extensions are not warranted.

- Mine management's desire to encourage the Bureau of Mines and ESD to make the system MSHA approved for use in return air is justified.

- Attaining MSHA approval is feasible by using a combination of permissible enclosures, MSHA classified intrinsic safety barriers, special power supplies, and MSHA classified or approved sensors. Component modifications, submittal, and follow-up efforts would be time-consuming, but the existing hardware and need appear to justify the effort.

2.2 RECOMMENDATIONS

On the basis of the Phase I effort of this program, it is recommended that future programs also incorporate such an initial phase. This time of planning and orientation of personnel provides a solid foundation to support the subsequent phases of the program.

Based on the Phase II effort, Table 1 is a tradeoff chart measuring the three alternate systems against an optimum system. Figure 7 illustrates the general arrangement of the recommended system. Figure 8 is a block diagram of the recommended system. While the optimum system was not within the contract guidelines, Alternate I offered a reasonable test example of controls and state-of-the-art sensors to perform the required functions. The system provides the following features:

- It is a flexible-design system allowing for the addition of sensors or other modifications as the mine changes or as components of the system change.

- It includes several of each type of fire and smoke sensor so that results of tests can be compared with like items.

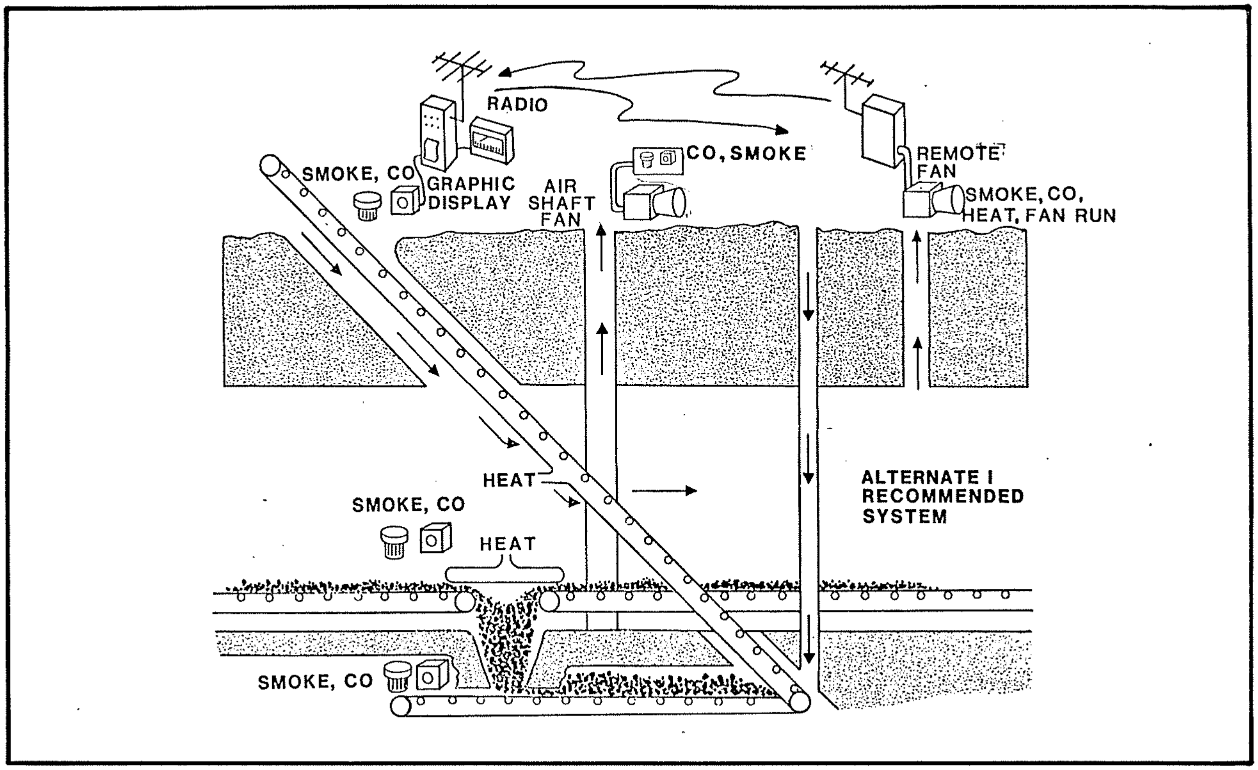


Figure 7 RECOMMENDED COAL MINE SHAFT FIRE AND SMOKE PROTECTION SYSTEM

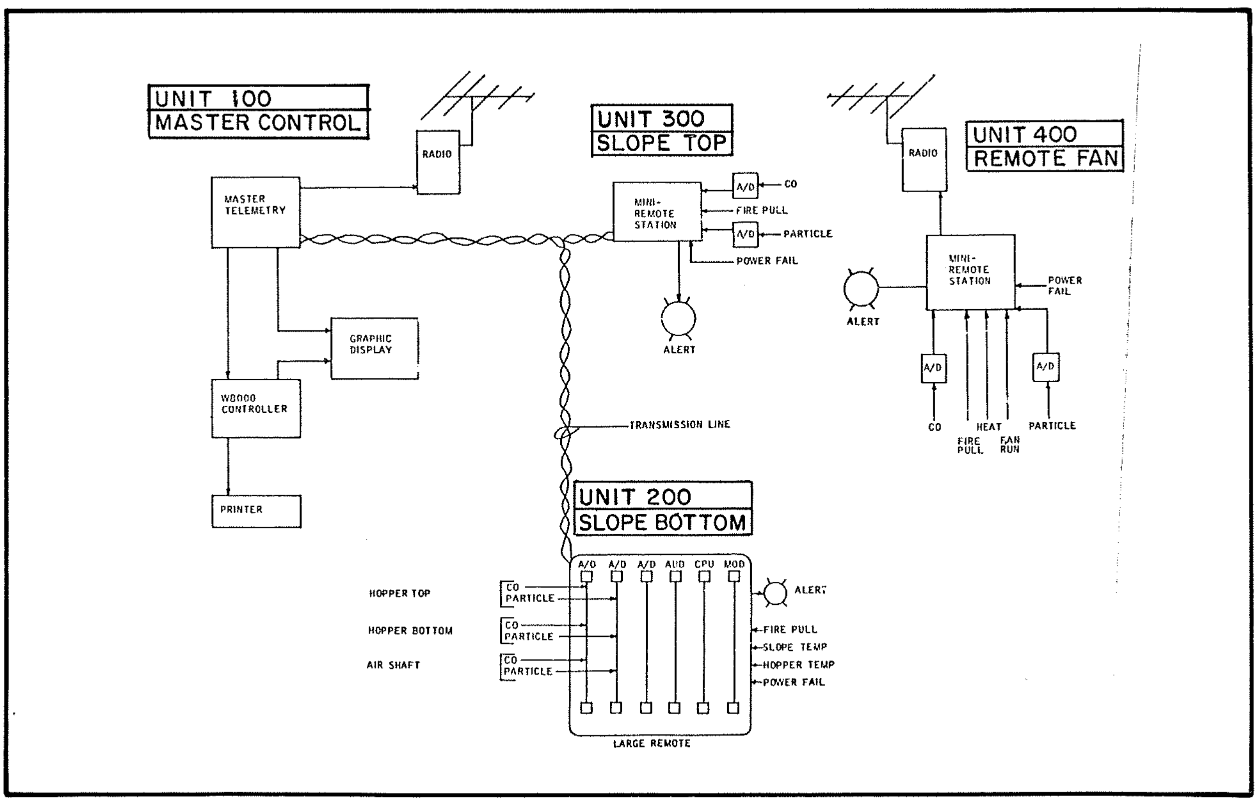


Figure 8 BLOCK DIAGRAM OF RECOMMENDED SYSTEM

- o It uses MSA and ESI CO sensors, Wormald International Becon particle sensors, and Protectowire heat sensitive wire in areas with the potential for fire and smoke which may contaminate the shaft or mine.

- o It utilizes radio interconnection and logic for remote fan sensing. Data collection from the 5-miles-distant fan will demonstrate an integrated hardwire and radio system and provide redundancy for added reliability.

On the basis of Phase III efforts, the following are recommendations for future work to expand the current scope of work:

- o Establish comparative data from the prototype mine shaft fire and smoke protection system with other output data of fire and smoke sensors that already exist at the mine.

- o Instruct the mine personnel in the expanded capabilities of the prototype mine shaft fire and smoke protection system. The system has expansion potential, and the cooperative mine can benefit by placing additional production and safety signals into the system.

- o Consider evaluation of oxygen analyzers in fixed locations throughout the mine. Mine management has expressed interest in obtaining tradeoff data on oxygen analyzers in order to make a qualified selection. Current literature that provides correlating data to select an oxygen analyzer for long-term use in underground coal mines is not available.

- o Continue to promote technology transfer of Bureau of Mines research data by giving technical papers and talks to mining groups.

- o Submit components of the system to MSHA for Mine-Wide Monitoring System (MWMS) evaluation and intrinsic safety barrier and sensor classification.

The following recommendations are based on the Phase IV effort:

- o Some type of remote air monitoring device to indicate air quality entering or passing a major shaft, incline, or bore hole of underground coal mines is recommended for mines with the proper profile.

- o Leading candidate fire and smoke sensors for use in mine shafts are those which possess high stability, accurate signal levels, and low maintenance. This contract defines the Protectowire heat sensitive wire and the Becon particle sensor as possessing most but not all of the criteria.

- o Thermal wire sensors are an inexpensive addition to complement the primary primary fire and smoke sensors but require a long time to react. They are thus not recommended for further testing with the system.

- o The fire and smoke protection system must be of flexible design, allowing for the addition of sensors or other modifications as the mine changes or as system components change.

- We recommend continued evaluation of diffusion-type CO analyzers to eliminate the high maintenance and cost associated with analyzers having mechanical pumps.

- A visual presentation of the mine map should be provided, with visible indicators at sensor locations so that personnel can readily observe and identify their activities.

- Radio interconnection with supporting logic controls is recommended for monitoring devices at distant (above 5 miles) locations.

- Contractor on-site attendance should be continued to maintain and upgrade systems being tested by the Bureau of Mines.

- Mine and agency personnel should be familiarized with the system operation. Their interest in using the system capabilities should be monitored.

- We recommend that personnel be provided to assist filmmakers in carrying cameras and lights during underground filmmaking.

- Smoke contamination from test candles should be avoided in low ventilated areas. Sensors in extremely high air flow areas should be either shielded or relocated when performing smoke candle tests.

- Mining safety procedures and management guidelines must be observed during all mine activities. Documentation, photographs, and film must be submitted for approval prior to release.

- Mine management should be assisted in processing MSHA variances and Federal Communications and Nuclear Regulatory Commissions' approval forms when necessary.

- Remove all draw-tube air monitoring systems, or obtain mine or outside contractor commitment to maintain the systems and improve overall confidence that they will be operational during mine fires.

- Modify, as required, one of each component mentioned in this report and submit them to MSHA for classification and evaluation. Supply the necessary power supplies, intrinsic safety barriers, and drawing documentation as outlined.

- Continue long-term testing of the mine shaft fire and smoke protection system at Peabody Mine and upgrade sensors and components as necessary. Include radio telemetry monitoring of Peabody-supplied sensors at the south shaft to evaluate the retrofit add-on complexities involved.

- Add modem telemetry interface to allow contractor and Bureau of Mines surveillance of signal activities, and establish reporting schedules to ensure that system maintenance tasks are handled quickly.

III TECHNICAL DISCUSSION

3.1 PHASE I, DATA HANDLING PLAN DEVELOPMENT

The 1-month contract activity for Phase I, Data Handling Plan Development, was structured to provide a systematic approach to the acquisition of data and to establish guidelines for the remainder of the program.

Efforts were directed toward obtaining and utilizing information to determine the technical parameters of and solutions to mine shaft fire and smoke hazards in domestic, underground coal mines. The plan provided for identification of, and information regarding, the following factors:

- Data to be acquired and the format for presenting such data that would lead to a viable, reasonably priced coal shaft fire and smoke detection system
- Specific use of the data
- Data sources and means by which data may be acquired
- Utilization of untranslated foreign literature
- Proof of agreements with data sources
- Staffing and travel plans.

3.1.1 Information Sources

During this phase, plans were made to identify and contact several sources of information. Anticipated sources were FMC files; management and personnel of underground mines; Mine Safety and Health Administration (MSHA), Bureau of Mines, and other Government agencies; union organizations; consultants in fire-research-related fields; and equipment manufacturers. Plans were also made to contact mining companies. Appendix C contains the specific topics addressed by the data collection effort.

3.1.2 Specific Use of Data

Data gathered from the information sources was analyzed to develop established criteria from which a mine shaft fire and smoke protection system could be successfully designed, developed, and tested.

Based on existing indicators for design criteria, it was determined that the system should be rugged, reliable, easy to maintain, cost effective, and available. The data search was to expand and to quantify those conditions that would permit alternative approaches to various solutions.

Search and translation of literature was conducted by utilizing staff and resources available in the FMC technical library. These resources are as follows:

- <u>Applied Science and Technology Index</u>
- <u>Government Reports Announcements and Index</u>
- <u>List of Bureau of Mines Publications and Articles</u>
- <u>Engineering Index</u>
- <u>Fire Research Abstracts and Reviews</u>
- Agencies for translating foreign literature
  - AD-EX
  - The Ralph McElroy Company, Inc.

3.2 PHASE II, DATA ACQUISITION, DATA ANALYSIS, AND DESIGN CONCEPT DEVELOPMENT

The 3-month Phase II effort to acquire and analyze data to substantiate the selection of a recommended design concept began in January 1980, following Bureau of Mines approval of the Phase I program plan and report.

The objectives of the Phase II study were to evaluate the coal mine shaft/shaft-station fire and smoke hazard in the domestic coal industry, and to develop design concepts (including performance requirements) for a reasonably priced, reliable fire and smoke protection system for coal shafts, including inclines.

Three groups of data were necessary to satisfy the program objectives as outlined during the Phase I planning:

- Data related to the mine profile
- Data providing fire and injury relationships
- Information about available components and systems to protect against the identified hazard.

Describing the mine configuration with respect to mine entry type, working depths, ventilation, and number of persons underground allowed analysis of hazard relationships.

The fire and injury statistics identified the magnitude of the problem with consideration given to rates, accident location, related costs, and potential losses.

Investigation and tradeoff analyses of components or systems to protect mine shafts from the fire and smoke hazards would allow mine companies to evaluate the overall cost benefits of a protection system.

3.2.1 Data Acquisition and Analysis

Data collected during Phase II included that information available in literature and that gathered during visits to mines and agencies and from contacts with various vendors.

Current statistics indicated that there were a total of 221,000 coal mine workers in the United States.[2] Of this total, 146,000, or 66 percent, were employed in underground mines. Of the underground mine workers, 70,000, or 47.9 percent, were employed in shaft and slope mines.

A data source indicated that the workers were exposed to a total of 1,014 underground coal mine fires from 1950 through 1977.[3] Fires that resulted from explosions or ignitions of gas or dust were specifically excluded from this number, making this number was conservative. Forty-four of the underground fires, or 5 percent, occurred in shafts and slopes, but they accounted for 37, or 14 percent, of the deaths and injuries related to fires. Analysis showed that fires resulting in death or injury were three times more likely to occur in the shaft or shaft area of mines than in other locations. This data source indicated 28.4 injuries or deaths per 100 fires, or roughly a 3-to-10 ratio between injuries or deaths to fires.

Of the 1,014 underground coal mine fires mentioned above, 904, or 89 percent, caused no injuries. However, costs in terms of equipment loss and production loss must be assumed to be significant. Based on the data available, direct losses from deaths and injuries resulting from underground fires, excluding equipment and capital investment loss, total $3.4 million annually.[4]

Methane control, ventilation recording, and belt-fire systems are important to mines in terms of safety laws and production. However, few early-warning gas-detection systems exist as fixed installations in coal mines. The scarcity of such fixed-installation mine-monitoring systems may be due to their complexity and initial cost. Most gas analysis is done with portable electronic devices or color stain tubes. Elaborate and costly systems are more often installed for production and maintenance improvement rather than for safety reasons. Also, belt-fire sensors require constant attention to repair damaged lines or to replace faulty sensors.

Tube-bundle systems have only token acceptance in the industry except where used specifically as a production tool. Carbon monoxide gas is the recognized gas of interest for fire detection in domestic coal mines, and CO_2 analysis will reflect good comparison data.

Although mines recognize the validity of checking the quality of the air entering the shaft or slope, only one intake air monitor was found in 14 mine visits. Systems installed in intake air are exempt from permissibility and intrinsic safety requirements. Permission to use belt air at the face is possible when approved gas sensors are installed.

Regulations require that all underground power be shut off if the main ventilation fans stop for 15 minutes. A shaft fire and smoke protection system need not operate when the mine power is shut off. Any battery-powered sources must be permissible or intrinsically safe when mine fans are off.

Shaft construction materials are primarily concrete and steel, while slopes and inclines often have wood supports. Underground transformer stations, maintenance shops, and storage and assembly areas are often located near the shaft bottom, clearly affecting fire danger.

3.2.2 Concept Development

Four different concepts were developed to protect underground coal mine shafts from fire and smoke. The systems varied in size and component selection depending on the mine profile and contract requirements. The recommended system uses heat, gas, and particle sensors in three remote locations. Data is transmitted by a combination of underground multiplex transmitters and surface radio signals to a central station. A printer, graphic display, and microprocessor-based control unit records and displays analog and digital data.

3.2.3 Information From Literature

Several data sources which describe coal mine fire and smoke hazards and the work that has been performed to reduce the hazards are available. Those selected to serve as primary data sources were the following:

- Accident Cost Indicator Model to Estimate Costs to Industry and Society from Work-Related Injuries and Deaths in Underground Coal Mining. FMC Corporation Engineered Systems Division, Santa Clara, California, September 1976.

- An Annotated Bibliography of Coal Mine Fire Reports. Allen Corporation of America, Alexandria, Virginia, February 1979.

- 1979 Coal Mine Directory. Keystone Coal Industry Manual.

Hazard analysis was performed on the data collected from these primary sources, the objective being to develop understanding of the magnitude of the problem of fire and smoke in underground coal mines, particularly for fires that occur in shafts or that have shaft-contamination potential.

3.2.3.1 Keystone Coal Industry Manual 1979 Coal Mine Directory Data and Analysis

According to the 1979 Coal Mine Directory, in 1978 approximately 221,000 miners worked an average of 207 days each in bituminous and lignite coal mines in the United States. Underground mining operations accounted for 64 percent of industry production hours with 146,000 miners employed an average of 201 days each. These operations accounted for 37.1 percent of the total coal production of 653.8 million short tons. These statistics are illustrated in Figures 9 and 10.

This data source was analyzed to determine the number of underground workers employed in shaft/slope mines and the distribution of the labor force by mine size and type (i.e., slope, shaft, drift). A population of 670 coal mines was identified as falling within the scope of this contract for demonstration of a mine shaft fire and smoke protection system (see Appendix C). This sample population of 670 coal mines employed a minimum of 25 people each and were operating during the calendar year of 1978. A distribution of these mines by state is shown in Table 2.

Approximately 16 percent of the mines in the sample population did not specify the number of workers employed by those mines. In these cases, the number of underground workers was approximated by dividing each mine's annual coal production by 1,658 tons per man year. The latter figure was derived from the data source, which indicated that the productivity rate for underground operations in 1978 was 8.25 tons per man day, and that the average number of days worked was 201. Thus, 8.25 times 201 equals 1,658.25, or 1,658 tons per man year. For mines which specified numbers of employees (the remaining 84 percent of the sample population), the number of workers actually employed underground was approximated by subtracting an average of 5 percent for the aboveground work force, with a minimum of 6 persons per mine employed above ground.

The totals resulting from the sample population are shown in Table 3.

The percentages in Table 3 are expressed graphically in Figure 11, as are the percentages of mines by type. As shown in the figure, drift mines account for almost 58 percent (386 mines) of the mines in the sample. However, they employ only 45 percent of underground workers, as drift mine operations are typically conducted on a smaller scale, as is clearly shown in Figure 12. Taken together, then, shaft and slope mines account for 30.3 percent of underground coal mines with 35 or more employees, and employ 47.9 percent of the people working underground in these mines. Typically, slope/ shaft mines have a larger average work force, as shown in Table 3. The distribution of work force per mine by mine type is shown in Figure 12.

This study, then, indicates that although there are more underground drift mines, slope and shaft mines have, on the average, a greater number of workers underground per mine. In addition, the total number of workers in slope and shaft mines exceeds the total number of workers in drift mines.

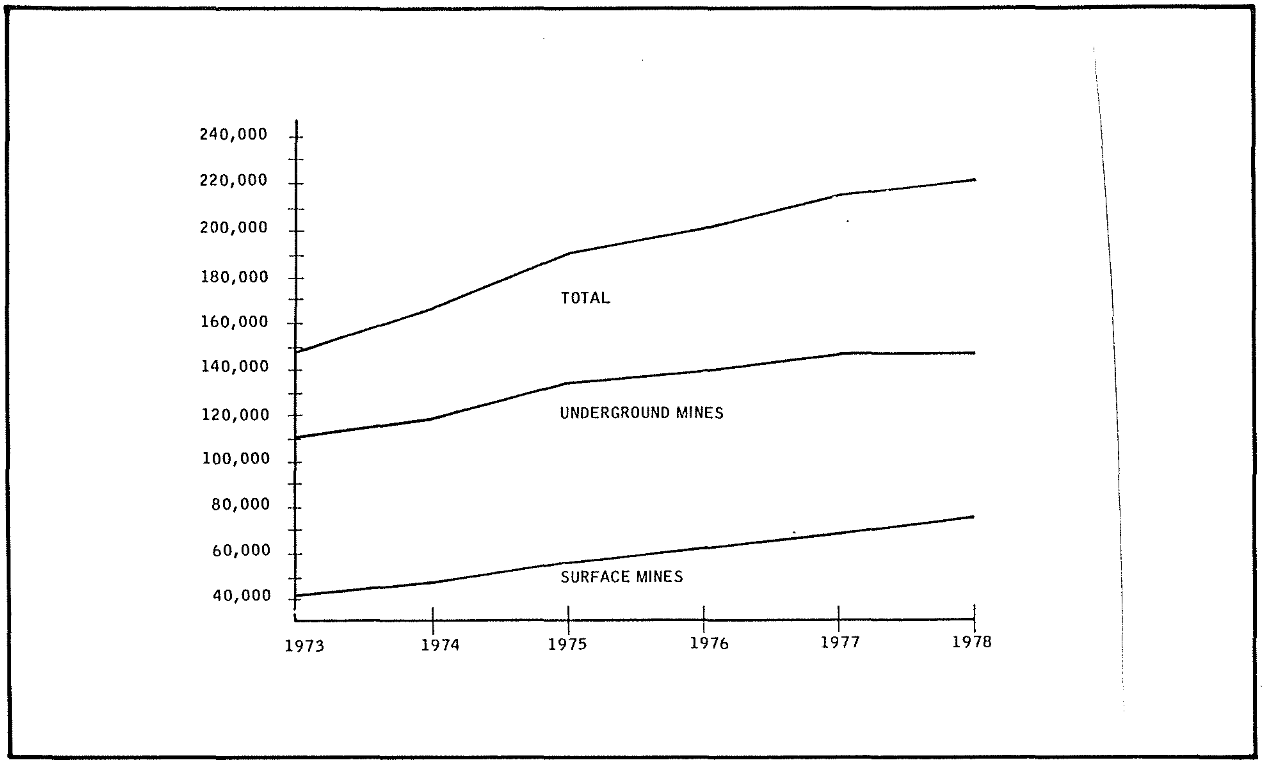


Figure 9 AVERAGE NUMBER OF MINERS WORKING DAILY

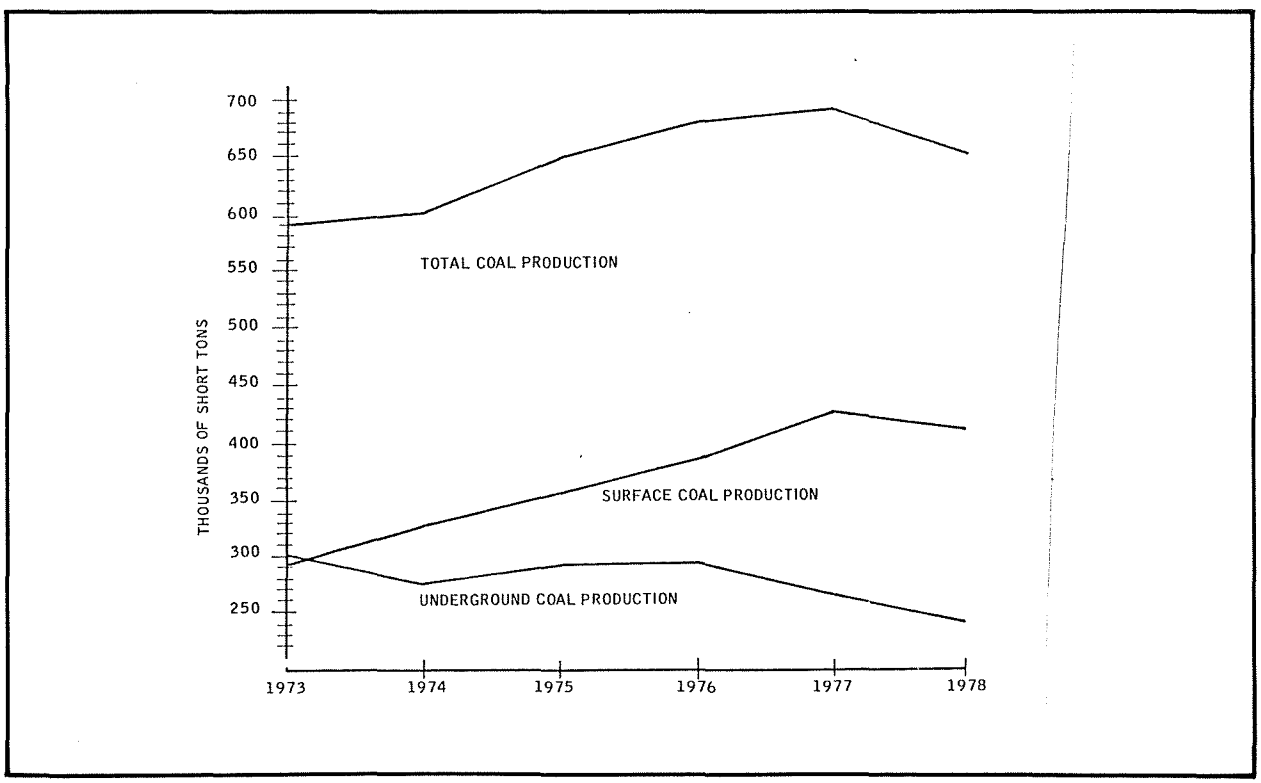


Figure 10 ANNUAL COAL PRODUCTION 1973 TO 1978

Table 2 UNDERGROUND COAL MINE DISTRIBUTION BY STATES

State and abbreviation	Quantity	Slope	Shaft	Drift	Not defined
Alabama (AL)	15	9	4		2
Arkansas (AR)	2	1			1
Colorado (CO)	14	7	4	2	1
Illinois (IL)	27	13	12	1	1
Iowa (IA)	2	2			
Kentucky (KY)	154	9	8	79	58
Maryland (MD)	1			1	
New Mexico (NM)	1			1	
Ohio (OH)	19	8	5	6	
Pennsylvania (PA)	83	17	23	38	5
Tennessee (TN)	16	2		5	9
Utah (UT)	15	6		8	1
Virginia (VA)	47	1	5	39	2
West Virginia (WV)	266	34	27	204	1
Wyoming (WY)	2	1		1	
Canada (CN)	6	4	1	1	
Total	670	114	89	386	81

Table 3 NUMBER OF UNDERGROUND WORKERS BY MINE TYPE

	Slope mines	Shaft mines	Drift drift	Entry not specified	Total
Number of underground employees	29,575	30,385	55,853	9,274	125,087
Percentages of all underground employees	23.6	24.3	44.7	7.4	100
Average number of workers underground	259	341	145	114	187

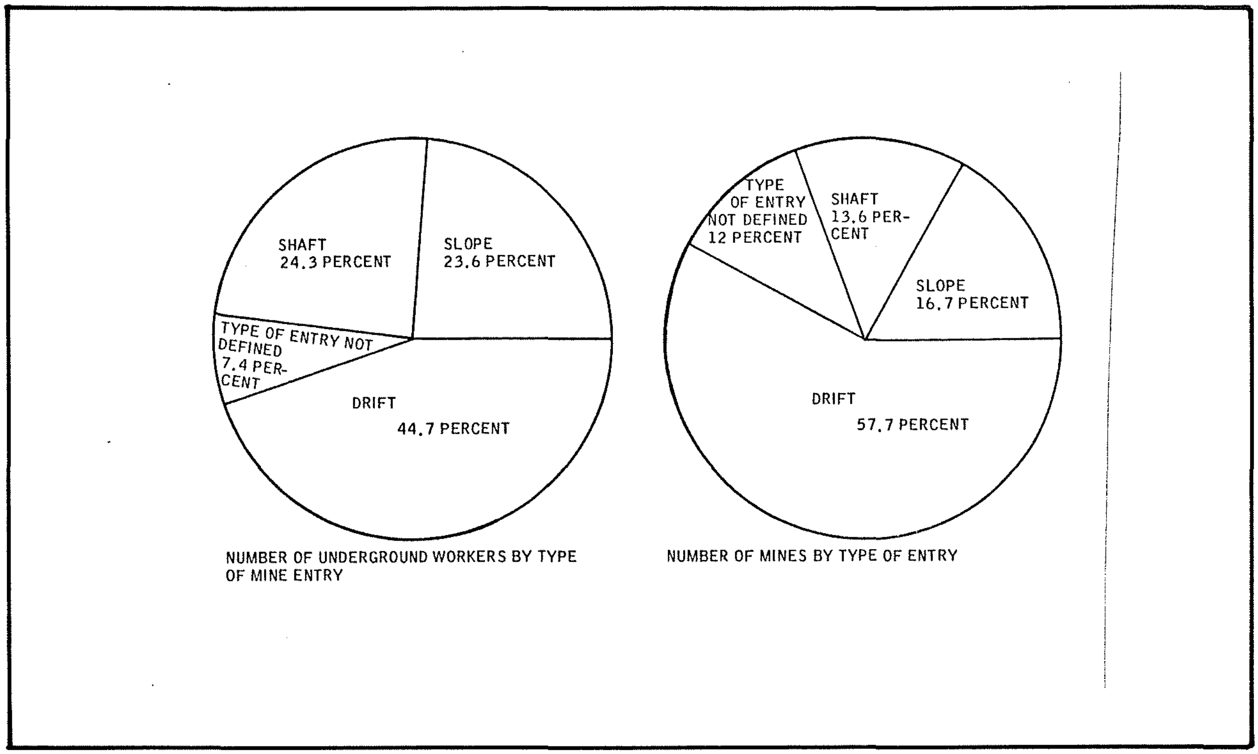


Figure 11 PERCENTAGE OF UNDERGROUND MINES AND WORKERS BY MINE TYPE

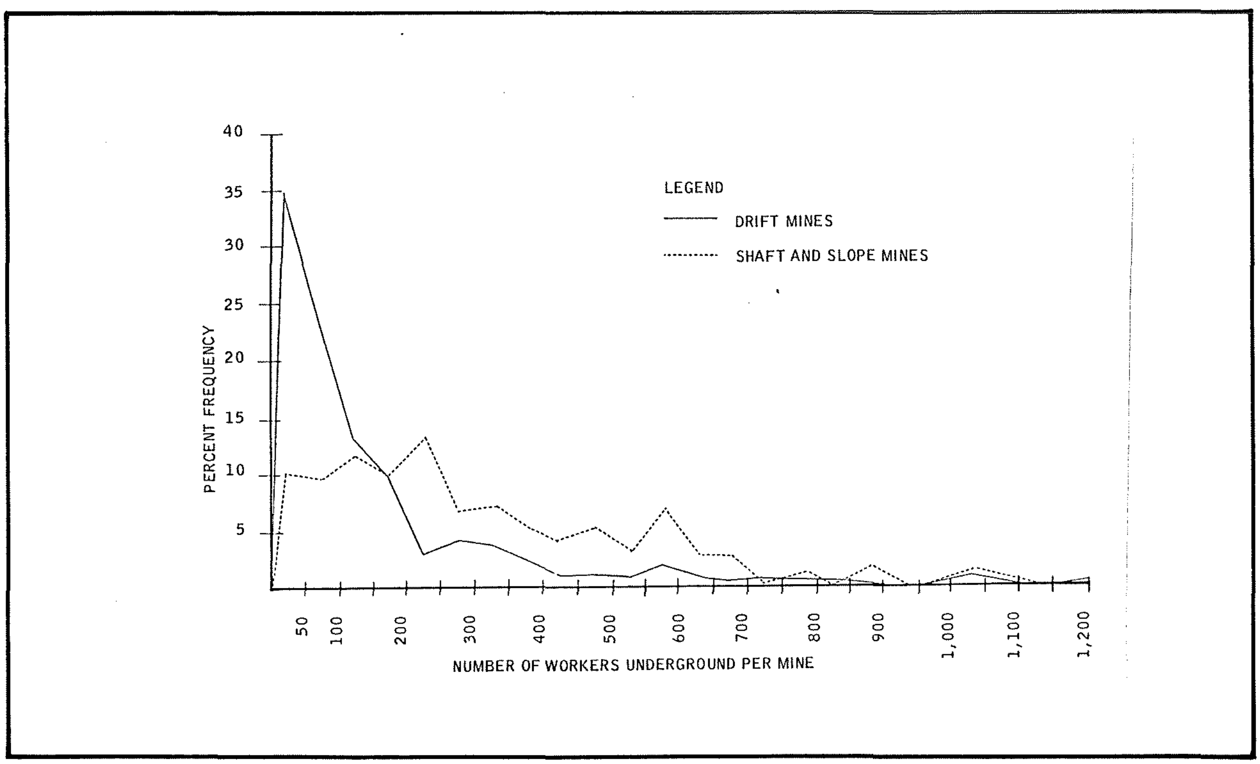


Figure 12 DISTRIBUTION OF NUMBER OF WORKERS UNDERGROUND PER MINE BY TYPE OF MINE

3.2.3.2 Allen Corporation Annotated Bibliography of Coal Mine Fire Reports, Data and Analysis

The Allen Corporation bibliography includes 1,014 fires in underground coal mines from 1950 through 1977. This information is summarized in Table 4, and is shown in Figure 13. See Appendix D.

Table 4 FIRES, INJURIES, AND DEATHS

	Number	Percentage
Injuries	215	21.2
Deaths	73	7.2
Total injuries and deaths	288	28.4
Total number of fires	1,014	100.0
Fires resulting in injury	86	8.5
Fires resulting in death	28	2.8

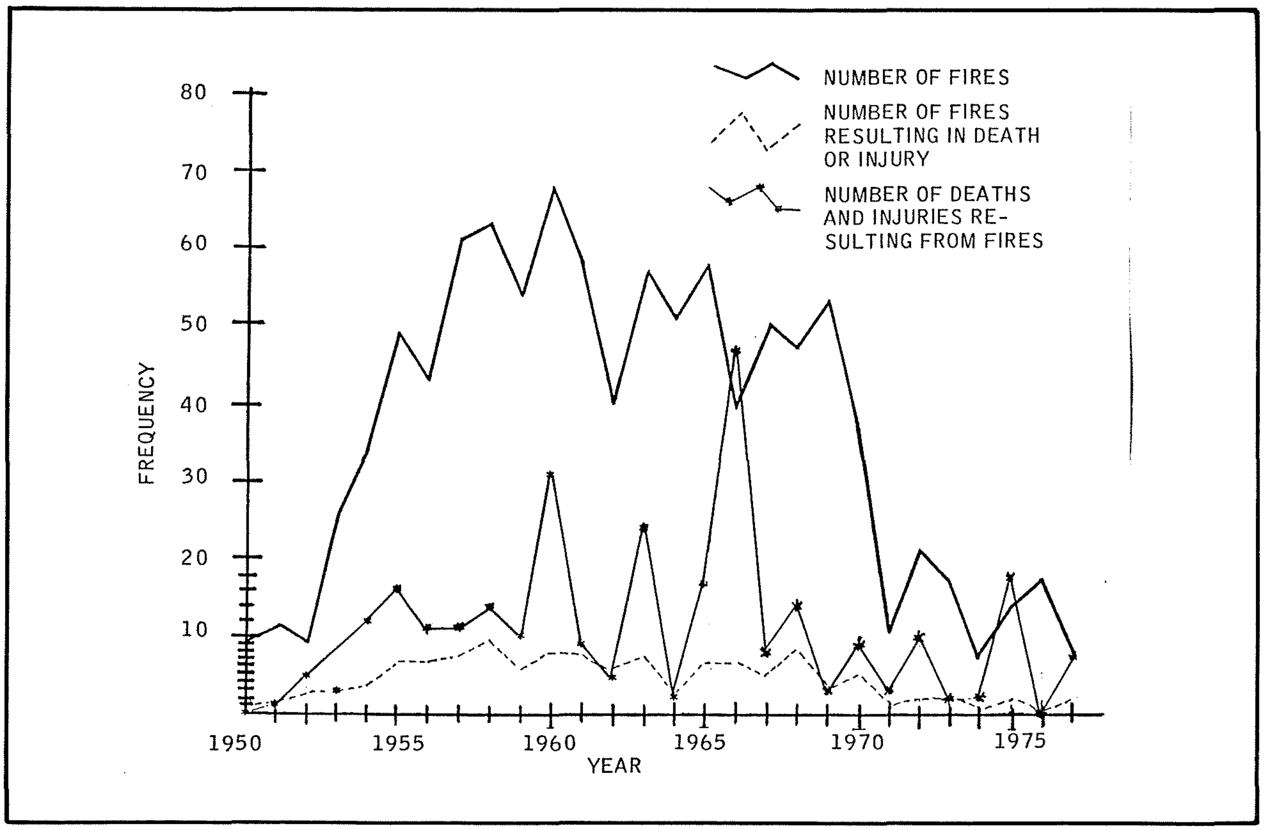


Figure 13 DISTRIBUTION OF FIRES AND DEATHS/INJURIES

According to this sample, there is approximately an 11-percent chance that a fire which occurs in an underground coal mine will result in death or injury to mine workers. This study yielded an overall ratio of 28.4 injuries and deaths per 100 fires.

The Allen report indicates that 86 percent of underground fires occurred in areas other than the shaft or slope. The underground location of the fire was not specified in 9 percent of the reports. Fires occurred in the shaft or slope area in 5 percent of the occurrences. A summary of underground fires by location is given in Table 5 and is shown in Figure 14.

Table 5 DISTRIBUTION OF FIRES, INJURIES, AND DEATHS BY MINE LOCATION

Underground location	1 Number of fires	2 Number of injuries	3 Number of deaths	4 Number of deaths and injuries	5 Number of fires resulting in death or injury	6 Percent of all fires	7 Percent of all deaths and injuries	8 Percent of all fires resulting in death or injury
Non-shaft/slope	877	154	73	227	96	86	79	87
Location not specified	93	24	0	24	11	9	8	10
Shaft/slope	44	37	0	37	3	5	13	3
Total	1,014	215	73	288	110	100	100	100

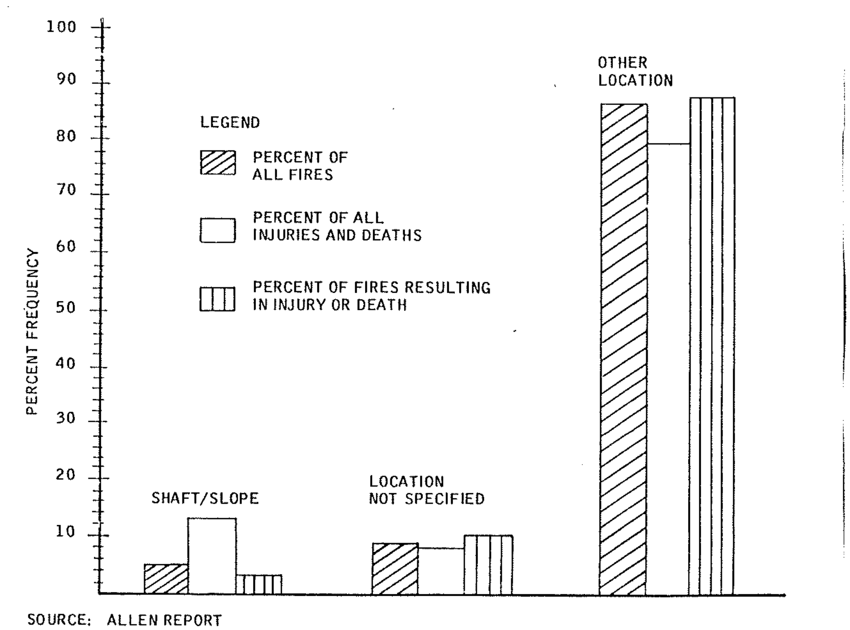


Figure 14 DISTRIBUTION OF FIRES, INJURIES, AND DEATHS BY MINE LOCATION

By comparing Columns 6 and 8 of Table 5, one can conclude that the likelihood that injury or death would occur in conjunction with a shaft or slope fire was no greater than for other underground locations. By comparing Columns 6 and 7, however, one must conclude that the number of deaths and injuries resulting from shaft or slope fires was almost three times as great as for fires in other locations. In other words, the danger (in terms of injury and death) was three times as great for fires occurring in the shaft or slope area of the mine. In addition, by comparing Columns 7 and 8, it is apparent that the percentage of deaths and injuries resulting from shaft or slope fires where deaths or injuries occurred was over four times that for injury or death fires in other locations. It must also be seen as likely that many of the nonshaft or nonslope fires contaminated, or had the potential to contaminate, the shaft or slope area.

Fires which resulted from explosions were not included in the Allen study. Presumably, such fires would include those resulting from ignition or explosions of dust or gas, as well as those resulting from actual explosives. The primary data source for the Allen Corporation study was MSHA fire reports contained in the files of MSHA coal mine health and safety district and subdistrict offices, and major study results are summarized in Table 6.

3.2.3.3 Accident Cost Indicator Model (ACIM)

Another data source used for the data analysis was the computer data-base called Accident Cost Indicator Model (ACIM) developed under Bureau of Mines Contract J0255031. ACIM currently contains accidents which occurred underground in bituminous coal mines for the years 1974 through 1978 and which caused death or traumatic injury. These accident records were selected from the Coal Accident and Injury File (CAIF), maintained by the Health and Safety Analysis Center of the Mining Safety and Health Administration located in Denver, Colorado.

The ACIM accident data-base exhibits three characteristics which should be noted. First, the data-base includes only accidents which resulted in death or traumatic injury and does not, therefore, represent a complete listing of mine fires for the years involved. Second, each accident record corresponds to one injury, rather than one fire report. For this reason, it is not possible to count the number of fires. Third, each accident record contains 16 different accident characteristics, many of which may be important in terms of identifying accidents associated with fire.

Accidents listed in Table 7 have one or more of the following characteristics:

- The accident injury code (AIC) is fire.
- The accident injury code (AIC) is ignition or explosion of dust or gas.
- The source of injury (SOI) is fire or smoke.

Table 6 MAJOR STUDY RESULTS OF MINE FIRE REPORTS (ALLEN CORPORATION)

Category	Reportable Fires						Non-Reportable Fires			
	Underground			Surface			Incident Descriptions		Opinion Data	
	Overall	Injury	Fatal	Overall	Injury	Fatal	Underground	Surface	Underground	Surface
Ignition Source	Electrical, Spontaneous, Welding	Electrical, Welding	Electrical	Electrical, Welding, Spontaneous	Welding, Electrical	Welding, Open Flame	Electrical, Friction	Electrical, Welding	Electrical, Friction, Spontaneous	Engine Heat, Cutting Torch, Electrical
Burning Substance	Wiring Insulation, Coal, Rubber			Timber/Wood, Coal, Rubber			Wiring Insulation, Coal	Oil and Grease, Hydraulic Fluid, Diesel Fluid	Wiring Insulation, Coal, Grease	Oily Rags, Grease, Hydraulic Fluid
Equipment Involved	Belt, Cutter, Locomotive	Welding Equipment		Crusher/ Breaker, Tipple, Cleaning Plant			Conveyor Belt, Shuttle Car, Scoop Tram	Dragline, Bulldozer, Haulage Truck	Conveyor Belt, Shuttle Car, Locomotive	Front-end Loader, Dragline, Haulage Truck
Location	Outby Face, Working Face, Haulageway	Outby Face, Haulageway	Outby Face, Working Face	Tipple, Crusher/ Breaker, Cleaning Plant			Main Haul-ageway, Haulageway	Mobile Machinery, Mainten-ance Shop, Conveyor Belt		
Successful Extinguishing Agent	Water, Dry Chemical, Rock Dust			Water, Dry Chemical, Rock Dust			Portable Extinguisher, Water, Power Disconnect	Portable Extinguisher, Water, Self-Extinguishing		

Table 7 ACCIDENT CAUSES FROM ACIM

	1974	1975	1976	1977	1978	Total
AIC fire	1	9	28	33	18	89
AIC ignition or explosion of dust or gas	7	9	28	5	1	50
SOI fire or smoke	12	27	30	28	23	120
Total	20	45	86	66	42	259

It is true that accidents involving the ignition or explosion of a gas or dust do not always result in a fire. These accidents, however, are included here because they represent a very real hazard in themselves and because they have the potential to cause mine fires. Indeed, many of these accidents report "fire or smoke" as the "source of injury." These accidents are thus relevant in determining the hazards of underground coal mine fires. We have, however, shown these accidents separately in the following ACIM analysis. This information is shown in Figure 15.

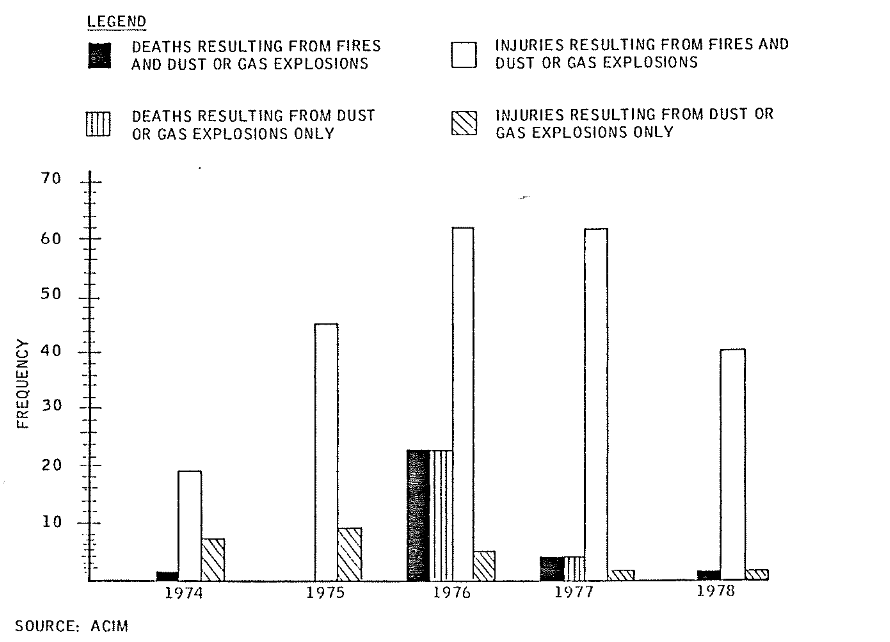


Figure 15 DEATHS AND INJURIES RESULTING FROM FIRE/DUST/GAS EXPLOSIONS

In this ACIM sample of 259 accidents, 15 percent of the injuries and 3 percent of the deaths resulted from a fire in the shaft or slope area. Taken together, 14 percent of the deaths and injuries in this sample occurred in the shaft or slope area of the mine. This statistic is within the same range as that indicated by the Allen report, which shows that 13 percent of deaths and injuries occurred in the shaft or slope area.

The ACIM model also computes the cost of an accident in 1977 dollars. The total expected values of the following tangible cost elements were computed by ACIM from the data in a CAIF record, from a stochastically-generated profile of the characteristics of the miner and the composition of his family, and from base cost data contained in the model:

- Loss in personal income
- Compensation of wages from state, federal, and union funds for disabling injuries
- Benefits for injuries resulting in death or permanent disability
- Medical treatment and hospital care
- Immediate and post-accident production losses as the result of a fatality or amputation injury
- The investigation of a fatal accident.

Table 8 shows the ACIM sample of 259 accidents by underground location for the years 1974 through 1978.

Table 8 ACIM ACCIDENTS BY UNDERGROUND MINE LOCATION

Underground location	Explosion or ignition of dust or gas		AIC of fire or SOI of fire or smoke		Total	
	Number of injuries	Number of deaths	Number of injuries	Number of deaths	Number of injuries	Number of deaths
Non-shaft/slope	14	26	162	1	176	27
Location not specified	7	0	12	1	19	1
Shaft/slope	2	1	32	0	34	1
Total	23	27	206	2	229	29
Underground location	**Percentage of injuries**	**Percentage of deaths**	**Percentage of injuries**	**Percentage of deaths**	**Percentage of injuries**	**Percentage of deaths**
Non-shaft/slope	61	96	79	50	77	94
Location not specified	30	0	6	50	8	3
Shaft/slope	9	4	15	0	15	3
Total	100	100	100	100	100	100

Listed in Table 9 are ACIM costs for the sample of 259 accidents.

Table 9 ACIM SAMPLE ACCIDENT COSTS

	Explosion or ignition of dust or gas			AIC of fire or SOI of fire or smoke			Total		
Underground location	Cost of injuries, $	Cost of deaths, $	Total cost, $	Cost of injuries, $	Cost of deaths, $	Total Cost, $	Cost of injuries, $	Cost of deaths, $	Total cost, $
Non-shaft/slope	48,700	14,145,200	14,193,900	424,500	1,019,400	1,443,900	473,200	15,164,600	15,637,800
Location not specified	7,200	0	7,200	9,400	942,200	951,600	16,600	942,200	958,800
Shaft/slope	15,300	294,000	309,300	70,400	0	70,400	85,700	294,000	379,700
Total	71,200	14,439,200	14,510,400	504,300	1,961,600	2,465,900	575,500	16,400,800	16,976,300
Underground location	Percentage of total cost	Percentage of total cost	Percentage of total cost	Percentage of total cost	Percentage of total cost	Percentage of total cost	Percentage of total cost	Percentage of total cost	Percentage of total cost
Non-shaft/slope	.3	97.5	97.8	17.2	41.3	58.5	2.8	89.3	92.1
Location not specified	.1	0	.1	.4	38.2	38.6	.1	5.6	5.7
Shaft/slope	.1	2.0	2.1	2.9	0	2.9	.6	1.7	2.2
Total	.5	99.5	100.0	20.5	79.5	100.0	3.4	96.6	100.0

The average ACIM costs for accidents resulting from fires are shown in Table 10.

Table 10 AVERAGE ACIM COSTS FOR FIRE-RELATED ACCIDENTS

All locations	Explosion or ignition of dust or gas	AIC of fire or SOI of fire or smoke	Total
Average cost per injury	$ 3,096	$ 2,448	$ 2,502
Average cost per fatality	627,791	280,229	565,545
Average cost per accident	315,443	11,577	65,546
Total accident cost	$14,510,400	$2,465,900	$16,976,300

The ACIM average cost per year of fire accidents for the period 1974 through 1978 is $16,976,300 divided by 5, or $3,395,260. This $3.4 million annual figure does not include lost or damaged equipment and machinery. The ACIM model does include immediate and post-accident production losses when a fatality or amputation occurs, but the algorithm used assumes that production returns to pre-accident levels. A fire, however, has the potential to close down entire sections of the mine. Indeed, there have been fires which resulted in the permanent sealing of a mine. These occurrences would result in great costs, both in terms of employment and capital investment, to the industry and mining company.

In summary, the Allen and ACIM data sources indicated that approximately 5 percent of underground coal mine fires occur in the shaft or slope area and result in 14 percent of the deaths and injuries due to fires. It was apparent that a portion of the fires occurring in other mine locations contaminate or have the potential to contaminate the shaft or slope area, but figures illustrating this hazard were not available. ACIM indicated an average fire accident cost per year of $3.4 million, but this figure had some deficiencies in terms of quantifying equipment loss, capital investment, and lost production.

In comparing the data sources of Allen and ACIM, it must be noted that the Allen report is a summary of the number of mine fires, while ACIM is a summary of accident reports. Each injury or death is represented in ACIM by one accident record. No provision was made in this data base for identifying related accident records or indicating the number of fires responsible for the 259 injuries or deaths in the sample of 1974 through 1978. The Allen report specifically excluded fires caused by the ignition or explosion of a gas or dust. In this analysis, however, these fires are indeed a hazard and, regardless of the source of the fire, represent a threat to the integrity of a mine shaft or slope area. In an attempt to quantify these differences and incorporate their numbers into this analysis, Allen and ACIM statistics were compared.

First, the question of how many fires were responsible for the injuries or deaths in the ACIM sample was addressed. Thirty-four percent of the ACIM accidents were termed "fire accidents." (Eighty-nine records had an accident injury code of fire.) This portion of the sample may be considered comparable to the types of accident reports listed by Allen. The Allen report yielded 28.4 injuries or deaths per hundred fires, or roughly a 3-to-10 ratio of injuries or deaths to fires. If this Allen statistic is applied to the ACIM sample, it may be thought to represent 897 fires.

Only 297 of these fires (34 percent) would be termed "fire accidents." Another 46 percent (416 fires) would be accidents not termed "fire" (i.e., entrapment, electrical), but which had a source of injury of fire or smoke. The remaining 20 percent (184 fires) would be caused by the ignition or explosion of a gas dust. By applying the Allen 3-to-10 ratio of injuries or deaths to fires to the ACIM sample of five years, it was concluded that there are approximately 180 fires per year in underground coal mines.

3.2.4 Mine Visits

3.2.4.1 Locations

Fourteen underground mines were visited during the Phase II data collection effort. The mines are located in seven states as shown in Figure 16. Five are in the western states, four in Illinois, and five in the east and southeastern states. One visit to a western mine was made in early January 1980, and the other 13 mines were visited on three separate trips during February 1980. Numerous letters and phone calls were necessary to obtain visit approval, though very few mines declined our request for visit. An important benefit was the exchange of information on the phone and through letters. Admittedly, though, mine personnel were generally skeptical of the direct benefits to be gained from the program efforts.

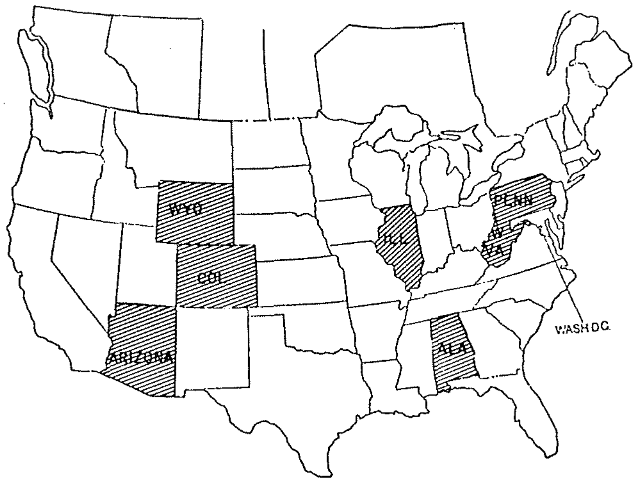


Figure 16 MAP OF COAL MINE STATES VISITED

3.2.4.2 Mine Data

Data of interest was divided into three groups in accordance with the contract guidelines. Table 11 is a summary of the mine profiles, and Table 12 gives related information of mine data collection systems observed and fire and smoke protection systems or components. These tables were consulted during formulation of the mine profiles in the tradeoff chart of mine shaft fire and smoke protection systems (see Table 1). This chart outlines mine shaft fire and smoke protection system concepts, comparing the optimum recommended system and three alternate systems with respect to underground mine conditions and fire protected areas. Table 13 summarizes the decision criteria used by mining companies for selecting data collection systems, including fire safety components.

3.2.4.3 Mine Configurations

The configuration of the mine data includes the mine equipment, ventilation, and type and function of shafts, inclines, and escape routes of workers. Other factors include depth, age, expected life, fire history, labor force, size, and management commitments.

Table 11 GENERAL CONFIGURATIONS OF MINES VISITED

Mine visit	Location	Mine methods	Mine type	Haulage type	Depth	Age	Life expectancy	Fire history	Labor force	Shafts/inclines		Production tons per year
										Type	Function	
1	Wyoming	Ct., Cv., starting Lw.	Underground trona	Shuttle car, conveyor belts	1,600 feet	32 years	>25 years	Not a problem	700	Shafts only	People, materials, production	10^6
2	Arizona	Cut and fill	Underground copper	Rail	4,000 feet	70 years	10-year proven reserves	Yes, spontaneous combustion of old areas	1,200	Multiple shafts and adits	Production via adits	971,000
3	Colorado	In situ	Oil shale	Pipe	Shallow (2,000 feet by 1985)	5 years	Pilot project	Two incipients mentioned	100 (2,000 by 1985)	Adits only	People, material	Nonproduction
4	Colorado	Ct., Cv.	Underground coal	Belt, shuttle car, track	Deep	≅20 years	Unknown	Yes, in heated areas	277	Unknown	Unknown	650,000
5	Colorado	Ct.	Underground coal	Shuttle car, belt	Shallow	≅10 years	Unknown	Unknown	100	Shaft, slopes, drift	Production via drift	435,000
6	Illinois	Ct., Cv.	Underground coal	Belt, shuttle car	340 feet	≅25 years	Unknown	Yes, spontaneous combustion and other	908	Shaft and slope	Production via slope; remote fans	2,096,000
7	Illinois	Ct., Cv.	Underground coal	Belt, shuttle car	750 feet	12 years	>25 years	Not a problem	625	Shaft only	People, material, production	1,594,000
8	Illinois	Ct., Cv.	Underground coal	Belt, shuttle car, track	800 feet	<10 years	>25 years	Few	690	Shaft and slope	Production via slope	1,718,000
9	Illinois	Ct., Cv., Lw.	Underground coal	Belt, shuttle car	666 feet	≅30 years	>20 years	Concern of hopper	477	Shaft only	People, material, production	1,746,000
10	Pennsylvania	Ct., Cv.	Underground coal	Belt, shuttle car, track	Deep	≅30 years	20 years	Few	346	Shaft, drift	Production via drift, remote fans	380,000
11	Pennsylvania	Ct., Cv.	Underground coal	Belt, shuttle car, track	Shallow	>40 years	10 years	Not a problem	311	Slope, drift	People, material, production	393,000
12	West Virginia	Unknown	Underground coal	Belt, shuttle car	Shallow	<10 years	≅20 years	Minimum	318	Shaft only	People, material, production	284,000
13	Alabama	Ct., Lw.	Underground coal	Belt, shuttle car, track	2,000 feet	<5 years	25 years	CH_4 problem	84	Shaft only	People, material, production	57,000
14	Alabama	Unknown	Underground coal	Shuttle car, belt	Deep	Unknown	Unknown	Minimum	508	Unknown	Unknown	740,000

Note: Ct. = Continuous; Cv. = Conventional; Lw. = Longwall

Table 12 CONFIGURATION OF REMOTE DATA SYSTEMS OBSERVED DURING MINE VISITS (Sheet 1 of 2)

Visit number	Type of system(s)	Components		Operation	Performance	Estimated cost
		Location	Function		Limits, stimuli, speed, maintenance	
1	Fifty-station underground monitoring system by Aquatrol Corporation	Sensors for belts, hoppers, fans, pumps	Twelve per station. Slip, sequence, stop, spill, fill, skip, service, etc.	Frequency Shift Key Multiplex Telemetry has graphic display and printer	Sensors respond to central station, maintenance corrects problem, saving estimated 2 hours per shift. Circuit cards and printer required servicing.	$150,000
2	Single-station underground spontaneous combustion reporting system by USBM	7,000 feet underground in exhaust drift	CO, CO_2, SO_2, O_2, and temperature	Continuous recording of analog data from each sensor	CO, CO_2 and temperature most stable during 1-year evaluation. Relocation closer to production or heated areas desired. Maintenance on CO and O_2.	$25,000
3	Twenty-four point tube bundle gas analysis system by Devco plus chromatograph	Throughout mine and in retorts	CO, CH_4, O_2, plus others	Trailer mounted sensors analyze air from pilot-production zones	Continuous sensor calibration and gas analysis performed to meet production needs.	$150,000
4	Nineteen-point underground spontaneous combustion reporting system by USBM	Tubes behind seals and on open areas	CO and O_2	Surface sensors analyze/record CO and O_2 concentrations for telemetry to USBM	Underground tubing and surface equipment maintenance required. Moisture in suction lines.	$100,000
5	Individual vehicle and belt fire protection. New gas chromatograph planned.	Diesel equipment and belts	Fire sensors and diesel emission test	Automatic heat sensors on equipment and manual air quality tests	Performance satisfactory on dry powder vehicle systems. Mine to perform air tests.	$15,000 to $20,000
6	Forty-two underground main belts have remote heat sensing by N.M.S. Fan shaft air sensor by MSA.	Sensors for belts and exhaust air	Heat and CH_4	Overheat condition on belts or excessive CH_4 in exhaust shaft alarms surface	Maintenance for nuisance alarms.	$50,000
7	New large computer system reports production and downtime. Pyott-Boone heat sensors on belt.	CRT and terminals on surface and underground	Foreman reports every 2 hours -- improves communications	Central operator receives phone calls (radio in process) and enters on CRT	System continuously operating -- mine fully committed to use system -- quick response to problems -- expansion planned.	$250,000
8	Complete mine monitoring system. Production, security, and maintenance by Larse Corporation; Belt Fire System by N.M.S.	Sensors for belts, hoppers, fans, pumps	Several 12-point scanners, television and printer	Surface controller observes input on scanners or graphic display -- uses phone to resolve problem	System designed to complement new phones. New graphic panel and expansion of system capabilities in process. N.M.S. Belt Fire System has maintenance problems.	$250,000

Table 12 CONFIGURATION OF REMOTE DATA SYSTEMS OBSERVED DURING MINE VISITS (Sheet 2 of 2)

Visit number	Type of system(s)	Components		Operation	Performance	Estimated cost
		Location	Function		Limits, stimuli, speed, maintenance	
9	Diode-controlled belt fire sensors. Automatic ventilation door.	Belts and hopper	Overheat signal on belts -- smoke closes door	Heat and smoke sensor alarms in underground station	Frequent repair of belt sensors and deluge water spray. Surface-type smoke sensor and magnet door-hold not operating since 1977 purchase.	$12,000 (smoke) sensor
10	Voice alarm system by Jabco, remote fan monitor by Motorola. Television monitor on scales.	All belts, four fans, and scales	Heat, slip, sequence, stop, etc., and fan stop (via radio), security on scales	Any sensor on belts or fan actuates voice recording on phone system. Trucks recorded via television monitor.	Interference with mine phones during alarm condition. Ventilation engineer has 24-hour printout of all functions.	$100,000
11	Voice alarm system by Jabco remote fan monitor by Motorola. Television monitor on scales.	Belts and scales	Heat, slip, spill, water flow	Any sensor on belts or fan actuates voice recording on phone system. Trucks recorded via television monitor.	Interference with mine phones and problems with open-contact heat sensors	$100,000
12	Voice alarm system by Jabco for underground belts	All belts	Heat, slip, spill, water flow	Sensor actuates 8-track recorder onto mine phone system	Voice alarm conveyor fire protection system being replaced with National Mine Service Tone System. Sealed sensors reduce maintenance.	$25,000
13	Remote telemetry of gas concentration from seven underground locations. (RFL, ESI and Bacharach).	Two gas sensors at end of each of seven belts (14 sensors total)	CO, CH_4	Analog signals transmitted to surface printer and graphic display	Acceptable performance allows mine to use belt air at face. Monthly calibration, weekly electrical check, daily inspection. RFL lacks carrier.	$50,000 to $75,000
14	Voice alarm system by Jabco for belts, heat, stop, etc.	Sensors on 12 conveyor belts	Heat, slip, stop, water flow	Any sensor on belts.	Humidity a problem with open contact sensors, more frequent nuisance alarms in summer. Motion sensors bigger problem.	$25,000

Table 13 MINE DECISION CRITERIA FOR SYSTEM SELECTION

Visit number	Need for system Safety, production, law	Performance Reliability, response, maintenance	Cost/status
1	Improve production by decreasing downtime; large operation has 40 conveyors, multiple fans, shafts, pumps and hoppers. Safety devices (smoke-fire) to be added.	System is achieving quicker response to equipment failure and maintenance. System service by supplier important.	Purchase and operation costs recoverable by improved production.
2	Safety system and cooperative test agreement with USBM. Mine has experienced spontaneous combustion fires in past.	Diffusion sensors desired rather than mechanical pumps to reduce maintenance.	Mine is considering expanding system to three new areas.
3	Safety system developed following mine closure due to 1972 spontaneous combustion fire.	Reduced maintenance required. Full-time employee to service system not committed.	Mine is reassessing need.
4	Safety system to meet laws and facilitate ventilation requirements for diesels.	Accurate gas analysis desired to conform to Acceptable Threshold Levels.	Funds budgeted as needed.
5	Production and safety system for unique mining methods (in situ).	Accurate gas analysis important to mining method.	Costs commensurate with pilot production method.
6	Safety system on conveyor belts to meet law. Gas analysis and fan operation check for combined safety and productivity.	Many nuisance alarms on belt system. Longer time between maintenance desired. Management seeking fast alarm to increasing gas levels.	Trial installation allowed to prove system.
7	Corporate management desired better reporting and control of production, inventory, and labor.	Effectiveness demonstrated well during visit; face equipment down; many departments entered repair action via central control.	Large budget allocated at corporate level. Many full-time persons added to promote success.
8	Adding new phone system prompted production data reporting system.	Control center operator quickly identifies trouble source and phones investigation and repair. Success proven and large expansion planned.	System cost benefit evidenced by planned expansion.
9	Safety system to meet laws and anticipated transfer of fire or contaminated air from hopper into mine.	Generally nuisance alarms and breakage. Smoke alarm not functioning.	Added effort needed to make system functional; not committed.
10	Safety to meet law and improve production. Four distant fan locations difficult to check. Scale surveillance to check trucks entering/leaving.	Voice message of Jabco recorder over mine pager system identifies trouble spot to entire mine. Some nuisance alarms. Daily log from printer allows analysis. Type of failure rather than just location needs identification.	Separate systems (fan and belts) combined over voice recorder.
11	Safety to meet law and improve production. Four distant fan locations difficult to check. Scale surveillance to check trucks entering/leaving.	Voice message of Jabco recorder over mine pager system identifies trouble spot to entire mine. Some nuisance alarms. Daily log from printer allows analysis. Type of failure rather than just location needs identification. Trial indicates tape worn or dirty; repeats necessary for information.	Installation common with corporate facilities.
12	Safety system to meet law for belt fire protection and to improve production.	Poor performance; system being removed. New NMS tone system installation scheduled to reduce system maintenance. Trial of voice recorder inaudible.	Initial system not designed for mine conditions; costs to purchase, install, and maintain lost.
13	Safety system due to high CH_4 emissions in deep mine requiring added air at face for dilution.	Performing satisfactorily; weekly checks and monthly calibration acceptable due to strong need to use belt air at the face.	Costs commensurate with mine method and need; system expansion planned.
14	Safety system to meet law and improve production.	System maintenance due to nuisance alarms is a problem. Dust and moisture improvements needed.	Maintenance commitment needed to support system. Nuisance alarms promote lack of confidence.

3.2.4.4 Mine Fire and Smoke Systems

The configuration of the installed fire and smoke protection systems includes the effects of ventilation, identification of elements of the system by location and function, overall operation of the system, limits, characteristics of stimuli, capacity to sense and extinguish fires and/or control smoke, capability to protect mine workers and permit escape, operating time, all costs, reliability, deterioration factor, maintainability, and history of performance.

3.2.4.5 Mine Decision Criteria

Also included are the decision criteria used by mining companies in their selection of a shaft fire and smoke protection system. The criteria are as follows:

- Need for system (based on potential hazards, personal injury, and production losses)
- Acceptable installed cost, maintenance cost, and operating cost of the system
- Performance requirements of the system.

3.2.5 Visit Descriptions

3.2.5.1 Mine Visit Number 1, January 11, 1980

The visit to this 1,600-foot-deep western trona mine coincided with the USBM/Contractor Phase I meeting at San Jose. In January 1980, about 700 miners worked underground at this mine and used continuous and conventional mining equipment. The noncombustible ore does not present a fire hazard when traveling the 42 different conveyor belt systems that cover 10 miles in length.

Shaft contamination from fire and smoke in the mine rather than within the four concrete-lined shafts or shaft bottoms was observed, and fire doors were evaluated.

Due to the extensive conveyor systems and the time lost in searching and correcting conveyor problems, the mine was using a new 50-station microprocessor-based mine data acquisition and control system to record the following:

- Interlock
- Emergency stop
- Belt plug-up
- Belt slip
- Incomplete sequence
- Failure to stop
- Undervoltage
- Side motion
- Motor overload
- Full ore pocket
- Remote stop
- Running.

Return commands, such as for starting and stopping the belts, were also part of the system. Each of the above indications or commands could be generated from or sent to any of the conveyor belt stations. If the remote station was for a hoist, other data relating to power, rope condition, hopper capacity, pressure, gates open, etc., were displayed. The complete system was zoned into three sections to eliminate total disability during maintenance or malfunction. To increase system reliability, a multiconductor cable to each of the three zones was used. Normal operation required only a single pair of wires, but added pairs were installed in case the operating pair should fail. Except for adjustments in the system's three printers and occasional replacement of plug-in circuit boards or bulks, the system performed well, and a 100-percent expansion has been planned. Future plans include the addition of fire and smoke sensors.

3.2.5.2 Mine Visit Number 2, February 6, 1980

This southwestern metal mine has a history of heated areas. It has concrete and rock shafts, with multiple adits as alternate escape routes. This cooperating mine has worked with contractors on many occasions, and it was a candidate mine during Contract H0282002, Improved Spontaneous Combustion Protection for Underground Metal Mines. A wood-lined sub-level shaft used for men and materials was of particular interest.

The CO_2, SO_2, and telemetry system from Anglo American Electronics, the temperature sensor from Hy Cal, and recorder (ELNIK) have functioned well and without maintenance since installation. The CO analyzer from Energetic Science had several circuit boards and pumps replaced but was also functional, as was the CO unit from Dynamation, which also did not require maintenance. The mine considered the TGS sensor from Dynamation more acceptable, because it did not have a pump, and it compared favorably with the Ecolyzer 4125 CO analyzer that is more selective to CO than the Dynamation unit. Additional units were proposed for other sections of the mine, and particle analyzers were being considered, along with CO and CO_2.

3.2.5.3 Mine Visit Number 3, February 7, 1980

This drift-entry mine is located in a western state and is currently in the pilot-production phase with full production planned for 1985 at a nearby location. Considerable use of tube-bundle systems from Devco and total mine commitment to collect and analyze data on a per-shift basis were observed. Analyzers with tubes extending to five different zones were collecting CO, CH_4, and O_2 information on the Devco system. One tube was seen at the portal. Additional gas chromatograph checks were made to evaluate 21 other gases. Chart recorders continuously collected data, and manual checks were made twice each shift. The analyzers were located in trailers inside the drift-entry mine and were each calibrated twice weekly. The mine configuration is unlike other mines in that the production zones are normally unoccupied and inaccessible, and the measurement and control of gases had the highest priority.

3.2.5.4 Mine Visit Number 4, February 8, 1980

This slope-entry coal mine is also in a western state and has a 19-tube-bundle system installed in conjunction with a USBM contract. Commitment was lacking from the mine management, USBM, and equipment manufacturers to fully utilize the system capabilities. Regular maintenance was not performed, and although the data collection system had recently been modified for data storage and retrieval at a USBM research facility, the accuracy of the data received was questionable. For example, one tube (number 16 of 19) was disconnected, and two filters were one-half to three-fourths full of water. Also, all of the cylinders containing span and purge gases (CO, CH_4, N_2, and O_2) were turned off, rendering the automatic calibration system ineffective.

It was recommended that emphasis should be placed on making this system functional by relocating it in a mine having the need and interest to commit maintenance and data collection personnel.

3.2.5.5 Mine Visit Number 5, February 8, 1980

This drift-entry coal mine is also in a western state. The mine used diesel LHD vehicles and had budgeted $14,000 for a gas chromatograph to analyze mine gases. The mine's safety personnel were concerned that the new oxygen-supplied self-rescuers be fully proven prior to regulating standards. Shaft and drift fire and smoke protection was not of immediate concern, but the diesel equipment and fuel areas had dry chemical systems. Normal mine downtime was 2 to 4 days, but they had experienced as much as 14 days of inactivity. Longer mine inactivity may suggest a greater need for a fire and smoke protection system.

3.2.5.6 Mine Visit Number 6, February 11, 1980

This large, central-states coal mine had two remote man-shafts, each 5 miles distant from the main slope. Intake air quality at the slope was discussed, as was gas measurement at the underground central hopper at the slope bottom. Exhaust air at the remote shafts was also of interest. A mine fire area had recently been sealed, and MSHA personnel were still on the property to record gas concentrations from the fire zone. Prior to MSHA's arrival, mine personnel attempted to utilize a 4-tube-bundle system, but abandoned the effort when the plastic tubing began cracking in the freezing temperature.

This large mine had the National Mine Service (NMS) Continuous Belt Fire Detection System on each of 42 main belts of which totaled approximately 140,000 feet. They were also installing an MSA remote methane monitor in one of the remote shafts to measure return air.

3.2.5.7 Mine Visit Number 7, February 12, 1980

This 750-foot-deep shaft-entry coal mine, located in a central state, had the most elaborate mine data collection system observed during all of the visits. This had been achieved because of the total commitment to the system by upper management.

The 10-terminal CRT display system (4 underground; see Figure 17) was used as a production and maintenance tool, but the mine planned to begin a safety program within 60 days and a personnel program within 6 months. All underground foremen report by telephone to a central control station every 2 hours. The operator used the CRT to type information regarding production, equipment, and personnel that was then displayed on all monitors.

The mine expressed interest in analyzing continuous information about return air from gob sections. They considered remote methane analysis and adjustable air regulators beneficial. Their Pyott-Boone belt fire system was noted as being troublesome and maintenance prone.

The mine was in the process of installing a Motorola radio system utilizing portable radios to transmit and receive from Radiax cable and antennas throughout the mine.

3.2.5.8 Mine Visit Number 8, February 13, 1980

This shaft-entry coal mine, again in the central United States, had committed large funding to a total mine data collection system during mine construction. At the time of this visit, the mine was approximately 4 years old, and there were plans to expand the data collection system.

Discussion with the system designer indicated that the multiplex data collection and TV surveillance system (costing approximately $250,000) grew from the need for a mine-wide phone system. Information about belt slippage, spillage, fire, coal hopper and rock dust hopper levels, water levels, pumps, motors, etc., was being collected and visually displayed on large graphic panels in a surface control center.

The NMS belt-fire system controls were located in the dispatcher's office. Opinions about the usefulness of, reliability of, and maintenance required for this system varied between the dispatcher, who objected to constant alarms, and the maintenance man, who said it was much better than the former "air-alert" belt-fire system which had air-pressure sensors. Maintenance personnel spent approximately 2 hours weekly to correct a problem or check the system.

Of special interest to the ESD design team was the use of graphic panels to display all system locations and conditions. The Aquatrol system at Mine Number 1 was the only other system observed during the 14 mine visits having such a large, easy-to-interpret graphic panel. This successful installation was being used frequently, and 100-percent expansion was in process.

3.2.5.9 Mine Visit Number 9, February 14, 1980

This central-states shaft-entry coal mine had installed an ionization-type smoke sensor and magnetic door-control system at its underground hopper area. Doors near the hopper allowed air into the mine during summer months and, should a fire occur, the doors will close automatically. Their conveyor-belt-fire system had four heat sensors with a diode at the end of the line. The belt sensors were connected to automatically discharge water onto the conveyor belt. The water supply pipe was found broken, as were

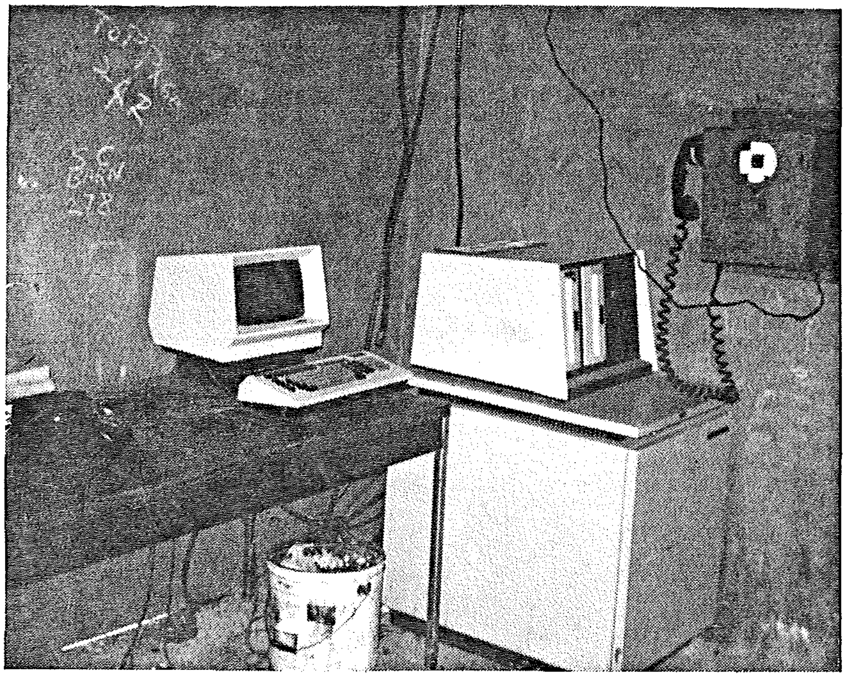


Figure 17 UNDERGROUND CRT DISPLAY

several sensors. The $1,200 ionization sensor was purchased in May 1977 and was not completely functioning during our visit. The hot, humid air had corroded the housing and, most likely, much of the interior of this surface-type smoke sensor from Simplex.

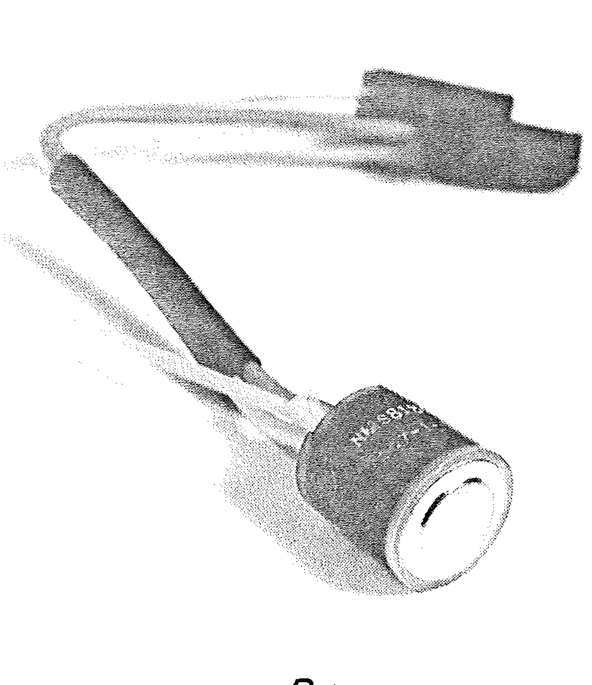
3.2.5.10 Mine Visit Number 10, February 26, 1980

This visit was to an eastern, shaft-entry coal mine with an extensive fan monitoring system (via an $80,000 Motorola radio system) and Jabco voice-on-phone tape recording systems for belt as well as fan monitoring. Each of the four $1,600 Jabco units has a woman's voice pretaped for coupling to the phone system. When any sensor (i.e., motion, spillage, heat, on, off, etc.) from belt or fan occurs, the voice identifies the belt or fan (but not the sensor) by alarm. Although persons we spoke to at this mine expressed satisfaction with the Jabco system, other mines were replacing it due to phone interference. The tape recorded voice continues until someone goes to the source to cancel it. During this time, the telephone system was disabled.

3.2.5.11 Mine Visit Number 11, February 26, 1980

This mine was another eastern, shaft/slope coal mine utilizing the voice-recording system over telephones. Nuisance alarms were mentioned as a problem. The simple and inexpensive blade-contact heat sensors (see Item A, Figure 18) were being replaced by the potted sensors (see Item B, Figure 18) to decrease the false alarm problems. This mine had remote TV monitors to observe trucks entering and leaving scales at the surface loading area.

A



B

Figure 18 CONVEYOR BELT FIRE DETECTORS

3.2.5.12 Mine Visit Number 12, February 27, 1980

This southeastern, shaft coal mine was on strike when we arrived. They were in the process of removing the Jabco voice-recorded belt-fire alarm system due to excessive phone interference. They recently extended a new 11-pair wire down the shaft and will use one pair for their new NMS belt-monitoring system. The potted thermal sensors were mentioned as being the solution to many false alarms, as was observed on numerous occasions during the visits.

3.2.5.13 Mine Visit Number 13, February 29, 1980

Due to excessive methane emission, this deep-shaft coal mine in a southeastern state had a special permit to use belt air at the face, in conjunction with an approved CO gas sensor. The seven Ecolyzer 4000 series CO monitors were at the ends of the belt-ways. Three of their six mines owned by this mine company had the Ecolyzer units, and plans to incorporate J-Tech airflow sensors were in progress. NMS and Pyott-Boone belt-sensors were used. Some dislike of the RFL telemetry used to transmit the analog CO data was expressed, and such telemetry may not be included in future plans for microprocessor-controlled airflow CH_4 measurements in pipes. Mine personnel expressed interest in data recording and remote control capabilities of air regulators. Installation and remote data telemetry of additional CO analyzers were planned.

3.2.5.14 Mine Visit Number 14, February 29, 1980

This deep-shaft coal mine, again in a southern state, had the Jabco voice-recorded message system on its belts. Mine personnel expressed dislike of their inability to use the phone system when the voice system was activated. Nuisance alarms were approximately two per day in the summer and half that in winter, with the belt-motion sensors being the greatest problem. Dust and humidity was a problem with the underground-located 8-track cartridge players.

3.2.6 Conclusions from Mine Visits

The following conclusions were drawn from the mine visits:

- Only a token representation of mine shaft fire and smoke protection systems were found in the 14 mines visited. At four mines there was evidence of concern for quality of intake air by installing sensors and/or doors at the portal or at underground entries. Discussions with mine personnel indicated that there was more concern about the fire hazards of facilities on the surface near the shaft intake, or fire potential within the mine, than fire hazards in the shaft. Most of the shafts observed were constructed out of concrete and steel.

- Mine management will more readily commit funds and labor force to mine safety systems if the systems perform in conjunction with other direct-production-oriented data analysis or recording systems. Two of the 14 mines visited had each expended over $250,000 in remote data-collection equipment, and five others had each expended over $100,000. The upper limit appears to be about $250,000, and each of the mines planned for additional expansion of its system.

- It was evident that addition of fire and smoke safety components would be readily acceptable to mines that already have production-data recording systems, or mines where management was convinced that other direct benefits could be realized from production-oriented activities coupled to a new safety system.

- Because of statutory requirements, conveyor-belt-fire control systems were common. Mines exhibited a trend away from heat sensors which have open contacts that short easily in humid environments. Many belt-fire systems were regarded as a nuisance, as troublesome, and as the cause of frequent maintenance. Complete and periodic tests of the systems were not evident, and several systems had failures in evidence when our visits were made. The MSHA-approved Ecolyzer 4125 CO gas analyzer was recognized as a reliable sensor for use in underground coal mines. Continued USBM-MSHA evaluation of the Ecolyzer CO analyzer in various mine situations is recommended.

- Ten of the 14 mines visited had operational electronic data recording systems between remote sensors and a surface control center. Applications of fire and smoke sensors were either already on the systems or in the planning stages. Continued use of electronic systems for production and safety appeared evident. Fire and smoke sensors seen at two of the mines (Numbers 2 and 13) were designed for underground installation through efforts of USBM and MSHA. Added technology transfer of mine-proven sensors, and continued research, will promote acceptance and more reliable systems.

- The extensive tube-bundle system observed during the visit to Mine Number 3 cannot be compared to a typical coal-mining operation. High priority, commitment, and daily maintenance and calibration are the result of the unique in situ production methods used. The USBM/contractor-installed tube-bundle system at Mine Number 4 was not favored by mine personnel. The system should either be removed to a cooperative mine site for continued evaluation, or new programs generated to convince mine management, the domestic mining industry, and other agencies or contractors of its benefits.

- o Graphic panels or CRT graphic displays quickly interpret alarm situations, while coded printouts and chart recorders provide historical data. As both production and safety rely on quick response to abnormal conditions, the use of easily interpreted displays is encouraged.

3.2.7 Agency, Contractor, and Vendor Information

Government and private agencies, USBM contractors, and equipment suppliers were contacted during Phase II data collection efforts. Other reports and file data were reviewed for relevant information. The following paragraphs relate data from these sources.

3.2.7.1 USBM

The USBM Pittsburgh Research Center was visited February 25, 1980. The Pittsburgh research efforts are directed at many areas of the mining industry. Discussions of fire and smoke safety efforts follow:

- o Submicron particle analysis, and development and test of the USBM particle analyzer, were continuing. Application to the coal mine shaft fire/smoke protection contract appears marginal, due to delivery times and the scope of the contract promoting off-the-shelf hardware. Other particulate analyzers, such as those from Brunswick, Environment/One, and Becon, are possible candidates.

- o Operational problems with the USBM tube-bundle system at the western coal mine were explained. Several changes, and the lack of strong mine commitment over the past years, resulted in the inactivity of the system. Tube-bundles at the FMC candidate test mine would eliminate the permissibility requirements. System discussion was limited to conditions known at the time regarding the application at the mine and the need for a permissible system. Additional information suggests data collection is performed from fans located 5 miles from slope entry. Also, response commands for remote alarms are suggested for the mine shaft system; this would preclude use of a tube-bundle.

- o The clean-air-quality integrity of shafts and shaft stations includes potential conditions that occur at the surface, near the air intake, as well as those that occur in the shaft bottom, near the shaft bottom, or deep within the mine.

- o The USBM-TPO for the Accident Cost Indication Model (ACIM) was consulted for permission to use the data base for this mine shaft fire and smoke contract.

3.2.7.2 MSHA

Pittsburgh and Triadelphia MSHA offices were visited on February 25 and 28, 1980, phone contacts were made with the Denver office, and several MSHA persons were consulted during their visits to ESD on March 18, 1980. New developments, testing, and approvals of fire and smoke sensors were of primary concern during discussions.

- The USBM-Pittsburgh office performed evaluations of many fire and smoke sensors. The new electrochemical-cell CO analyzers from MSA (Models 570, 571, and 572) were of interest because the electrochemical cell does not have a pump, a design consideration for underground sensors. Operating data and underground mine testing need to be reviewed.

- It was learned that ESD must contact Maurice Childers at the Vincennes, Indiana, district office, and Carl Adams at the Benton, Illinois, subdistrict office, for clarification of MSHA requirements when installing a system in the candidate test mine.

- An existing general guide is to have an alarm when CO level is 10 ppm over the established background. A ratio of CO concentration to the air volume was not discussed, but would appear to have merit due to the varied mine conditions.

- Any sensor in return air must be permissible or intrinsically safe. A pitot tube into a return air shaft would allow instruments to be nonpermissible, although if the mine fans are shut off for 15 minutes, all power underground must be shut off. All electrical components operating underground after the mine fans are off must be permissible regardless of location.

- The precursor gas for coal mine fire detection is carbon monoxide (CO). The original fuel burning may not give off large amounts of CO, but due to the potential for coal to become quickly involved, CO will soon follow. CO_2 was not considered practical as an alternate gas to monitor for fire indication. It was mentioned that only limited information exists to support the monitoring of CO_2, though this lack of support may be partially due to the scarcity of in-mine CO_2 analyzers in the domestic coal mines. Some laboratory data exists[5], as do reports from tube-bundle systems; however, the data does not appear so conclusive as to prohibit trial testing of a CO_2 analyzer in the mine shaft fire protection contract. As an example, a fire in a surface facility near an intake portal may contaminate the shaft and mine. An oxygen-rich burning structure will be very high in CO_2 but low in CO. The same is true for possible fires of wooden roof supports in the shaft or in lagging at the shaft bottom.

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5. Chamberlain, Hall, Thirlaway, "The Ambient Temperature of Coal in Relation to the Early Detection of Spontaneous Heating," The Mining Engineer, October 1970.

- During an MSHA visit to ESD facilities in San Jose on March 18, 1980, a general discussion took place regarding the need for the mine shaft fire and smoke system to continue operating if the mine fans are off. It was considered unnecessary to extend the system operation, since the mine would be evacuated and all mine power would be off, including power for other mine fire safety systems. This may, however, be considered the opportune time for fire occurrence, since heated belt rollers, stopped motors, or coal piles will be collecting or generating heat that may cause a fire. In metal mines, the restarting of fans and underground mine power following days of inactivity is an equally opportune time for spontaneous combustion, due to increasing oxygen supply and electrical arcing.

- It was considered that the prototype mine shaft fire and smoke protection system does not need to be permissible or intrinsically safe, as long as the electrical components are not in return airways.

- The Becon smoke detector from Australia, containing 5 millicuries of krypton 85 radiation source, is a candidate particle sensor. Approval for using the device in underground coal mines was discussed. It was suggested that the regulations for using it in any surface facility be reviewed and, if the device is approved, it should have no restrictions other than permissibility for similar use in coal mines.

- The MSHA-Denver Technical Support Branch was contacted for information on sensor and control systems for mines. Carbon monoxide sensors, central monitoring with remote alarm, and solenoid actuation to close smoke doors are being recommended in several underground metal mine applications. Sealed areas and new openings also create unfavorable conditions where remote data systems will be needed.

3.2.7.3 National Coal Board

Conversation and/or correspondence with Messrs. Jim Onley, Chief Project Manager (Transport), L. R. Cooper, Head of Instrument Research Branch, and A. D. Makower, Director of Scientific Control, provided the following:

- The surface CO analyzer used in tube-bundle systems is an infrared unit from Analytical Development Company in Hertfordshire. It is a standard device with a tube-bundle concept, but is slow responding.

- The British are still looking for a good, reliable, inexpensive CO sensor to place underground to complement the tube-bundles.

- The pump of the Ecolyzer CO analyzer is the device's weak point. This is replaced with a British-designed pump. Diffusion-type CO analyzers are preferred.

- o The new MSA CO analyzers are not familiar items at NCB, but interest is only in their electrochemical cell design.

- o There is similar unfamiliarity with the Anglo American Electronics Spanair CO_2 analyzer and the Becon ionization detector. The Trolex unit was mentioned as a particle sensor used in underground mines.

- o J. S. Sieger supplies the BMI in-mine methane sensor which serves as the basic indication for safety.

- o CO and particles of combustion receive the most attention in research. CO_2 is not a gas of interest for coal mines but may have application in other mines, such as South African gold mines having numerous timber packs.

- o The need of and use for tube-bundle systems varies with each mine, as does the need for in-mine sensors. Each system has unique features, and the systems tend to complement each other. The use of in-mine sensors to telemeter data out of the mine is increasing.

3.2.8 Contractors, Vendors, and Support Groups

The various persons and groups contacted during the data collection effort include USBM contractors, equipment suppliers, licensing agencies, fire research agencies, and mine personnel who have designed mine data acquisition systems.

3.2.8.1 Allen Corporation of America

USBM Contract J0275008, An Annotated Bibliography of Coal Mine Fire Reports (February 1979), provided information on fire reports recorded from 1950 through 1977, including MSHA accident reports and periodicals including several nonreportable fires (i.e., fires of less than one-half-hour duration). The data was analyzed by time trends, state, ignition source, burning substance, location, equipment, detection, duration, injuries, fatalities, and successful extinguishing agent. This bibliography does not include explosions, or ignitions or fires that resulted from explosions. Study results indicated that electrical causes were predominant in most cases of surface and underground, reportable and nonreportable fires. Nonreportable fires accounted for less than 5 percent of the fire total.

As was indicated earlier in this report, 5 percent of underground coal mine fires occurred in the shaft or near-shaft areas of the mines, but these fires accounted for 13 percent of the deaths and injuries related to fires. Several report abstracts are listed in Appendix D and describe fire or smoke conditions that occur in or near mine shafts.

Because the Allen report was assembled manually, quick data manipulation by computer was not possible. This data comparison might yield additional insights into the magnitude or potential of mine fires. ESD suggests that the Allen report and future similar studies be made available on machine readable storage medium. An additional factor that appears significant to this hazard analysis for the mine shaft fire contract was that fires resulting from explosions were not included. Considerable losses have occurred due to these types of fires, and where contamination of escape ways is evident, listing of such fires in one document would be beneficial.

3.2.8.2 University of Utah

The 27-month Bureau of Mines Contract J0100004, Development of a Mine Air Contaminant Measurement Program, was started in December 1979. Personnel exposure to contaminants from diesels, explosives, and other products was studied for metal/nonmetal and coal mines. Types and locations of instruments used were of interest. The study was considered to be too early for application.

3.2.8.3 National Bureau of Standards, Center for Fire Research

Two documents were received regarding water sprinklers: "Proving Spray Sprinkler Efficiency," Factory Mutual Laboratories Report, Quarterly of NFPA (January 1954) and "Sprinkler-Vent and Spray Nozzle Systems for Fire Protection of Openings in Fire Resistive Walls and Ceilings -- The State-of-the-Art and a Plan for Future Research Work" (January 1979).

The Factory Mutual report compared regular sprinklers with upright spray sprinklers. The test model fire originated in a crib below and spread to ceiling joists. The spray sprinklers provided better fire extinguishing of ceiling joists. The second article concluded that small droplet size is important, and that higher nozzle pressures create greater air movement that also acts to counter buoyant forces.

3.2.8.4 University of West Virginia

The ESD design team visited the University to discuss its past Bureau of Mines activities with mine monitoring systems. Several papers were acquired describing their work done over several years:

- "Coal Mine Ventilation Remote Control Utilizing a Microprocessor"
- "An Experimental Ventilation Control System"
- "A Loosely Coupled Microprocessor Network for Underground Coal Mines"
- "A Distributed Microprocessor Monitoring and Control System for Coal Mines"
- "Electronic Remote Controlled Mine Ventilation Regulator"
- "Mine-Wide Test of the WVU Monitoring Concept."

Hardware systems had been returned to the University following underground mine testing, and future plans were uncertain. Features of interest were the remote-controlled ventilation regulators and the environmental sensors. Measurements for CH_4, CO, air velocity, and differential pressures were more useful than temperature and relative humidity. Lengthy software programs and employee/student turnover were mentioned as problems with the projects.

3.2.8.5 Analytical Development Co., Ltd.

This company was referenced by Mr. L. R. Cooper of the National Coal Board as suppliers of the carbon monoxide sensor Type 314 that is used in British tube-bundle systems. The company also makes a methane instrument Type 316, but the BMI methane monitor by Siegers reportedly is used underground and serves as the basic indication for safety.

3.2.8.6 Environment/One Corporation

A visit by Mr. Ernest Steinmann, President of Environment/One, to ESD resulted in follow-up by Frank Van Luik and discussion of their submicron particle analyzer. Limited mine application of this instrument exists, and future trials in Kentucky's Black River Mine may provide relevant data. The standard unit is a four-zone system designed for warehouses, offices, computer rooms, and other surface facilities. Distance that particles must travel, moisture, and particle coagulation must be considered.

3.2.8.7 State of Illinois-Mine Rescue Station

During visits to coal mines in the central states, ESD visited Benton, Illinois, site of one of the six Illinois mine rescue stations. The station is well-equipped and staffed for coal mine training, and training and assistance for mine fire fighting and rescue. Future safety presentations by the Bureau of Mines and research contractors at the Benton facility are planned, and advance scheduling was suggested for potential attendees.

3.2.8.8 State of California-Radiologic Health Section

It was ascertained that previous import license arrangements might not be acceptable for anticipated new purchase of ionization sensors containing 5 millicuries of krypton 85 radiation source. New license arrangements were negotiated.

3.2.8.9 Mine Safety Appliance (MSA)

Mine Safety Appliance was contacted after ESD/MSHA discussions of the MSA diffusion-collection electrochemical-cell CO analyzer. The unit is in production and contains a unique cell design. There is no mechanical pump, but gas interference may occur. Approximately 200 exist in dust-laden steel mills. These devices appear suitable for mine test and evaluation under this contract.

3.2.8.10 Energetic Science, Inc. (ESI)

Correspondence was conducted with ESI for price and availability of their Ecolyzer 4125, 8000 (tube-bundle), and new diffusion-collection carbon monoxide sensor. The 4125 unit with the mechanical pump costs approximately $1,500 with necessary attachments. The 8000 series price range is $10,000 for a 4-point system to $18,000 for a 16-point system with options. The new diffusion sensor was of interest for this contract. The 4125 series unit was recommended for testing until the new unit is available.

3.2.8.11 Interscience Laboratory

Mr. Steve M. Toy has introduced Model CH-2F2 methane gas detector that, with modification, could be selective to carbon monoxide when used as a gas chromatograph. The unit is currently a portable device and sales of this device have not been extensive. Evaluation of the device appeared better suited under another development contract.

3.2.8.12 Mine Data Collection System

Mr. Dave Caston, a mining engineer who was instrumental in the design, development, and testing of a mine data collection system, was consulted for background information. The mine where this system is installed was relatively new and the extensive data collection system (see Mine Visit Number 8) developed from the need for telephone systems. Mine management allowed expansion of the phone system in an effort to assist production and maintenance. The effort was very successful, and an expansion of the system was in process.

3.2.9 Conclusions from Agency, Contractor, Vendor, and Support Groups

Several conclusions were made from the information gained from the visits and contacts with the contractors, vendors, and support groups. This data is summarized below:

- Particulate analysis for indicating fires is a proven method, and work to improve coal-mine-worthy particle analyzers is increasing within the USBM. Foreign agencies and mining companies already use particle analyzers. The mine shaft fire and smoke protection program should continue evaluation of particle analyzers.

- The USBM particle analyzer may offer significant advantages as an early fire warning sensor, but a mine-proven unit was not commercially available to use in this program during early design Phase III. It was concluded that the program followed USBM activities and allowed space to install a trial unit if one became available during the Phase IV in-mine demonstration.

- Review of other particle analyzers, such as those from USBM contractors, was updated and space was made available on the system for Phase III evaluation. At the time that information was gathered, the alternate USBM particle analyzers were expensive and not fully proven for underground coal mine application.

- The analog Becon ionization detector is a mine-proven fire detector used in South African gold mines. Efforts should continue to evaluate the device for use in domestic underground coal mines.

- Tube-bundle systems do not offer the speed of response and flexibility of an electronic data-reporting system, nor is remote control easily provided. Except for direct production-oriented applications, the domestic coal mine industry has not demonstrated sufficient interest by committing the funds for purchase and installation of tube-bundle systems.

- o Permissibility of a mine shaft fire system does not seem to be a needed factor unless the system must remain operational when the mine is evacuated. The nonpermissible components must remain in intake air.

- o Quality of intake air was considered important by many, but monitors to detect contaminated air were found in just two instances, and functional operation of one of these was questionable. Recording quality of intake air appears to be a viable and acceptable recommendation.

- o The Ecolyzer 4125 CO analyzer is an acceptable device to install in underground mines, although the deletion of the mechanical pump is desirable.

- o The new electromechanical-cell CO analyzer by MSA does not have a pump, as does the Ecolyzer 4125.

- o A CO_2 analyzer may give an equally good fire indication in or near intake shafts, as will the CO analyzer. Space was available in the system for possible addition of a CO_2 analyzer during Phase III.

- o Several USBM contractors had tasks that overlapped this program. USBM, MSHA, contractors, and equipment suppliers should conduct an open conference for exchange of information.

3.2.10 Remote Reporting Systems

In phone calls to mines during early Phase II, it was learned that mine shaft fire and smoke protection systems in coal mines consisted mostly of manual observations and actions of personnel in or near the vicinity of the shaft. Conveyors in slopes had heat sensors, few mines measured air quality entering the shafts, and several had fixed sprinklers. Most mines had portable fire-fighting equipment, as well as some type of remote data-collection system.

In addition to gathering data on mine shaft fire and smoke systems during mine visits, ESD compiled a cross section of the types of remote data-collection systems that were installed and in use within the industry (see Appendix E). Evaluating the features of a mine-accepted, remote reporting system provided insight into the design of a mine shaft fire and smoke protection system concept. Mine commitment to purchase, install, and maintain a data-collection system was found to be contingent upon three factors:

- o Compliance with the law, such as for conveyor belt fire systems.

- o Improvement of production by quickly locating required maintenance sources, such as belt or fan stoppages, equipment or labor needs at the face, inventory control, etc.

- o Ancilliary purposes, such as cross-checking production rates of buggies versus skips or belt tonnages, checking bin levels and scales, performing mine gas analysis, and maintaining security.

3.2.10.1 Conveyor Belt Fire Protection Systems

The most common remote reporting systems (other than the mine telephones) found in underground mines were conveyor belt fire protection systems. The following paragraphs contain brief discussions of several such systems.

3.2.10.2 Tone Telemetry System

The National Mine Service Continuous Belt Fire Detector System is an underground remote station that monitors heat sensors on two belt flights and transmits specific frequency-shift audio tones to a central station, generally located on the surface. A single-surface module serves up to eight belts, and modules can be joined together. Transmitters and receivers can be added (when belt lines are added), or replaced if a failure occurs on a line. Each transmitter sends a carrier tone, and failure to receive the tone indicates trouble or a faulty transmitter. The transmitter shifts frequency between two belts.

3.2.10.3 Resistance Telemetry System

The Pyott-Boone fire detection system for underground belt conveyors utilizes changes in the line-resistance measurements, such as those due to switch closure, breaks, or shorts, to locate the area for investigation.

3.2.10.4 Diode System

Personnel at Mine Number 9 explained that their belt fire system had a diode at the end of the twelve belt lines. A complete description of the system was not available, and the manufacturer's name plate was missing from the underground central station panel. When a diode is used in this manner, a fire is evident following sensor switch closure due to the presence of a full-wave AC. If there is no fire and no alarm, the diode provides a half-wave rectified AC. An open line or other trouble will be indicated if no signal exists.

3.2.10.5 Voice-Announcing System

The Jabco voice-announcing system was found in several mines. Each belt run has a remote panel with a specific voice message on a standard cartridge tape player. This message couples to the mine phone system and indicates location, rather than event. Heat sensors on conveyor belts, water flow switches, centrifugal switches, spillage switches, sequence devices, belt stoppage switches, or other ON/OFF devices can be converted to this system. All such inputs give the same voice message, and phone service is temporarily interrupted until someone disables the recorder at the trouble source.

3.2.10.6 Production Reporting System

Every two hours, shift supervisors call a central operator and relate all problems, needs, delays, and production levels. This information is typed into a local computer system which serves ten cathode ray tubes (CRT's) at the mine and others in mills and corporate headquarters. Four CRT units and an 8-inch floppy-disk drive are in underground locations. The system is in constant use, and the mine using this system plans to expand the programs to include safety and personnel data.

3.2.10.7 USBM Remote Air Sampling

The new USBM system for mine monitoring has five remote units, each of which contains an Ecolyzer 4125 CO analyzer, J-Tech air-velocity indicator, and J-Tech methane sensor mounted to a telemetry package by Conspec. The 8080 computer-based system and Conspec master unit contain a CRT and printer.

3.2.10.8 CO Analysis in Conveyor Beltways

This system uses seven Ecolyzer 4125 CO analyzers and Bacharach CH_4 analyzers on the end of conveyor belts. Monitoring the CO content allows the mine to provide belt air to the work face under a special MSHA permit. The RFL Series 6405 UF telemetry system includes printer and graphic display. Voltage and time are printed at specific sensor locations every 20 minutes. The observer consults a chart to convert voltage to ppm levels of CO. After the background is established, the alarm points are set so that a 10 ppm increase will provide an alarm, and a 15 ppm increase will provide an underground alert. The printer then prints out data every few seconds.

3.2.10.9 Smoke-Actuated Door Closer

The automatic door-closure system utilizes an ionization smoke sensor and self-closing door. The Simplex Type 4262-4 smoke sensor is connected to operate a magnet-latched ventilation door near an underground hopper. Contaminated intake air from the hopper area will automatically close the door. Functional operation of the 1977-purchased hardware has not been accomplished, and system operation is questionable due to corrosion and the dust-laden appearance of the sensor.

3.2.10.10 Radio Control System for Remote Fans

This system is a Motorola Intrac control with a printer to printout fan operation, temperature, vibration, high current, power failure, and auxiliary generator. A 50-to-1 reducer drives breaker points which operate a relay over DC phone lines. The radio data-reporting system checks and controls four remotely-located ventilation fans.

If the relay stops pulsing, one of two thermal delays begins, and a trouble indication is automatically coupled to the Jabco voice-alarm system. This same radio-reporting system includes a water-level indication at a sump several miles away. Personnel in the warehouse monitor the system, and a mine ventilation engineer is provided a 24-hour summary printout of events.

3.2.10.11 Bureau of Mines Tube-Bundle System

During this contract, the Bureau of Mines tube-bundle gas analysis system was being assembled for trial installation. The 12-tube system monitored for CO gas and particles of combustion. Long-term operation with responsible commitments by Bureau of Mines and the cooperating mine company should yield important information for mine fire warning systems.

3.2.10.12 ESD/USBM Spontaneous Combustion Protection System

This is an ESD/USBM system installed in an underground copper mine under Contract H0282002, Improved Spontaneous Combustion Protection for Underground Metal Mines. The remote-located sensors are CO (Ecolyzer 4125), CO_2 and SO_2 (AAEL), O_2 (Teledyne), and temperature (Hy Cal). The sensors and AAEL frequency-division multiplex telemetry system were installed for one year, and plans were also made to add additional CO and CO_2 sensors.

3.2.11 Fire and Smoke Sensors

Fire and smoke sensors found during Phase II mine visits were primarily heat sensors on conveyor belts and fan bearings. Portable gas sensors were observed in all mines, and fixed-location gas sensors were found in 18 of the 20 mine or agency visits. Four of the fixed sensors were for underground installations and telemetry systems, and four were located on the surface in some form of a tube-bundle system. Half of the systems observed were either direct USBM programs or a result of USBM/MSHA activities.

3.2.11.1 Fire Heat Sensors

Table 14 lists different types of heat sensors, their operating characteristics, and several tradeoff comments.

Table 14 TEMPERATURE SENSORS

Type		Characteristics	Advantages	Disadvantages
Fusible link (or wire)		Control fire doors, shut down equipment, activate sprinklers or extinguish systems in belt lines	Inexpensive, nonelectrical, accurately indicates temperature increase	Time lag to operate, point sources extend alarm time and increase fire size
Pneumatic (pressurized tube)	Line type	Ansul's SCAD melts plastic tube, releasing mechanical valve to discharge agent on trucks and other equipment. Systron Donner has pressure tube.	True indicator of heat rise	Point source and time lag, depends on heated air in vicinity of sensor
	Point type	FMC Northern Ordnance for use on board Navy ships		
	Liquid	Hand-held thermometers		
Electrical (point or line type)		Uses electrical power with either N.O. or N.C. bimetallic switches with thermistors, thermocouples, or line-type twisted conductors with fusible insulation	Capable of remote monitoring, readily adaptable to telemetry and recorder systems	Needs electrical power and protected connectors
Chemical (color change)		Index markers on motors, perishables, or areas subject to temperature control	Quick visual indicator of periodic temperature changes	Limited to specific ranges
Radiation (generally hand-held)		Measures spectral radiation	Noncontact, measures remote temperatures	Measures surfaces only, costly, line of sight

The heat sensors found most often in mines were the electrical type and were used in conveyor fire detection systems. Line-type thermal sensors, as shown in Figure 19, were seen at several belt heads during mine visits. These sensors allow wider area coverage since the entire wire, not just points along the wire, is temperature sensitive. The Protectowire thermal-wire, line-type heat sensor is an inexpensive, backup fire sensor. The detector is composed of two actuators individually encased in a heat-sensitive material. The encased actuators are twisted together to impose a spring pressure between the two, and are then wrapped with tape and an outer covering, protecting the sensors from the environment. At the critical temperature, the heat-sensitive material yields to the pressure on it, and the actuators make contact, causing an alarm.

Because these sensors respond to heat only, high air flows in the manways of shafts may delay their response time, making them less responsive than the smoke or carbon monoxide sensors. Reasonable costs make this sensor an effective backup sensor to complement the faster-responding sensors.

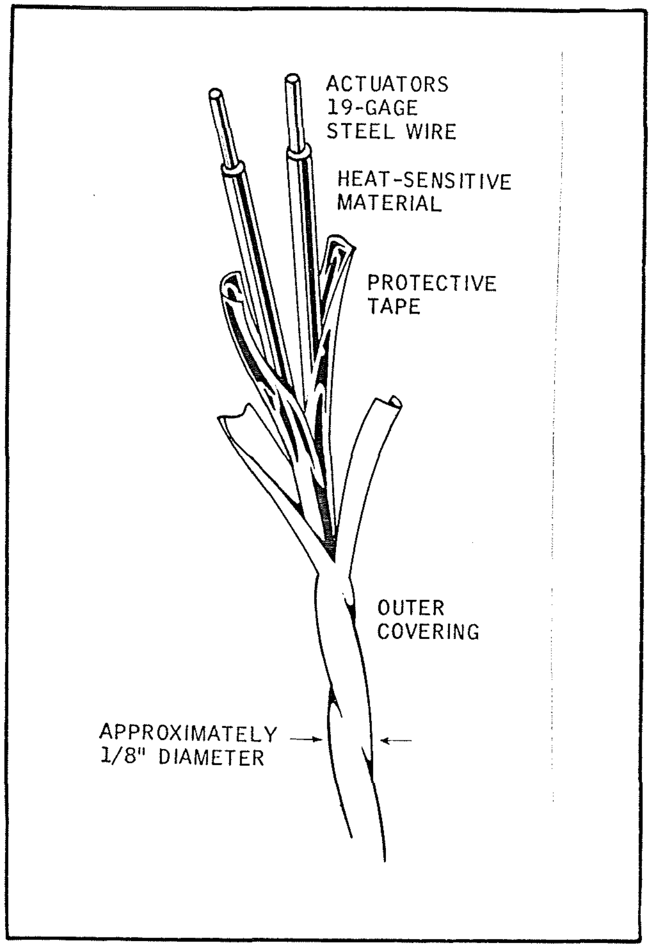


Figure 19 LINE-TYPE HEAT SENSOR

3.2.11.2 Fire Gas Sensors

Table 15 describes features of several leading candidate fire gas sensors selected for evaluation during Phase II.

Carbon monoxide sensing was identified by a majority of those interviewed as the predominate gas to observe within this contract. However, combustibles burning in or near the intake airway may provide good CO_2 radiation. Likewise, fixed CH_4 analyzers could be suggested for remote mine areas, such as in bleeder returns or near the face.

A general description of sensors found in underground mines, or that have the potential to be used in a mine shaft fire and smoke system, is given in Appendix E. The price, availability, mine durability, and maintenance requirements were considerations for selection.

Table 15 UNDERGROUND FIRE GAS DETECTORS (Sheet 1 of 2)

Description	Vendor							
	Andros, Inc.	Anglo American Electronics Laboratory	Beckman, Scientific and Process Instruments	Dynamation, Inc.	Energetics Science, Inc.	Mine Safety Appliance	International Sensor Technology	Bendix (Maihak)
Model	238B 352	Spanair	868	CO-2301	Ecolyzer 4125	570, 571	AG2000	UNOR1
Type	NDIR	NDIR	NDIR	TGS (Taguchi Gas Sensor)	Electrochemical Cell	Electrochemical Cell	Solid State	IR
Gas	238B: CO_2 352: CH_4	CO, CO_2, SO_2, CH_4	CO_2	CO	CO	CO	CO, CH_4	CO, CO_2, SO_2, CH_4
Desired range	238B: 0 to 1 percent 352: 0 to 5 percent	300 to 30,000 ppm 30 to 3,000 ppm 25 to 2,500 ppm 500 to 50,000 ppm	0 to 1.5 percent	0 to 300 ppm	0 to 50 ppm 0 to 500 ppm	0 to 100 ppm 0 to 500 ppm	3 to 100 ppm 100 ppm to percent LEL	0 to 100 ppm 0 to 1 percent 0 to 500 ppm 0 to 3 percent
Underground history	Michigan Technological Institute test	450 in deep gold mines in South Africa	Michigan Technological Institute test	Unit tested on USBM Contracts 1974 to 1976 and 1979 to 1980	Yes, see RI8253 for an earlier model experience	Unknown. 200 used in steel mills.	Unknown	Common in European coal mines
Environmental effects	Developed for underground mobile equipment	Designed for underground mine use	Developed for underground mobile equipment	NEMA 4, dual element, humidity not a problem	NEMA 4 style	NEMA 4 style	NEMA 4, explosionproof	Designed for underground mine use
Maintenance	Replace filter 2 months to 1 year; recalibration	Replace filter, clean, recalibrate (N_2 purge) when signal falls off due to dusty atmosphere	Periodic calibration	Monthly calibration	Monthly: calibrate; yearly: replace cell. No water required.	Unknown. Anticipate bimonthly calibration	Calibration 6-month intervals	Periodic calibration

Table 15 UNDERGROUND FIRE GAS DETECTORS (Sheet 2 of 2)

Description	Vendor							
	Andros, Inc.	Anglo American Electronics Laboratory	Beckman, Scientific and Process Instruments	Dynamation, Inc.	Energetics Science, Inc.	Mine Safety Appliance	International Sensor Technology	Bendix (Maihak)
Input power	12 volt DC 120 volt AC	120 volt AC	12 volt DC	120 volt AC	120 volt AC 12 volt DC	120 volt AC 12 volt DC	120 volt AC 12 volt DC	110/220 volt AC
Signal output	Analog	Analog 0 to 1 volt 0 to 1 milliampere or alarm	Analog available	Analog 0 to 1 milliampere or alarm	Analog 0 to 1 volt or alarm	Analog 0 to 1 volt	4 to 20 milliampere from sensor	0.1 to 1 milliampere
Approximate price	$6,000 (projected production cost)	$1,700 to $2,100 per head, current loop or multiplex data link included	$2,500 (projected production cost)	$ 950	$ 995	$1,570	$1,230	Quote requested. estimate $3,000 to $5,000 each unit
Advantages	Low maintenance anticipated	Proven system, no moving parts, built-in data link	Low maintenance	Improved TGS, no moving parts, low cost	Selective to CO	No mechanical pump	3,000 feet data link included, multiple channels in one housing, no moving parts	Built-in battery for emergency power
Disadvantages	Not in production; built-in pump (moving parts)	No USA distribution; high humidity clouds mirrors (above 95 percent RH)	Needs frequent recalibration for zero drift	Nonspecific to hydrocarbons, other gases. Needs purge. Can be saturated	Mechanical pump and cell must be balanced to humidity ranges; 10 to 85, 0 to 60, 60 to 100 percent	Interference gases uncertain	No underground history	30 to 60 minutes warmup; expensive; built-in pump; SO_2 high range only.
Notes	USBM has prototypes for testing; linear output by design of cells	Systems on shelf	Also have process gas analyzers for most gases (except low level SO_2)	Used in HO242016 and HO282002. Unit follows selective CO analyzers well.	Considered a proven sensor by industry, suggested by USBM as good candidate. Used in USBM HO282002.	USBM and MSHA planning additional testing	Total hydrocarbons also available	Described as "delicate, expensive, prone to calibration drift" by users

3.2.11.2.1 Spanair Analyzer

The Anglo American Electronics Laboratory Spanair nondispersive infrared analyzer detects the attenuation of radiation due to molecular absorption by the sample gas (see block diagram Figure 20). A nichrome filament pulsed at a specified frequency radiates broad-band energy. This energy passes through the sample gas in a reflective optical chamber, through a spectral filter, and is measured by a pyroelectric-cell photo detector. The electrical signal output is inversely proportional to the gas concentration and varies logarithmically with concentration. Selectivity to the sample gas is determined by the band-pass spectral filter.

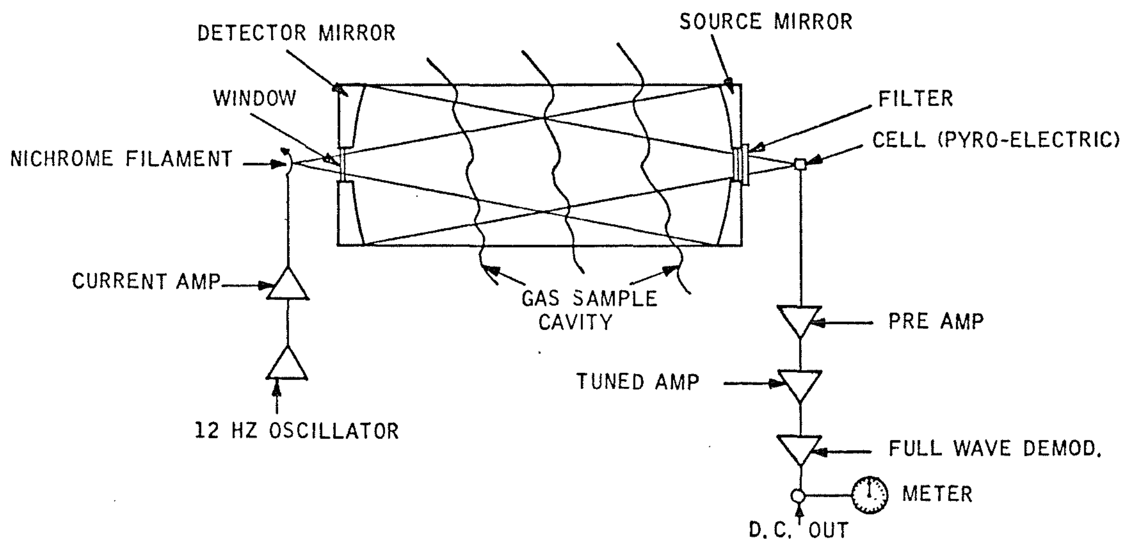


Figure 20 SPANAIR ANALYZER, FUNCTIONAL DIAGRAM

Both analyzer head and power supply are mounted in a fiberglass enclosure designed for underground installation. A dust filter is fitted to the sample plenum. No pump or thermal controls are required. Electrical connection is made in a junction box partitioned from the analyzer. Input power is 110 volts AC, 50 to 60 cycles per second; output is 0 to 1 volt DC or 0 to 1 milliampere DC analog.

Calibration curves provided for each unit allow determination of gas concentration, but changes from a stable background trace are of more importance than specific concentration levels.

3.2.11.2.2 UNOR Analyzer

The UNOR infrared analyzer is widely used in British and German coal mines for detecting low levels of carbon monoxide. This instrument is marketed by Bendix in the United States.

A pump draws the sample gas through the infrared analyzer, and an electronic control system compensates for temperature variations.

The instrument is available in many variations, including an explosionproof remote analyzer with intrinsically safe measuring circuit and backup battery power.

Instrument-type UNOR analyzers are used with tube-bundle systems in England, explosionproof underground UNOR analyzers are used in Germany as remote detectors. No installations of the UNOR CO analyzers are known to exist in domestic underground coal mines.

3.2.11.2.3 Dynamation CO Monitor

Figure 21 shows the construction of the Taguchi Gas Sensor (TGS) of the Dynamation CO monitor. Their CO-2301 model contains two TGS sensors. The twin TGS sensors automatically compensate for humidity variations. No pumps, filters, dryers, humidifiers, or chemical cells are needed. A fault-detector circuit is built in, and the sensor is purged by an automatic cycle when power is applied.

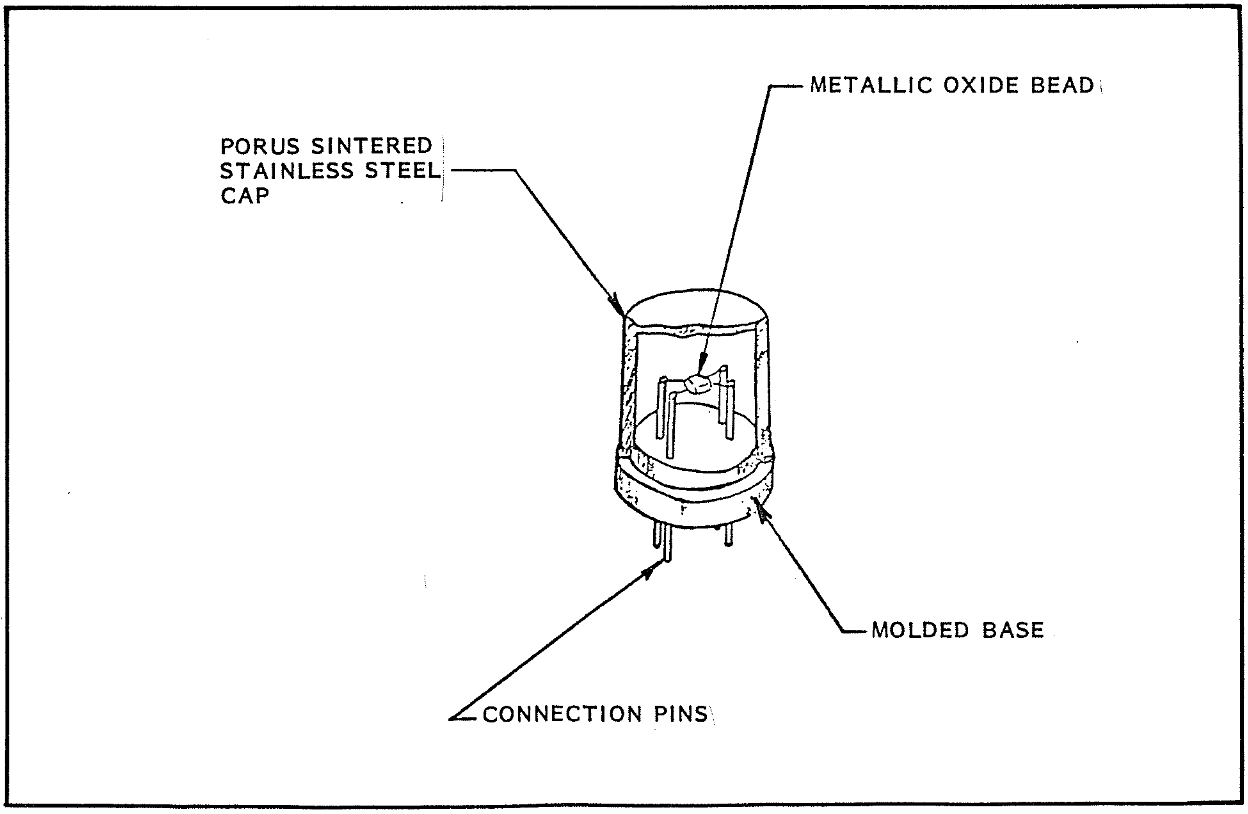


Figure 21 TGS SENSOR CONSTRUCTION

The TGS sensor consists of a sintered n-type semi-conductor bead mainly composed of SnO_2 (tin dioxide), and two small coils of wire. The conductivity of the bead increases in the presence of combustible gases, such as hydrogen, carbon monoxide, hexane, ethane, or propane, or organic solvent vapors belonging to the alcohol, keton, ester, and penzol families, etc. The bead is heated by passing a current through one coil of wire. When a gaseous molecule is absorbed on the surface of the heated semi-conductor bead, an electric charge transfer occurs between the surface of the semi-conductor and the absorbed molecule because of the difference in the electron energy between them. This charge transfer increases the electrical conductivity between two measuring points on the sensor bead surface, and between the two small coils. The increased conductivity of the sensor bead when exposed to even a low concentration of gas can be as high as 20 times that of its conductivity in air. The monitor reportedly requires periodic calibration using factory-supplied test gas.

TGS elements used in this monitor are not known to be specific to CO; however, underground mine tests conducted during 1978 through 1980 under Contract H0282002 indicate good correlation with the Ecolyzer 4125 CO analyzer. The Dynamation CO monitor is reasonably priced and readily available.

3.2.11.2.4 Energetic Science, Inc., Ecolyzer CO Analyzer

Zero to fifty parts-per-million levels of carbon monoxide can be detected with the Ecolyzer (see Figure 22). It is currently being marketed for industrial and mining use in several sizes, including portable units. The analyzer operates on the principle of electrochemical oxidation of CO into CO_2 at a potential-controlled electrode, where the current generated by the electrochemical reaction is proportional to the CO concentration.

This sensor is used in several domestic and foreign mines as a health safety instrument monitoring air going to working sections and as a spontaneous combustion sensor in Contract H0282002. Energetic Science has recently changed the pump design that had caused problems, and a unit without a pump is soon to be marketed.

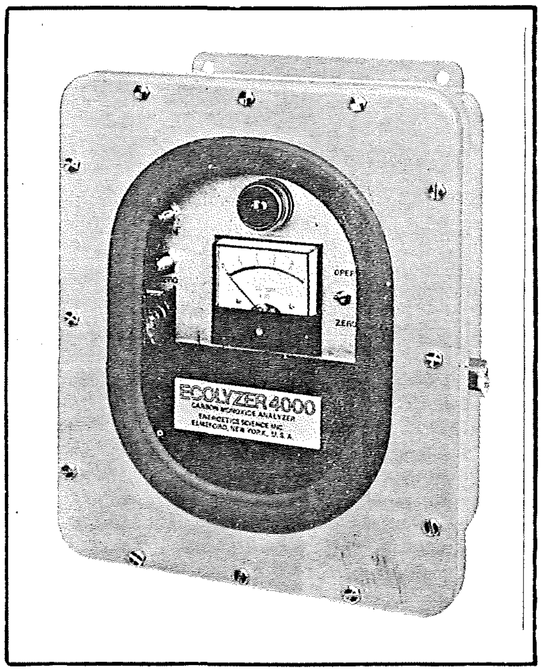


Figure 22 ECOLYZER 4125 CO MONITOR

3.2.11.2.5 Mine Safety Appliance (MSA) Carbon Monoxide Alarm

MSA has been actively marketing their Model 571 CO analyzer (see Figure 23). Over 200 units were reported to be in steel mills in 1980, and MSHA-Pittsburgh is interested in it for use in underground mines. The sensor is an electrochemical cell, as is the Ecolyzer unit. It is temperature-compensated, and gas enters the cell by diffusion since there is no pump, a highly recommended design feature of sensors for use in underground mines. Different models are available to sample CO in ranges 0-100 ppm or 0-500 ppm.

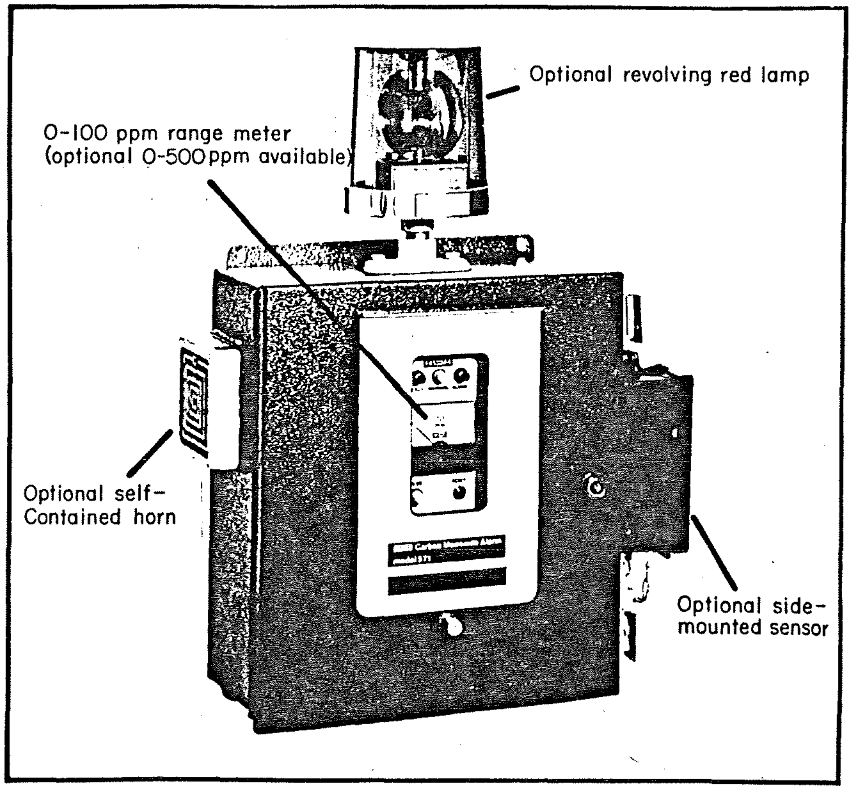


Figure 23 MSA CO ANALYZER

3.2.11.3 Fire-Combustion Particle Detectors

Table 16 describes features of several leading candidate fire-combustion particle analyzers selected for evaluation during Phase II.

Products of combustion in fires include solid particulates, liquid mists, ionized species, gases, and radiant energy. Studies have revealed that invisible submicron-size particles are generated by self-heating of combustible substances in large volumes at relatively low temperatures, i.e., between 100 to 150 degrees C. For early heating of paper, wood, rubber, simple organic compounds, polymers, carbon, paints and varnishes, cloth,

Table 16 FIRE-COMBUSTION PARTICLE DETECTORS

Description	Vendor				
	Wormald International	Afa-Minerva	Environment One Corporation	Brunswick	USBM
Model	Analog Becon C121B	Minerva (Trolex)	Incipient Fire Detector	MK2PD	N/A
Type	Ionization, beta source	Ionization, alpha source	Condensation nuclei	Ionization, alpha source	Ionization, alpha source
History	2500 installed in deep metal mines, South Africa. Used in USBM H0212015	Many installed in English coal mines	Tested by USBM for tube bundle systems	Spacelab, space shuttle, vertical blasthole drill	USBM Research Sensor
Environmental effects	Designed for mine environment	Designed for mine environment	Surface installation suggested	Surface installation suggested	Designed for incipient fire detection
Maintenance	None	Clean (dust) every 3 months	6 months for water supply. Weekly for dust filter.	Unknown in underground use	USBM progressing with research and evaluation. The unit is not commercially available.
Input Power	15 volts DC	15 volts DC, internal battery option	110 volts AC	115 volts AC	
Signal output	Analog signal	On-off, alarm	0 to 10 volt analog	As required, microprocessor controlled	
Approximate unit cost ($)	600	700	3,400	5,000 to 6,000	
Advantages	Power from surface	Commonly used device in England	Combustion particle sensitive instrument	Detects wide range of combustion particles	
Disadvantages	Australian distributor	Frequent cleaning required to avoid false alarm	Maintenance and calibration	Sophisticated system, costly	
Notes	Used in 1974 to 1976 USBM H0242016 as digital (on/off) Becon		Being tested under HO387025	Not production item. Working with MSA for future sales.	

hair, foods, etc., a means of detecting these submicron particles given off would provide early warning of fire. Tests by the Bureau of Mines compared detection of CO and submicron particles for heating of coal and wood (see Figure 24). Results showed that for wood fires, submicron particles were detected well below temperatures where an exothermic reaction occurred and where CO had yet to reach a detectable level.

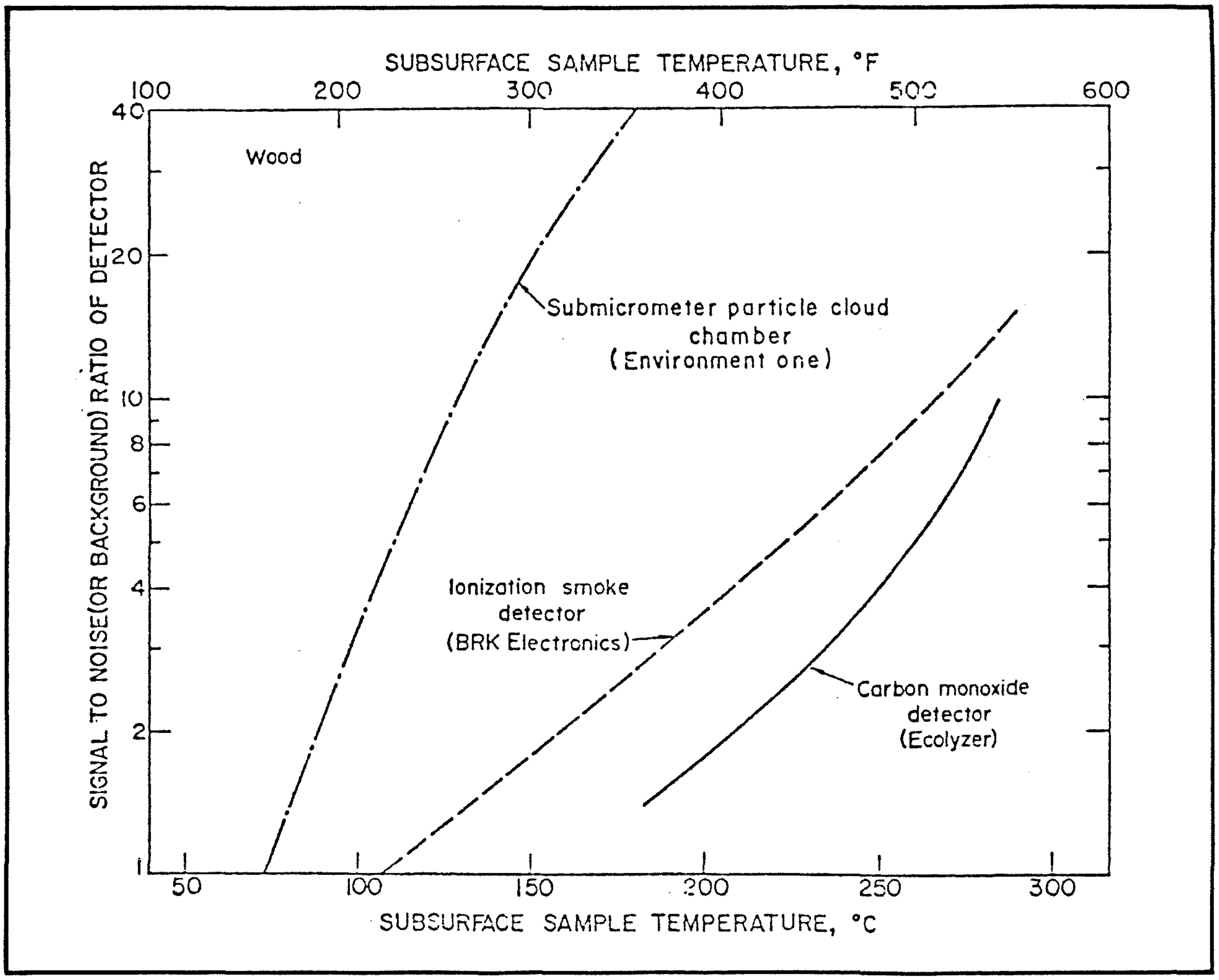


Figure 24 BUREAU OF MINES TEST COMPARISON OF PARTICLE/GAS/IONIZATION SENSORS
(Report of Investigations, Number 8206, Studies of Incipient Combustion and Its Detection, Bureau of Mines, 1977.)

3.2.11.3.1 Environment/One

The Incipient Fire Detector manufactured by Environment/One Corporation, measures concentration of particles as small as 0.002 micron diameter by pressurizing a saturated sample and counting the resulting condensation nuclei. This unit is being tested with a tube-bundle system under Bureau of Mines Contract H0387025.

3.2.11.3.2 Ionization Sensors

Ionization sensors employ a radioactive emitter of either alpha or beta particles to ionize air in a chamber between two electrically charged plates. A current is conducted between these plates by the ionized molecules.

A decrease in the current results when combustion particles are present, because of their low effective ionic mobility and increased absorption and scattering of the alpha or beta particles by the aerosol fraction of the gas. The decreased current is monitored electronically.

Many home smoke detectors use an alpha source, as is also found in the Minerva particle sensor from England. Becon particle sensors from Australia use a beta source.

The Becon particle sensor from Anglo American Electronics Laboratories in South Africa was tested during Bureau of Mines H0242016 from 1974 through 1976 as an ON/OFF signal device (see Figures 25 and 26). Since then, it has been redesigned to provide an analog output.

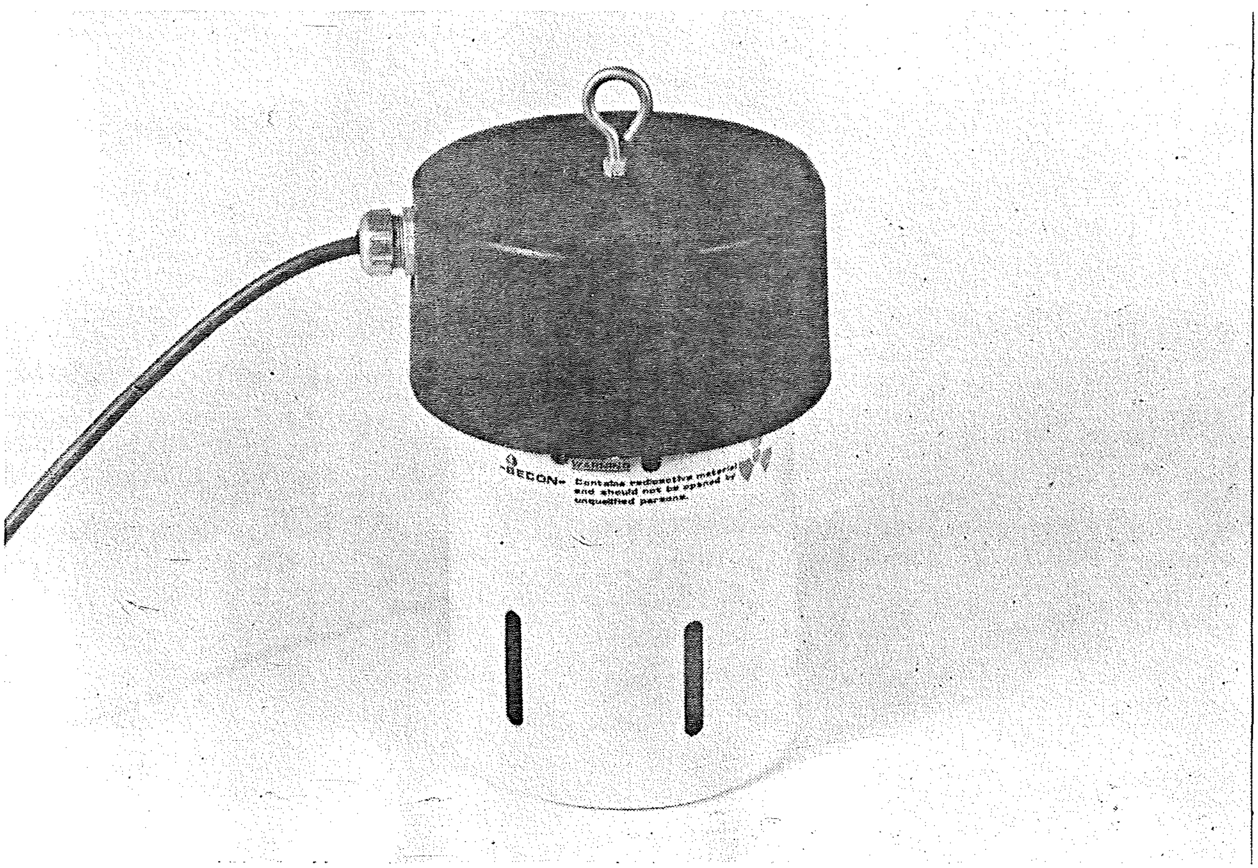


Figure 25 BECON IONIZATION DETECTOR

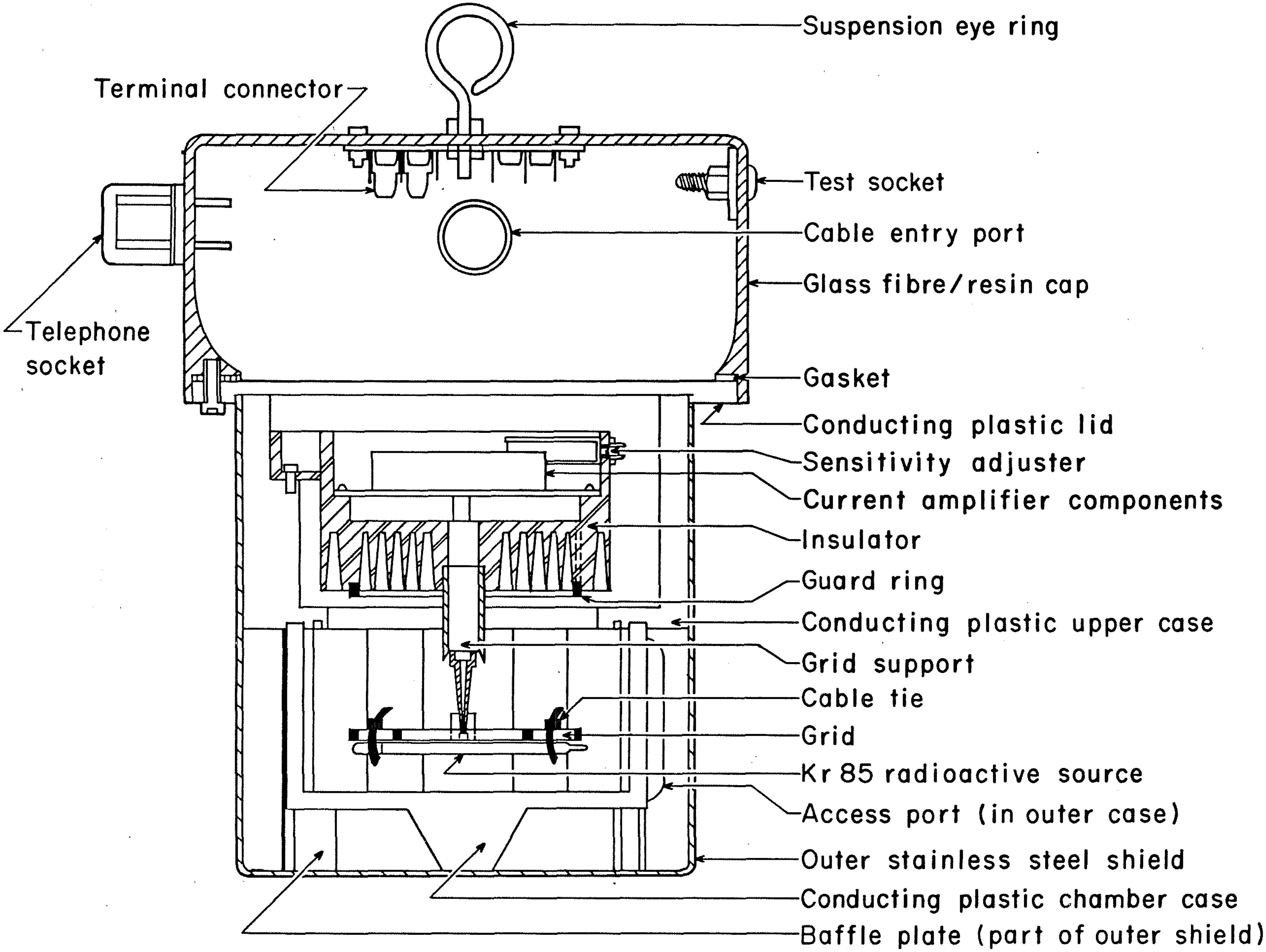


Figure 26 CONSTRUCTION AND FEATURES OF THE BECON C121B

The Becon detector employs a fairly high radioactive beta emitter (5 millicuries of krypton 85) to ionize the air between the electrodes in its single chamber. The device was designed to overcome stringent environmental conditions common in deep South African gold mines by offering the following features:

- The detector has no metal parts exposed to the atmosphere other than a few stainless-steel screw heads and cable glands. It does not corrode, even in atmospheres with a high nitrous fume content.

- Air velocities up to 6 meters per second (1,180 feet per minute) from the forced ventilation of the mine have no effect on the unit's operation. Sensors in relatively low-velocity areas (less than 50 feet per minute) are reported to take longer to alarm.

- Temperatures of 0 to 40 C (104 F), and probably considerably higher, have no effect on sensor operation.

- The detector will operate satisfactorily in supersaturated atmospheric conditions (i.e., humidities as high as 100 percent in which condensation takes place).

- It has not been necessary to clean dust from detectors which have been in continuous underground use for up to 18 months. The high radiation source is reportedly able to penetrate dust buildup.

- The life of a detector can presumably be determined by the half-life of its radioactive source, which is 10.6 years.

- Installation of the sensor is easy, and maintenance requires no special skills.

3.2.12 Design Considerations and Concepts

The magnitude of the fire and smoke hazard varies with respect to the location of the combustible materials present and the ventilation controls available. Some of the variables are as follows:

- LOCATION: Workers inby or outby the fire and alternate routes of escape available.

- COMBUSTIBLES: Gob, coal, timber, motors, or piles of rags.

- VENTILATION: Velocity and regulation.

Figure 27 shows several mine areas where fire and smoke could occur.

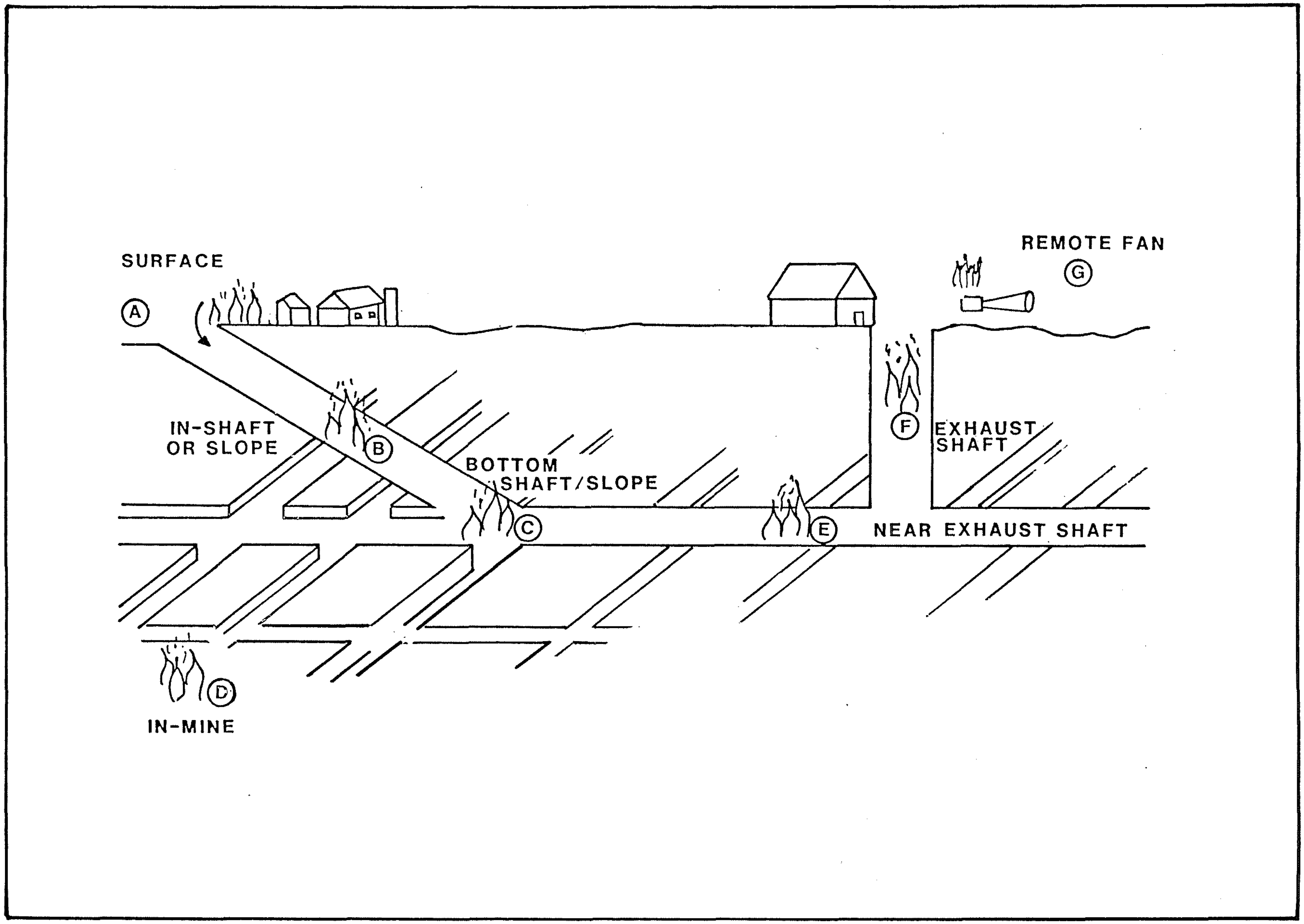


Figure 27 FIRE AND SMOKE HAZARD ZONES

3.2.12.1 Surface Location Near Slope or Shaft (Figure 27, Location A)

Shops, offices, and other surface structures, as well as mobile equipment, are generally located near the intake slope or shaft. A structure or equipment fire near an intake portal or collar could cause contaminated air to enter the mine.

The combustible could be a wide variety of building materials, oil or fuel, or mining support materials, such as brattice cloth, timber, conveyor belt, cables, etc. The fire can also be slow growing or explosive in nature. Control and containment is probably easier for a surface fire than for an underground fire, because access for fire fighting is easier. Finally, the contamination entering the mine may be a small amount if the shaft/slope entry is some distance from the fire, or it may be in great amounts if the fire source is near. A sensor to alarm personnel when intake air is above the acceptable threshold level, or is increasing rapidly, can be considered for the portal or collar of intake air shafts.

3.2.12.2 In Shaft or Slope (Figure 27, Location B)

Fire problems in the shaft or slope are of the greatest magnitude, due to the intake air pulling the fire gases into and throughout the mine.

Combustibles present can be timber for roof support, gage guides, rail supports, conveyor belt pulleys, or materials entering the mine. Travel time of contaminated air from a shaft fire is rapid. Fire fighting is difficult, and many mines have installed fixed sprinkler rings (in shafts) or lines (in slopes). The shaft will quickly become impassable, and early alarm and evacuation by alternate routes must be exercised rapidly.

3.2.12.3 Bottom of Shaft/Slope (Figure 27, Location C)

The shaft or slope bottom often contains storage areas, transformer rooms, equipment repair facilities, conveyors, power distribution centers, and lunchrooms. Fires from these would contaminate the intake air and prohibit access to the shaft. Fire fighting here is less difficult than in shaft fires, and isolation with fixed extinguishing systems is often used for fire control. Heat- or smoke-actuated doors on transformer rooms, storage areas, and hoppers should be considered.

3.2.12.4 In-Mine (Figure 27, Location D)

Fires deep into the mine and away from shafts present an accessibility problem for fire fighting. Oxidation of fresh coal, friction on conveyor parts, heating of gob areas, equipment fires, and methane emissions contribute to the fire problem deep in mines. Prompt fire fighting activity is possible when personnel are available in or near production face areas, but fires often occur between shifts, during downtime, and in remote areas. Air sampling points at several different zones deep within the mine should be considered.

3.2.12.5 Near Exhaust Side (Figure 27, Location E)

Fires near the exhaust shaft represent less of a hazard to mine personnel, but fire-fighting abilities may be worsened due to the remote location. The integrity of the main shaft escape is not lost, and fan shutdown to isolate and lessen the fire growth is possible. Combustibles could be mine equipment, conveyor components, timber, transformer stations, or storage materials.

3.2.12.6 In Exhaust Shaft (Figure 27, Location F)

Immediate shutdown of the fan is most probable if a fire occurs in the exhaust shaft, but any hazard to underground personnel is almost nonexistent, although the mine power will be off and the mine evacuated if the fan is off for 15 minutes. Combustibles would be support timber and cables. Fire fighting is restricted, and sprinkler rings might be considered. Air-quality measurements from the exhaust shaft would reflect total mine air and would be very diluted due to high volume of flow. Any instruments here must be very sensitive, as a few parts-per-million increase could mean considerable fire activity underground. A ratio of gases may be more meaningful than specific gases.

3.2.12.7 Remote Fan or Other Areas (Figure 27, Location G).

Since the mine ventilation is such a critical factor in mine fire control, the fan is included as a location to consider when designing a mine shaft fire and smoke protection system.

Chapter 75.321-1 of Title 30 Code of Federal Regulations requires that all persons evaluate the mine within 15 minutes of fan shutdown. Although the magnitude of fire hazard is low with a fire at the exhaust fan, methane buildup underground and other potential mine problems occur, such as spontaneous combustion, fire, and explosion.

Signaling devices to record when the fan is operating could be considered, as well as other fan information, such as bearing temperature.

3.2.13 Decision Criteria

Just as planning a new mine development requires analysis and tradeoffs of many factors, so does the selection of a mine shaft fire and smoke protection system.

Developers of new mines must analyze the geographic location of the coal reserves and consider the coal type, current and long-range market, environmental constraints, anticipated operating duration, mine method(s), equipment options, reliability, service, environmental conditions, ventilation needs, financial base, labor conditions, and various legal constraints.

The decision criteria used by mine operators to select a mine shaft fire and smoke protection system may have similar factors. For purposes of this contract, they shall be grouped into four general categories:

- o Mine Profile and History - What magnitude of hazard and need exists?

- o System Cost and Availability - Are system cost and availability reasonable?

- o Component Performance and Reliability - Are components test-proven reliable and relatively maintenance free?

- o Contract Guidelines - Can the system be purchased, assembled, tested, installed, and field tested within contract timeframe and budget?

3.2.13.1 Mine Profile and History

The mine profile and history will relate the basic needs of a fire and smoke protection system. Whether a new mine is being developed, or an existing mine is considering retroactive installation of a fire and smoke protection system, the total mine profile must be considered for selecting a system to maintain the safe integrity of entry/egress areas such as shafts, slopes, or drifts. Size and depth of the mine are considerations that indicate the magnitude of the system being considered. The larger mines are often spread out over wide areas, and workers are dispersed in many sections.

Deeper mines may have longer wait-periods at the shaft bottom for cage access, resulting in longer evacuation times. Also, climbing out of a deep mine having shaft or fire problems will be more difficult than if the mine were shallow.

Entry type, construction, and quantity will compare the alternative egress routes and the chance of the shaft becoming involved in fire or contaminated with bad air. Wood-lined shafts or older shafts having sufficient grease or oil accumulation may be considered more hazardous than new concrete and steel shafts. Also, mines having belt conveyors in the slope entries may be considered hazardous, as will mines having storage areas, transformer rooms, hoppers, and other combustible sources nearby the shaft slope bottoms.

Two of the 14 mines visited had remote data-reporting systems at an estimated cost of over $250,000, and five other mines had systems costing over $100,000. The costs of the four alternative systems described in this report compare favorably with costs of other available systems and those found in the industry.

Hoppers located near a shaft or slope bottom may become heated areas for spontaneous combustion as fresh mine coal waits for transport. A mine with multiple entry/egress routes that are not too distantly separated will provide more alternative escape routes from fire than would a mine with fewer entries.

Fire history of the mine is of major importance in providing evidence of safety needs. Self-ignition of coal piles and gas ignition are more common to some mining districts than others. Management decision to hire responsible, qualified personnel and to provide the necessary fire prevention and control measures certainly affects the mine fire history. Mines with fire history may have the management support and fire-conscious personnel needed to implement a variety of fire prevention measures, including additional fire training and fire warning devices, such as remote sensors.

Other mine profile considerations used to formulate decisions to install a mine shaft fire and smoke protection system are as follows:

- Age and Estimated Close Date of Mine - Do many old working areas exist? Is the mine about to close?

- Remote Equipment (Fans, Shafts, Shops) - What critical equipment areas exist, and what is their distance from primary entries?

- Mining Type, Gobs, Bleeders - Does the mining method leave pillars or create large gob areas?

- Haulage Type - What type of haulage systems exist, and how extensive are they?

- Work Force Size, Training, Skills - Is the labor force safety conscious and well trained for emergencies?

- Distance of Work Force from Egress Shaft - Do workers travel long distances to work sites, and how long does it take to evacuate?

- Mine Downtime - How long is the mine closed, leaving only token personnel in the area?

3.2.13.2 System Cost and Availability

System cost will vary with mine profile and complexity. Volume purchasing will yield the investor smaller unit costs, as will tradeoff analysis if a costly system eliminates or reduces manually-performed tasks.

Fixed-location sensors may eliminate the need for persons to make frequent trips to distant areas of a mine. Manual labor savings can also be realized by installing remote control devices for fans, pumps, air regulators, ventilation doors, or fire extinguisher systems. An example of remote control benefits occurred during ESD/Bureau of Mines Contract H0242016. An electrical storm and mine power failure caused mine fans to shut off 20,000 feet from the mine office, the control operator was able to restart the fans immediately when other power was restored. Without the remote control devices, it would be necessary to send personnel to the fans in order to restart them.

As another cost comparison, automatic fire protection systems for mobile mining equipment resulting from several research contracts can be evaluated. A typical system may cost 1/2 to 1 percent of the vehicle value. If the vehicle is a 100- to 170-ton truck that costs $400,000 to $900,000, a fire protection system having 10 event functions, including multiple sensors, visual/audible alarms, line test, and manual pull switches, will cost $4,000 to $6,000 total or $400 to $600 per function. These types of systems are "hardwire" systems that are not expandable, unless another pair of wires is routed. Also, the events are ON/OFF switches only.

The multiplex data telemetry systems described in this report use a single pair of wires; sensors, alarms, or other remote devices can be added easily. Many of the events are analog displays that show trends and history, or they can be programmed to compare or ratio various events.

The estimated cost per function for the systems described in Section 3.2.14 range from $1,500 to $4,000 per function, with the lesser cost associated with the optimum system having the most functions. Since all systems described can have additional analog or digital (ON/OFF) signals, the unit costs for a system near its capacity limit could be comparable with other automatic fire protection systems.

The Alternate I system, recommended for design and demonstration in Phase III, was within the contract cost budget, as were Alternate Systems II and III. The optimum system exceeded the budget of this contract.

Availability of components is a factor as important as cost when evaluating fire and smoke protection systems. Several component sources did not indicate early availability of their products, as the components were not "off-the-shelf" items. The components selected for the Alternate I demonstration system were common production items and were readily available.

3.2.13.3 Performance and Reliability

The system must meet the design performance requirements for successful operation in underground coal mines.

Several of the most severe conditions found in mines were:

- o Humidity - High humidity is common and very detrimental to equipment function.
- o Dust - Heavy dust settles in filters and sensors, making them insensitive or causing erroneous data to occur.
- o Temperature - Seasonal weather is often found in intake shafts, and subzero to over 100 F temperatures are common.
- o Voltage Fluctuations - Erratic mine power demands and electrical storms occur frequently.

The components selected in the Alternate I recommended demonstration system for Phase III and Phase IV tests have, for the most part, been field proven and accepted by the industry, as indicated by the following:

- o Over 3,000 Becon particle sensors are used in deep South African gold mines.
- o The Ecolyzer CO analyzer has a redesigned pump assembly and is the fire sensor that allows a mine to use belt air at the face.
- o Thousands of feet of Protectowire's heat-sensitive wire is used in underground mines.

- Aquatrol's multiplex and radio telemetry systems are found in municipal installations throughout the country. A large system is installed and is now undergoing 100-percent expansion in an underground mine.[1]

A design goal for underground mine fire and smoke protection equipment is maintenance-free operation for a minimum of 6 months. Past experience with components of the recommended system was favorable.

3.2.13.4 Contract Guidelines

Figure 4 in Section I describes the timeframe of all phases of this contract. The duration and budget of separate phases, such as investigation, concept, design, assembly, and test were guidelines for the efforts made and components to be selected. Although several other components may have provided better fire and smoke protection characteristics, their availability and cost did not meet the Bureau of Mines desired guidelines. Sensors such as the Bureau of Mines, Brunswick, and Environment/One particle sensors are examples.

3.2.14 System Considerations

3.2.14.1 System Tradeoff

Various component tradeoffs are described in previous sections of this report. The following features relate to a total system:

- Automatic Versus Manual - What devices will operate automatically, and what components will operate manually?

- Functions - How many and what type of functions are included in a mine shaft fire and smoke protection system?

- Locations - Where will devices be located, and what can be expected of them in these locations?

3.2.14.1.1 Automatic Versus Manual

Other than automatic data recording and alarm indications, no devices offered in any of the four recommended design concepts have components that operate automatically.

Several automatic systems that were observed during mine visits can be compared, even though they relate to different needs. Switches that sense coal spillage on conveyor belts, sequence switches if one belt stops, and heat-sensitive switches that activate sprinklers or stop motors or fans are examples.

Closure of ventilation doors or fire doors to stop heat or contaminated air from propagating is a viable automatic function for a fire and smoke protection system. However, alteration of mine ventilation should be done manually and only by knowledgeable persons who are cognizant of the results of ventilation changes. Ventilation doors designed to close automatically upon signal by a smoke or gas sensor have been found in mines to be readjusted to high levels so that automatic closure does not occur in response to blasting, diesel exhaust, or other common mining event.

3.2.14.1.2 Functions

The various reporting and command functions of the four optional system concepts are described below:

- Reporting functions are automatic and include analog signals of CO, particle and heat sensors, combustible-gas sensor, air regulator position, and air flow. The digital (ON/OFF) reporting functions include the alert or alarm device, power-fail, fan-run, and fire-pull.

- Command functions are all manually activated and include ON/OFF switching for door-open, door-close, TGS gas-sensor purge, CO range switch (low to high), CO_2 valve activation, sprinkler activation, and audible/visual alert alarms. The single analog command function is for the air regulator positions control. The surface controller includes analog displays, printers, and CRT and/or graphic panels. The above functions provide instant reporting of air quality in or near mine shafts, and relay fan conditions to facilitate timely action in the event of fan or fan shaft problems.

3.2.14.1.3 Locations

The locations selected were based on the configuration of the candidate test mine, but were not unlike many other mines observed during Phase II mine visits:

- Location Number 1 is the shaft or slope bottom where men and materials transfer into or from the mine. Mine air is distributed from the slope bottom, and a hopper collects all coal being transported out of the mine via a conveyor in the slope. A transformer station is also in the slope bottom. Particle sensing, CO analyzers, heat sensors, sprinklers, CO_2 in the transformer area, smoke door, regulator, air flow device, fire-pull, power-fail, and an alert device are located here.

- Location Number 2 is the shaft or slope collar or surface location, where activities include men and materials being boarded on rail cars for transport underground. Surface buildings and shops are near the collar area. CO and particle sensors are located here, as are fire-pull, power-fail, and an alert device.

- Location Number 3 is the remote south fan located approximately 5 miles away. Due to the distance and consideration of wire problems if run underground, radio telemetry was recommended to send operational data of the fan, CO analyzer, particle sensor, heat, fire-pull, power-fail, and the alert device.

- Location Number 4 is another remote fan location that has the same functions as Location Number 3.

3.2.14.2 Design Concept Description

For comparison purposes, four different systems were developed to satisfy the criteria of a mine shaft fire and smoke protection system. The system concepts described in Table 13 (refer to Subsection 3.2.4.2) and shown in Figures 28 through 35 are related to mine profiles of Section 3.2.13 and zones identified in Figure 27. Each was intended to include the recommended variety of components to meet the various mine profile conditions.

- Optimum - Recommended System
  This system was designed for large operations where the magnitude of the hazard and consequences are greatest.

- Alternate I - Recommended System
  Designed for large mines, this system reflected contract guidelines for selecting readily available and field-proven equipment.

- Alternate II System
  The mine profile, size, personnel, distance, fire, load, and needs were less for this system than for Optimum and Alternative I.

- Alternate III System
  This basic system was provided for the minimum mine profile.

All of the above systems can be expanded for additional multiple-area fire and smoke protection. Each system is described below.

3.2.14.2.1 Optimum System - Recommended System (Figures 28 and 29)

Four remote controllers are included in this large system.

Location Number 1 is the slope bottom and hopper area. It has a large Aquatrol remote station for transmittal of analog input data from three CO analyzers (two MSA and one Ecolyzer), three particle analyzers (two Becon and Bureau of Mines), and two heat sensors (Protectowire), one in the slope belt and one over the hopper. Analog data is also received by a ventilation regulator positioner (W.V.U.), from a combustible gas sensor (Dynamation) in the transformer area, and from an air flow indicator (J-Tech) near the regulator. Other switch-position data sent from Location 1 is fire-pull, power-fail, and door open and close. Signals sent to Location Number 1 from a surface operator are digital (ON/OFF) to purge the Dynamation gas analyzer, to change CO range (from 0-50 ppm to 0-500 ppm), to actuate solenoid valve of CO_2 in the transformer station, to actuate a water sprinkler system in slope area, to actuate door solenoid in the transformer room, and to alert. One analog command is sent to the slope bottom Location Number 1 to change the air regulator position.

Location Number 2 at the slope collar has a "mini-remote" that transmits analog signals of a CO analyzer (Ecolyzer 4125) and a particle sensor (Becon). Switch signals are from the manual fire-pull and power-fail indicator. The signal sent to Location Number 2 from the surface operator is for the alert device.

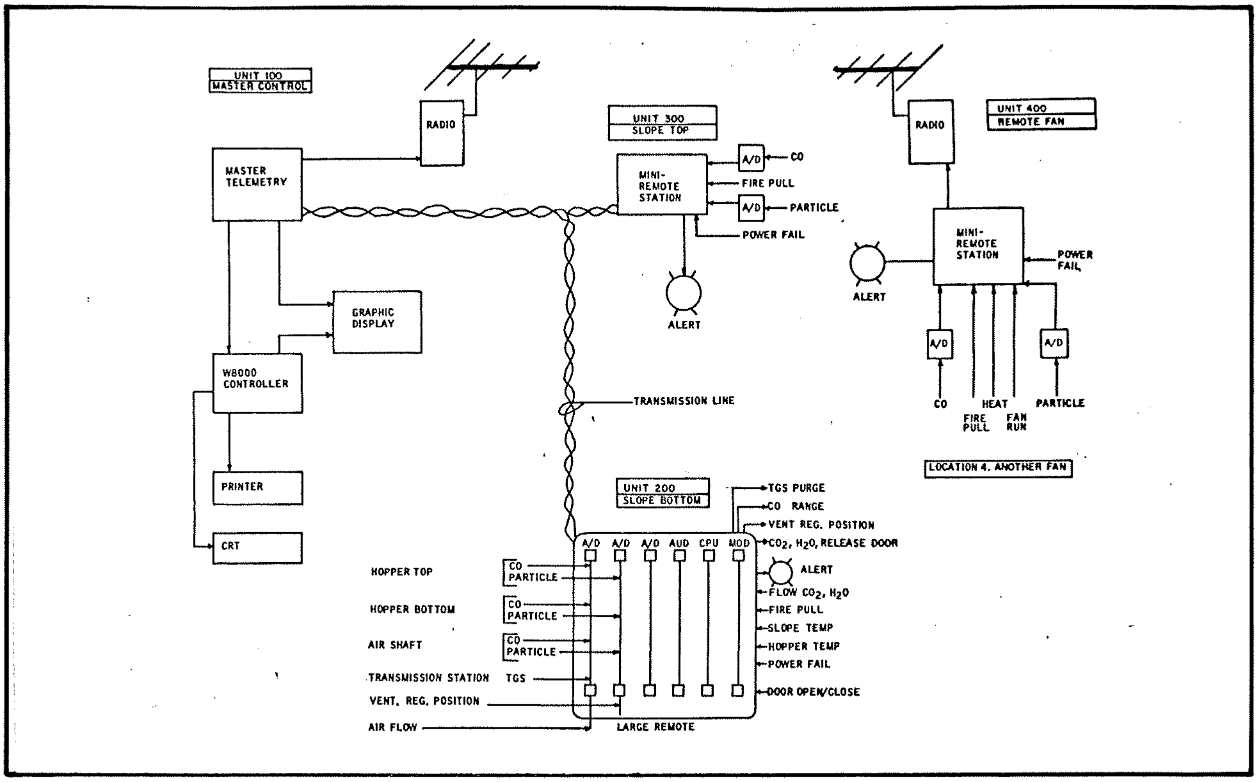


Figure 28 OPTIMUM SYSTEM - BLOCK DIAGRAM

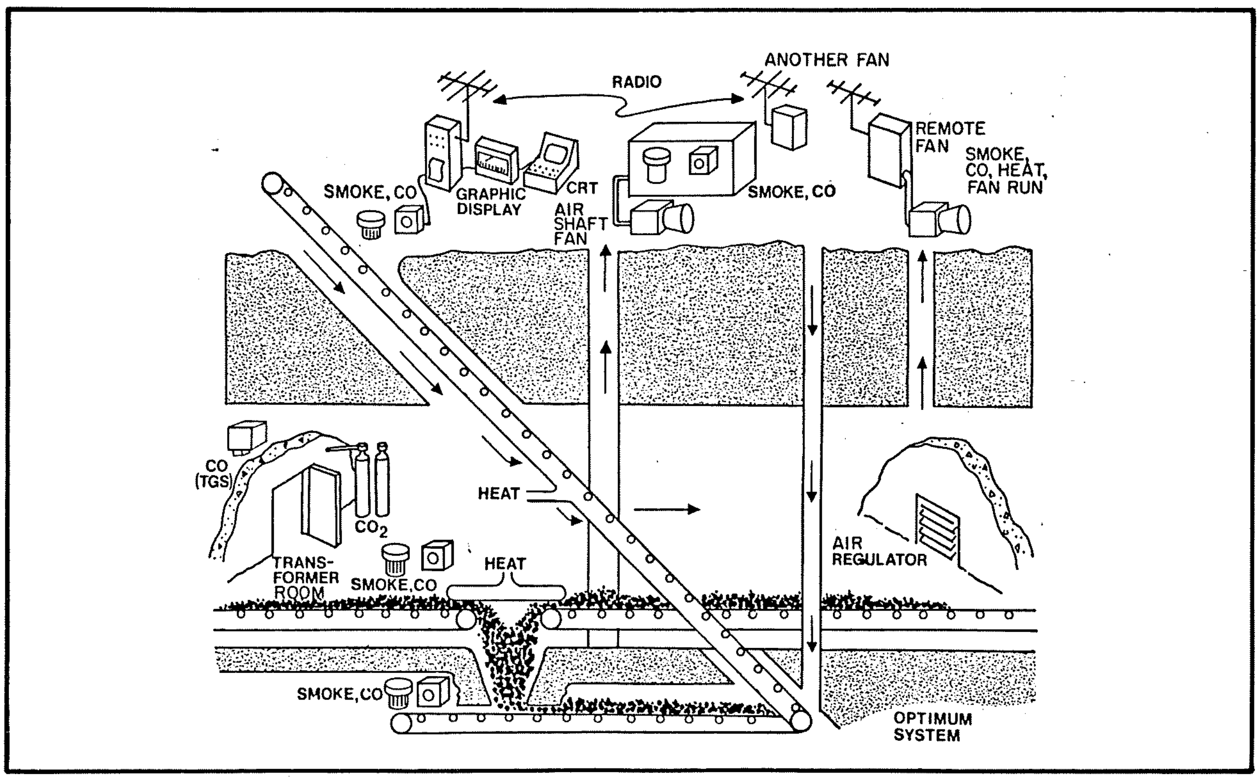


Figure 29 OPTIMUM SYSTEM - GENERAL ARRANGEMENT SKETCH

Locations Number 3 (remote fan area) and Number 4 (another fan area) are identical. Two "mini-remotes" are coupled by radio telemetry to the surface controller. Each location sends analog data from one CO analyzer and one particle sensor. Switch indications are sent from a fan-run indicator, heat sensor, fire-pull, and power-fail. The signal sent to Locations Number 3 and 4 from the surface operator is for the alert device.

The optimum system surface station has an Aquatrol W8000 system controller with printer, graphic display, CRT with keyboard entry, and a 33-point annunciator. The operator can enter setpoints via the keyboard, and add comments as desired. The CRT shows the analog and status points continuously. Alarms flash and are also indicated on a printer. The system memory stores the analog data and prints a graph showing trends and historical data every 24 hours or on demand.

Several components or features of the optimum system are not readily available from vendors or would require additional costs to install.

3.2.14.2.2 <u>Alternate I - Recommended</u> (Figures 7 and 8)

Three remote controllers are included in the Alternate I system.

Location Number 1 is the slope bottom and hopper area. It has the same large remote station as the optimum system for transmittal of data to or from the surface control station. Analog data is from three CO analyzers (two MSA and one Ecolyzer), three particle sensors (Becon), and two heat sensors (Protectowire), one in the slope belt and one over the hopper. Other switch position data sent from Location Number 1 are fire-pull and power-fail. The signal sent to Location Number 1 is for the alert device.

Location Number 2 at the slope collar has an Aquatrol "mini-remote" that transmits the analog signals of a CO analyzer (Ecolyzer 4125) and a particle sensor (Becon). Other signals are for the manual fire-pull and power-fail indicators. The signal sent to Location Number 2 from the surface operator is for the alert device.

Location Number 3 is the remote fan, and it is also identical to the optimum system concept. A "mini-remote" is coupled to the surface controller by radio telemetry. Analog data from one CO analyzer (MSA) and a particle sensor (Becon), and switch signals of a fan-run indicator, heat sensor, fire-pull, and power fail are sent via radio approximately 5 miles to the surface control center. The return signal sent to Location Number 3 from the surface operator is for an alert device.

The surface control is the same as the optimum system, except that it does not have a CRT or terminal input capabilities. Every midnight or at some other prescribed time, the printer automatically prints all setpoint values, the daily high, low, and mean for all analogs, and all alarms that occurred. A graph of each analog is printed for the last 24 hours of service. The graphic display identifies all remote locations and recording devices.

3.2.14.2.3 Alternate II System (Figures 30 and 31)

This reduced system includes fire and smoke sensors at Locations Number 1 (slope bottom) and Number 2 (slope top).

The slope bottom has the large remote station for transmitting analog data of three CO analyzers and three particle analyzers. Switch position data is sent to the surface from the heat sensor in the slope belt and from the one over the hopper. The fire-pull and power-fail indicators are also transmitted. Signals sent to this location are for the alert device.

Location Number 2 contains a "mini-remote" at the slope collar, and sends analog data of a CO and particle sensor and switch data for fire-pull and power-fail. The operator sends back a signal for alert. The W8000 computer system and printer is located at a surface control area. The printer prints data every 15 minutes. When a sensor exceeds a predetermined setpoint, the printer prints data every minute. All setpoint changes, alarms, and acknowledgements are printed. Alternate II does not have a graphic display.

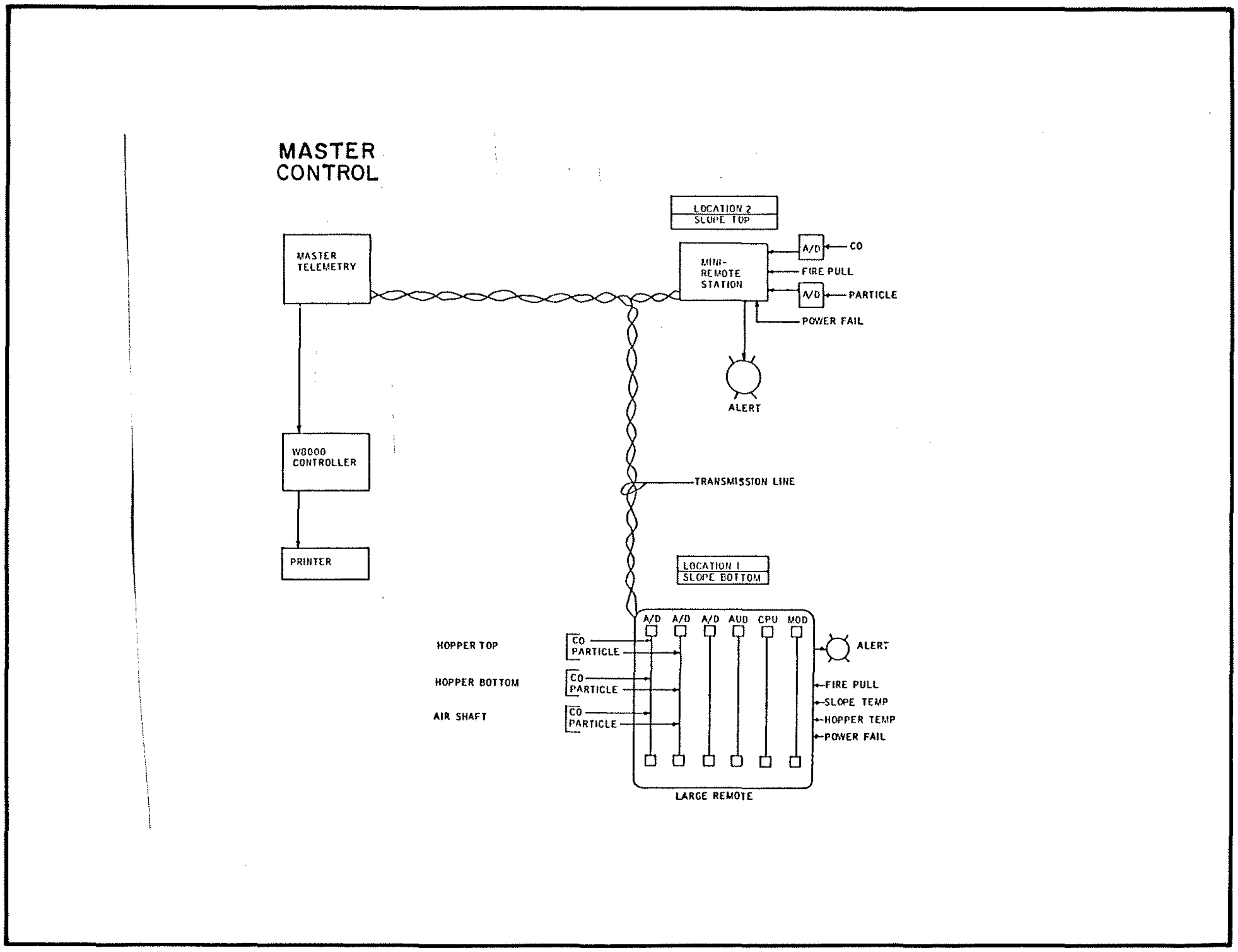


Figure 30 ALTERNATE II - BLOCK DIAGRAM

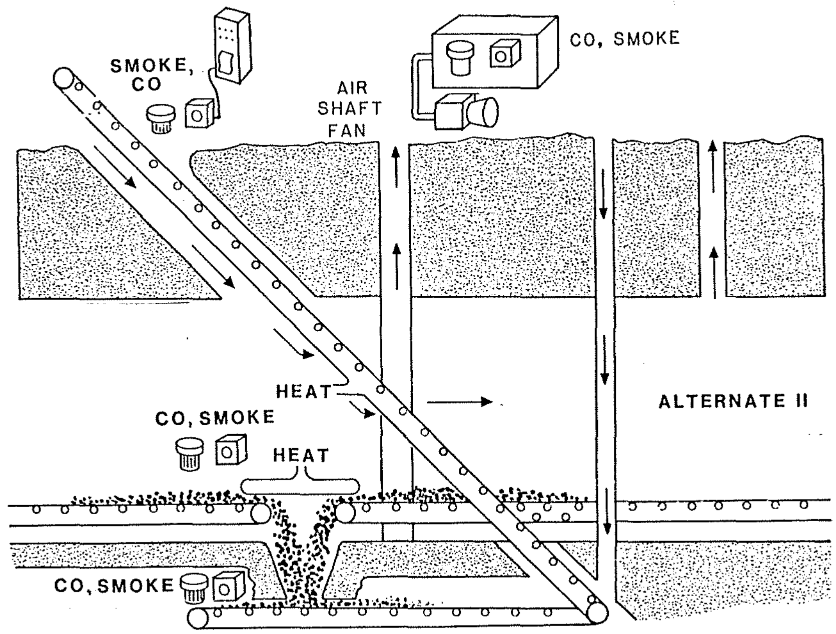


Figure 31 ALTERNATE II - GENERAL ARRANGEMENT SKETCH

3.2.14.2.4 Alternate III System (Figures 32 and 33)

Alternate III is a basic system for the Location Number 1 slope bottom area protection only. The large remote sends analog data of three CO analyzers and three particle analyzers, and switch signals for a heat sensor in the slope, a similar heat sensor over the hopper, and a fire-pull and power-fail indicator. The operator can send an alert signal to Location Number 1.

The surface control area has a 6-readout station that continuously displays analog data from the CO and particle sensors. The readout is in volts and, for interpretation, must be converted to parts per million or corresponding particle levels by a chart. Such a display has a thumbwheel setpoint which actuates the audible/visual alarm when the signal exceeds the value. There is no printer or graphic display with the Alternate III system.

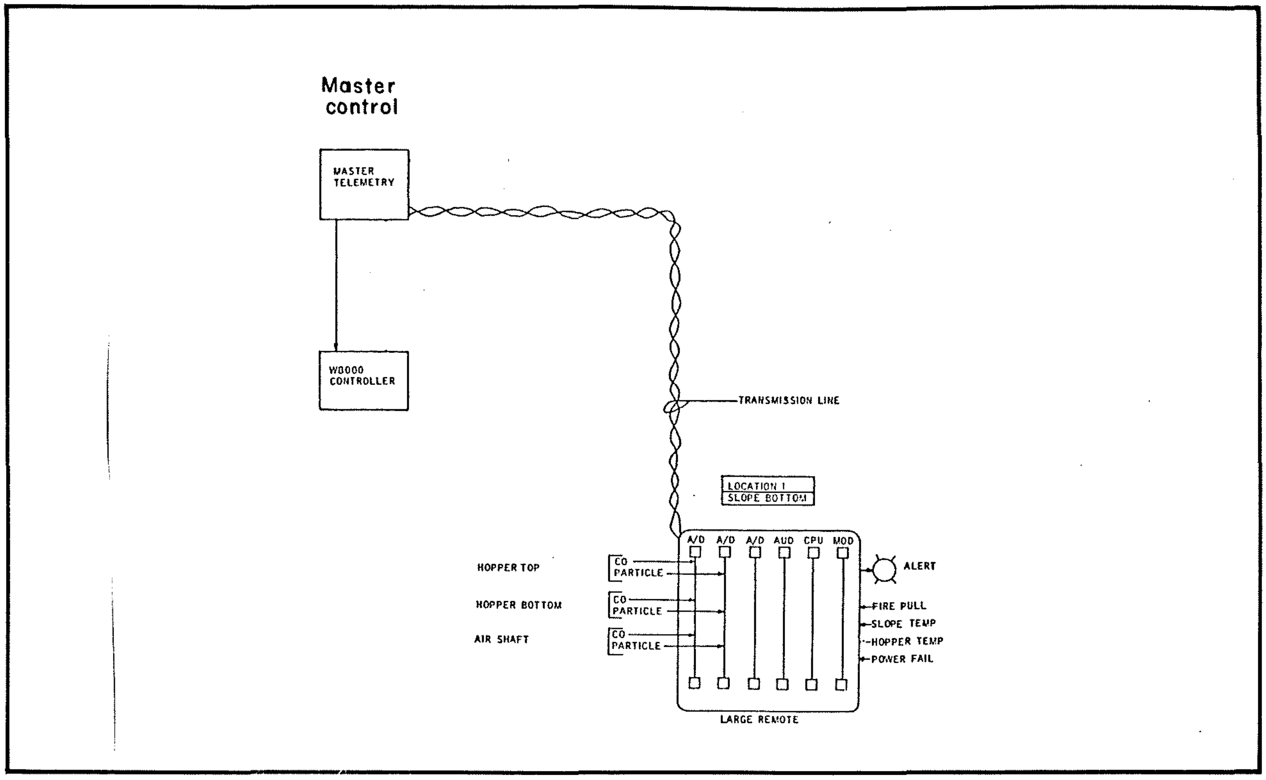


Figure 32 ALTERNATE III - BLOCK DIAGRAM

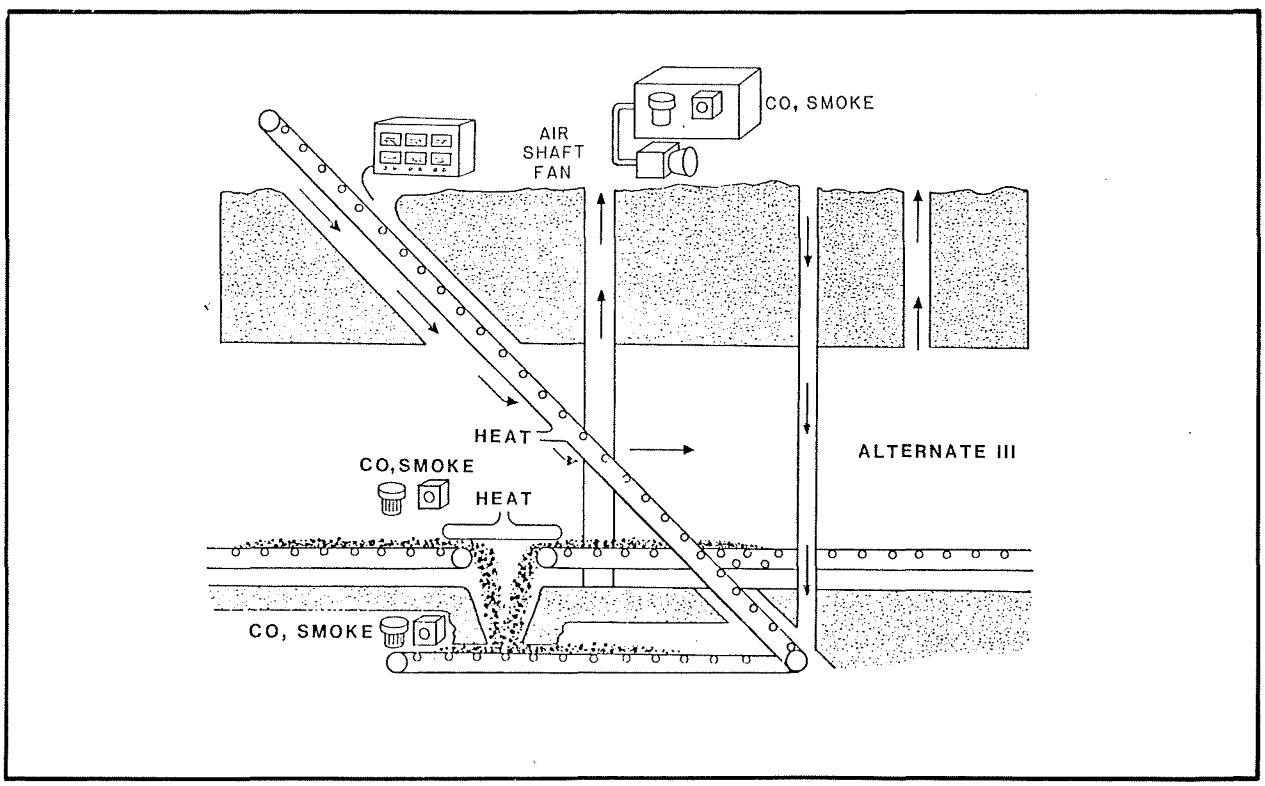


Figure 33 ALTERNATE III - GENERAL ARRANGEMENT SKETCH

3.2.15 Highlights of Phase II Report Oral Presentation

The 3-month Phase II data analysis, data acquisition, and design concept evaluation effort concluded on May 9, 1980, when an oral presentation was made at the Bureau of Mines Twin Cities Research Center. The presentation included a slide show which compared statistics of U.S. coal production in surface and underground mines, number of miners, numbers and types of mine entries, number of fires, location of fires, and number of injuries or deaths relating to fire. The highlights of the meeting are listed below:

- It was agreed that the Alternate I mine shaft fire and smoke protection system best met contract goals. This system concept was approved for development and testing in Phase III.

- Attendees from Peabody Mine Number 10 suggested design changes to accommodate planned ventilation changes near the slope. Another suggestion was to incorporate into the system the fire and smoke sensors already in operation at the mine in a distant location.

- The expansion of existing data collection systems to incorporate mine fire and smoke protection systems was discussed.

- Combinations of different manufacturers' carbon monoxide analyzers, particle sensors, and heat sensors were recommended to be located at air intake portals and exhaust shafts.

- The following sensors were recommended:

  - MSA Model 571 carbon monoxide sensors

  - Energetic Science Models 4125 and 5100 carbon monoxide sensors

  - Dynamation, Incorporated, Model CO-2301

  - Becon analog fire (particle) sensor from Wormald International of Australia

  - Protectowire thermal twisted-pair sensor, 155°F continuous wire.

- Ease of interpreting the data provided by the system was considered highly important.

- The microprocessor-based control system was to have the following features:

  - Graphic display of all shafts and general alarm areas

  - Easily identified visual and audible alarms

  - Printer-to-document incoming and outgoing signals

  - Adjustable alarm setpoints

- Summary printout of all data over the past 24 hours
- Adjustable printer speed to eliminate excessive paper collection
- Graphic representation of all analog signals for the 24-hour period
- Expansion capabilities to add or change components of the system.

3.3 PHASE III, DESIGN, FABRICATION, AND FACTORY TESTING

3.3.1 Design Review Meeting, June 4, 1980

In accordance with Section 3.2 of the contract schedule, a design review meeting was conducted at the Bureau of Mines Twin Cities Research Center on June 4, 1980. The highlights of the discussions are listed below:

- o Peabody Mine Number 10 personnel exhibited considerable interest in the USBM mine shaft fire and smoke protection program.
- o The additional sensors requested by Peabody would be added during future expansion of the mine shaft fire and smoke protection system.
- o The graphic display and surface master unit would provide for the expansion requested by the mine so that individual components could be easily added during future expansion.
- o The sensor locations at the underground mine were identified. Intake air was to be sampled for CO and particles in two areas: the slope collar and a 15-foot-diameter shaft near the slope. The area at the top of the underground hopper and below the hopper, where the slope belt is loaded with coal, was to be sampled for CO, particles, and heat. Return air was to be sampled for heat, CO, and particles at the remote portal upcast shaft by drawing air through a flame arrestor protected tube in the exhaust fan housing.

The preliminary system drawings were left with Bureau of Mines personnel. The revised contract schedule changed the surface factory demonstration to July 23, 1980, at Aquatrol Corporation in Minneapolis. The mine resumed production operation on August 11, 1980 (following regular summer vacation shut-down) so that installation of the mine shaft fire and smoke protection system could be scheduled for the week of August 18, 1980. Review of material supplier schedules indicated that the upcoming milestones of the factory demonstration and mine installation could be met.

3.3.2 Expanded System Concept

During the Phase II efforts, it was learned that token quantities of sensors and a limited control system would not yield the benefits desired of the overall program and of the mining industry. To best serve the needs of the majority of mine situations, additional sensors were required at strategic points of several intake and exhaust shafts. In reviewing the proposed system with the participating mine, several locations were identified as important areas for monitoring carbon monoxide and other products of fire. Because of this, the Mine Shaft Fire and Smoke Protection System has 10 analog signals and 15 status signals from four separate locations in the mine, with a fifth proposed location shown. The signal readouts have been partially designed into the graphic display.

3.3.3 Control System Description

The control system consists of four stations: a master station and three remote units. The master station contains all of the operator displays and controls. The remote station units receive inputs from the various sensors and send this information to the master station.

Table 17 lists the input and output signals of each control station unit. The system communication is handled by the Aquatrol W1300 telemetry system.

Table 17 INPUT-OUTPUT SIGNALS OF CONTROL OR REMOTE UNITS

Unit and location	Input signal(s)	Output signal(s)
1. Master Unit 100 located in slope hoist room	10 Analog (5 each CO and smoke particle) 15 Status (heat, fault, power fail, firepull, fan stop, etc.)	1 ALERT (to each remote)
2. Remote Unit 200 located at the slope bottom includes sensor inputs from:	1 ALERT (from master unit)	3 Status (firepull, power fail, and fault) in addition to the following:
Hopper bottom area		2 Analog (CO and particle) 2 Status (heat and fault)
Hopper top area		2 Analog (CO and particle) 2 Status (heat and fault)
Air shaft area		2 Analog (CO and particle)
3. Remote Unit 300 located at slope top	1 ALERT (from master unit)	3 Status (firepull, power fail, and fault) 2 Analog (CO and particle)
4. Remote Unit 400 located at Remote Portal connected to master via radio telemetry	1 ALERT (from master unit)	2 Analog (CO and particle) 5 Status (heat, firepull, power fail, fan run, and fault)

At each remote station, the analog signals are converted to digital form, and then transmitted along with the various contact closures and status signals which are already in digital form.

Each of the stations and their corresponding fire and smoke sensors and other inputs or outputs are interconnected as shown on Installation Drawing DC3634-10 (see Appendix F for system drawings). Incoming power for each of the four stations is 110 volts, 60 cycles.

The master station is installed in the mine slope hoist room near the slope portal. It communicates with the remote station at the slope top (portal) and the remote station near an underground conference room at the bottom of the slope via a pair of wires. The master station also communicates with the remote portal station via radio telemetry. If additional remote stations are to be added to this system, they may be added to either the hard-wired telemetry line, interconnecting the existing remote units, or they may be connected by a radio system, as necessary.

The radio connection provides an alternate signal path for the fire and smoke sensor signals to be transmitted to the master station. Transmission of signals via miles of underground wiring relies heavily on a secure system at all times to be effective.

Before a radio is added, it must be licensed, as each location must have a separate license. Aquatrol Corporation provides the licensing arrangement with the FCC during the normal course of design and installation of such components. See Appendix G for a copy of Peabody Mine's license from the FCC.

The remote station at the slope top transmits two analog signals and three status signals to the master station; the remote station at the remote portal transmits two analogs and five status signals; and the underground remote station at the bottom of the slope transmits six analog signals and seven status signals.

The following paragraphs describe the various remote stations. Discussion of the master station, which processes all signals that originate at the remote stations, follows.

3.3.3.1 Remote Unit 400 -- Remote Portal Upcast

The north portal upcast shaft is located 3.5 miles from the central area of the mine where the master station is located. Due to the distance between these stations and the anticipated problems with sending data via underground wiring, this station is connected to the master unit by radio. Drawing DC3634-9 shown in Appendix F explains the interface of Unit 400 with the master unit.

The sensors connect from TB-2 into the analog-to-digital converters. The thermal wire fire sensor input goes directly to interface board TS-311, then to contact input board CI-301. Note that interface board TS-311 has two LED indicators: one for Trouble (high resistance) on the thermal wire circuit, and one for Fire. The Carbon Monoxide Gas Analyzer signal is on the upper 8 bits of Word 1, while the contact input board CI-301 places Fire (bit 9) and

Trouble (bit 8) alarms on the lower group of 4 bits. The Fire-pull box transmits both of these bits together and overrides these signals. Logic at the master unit decodes the proper indication for Heat, Trouble, or Firepull. The signal from the Becon particle sensor is on Word 2.

An interface relay, CR-106, is to the fan pilot circuit. When the fan stops, CR-106 transmits an alarm to the master unit. Monitoring the mine ventilation fans was considered an important feature of all safety-related systems observed during Phase II.

If the AC input fails, remote terminal RT-201 will transmit the Power Fail signal to Master Station 100. Connector P2 pin 7 senses the 24-volt AC supply. Remote terminal RT-201 also controls the radio through connector P1. If the control operator at the master station manually transmits a fire alert, connector P3 pin 2 of RT-201 receives the command, and flasher TD-116 is energized to flash the external red light on each of the remote units.

An audio test switch allows the operator to hear the telemetry signals on the radio; however, this switch is normally left in the OFF position.

3.3.3.2 Remote Unit 300 -- Slope Top

Remote Unit 300 is located at the portal of the slope entry. Men and materials are hoisted through this entry, and a second section of this slope contains the production coal slope belt. Unit 300 is connected to the master station by a pair of telemetry wires. This station is very similar to Unit 400, except that there is no thermal wire and no radio connected to it. (See Drawing DC3634-8, Appendix F.)

The fire and smoke sensors connect to TB-2. The carbon monoxide signal is on the upper 8 bits of Word 1; the Becon particle sensor is on Word 2. The remote terminal, RT-201, audible connector (P1) goes directly to the telephone line protector. The Firepull box goes to remote terminal RT-201, P2, terminal 6. Terminal 7 is the Power Fail signal as described, and P3 terminal 2 is the Alert signal from the master station.

3.3.3.3 Remote Unit 200 -- Slope Bottom

Remote Unit 200 is the most complex unit, having a larger capacity than either Unit 300 or Unit 400. The unit is located on the wall of an underground conference room adjacent to the slope bottom. It is connected to the master unit by a pair of wires that may or may not be connected to Unit 300 at the top of the slope. Drawing DC3634-7 describes Remote Unit 200. See Appendix F for all drawings.

This station contains the large-capacity or "card box"-style remote unit, unlike Units 300 and 400. The fire and smoke sensors connect to terminal board TB-2, as labeled on Drawing DC3634-7. Drawings DC3634-10 and 5150171 may also be reviewed for installation connections. Terminal board TB-1 supplies 110-volt AC 60-cycle power for the distant carbon monoxide sensors. However, the sensor power may be taken from a source closer to the sensor location if desired. The sensors may be modified and controlled via low energy so that intrinsic safety guidelines can be observed and the sensors placed in return air at the bottom of the shafts, rather than mounted to exhaust fans on the surface.

The Unit 200 remote station transmits up to nine words of information to the master station. The present configuration uses seven words, leaving two spares. The six analog signals (three carbon monoxide sensors and three particle sensors) are on Words 2 through 7, as shown on the drawing. Word 1 is the Status and Alarm signals. The Power Fail relay is CR105. It transfers to battery power and transmits a Power Fail signal on Word 1, bit 2. The Fire-pull and Thermal Wire Fire alarms are on additional bits of Word 1.

Addition of more analog signals requires adding card T2031A01 in the C8 position of the card box and connecting it to the respective sensor.

3.3.3.4 Master Control Station Unit 100

The master control station is located in the hoist operator's area for 24-hour-a-day surveillance. Inputs to this unit are from hard wire connections of Units 200 and 300 and by radio connection to Unit 400. Drawings DC3634-3, -4, and -5 describe the master station Unit 100.

Time integrator TD-114 senses the master station output. If the master station fails to call a remote station for 60 seconds, TD-114 causes an alarm on the Alarm Annunciator 501 (see Drawing DC3634-4).

Multiplexed input boards SP201 through SP219 are for the Aquatrol W8000 logger controller (LC201). This controller reads the boards SP201 through SP219 to determine the operator-selected setpoints (what station to display) and the time and date. The digital clock, DC223, supplies time and date information.

The W1300 master rack (MTR301) connects to logger controller LC201 with three 14-conductor cables. The master station uses an audio-bridging amplifier (BA326) to transmit and receive both on the radio and telephone lines.

Push buttons (AAU-701 and 801 on Drawing DC3634-5) are connected as inputs to card C4 of logger controller LC201. The digital displays (DD907 and 911 on Drawing DC3634-5) are connected to output card C3 of logger controller LC201.

Alarm annunciators (AAU401-501) are shown on Drawing DC3634-4. The particle smoke detectors and carbon monoxide gas detector alarms come from logger controller LC201 C3 (see AAU401 and 409). Alarm annunciators AAU-417 and 501 receive alarms directly from the W1300 master rack (MTR-301), card C6.

Graphic lights (GL601 through 629 on Drawing DC3634-4) represent the lamps on the graphic display map. Each alarm annunicator unit has output drivers for external indicators. These are connected together and go to the Alarm indicator for each location. The Trouble indicators connect through diodes to several points, since they represent Power Fail, Data Fail, and Heat Thermal Wire open circuit.

3.3.3.5 Operating the System

The only operator attention required at the master station is entering or changing the alarm setpoints via the thumbwheels and pushbuttons or replacing the printer paper roll. These are periodic operations, with the frequency based on the amount of daily activity or change of alarm setpoints. Daily activity will consist of the operator's acknowledging all incoming signals that will silence the horn and cause the flashing light to remain steady.

The Display Select switch (Drawing DC3634-2, Legend 7 in Appendix F) governs both the displays (Legends 1 and 2) and the setpoints (Legends 5 and 6). Nameplate (12) shows the station numbers. The displays show Smoke (1) and CO (2) for the selected station (7).

The alarm setpoints for Smoke (5) and CO (6) will enter into memory when the operator pushes the corresponding button (3). In this way, each location has a separate setpoint for Smoke and CO levels with a minimum of operating controls on the panel. Setting the station selector to zero will blank out all the displays. The alarm setpoints may be left at any setting. They have no effect unless the operator pushes button (3) to enter the value. The value entered will erase any previous value.

The Alarm Annunicators (Legends 8 through 11) display all the various alarms that occur, while the graphic display located on the top of the master unit shows the general location. On the graphic display, a red lamp indicates an alarm condition, and a yellow lamp indicates a trouble condition that requires maintenance. A switch on each module tests the lamps and silences the audible alarm occurring on that particular module.

The operator can activate a flashing Alert beacon at all other remote stations by pressing the Alert button (4) and holding it for 2 seconds or more. The button lights when the Alert is transmitted. To cancel the Alert, the operator must push the button again.

The lamp test (4) tests all pushbutton and graphic lamps.

3.3.3.6 Printer Operation

The logger printer is located on a swing-out shelf within the master station. The power switch on the printer should be ON, and the reset switch should be OFF. Turning the reset switch ON stops the printing. The printer normally logs all signal data every 60 minutes, but this interval is adjustable from 1 to 60 minutes by an internal switch. If a high-level alarm occurs, the printer prints all sensor data every 10 minutes. This interval also is adjustable from 1 to 60 minutes.

Alarms other than from analog output gas or particle sensors also print out a message, but do not cause the printer to log the sensor data more frequently.

The operator can receive a copy of the high values of each sensor alarm setpoint stored within the computer memory by pushing Print Setpoints (Legend 4). Any change to these values will be printed when the change is entered and on demand when desired. The 24-Hour Summary button produces a graph for each location for the previous 24-hour period for the gas and smoke sensors. The smoke sensor value prints a "+," and the CO gas sensor value prints an "*" on the chart. The advantage of having both a data logger and the graphic representation is ease and speed of interpreting the data. An in-depth and time-consuming review of several columns of numbers is required when using only a data logger; a glance at a graph will quickly show rise or fall of signals.

3.3.4 Selected Fire and Smoke Sensors

This subsection provides brief descriptions of the different fire and smoke sensors that were selected for the various mine locations.

3.3.4.1 Energetic Science, Incorporated -- Ecolyzer Model 4125 Carbon Monoxide Gas Monitor

The Ecolyzer 4125 carbon monoxide gas monitor (Figure 22) contains an electrochemical cell and a mechanical pump to draw a specified amount of air over the cell and provide accurate low-level carbon monoxide monitoring.

3.3.4.2 Energetic Science -- Ecolyzer Model 5100 Carbon Monoxide Gas Monitor

The Ecolyzer 5100 unit has the electrochemical cell, but does not contain the mechanical pump. It is, consequently, a CO monitor by diffusion.

3.3.4.3 Mine Safety Appliance (MSA) -- Carbon Monoxide Monitor Model 571

The MSA Model 571 CO monitor (Figure 23) also uses the diffusion-type electro-chemical cell without a mechanical pump. Unlike the Ecolyzer unit, which has a digital output reading of parts-per-million CO, the MSA CO monitor has a standard range meter of 0 to 100 ppm, and an optional 0 to 500 ppm range meter is available.

3.3.4.4 Dynamation, Incorporated -- Carbon Monoxide Monitor Model CO-2301

The twin sensing head Tagushi gas sensor of the Dynamation CO Monitor (Figure 34) is designed to compensate automatically for humidity variations. No pumps, filters, dryers, humidifiers, or chemical cells are incorporated.

3.3.4.5 Wormald International -- Becon Intrinsically-Safe Analog Ionization Smoke Detector Model C121B

The Becon smoke detector (Figure 25) has unique mine design features. Its performance and sensitivity have been proven in the harsh environments of South African gold mines.

3.3.4.6 Protectowire Line-Type (Thermal) Fire Detector Model WPP155

The final sensor to complement the carbon monoxide and particle sensors in selected locations of the demonstration mine site is the common line-type thermal sensor (Figure 35) by Protectowire Company.

3.3.5 Alternate Sensors

Several alternate sensors which were being developed by Environment/One Corporation, Brunswick Corporation, and the Bureau of Mines were considered for use in the mine shaft fire and smoke protection system contract.

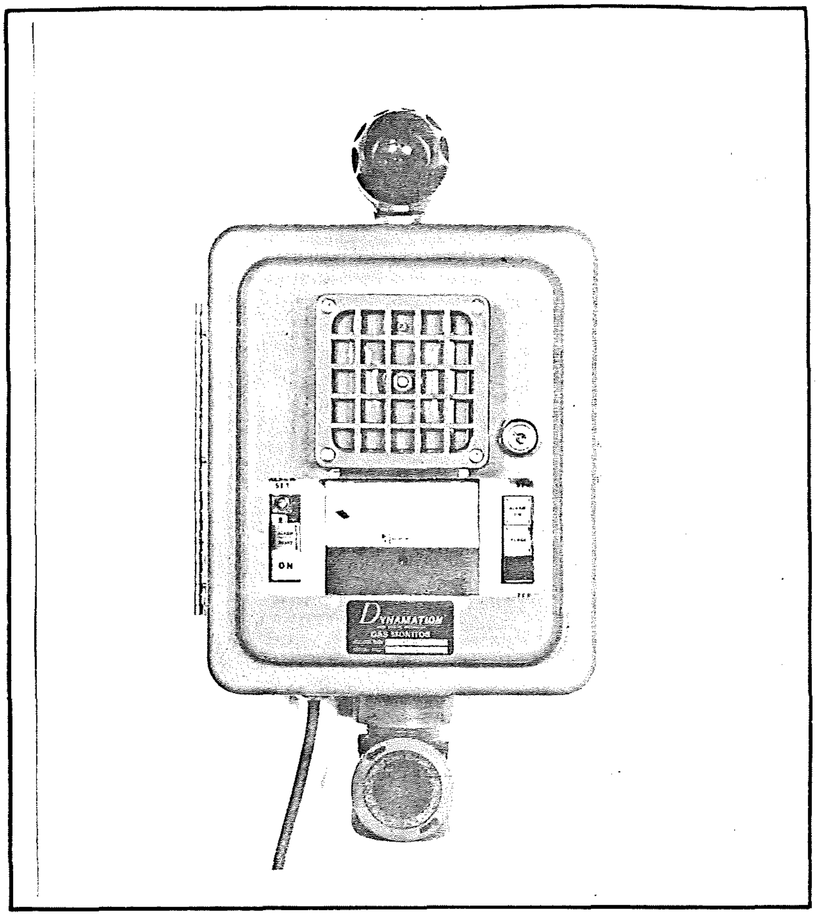


Figure 34   DYNAMATION MODEL CO-2301 MONITOR/ALARM

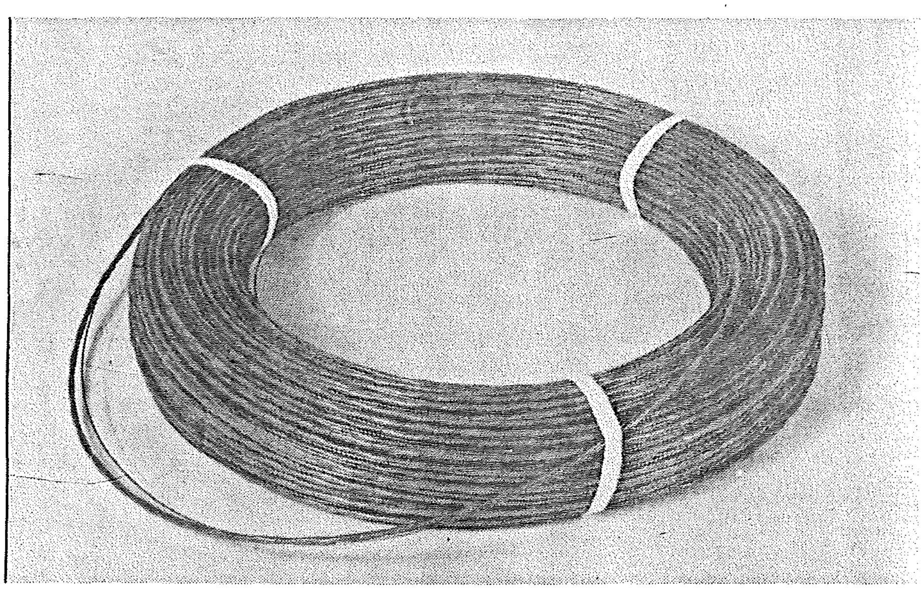


Figure 35   PROTECTOWIRE LINE-TYPE FIRE DETECTOR

Although cost, availability, and other contract constraints had precluded use of these sensors as primary candidates, it was decided that, should these sensors be offered for use within the contract timeframe, all efforts would be made to incorporate them for evaluation.

3.3.6 Factory Demonstration Arrangement of Components

During the factory demonstration, the surface master station was connected to the three remote units: Unit 200 representing the underground slope bottom, Unit 300 at the slope top, and Unit 400 at the remote upcast shaft. Figure 36 shows the interior and exterior views of each of the remote units. All units were in close proximity to one another to allow personnel conducting the sensor tests to observe the responses of the three remote stations and the surface master station.

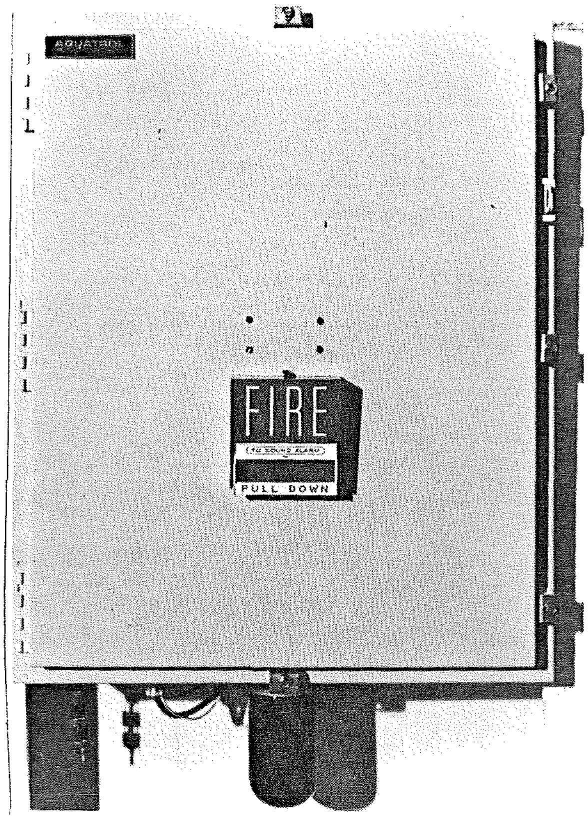
Although several of the primary sensors (such as the Ecolyzer 5100 diffusion head electrochemical cell sensor and the MSA diffusion head sensor) were not available, alternative sensors were substituted. One demonstration model MSA 571 did arrive on schedule and was calibrated on one of the remote stations.

The Aquatrol control system had been functioning on a bench simulator prior to the demonstration test. However, when connected to the actual mine hardware, mechanical deficiencies were noted, and interconnection of each component had to be retraced. Total system performance was thus limited during the July 23 demonstration. This did not detract from the hardware review and individual component demonstration; e.g., stimulation of the sensors to observe meter readouts. Transfer of the analog signals to the master station, however, was not performed. Previously recorded analog signals from the bench simulator were documented. The digital or ON/OFF signals such as the Fire-pull, Power Failure, Fan Run, and Trouble were operational and demonstrated on July 23. The system was completely operational and was demonstrated on August 8, 1980, to USBM-TCRC personnel.

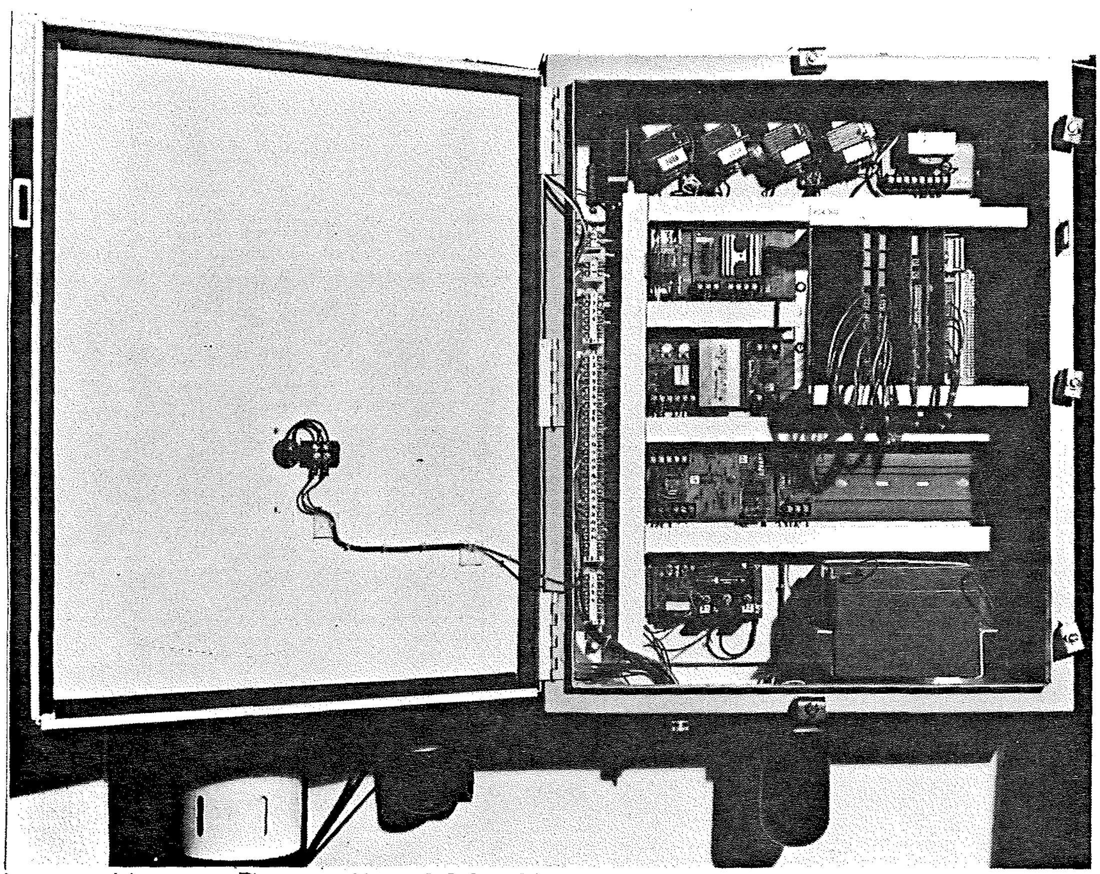
The following list summarizes the observations, conditions, and comments made during the factory demonstration test:

- Security of the surface master control Unit 100 was considered very important by visiting mine personnel. Covers and interlocks for levers, dials, buttons, etc. were strongly recommended.

- The graphic display panel was well received, although the spatial relationships of the various items to each other deviated from a proportional or scaled representation in order to accommodate all items in the limited panel space.

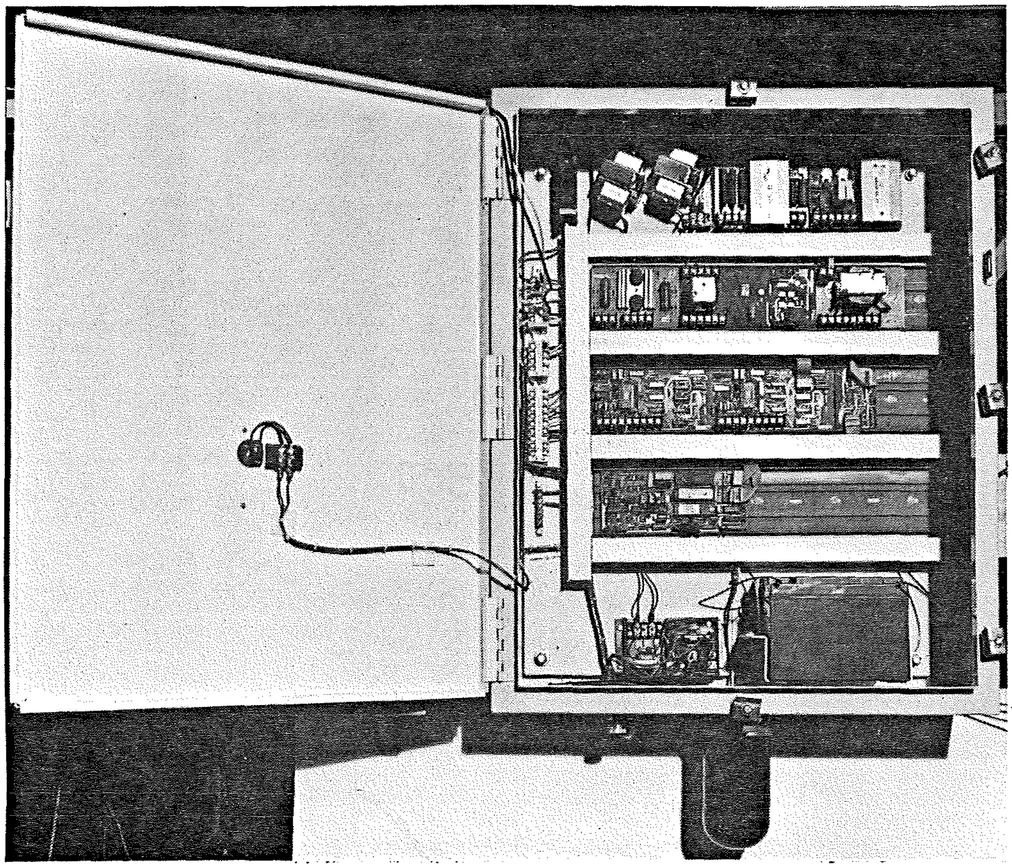


Exterior View — All Remote Units

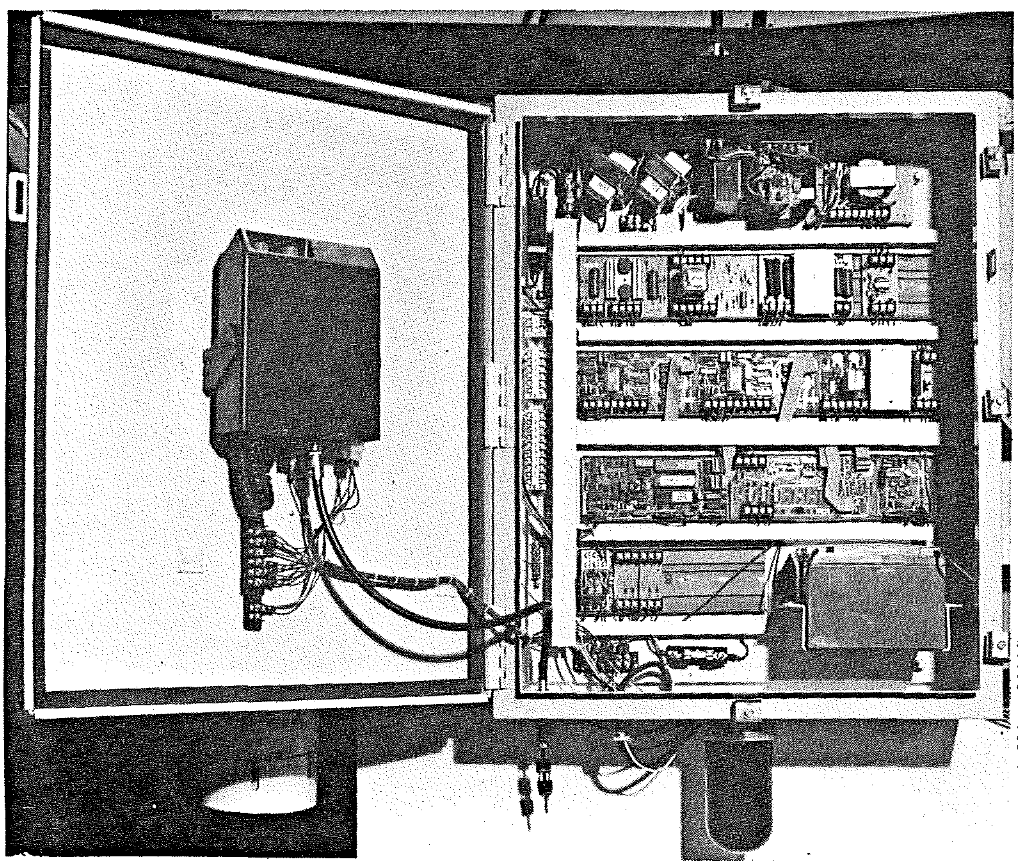


Interior View — Remote Unit 200, Slope Bottom

Figure 36 UNDERGROUND REMOTE UNITS (Sheet 1 of 2)



Interior View
Remote
Unit 300
Slope Top



Interior View
Remote
Unit 400
Remote Upcast

Figure 36 UNDERGROUND REMOTE UNITS (Sheet 2 of 2)

- All CO sensors were calibrated with 20-ppm span gas. The Ecolyzer 4125 CO monitors appeared easiest to calibrate and exhibited good stability following calibration.

- The substitute MSA Model 571 carbon monoxide monitor required several changes prior to the demonstration. The 0-to-500 circuit board was replaced with a 0-to-100 circuit board; the sensing head was assembled; the rotating light beacon was removed; and the 20-ppm gas was used for calibration. The zero and span settings were checked several times. Stability was monitored closely during demonstrations.

- The Dynamation carbon monoxide analyzer CO-2301 was also unstable when using the 20-ppm span gas. However, the system was constantly being shut off because of other tests, automatically recycling the Purge mode of operation. Sensor heater voltage is increased during Purge, and the unit is known to be unstable for up to 2 hours following the Purge cycles. The Dynamation analyzer also required repair of the door fastener and reconnection of a loose ribbon wire to its socket within the unit. After a phone call to Scott Stivers, Dynamation Technical Representative, it was learned that this is a plug-in ribbon wire that allows sensor elements to be easily replaced.

- One section of Protectowire was connected to display the digital ON/OFF Fire Alarm to the master unit. Other locations for the Protectowire were simulated with standard twisted wire.

- Each of the three Fire-pull handles on the remote units peformed well, sending signals for alarm and data logging to the master unit.

- The Becon smoke detectors from Australia were stimulated in the same way as the carbon monoxide sensors (i.e., burning or smoldering paper in a metal waste basket). Since the analog transmission to the master unit was not available, the sensor response was recorded on a voltmeter.

- Pictures were taken of each component so that documentation of the hardware could be presented in oral and written reports.

- Mine management recommended that sensors not be attached to exhaust fan housings by pitot tube arrangement. They also suggested that air contamination in the high velocity exhaust fan might be a cause of potential problems because of the water spray ring around the exhaust fan.

- It was suggested that Peabody assist ESD and the Bureau of Mines by modifying the sensors and acquiring the necessary field approvals.

- A Bureau of Mines research program to evaluate mine-worthy underground oxygen analyzers was recommended.

3.3.7 Mine Site Selection

3.3.7.1 Qualifications for In-Mine Testing

The primary requirements considered when contacting prospective mines for a demonstration site during Phase IV efforts of the contract were as follows:

- Mine management interest, awareness, and willingness to cooperate.
- Availability and accessibility of labor and maintenance personnel.
- Mines with a number of shafts, slopes, or inclines. (Mines with horizontal adits, rather than inclines and slopes, were not considered.)
- The mine's need for a mine shaft fire and smoke protection system, as determined by environment, working conditions, historical background, equipment used, coal seams, etc.
- Geographic location of the mine; i.e., mine's accessibility from ESD, material suppliers, subcontractors, and the Bureau of Mines.

Although several underground coal mines met the above considerations, mine management at Peabody Coal Company Mine Number 10 (near Springfield, Illinois) demonstrated the most interest in promoting Bureau of Mines research activities to develop an improved mine shaft fire and smoke protection system. This large mine was well-located, had multiple shafts, and a large work force with personnel available to assist in the program.

3.3.7.2 Mine Agreement for Cost-Sharing Support

Peabody Number 10 mine management agreed to cost-share in support of the mine shaft fire and smoke protection contract by providing the following:

- The labor to assist personnel from ESD, USBM (and their invitees), and any subcontractors and material suppliers during early mine visits, design review meetings, hardware installation, in-mine tests, equipment maintenance, and final demonstration.
- The test site to install and demonstrate the mine shaft fire and smoke protection system.
- The miscellaneous wires, fixtures, or brackets to install and maintain the system.

3.3.8 Radiation License for the Becon Smoke Sensor

In June 1980, an application was submitted to import and handle the Becon smoke sensors from South Africa. ESD was required to obtain a radiation license to import and test the Becon, which has a radioactive material source to ionize the air for detection of combustion particles. Radioactive License Number 3706-43 was issued to ESD by the State of California Department of Health.

The 5 millicuries of krypton 85 radiation source of the Becon ionization smoke sensor is above exempt limits and requires NRC licensing. Licensing by the manufacturer was encouraged to eliminate separate application by individual mines.

An application was submitted to the NRC in September 1980, and the license to use the Becon at the Peabody Mine Number 10 was received in February 1981. See Appendix H for a copy of the NRC License.

3.4 PHASE IV, COST-SHARING FIELD DEMONSTRATION AND FINAL REPORT

Phase IV was a 36-month effort, beginning in August 1980, devoted to installing the system at Peabody Number 10 Mine, conducting a functional demonstration of system and sensor reliability, evaluating operating, maintenance and permissibility characteristics, and preparing final documentation of the results. The following subsections contain more detailed descriptions of Phase IV activities.

3.4.1 System Installation

The system installation at Peabody Mine, interconnection of all components, and start-up were performed over a two-week period in late August 1980. Peabody Mine contributed over 200 man-hours of labor, and mine personnel installed 90 percent of the six-pair shielded signal wire prior to system arrival. ESD and Aquatrol labor used during installation was approximately 124 hours, for a total installation of 334 man-hours.

The following mine labor was used for system installation:

Management and chief electrician	20 hours
Installation (wire)	50 hours
Component installation	140 hours
Total	210 hours

The following summarizes component location after system installation. Types and locations of sensors were subsequently changed during testing to improve system performance.

- The master unit was located in the slope hoist room, within the hoist operator's audible/visual range. Some minor relocation was anticipated upon installation, due to an environmental enclosure planned for the hoist operator.

- The Remote Unit 200 was located at the slope bottom, receiving information from sensors at three different locations:
  - At the hopper bottom, an Ecolyzer 4125 CO analyzer, Becon smoke sensor, and heat-sensitive wire extending up the conveyor and back down the manway slope to Unit 200
  - At the hopper top, an Ecolyzer 4125 CO analyzer, Becon smoke sensor, and heat-sensitive wire
  - The 15-foot downcast shaft was changed to upcast on August 29, necessitating removal of the Becon from underground to the surface area. A CO analyzer was unavailable during initial installation, but was added upon receipt.
- The Remote Unit 300 was located at the slope top and initially received data from a Dynamation CO analyzer and Becon smoke sensor above the slope track for monitoring intake air.
- The Remote Unit 400 transmits data by radio from the Remote Shaft area, about 5 miles north of the slope. At the time of installation, a Becon smoke sensor and Ecolyzer CO analyzer were contained inside a housing in the fan motor room; a flame arrestor protected draw-tube allowed mine exhaust air to flow into the cabinet and over the sensors at about one-half air change per minute. Unit 400 also indicates when the fan stops, and 250 feet of heat-sensitive wire was located at the shaft bottom in fresh air.

Mr. Jerry Collier of MSHA District 8 office in Vincinnes, Indiana, visited and reviewed the installed system on August 28.

3.4.2 Analyzing Return Air Via Draw Tubes

When the 15-foot downcast shaft was changed to upcast (see Subsection 3.4.1), the air change necessitated removal of the Becon to the surface area. MSHA approval was required before this Becon could be used to observe the upcast air though a draw-tube in the fan housing.

In October 1980, MSHA approved temporary flame arrestor protected draw-tube installations at two return-air shafts including the Remote Portal return air fan and similar locations on an experimental basis for a period not to exceed six months. This approval permitted work at the 15-foot-diameter upcast to be completed.

Mine management was opposed to draw-tube monitoring of return air at the exhaust fan; permissibility or intrinsic safety is required for all sensors in return air. Possibility of air contamination in the high velocity exhaust fan duct was a potential problem.

During final demonstration of the system, it was ascertained that air flow through the draw-tube at the 15-foot-diameter shaft upcast was minimal and should be increased. It was hoped that the entire assembly would eventually be located underground, eliminating use of the draw tube concept in future applications.

3.4.3 Instruction Aids and Maintenance Manual

In November 1980, two instruction aids were prepared to facilitate mine personnel's operation and understanding of the system. Appendix I describes the operation and maintenance of the master control panel. Instructions are divided into alarm condition procedures and general operations during "no-alarm" conditions.

Appendix A is a one-page general arrangement diagram providing succinct information about the system to observers at each of the remote areas where equipment is located.

Procedures were also prepared for operation and maintenance under both "no-alarm" and alarm conditions (see Appendix J). These procedures were presented to mine personnel at meetings and training sessions conducted at Peabody Mine in December 1980 to officially commission the system.

3.4.4 Maintenance and Repair Visits

Two maintenance visits were made to Peabody Number 10 mine in September 1980. Two Bureau of Mines project personnel observed the system and the other sensors located in the mine. Bill Cross of Aquatrol Corporation came to the mine at the end of the month to review and correct problems in the master unit. Two computer programs were replaced, several parts were changed in the timing circuit, analog set-points adjusted, and smoke sensors and CO analyzers reset.

Two repair visits were made by representatives of Aquatrol Corporation in November to investigate erroneous and excessive printing of data. Corrections to system software were made (see Subsection 3.4.5.1), and the control system was free of errors by the end of November.

Vendor representatives from both Energetic Science and MSA came to Peabody Mine in March 1981 to attend the Final Demonstration.

3.4.5 System Performance

3.4.5.1 Surface Control Unit 100

During preliminary performance, unexplained signals were received at the Master Control Unit. The printout paper was monitored to determine a pattern or time intervals of the malfunction. Over the next several months of performance testing, until December 1980, program failure and software deficiency were recurring problems, causing erroneous and excessive printer activity. Circuit cards were removed in October of 1980 and examined, revealing that several components were out of tolerance and that malfunction of the bench simulator used to pretest all system programs was causing all of the programs checked on it to be in error. In November, the software program was revised twice to eliminate recurring errors, and new chips were made and installed to eliminate an error occurring only when the eleventh month was printed. By December 1980, the system performed as intended, except for a power supply failure in the remote shaft unit; the power supply was subsequently replaced.

Additional features were subsequently incorporated to enhance system performance, including the following:

- o Presetting the "sensor data" timing card for a one hour record level and pressing the button only on the hour, rather than between the hours. Sensor highs and lows printed automatically at midnight were then displayed on the graph.
- o An alarm delay for sensors or control systems which could withstand a longer response time.
- o A yellow light which illuminated whenever the system was operating on DC power only.

During final demonstration at Peabody Mine Number 10 in March 1981, the master control unit located in the slope hoist room accurately displayed alarm and warning signals.

3.4.5.2 Sensor Performance

The Dynamation CO analyzer at the slope would not stabilize and frequently required adjustment. It continually drifted upward following the PURGE cycle or calibration. Its nonlinear scale did not match the linear output indication at the master unit. In December 1980, the Dynamation analyzer was replaced by an Ecolyzer 4125 analyzer.

The Ecolyzer 4125 units at the hopper bottom and 15-foot-diameter upcast were replaced by MSA CO analyzers due to pump or cell failure. The MSA CO analyzer at the 15-foot-diameter upcast was subsequently replaced by an Ecolyzer 4125 with a new pump. The Ecolyzer at the north portal upcast operated without malfunction.

Upon its receipt in September 1980, an MSA 571 CO analyzer was installed at the 15-foot-diameter upcast. Due to continual false alarms, the cell was changed and sensor controls replaced in December 1980. Shorting the telemetry wires stopped the alarms, but no line voltage was found, and the problem was not resolved after a new cell was replaced in the sensor head. In January 1981, the MSA analyzer at the 15-foot-diameter upcast was replaced by an Ecolyzer 4125 CO analyzer. An MSA CO analyzer was used to replace the Ecolyzer 4125 at the hopper bottom.

Although the Becon smoke sensors became heavily coated with coal dust, rock dust, and moisture, they continued to perform accurately. The hopper-top Becon dust removal via a compressed air line became inconvenient since it required attention one to three times per week. Foam air filters attached to the Becon sides over the air entry slots would keep the dust from accumulating inside the Becon. But then, filter exchange or cleaning would be required more often than gas detector calibration while the filters also reduce Becon sensitivity and response time. At least, false high smoke alarms due to dust build up in the detector chamber notified mine personnel to remove the dust rather than make the sensor useless. Besides the false alarms confirmed the sensor circuit continuity and sensitivity point.

Most gas detectors require frequent inspections and at least semiannual calibration with high concentration (span) gas samples. The Becon detector does not contain the capability of adjustment for repeatable high smoke condition output values. Hence, the Becon output value can only be "zeroed" when no smoke is present and thereafter smoke concentrations would be referred to measurements made using a repeatable smoke source. The Gemini Scientific Model 501 Smoke Detector Analyzer Aerosol Generator can perform these correlations between Becon output and aerosol concentration. Once a new detector has been calibrated, that information can be used later to notice degraded sensor performance on subsequent calibrations before the detector is reinstalled in the future. The lack of Becon span adjustment does not rule out the need for spot checks during operation. As long as the Becon responds to blasting activity during production operations or diesel equipment activity, the sensor does maintain sensitivity. Any aerosol air freshener or compressed air line could be used to stir airborne particulates that may reside within the Becon's ionization chamber, thus creating a particulate concentration the Becon should respond to.

The Becon smoke detector output at the master control unit displayed three significant figures while the carbon monoxide detectors display two significant figures. Hence, any smoke detector drift would appear ten times greater than any carbon monoxide detector drift. Spurious alarms in either detector indicate the need to raise the high alarm level above the high value shown on the daily summary of readings printout. Without a span calibration adjustment in the Becon, repeatable smoke concentration measurements does not necessarily mean the same thing among different detectors. Consequently, any increasing smoke concentration lasting more than ten minutes should be investigated if accompanied by increasing carbon monoxide levels.

3.4.5.3. Baseline Zero

The smoke and carbon monoxide sensors have been "baseline zero" calibrated. This means that zero parts per million CO at the sensor is actually producing 0.1 volt output, yet the analog meter at the detector has been mechanically set back to 0 ppm. Consequently, the master unit CO PPM LEVEL digital display will always indicate 10 units above actual background CO ppm (display of 15 interprets to 5 ppm). Hence, any zero drift at the sensor or telemetry remote unit will indicate a corresponding change from the CO baseline zero of 10 at the CO PPM LEVEL digital display. Similarly, no smoke at the sensor actually produces 0.9 milliampere output. Consequently, the master unit SMOKE LEVEL digital display will always indicate 100 units above background smoke. Hence, any zero drift at the sensor or telemetry remote unit will indicate a corresponding change from the smoke baseline zero of 100 at the SMOKE LEVEL digital display yet tolerance of ±25-50 is to be expected normally.

3.4.6 Final Demonstration

The ESD program manager and a local photographer contracted to perform film services during the March 12-13 final demonstration visited Peabody Mine in February. Preliminary photos and movies were taken to enable necessary lighting and film adjustments.

The major purpose of the demonstration was to review and test each element of the mine shaft and smoke protection system. The following are highlights of control system and sensor performance during the final demonstration:

- The master control unit located in the slope hoist room accurately displayed alarm and warning signals.
- Hoist operators reported occasional dim-glowing lights, but they were not in evidence during the demonstration.
- The functional input/output buttons were exercised and, except for the output command to illuminate the red lights at each remote unit, all systems functioned properly.
- Switching off AC primary power and operating on DC power stopped recorder functions in accordance with the inherent design of the system. Restarting the AC power caused the computer program to print a long series of information.
- A fire scenario was accurately recorded and displayed when the "24-hour summary" button was pressed.
- The Ecolyzer 4125 CO analyzers in the slope top and the north shaft upcast (monitoring return air) performed well, although comment was made that the high-humidity cell should be used in the north shaft upcast due to the water condensed inside the tube. Similar comment was made regarding whether the Ecolyzer 4125 unit should return to other high humidity areas such as the hopper top. Stocking different cells for this analyzer is a consideration for future use.
- The Dynamation CO analyzer was removed from the slope top due to its high sensitivity and returned to ESD Corporation.
- Mine Safety Appliance Model 571 CO analyzers are located at the hopper bottom, hopper top, and 15-foot shaft upcast. Intermittent alarms had been experienced from the 15-foot shaft upcast for several months, and the vendor representative was unable to determine the cause during his visit. Later, the telemetry line was found to be intermittently operating.
- Replacing circuit cards in the sensor head of the MSA 571 CO analyzer appeared to increase the problem. Intermittent alarms then began from the hopper bottom.
- All Wormald Becon smoke detectors operated satisfactorily and continued to exhibit very low maintenance and ease of calibration.
- Peabody mine personnel expressed their interest in continued test and demonstration of the total system based on the performance of the Becon smoke detector to detect the heating incident from the belt-drive and in the hopper.

- Air flow through the flame arrestor protected draw-tube at the 15-foot-diameter shaft upcast was minimum and should be increased. This entire assembly will hopefully be located underground and the draw-tube concept not be used in future applications.

- Other sensing devices such as power failure, fire pulls and heat sensors performed well during the final demonstration tests.

3.4.7 Detection Events

Four notable events occured during mine testing that describe, (a) the system effectiveness, capabilities, and performance as well as, (b) the ability of mine personnel to properly respond, operate, and document events during an alarm condition:

- Carbon Monoxide In Intake Air

  Exhaust fumes from a truck parked near the slope intake-air caused the CO analyzer to alarm. Repeated alarms and investigation by the hoist operator confirmed the condition and cause. Intermittent parking of trucks near the slope collar was not considered a deterrent to health and safety, but was an example of mine intake air being effectively monitored.

- Overheated Motor

  A 150-horsepower belt-drive motor overheated, causing smoke to alarm the Becon particle sensor in the hopper-top area. Although the motor was fifteen crosscuts away, smoke particles consistently caused alarms which the hoist operator reported to the mine superintendent, who investigated and found the smoking motor.

- Heating Coal Pile

  Residual coal remaining in the hopper during the coal strike in May 1981 became sufficiently self-heated to alarm the Becon particle sensor. Although local underground power was occasionally off, the Becon has telemetry line power and remained on during the strike. The hoist operator observed the continuous increase in concentration and notified personnel who removed the heating pile.

- Mine Fire

  A smoldering fire from a worked-out section of the mine was undetected by the mine shaft fire and smoke protection system, although the exhaust was vented over a Becon and CO analyzer. Mine air was routed to the sensors through a flame arrestor protected draw-tube leading from the exhaust-fan housing to the sensor assemblies. The draw-tube was blocked with condensed water, and contaminated air did not reach the sensors.

The second of the above four events occured and diminished with the best documentation of what really happened. Alarms occured at 22:43 and 23:00 hours. Only the smoke sensor exceeded the alarm set-point but the hourly SENSOR DATA and the 24-hour graph shows high levels of both the CO and smoke detectors. The following paragraphs are from Mr. Thomas Herman's, Peabody

Mine #10 Superintendent, letter of March 20, 1981 to Mr. Guy Johnson former technical project officer for this contract.

> "The FMC/USBM mine shaft fire and smoke protection system has a particle (smoke) and CO analyzer located over a coal hopper at the bottom of the slope entry. Just prior to third shift on February 18, the hoist operator was alerted when an alarm persisted from the hopper-top smoke sensor. Because of the higher than normal smoke indication reported by the FMC/USBM fire protection system, Mr. Merle Allan, the hoist operator, requested that Clete Harris, second shift superintendent, investigate further. Mr. Harris then located an overheated drive motor fifteen crosscuts away from the hopper at the 1st drive south. Gas and smoke concentrations were naturally higher in the immediate area of the smoking 150 h.p. drive motor but self-breathing equipment and/or mine safety personnel were not necessary. Repair actions were immediately initiated and a new motor was in operation prior to the next shift.
>
> The attached recorder-paper "(Figure 37)" describes the heating incident. Some of the printed data is automatic and self-generating while other must be entered by manual operation. The graph "(Figure 38)" was initiated by the mine electrical personnel the morning following the incident and clearly shows the alarm points and concentrations of smoke and CO analyzers in the hopper-top area."

3.5 PERMISSIBILITY STUDY FOR MSHA INVESTIGATION

3.5.1 System Review

The system consists of particulate smoke detectors, carbon monoxide (CO) sensors, and line type heat detectors, appropriately located to protect the desired area underground. The control system consists of four stations: one surface located master control unit and three remote underground units with various sensors attached.

- o The master station, also known as Control Station Unit 100, is located in the slope hoist room. Inputs to this unit are from hard wire connections to underground remote Units 200 and 300 and by radio connection to Unit 400.

- o Remote Unit 200 is located at the slope bottom and receives information from sensors at the hopper bottom, hopper top, and 15-foot-diameter shaft. This station is the most complex of the four units and contains the large-capacity or "card box" style terminal unit.

- o Remote Unit 300, located at the slope top, receives data from sensors above the slope track for monitoring intake air. This unit is also connected to the master station by the same pair of telemetry wires as Unit 200.

- o Remote Unit 400 transmits analog CO analysis, particle (ionization sensor) data, temperature, and fan-stop signals by radio from the Remote Shaft area, about 5 miles north of the slope. These remote stations convert all signals to digital values and telemeter them to the surface control unit over one pair of wires.

* * * ALARM CONDITION * * *
FEBRUARY 18

22:43 HOPPER TOP SMOKE DETECTOR ALARM

Harris notified: AT 12:20 Harris called + said the motor on the [illegible] south was smoking, but was taken care of [illegible]

SENSOR DATA
FEBRUARY 18

MANUALLY ACTIVATED? See M[illegible]

22:43	SMOKE	CARBON MONOXIDE
SLOPE TOP	082.	019.
26 INCH UPCAST	082.	009.
HOPPER TOP	307.	017.
15 FOOT SLOPE UPCAST	105.	008.
NORTH PORTAL UPCAST	094.	015.
SOUTH PORTAL UPCAST	999.	000.

22:44 ALARM ACKNOWLEDGE

SENSOR DATA
FEBRUARY 18

23:00	SMOKE	CARBON MONOXIDE
SLOPE TOP	082.	011.
26 INCH UPCAST	083.	009.
HOPPER TOP	255.	017.
15 FOOT SLOPE UPCAST	105.	008.
NORTH PORTAL UPCAST	093.	014.
SOUTH PORTAL UPCAST	999.	000.

* * * ALARM CONDITION * * *
FEBRUARY 18

23:00 HOPPER TOP SMOKE DETECTOR ALARM

23:06 ALARM ACKNOWLEDGE

SENSOR DATA
FEBRUARY 18

MANUAL?

23:10	SMOKE	CARBON MONOXIDE
SLOPE TOP	083.	011.
26 INCH UPCAST	081.	009.
HOPPER TOP	298.	020.
15 FOOT SLOPE UPCAST	101.	008.
NORTH PORTAL UPCAST	094.	015.
SOUTH PORTAL UPCAST	999.	000.

FEBRUARY 19
DAILY SUMMARY OF READINGS

LOCATION	HIGH VALUE SMOKE	HIGH VALUE CO	LOW VALUE SMOKE	LOW VALUE CO	MEAN SMOKE	MEAN CO
SLOPE TOP	131.	036.	072.	008.	101.	022.
26 INCH UPCAST	108.	023.	077.	006.	092.	014.
HOPPER TOP	337.	022.	079.	000.	208.	011.
15 FOOT SLOPE UPCAST	107.	009.	091.	008.	099.	008.
NORTH PORTAL UPCAST	101.	021.	000.	011.	050.	016.
SOUTH PORTAL UPCAST	999.	000.	999.	000.	999.	000.

SENSOR DATA
FEBRUARY 19

OUT OF SYNC (GRAPH)

0:10	SMOKE	CARBON MONOXIDE
SLOPE TOP	086.	012.
26 INCH UPCAST	083.	009.
HOPPER TOP	097.	010.
15 FOOT SLOPE UPCAST	101.	008.
NORTH PORTAL UPCAST	094.	015.
SOUTH PORTAL UPCAST	999.	000.

Figure 37 SAMPLE OF DATA LOGGER PRINTOUT

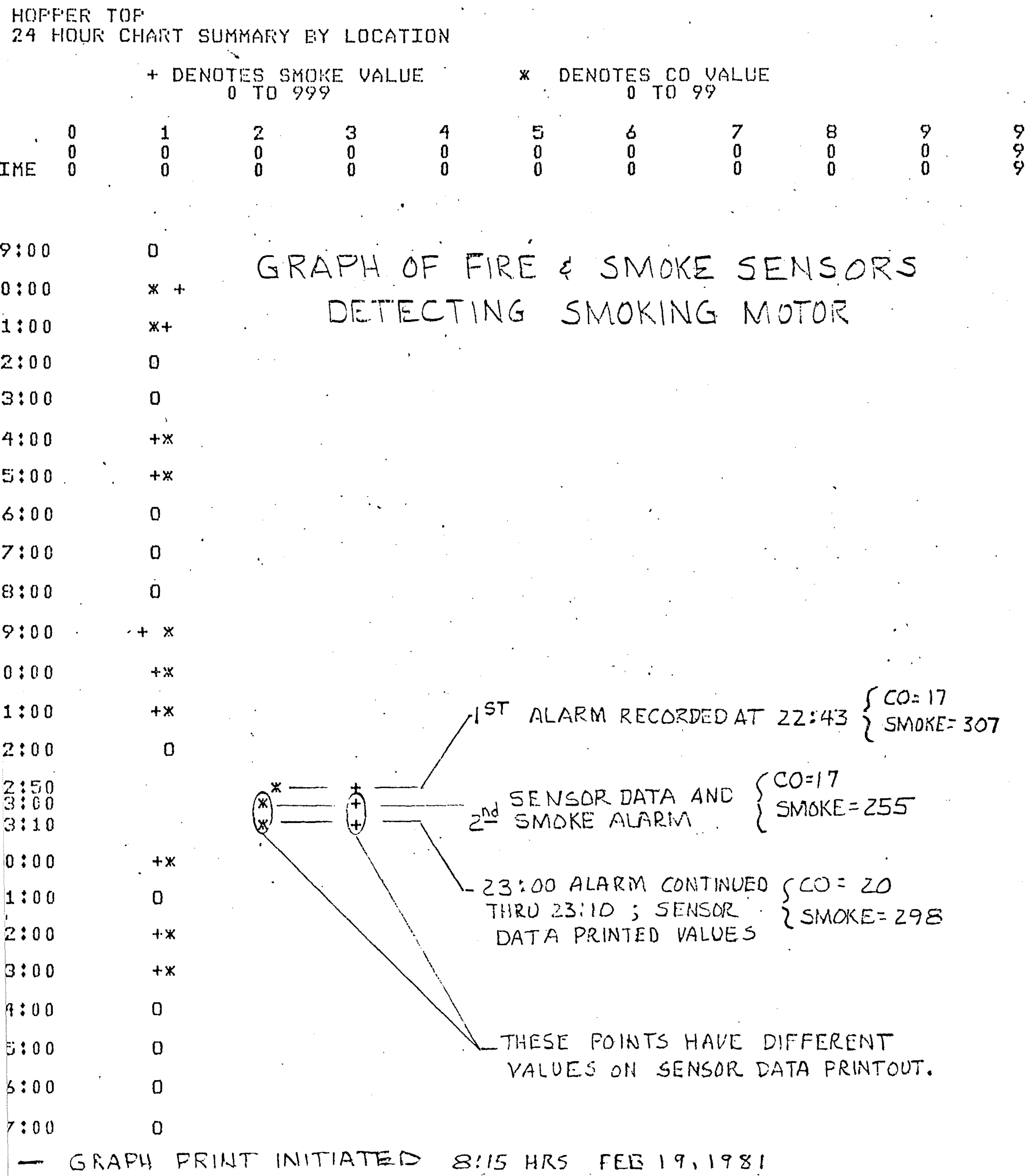


Figure 38 PRINTOUT OF GRAPHIC ANALOG SIGNAL (LINES HAVE BEEN ADDED FOR CLARITY)

Sensors extending from each remote unit are the Energetic Science Ecolyzer Model 4125 CO analyzer, the MSA Model 571 CO analyzer, Anglo American Electronics Laboratories (Wormald) Becon particle (ionization) analyzer, Dynamation Inc. CO-2301 CO analyzer, and Protectowire temperature sensing twisted wire.

The Ecolyzer and MSA units are electrochemical cell units, with the MSA being diffusion collection as opposed to needing the mechanical pump of the Ecolyzer. The Becon particle sensor and the Protectowire thermal sensor have no moving or maintenance parts.

In the test system, all sensors are mounted in fresh air because they are not permissible. The sensors are wired to a nearby remote unit, also underground.

The surface control unit contains a graphic display panel of the mine with alarm lights for all sensors, the telemetry system master, the computer system, operator manual controls to enter setpoints, and a printer that logs all alarms and operator entries to the system computer.

The carbon monoxide sensors, underground remote units, and surface control unit are all powered by 110VAC. To increase the usefulness of such a system, it is desirable to make the total system permissible so that it may operate during mine power shutdown or loss of ventilation. The surface control unit will also be considered briefly, since it is intended to be located either above ground or in a safe area. Especially, if it should not be required that permissibility allow monitoring during loss of power or ventilation, then a MSHA Mine-Wide Monitoring System Evaluation would suffice for system use during normal operations.

3.5.2 Alternative Considerations

Coal mine fire detection systems have different requirements, depending upon where they are installed. The following lists possible conditions:

(a) The instruments are located and make measurements only in fresh or neutral air. If the mine ventilation or electricity ceases, possibly increasing methane levels and hence the chance that the electrical circuitry in the instruments may cause an explosion, power to these instruments is removed, and the atmospheric condition of the area is not monitored. Power must be removed although, under normal functioning, the instruments would not cause an explosion. MSHA requires that electrically-powered components be built to certain rigorous standards and be given an MSHA approval as "permissible" before they can be used in a methane-air mixture.

(b) Most instrumentation is located in fresh or neutral air, but measurements are also made in return air with MSHA classified components. If ventilation air or electrical power is lost, power to all nonpermissible components must be removed after 15 minutes, ceasing nonpermissible fire detection.

(c) All fire detection equipment in fresh, neutral, or return air is permissible at all times, either because it has batteries that can be charged or replaced as part of an acceptable mine maintenance procedure, or because its electrical power source provides intrinsically-safe power (electrical power with low enough energy levels that its spark will not ignite a methane-air mixture). This allows atmospheric condition monitoring to continue when mine ventilation or electricity is lost. Normally, each instrument needing power is provided with batteries which continue to provide instrument power when mine power is removed. A minimum of 4 hours service from these batteries is generally desirable.

The existing fire detection instruments at Mine Number 10 fall under (a) above. This section explores how to upgrade them to (b) and (c) conditions. Condition (b) compels the implementation of MSHA's Mine-Wide Monitoring System (MWMS) concept which requires the use of MWMS evaluation and classification forms for the monitoring system and sensor/barriers, respectively. Condition (c) demands the use of Part 18, Title 30 Mineral Resources, Code of Federal Regulations (30 CFR) procedures which require Part 18, 30 CFR application forms for approval and certification actions or intrinsically safe and explosion proof apparatus, respectively.

3.5.2.1 Explosion-Proof Permissible Instruments

Instruments can frequently be made permissible by placing them in an explosionproof box. This box, which must be designed and tested according to MSHA standards, has walls sufficiently thick that an explosion in the box will not ignite an explosive mixture outside the box. Explosionproofing is frequently a fast and easy method of making an instrument acceptable for coal mines. If it is made according to (c) in Subsection 3.5.2, however, it will require a battery and some other special circuits, because mine power will be interrupted if ventilation is lost.

3.5.2.2 Intrinisically-Safe Permissible Instruments

Instruments of this type are designed with electrical power levels modest enough that they will not ignite a methane-air mixture. Many hand-held mine instruments are designed in this way, such as methane detectors and dust concentration measurement instruments. Many electrical instruments, such as a battery-powered wristwatch, are inherently intrinsically safe (according to law, these should not be taken into the face area of a mine, because they have not been approved by MSHA). Other instruments can be made intrinsically safe by making circuitry modifications. This type of instrumentation is often superior to explosionproof instrumentation, because it is easier to work on, less bulky, and less costly. It appears that the circuits of all of the instruments can be modified to be intrinsically safe. Moreover, the electrical energy levels of the components will be sufficiently small that MSHA will approve these instruments as modified without testing.

3.5.3 Modification of System Instruments

Many studies have been made of intrinsically safe circuitry, and many publications have been prepared that give charts and graphs based upon a multitude of tests using various gasses, voltage, current, capacitance, inductance, resistance, and sparking contact materials. Most of the published results support each other to a limited extent, but differences in test equipment do cause some variation in results. MSHA tends to use the more conservative of test results, so it is desirable to work appreciably below the energy levels given in these publications if possible.

One of the widely used publications is NFPA493 (Intrinsically Safe Apparatus For Use in Division 1 Hazardous Locations) published by the National Fire Protection Association. Figure 39, an excerpt taken from this publication, shows the values that are intrinsically safe in various types of gas mixtures. Of interest in this program are the methane tests with cadmium, zinc, or magnesium contacts, the "worst" of the contact materials. Figure 40 (from NFPA493) shows tolerable voltage capacitance values for cadmium, zinc, or magnesium contacts. The following paragraphs refer to these curves and describe the techniques for making the fire detection instruments intrinsically safe.

3.5.3.1 Becon Fire Detector

Figure 41 presents a schematic of the Becon sensor and shows that, at the required -15VDC power, the current requirement is 5.5 ma. Figure 39 shows that, at 5.5 ma, the potential can be several hundred volts. Figure 40, however, shows that C6 (100 uf) of Figure 41 stores sufficient energy that, at -15VDC, it will fail intrinsically safe testing if the spark gap apparatus is across C6.

MSHA tests at the 1.5 energy level, so they would test at

$$15^2 \times 1.5 = 18.4 \text{ volts.}$$

However, R7, R3, and R10 are resistors that are encapsulated along with C6 to isolate the energy at C6 and exclude methane and air from any area that can produce an incendiary spark. Everything except the ionization chamber is encapsulated so that only five leads are exposed to the mine atmosphere.

These energy levels show that the Becon instrument is intrinsically safe, so the only requirement for using it in return air is to provide it with intrinsically safe power or barriers and to send its signal to an instrument that will not apply a power source to these wires. For power, it needs a 15VDC power supply with a barrier. Commercially available barriers can be purchased. Commercial barriers tend to be expensive, because they are made for a wide variety of applications. Intrinsic safety in methane can often be provided with a single layer wirewound resistor. It is interesting to note that since, at the Peabody mine, the only Aquatrol converter below the surface is Unit 200, the Becon sensors connected to Units 300 (slope top) and 400 (Remote Upcast) would be able to monitor conditions regardless of whether or not there is mine ventilation. The Becons connected to the Aquatrol Unit 200 at the slope bottom could not be powered without mine ventilation, so these units would be in condition (b) of Subsection 3.6.2. To make the Becon comply with Subsection 3.6.2, condition (c), it would be necessary either to bring in intrinsically safe power from the top, or have a battery power supply.

The Becon draws so little power that it is relatively easy, when compared with other instruments, to provide its intrinsically safe power from the surface. Three 22 AWG telephone wires (the "+" is common for signal and

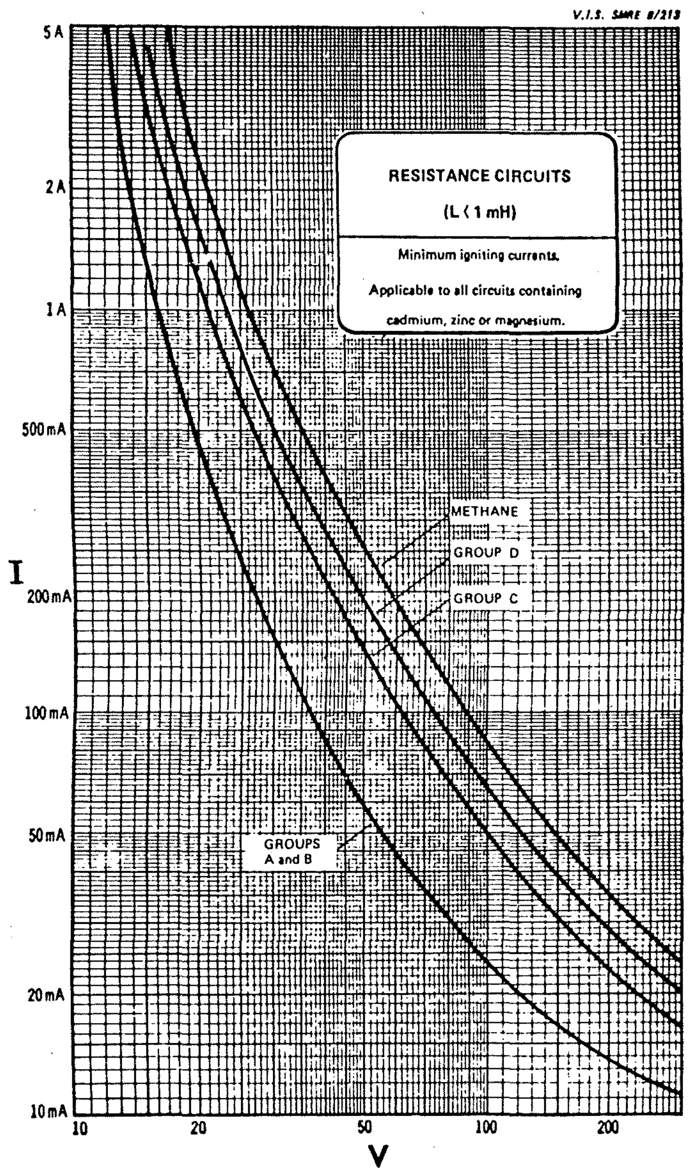


Figure 39 RESISTANCE CIRCUITS

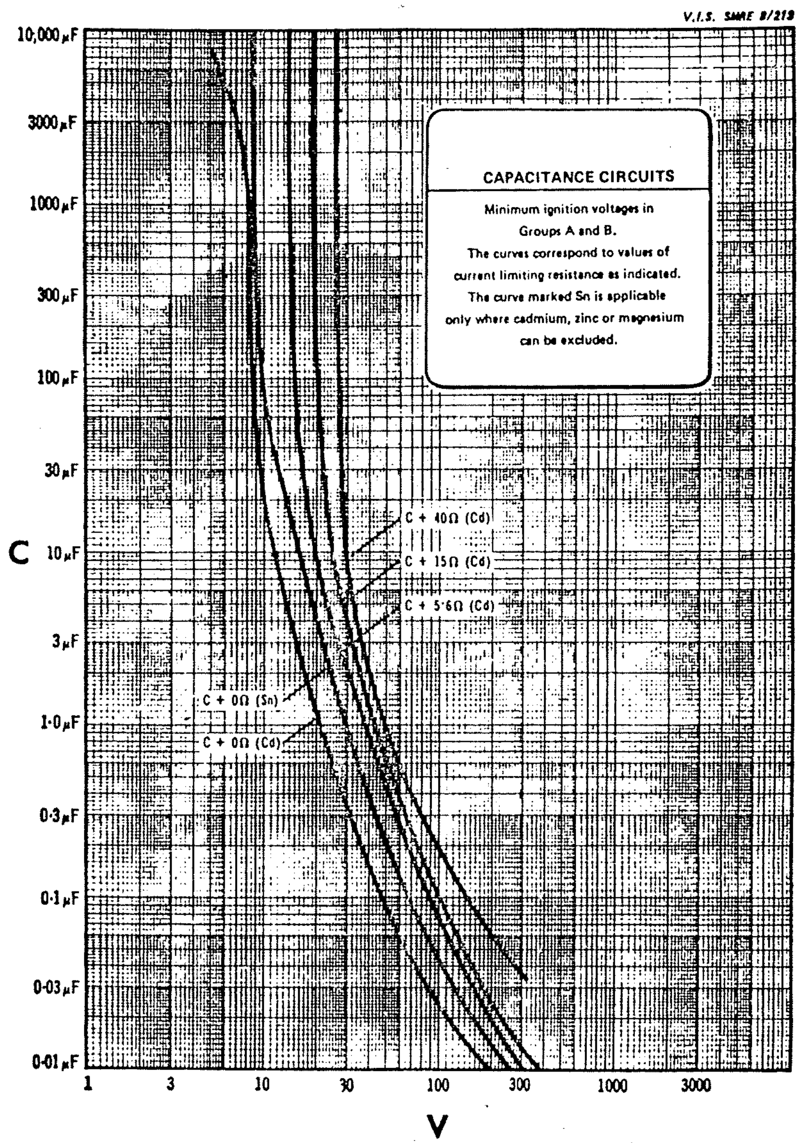


Figure 40 CAPACITANCE CIRCUITS

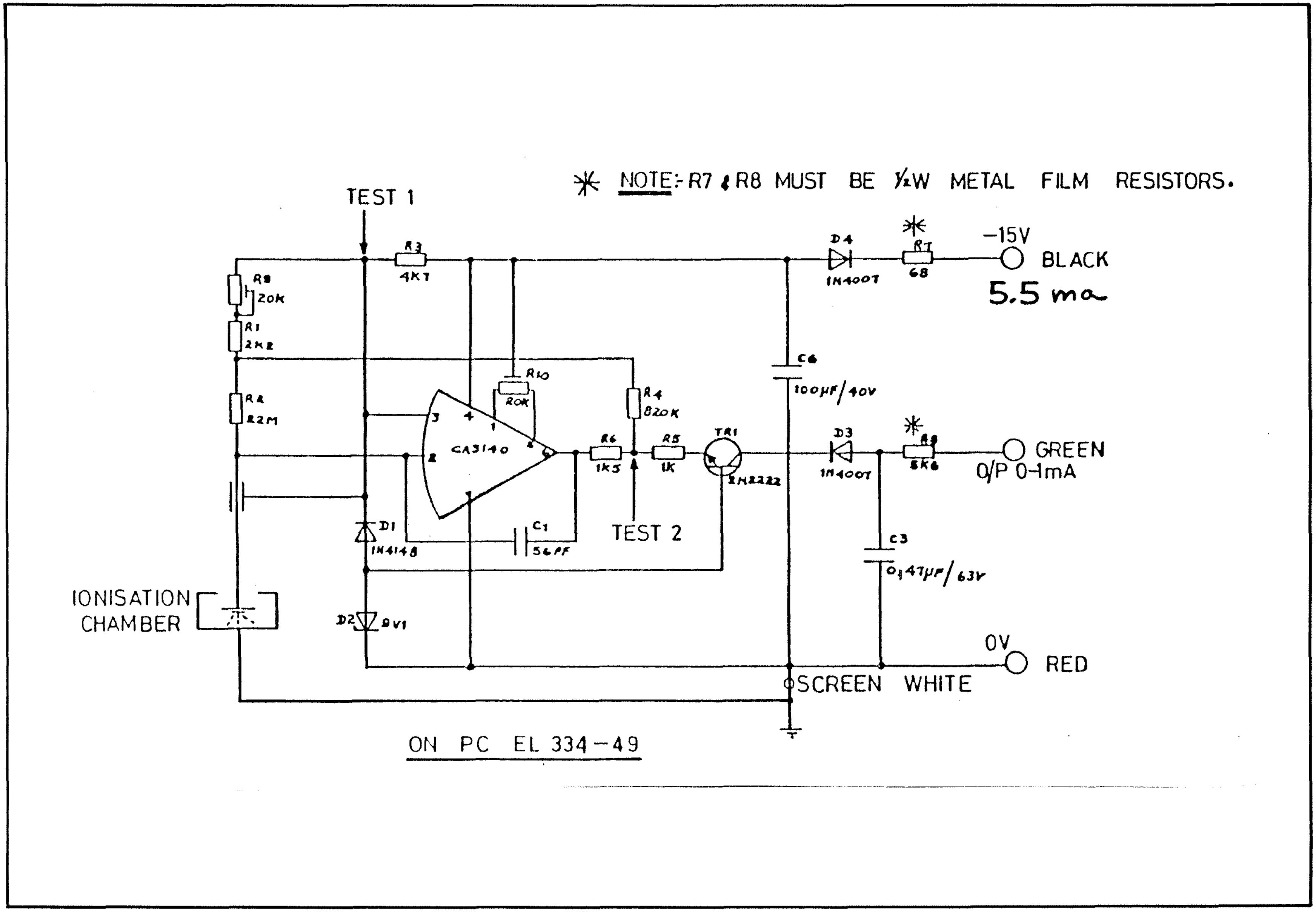


Figure 41 FIRE DETECTION HEAD, ANALOG "BECON" DETECTOR

power) could likely be routed at least 6,000 feet without appreciably degrading Becon performance.

Another method of complying with condition (c) of Subsection 3.6.2 is to have a power supply that converts 120 VAC power to DC power in order to keep a 16VDC chain of Gelled Electrolyte (Gel/Cells) charged to provide 15VDC intrinsically-safe power for the Becon. Figure 42 shows a suggested schematic for the power supply, along with the principal components. Figure 43 shows a suggested construction method. This unit must be located in fresh or neutral air. The Globe GRC 18060 CDF is a desirable battery charger for this application, because it has no capacitor to store energy, as its schematic (Figure 44) shows.

3.5.3.2 Ecolyzer CO Analyzer, Model 4125

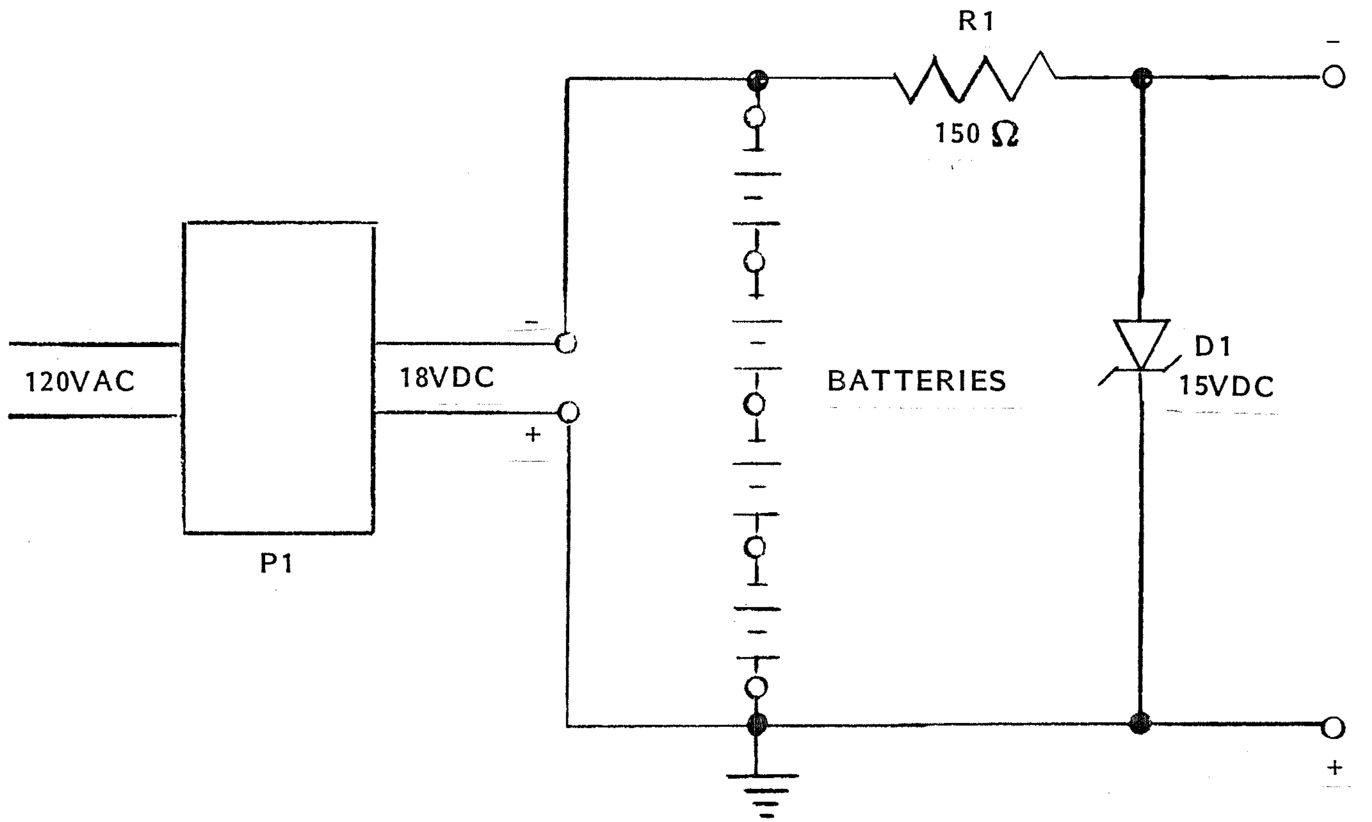
Figures 45 and 46 show the schematic of the Ecolyzer CO analyzer. It is not intrinsically safe for the following reasons:

- Use of 120 VAC power
- A 1,000 uf C5 capacitor
- An alarm light
- The coils of K1 and K2 relays that likely would store enough energy so as not to be intrinsically safe
- C1, C2, C3, C4, C7, C8, and C9 may have too much energy stored in them, as determined by Figure 47 for cadmium contacts

The relays and alarm lights are unimportant to the functioning of the Ecolyzer at Peabody mine. The 120 VAC power can be replaced with intrinsically safe DC power, and the 1,000 uf capacitor is a ripple filter for the AC power. Therefore, to make the Ecolyzer 4125 intrinsically safe, the following can be performed:

- Remove transformer T1.
- Remove capacitor C5.
- Remove K1, K2, and L1 (the relays and the light).
- Put diodes across the brushes at the pump. Two 1N4002 diodes connected in parallel would be satisfactory.
- Connect parallel 4.3-volt, 5-watt zener diodes (1N5336) across each of C7 and C8. This provides the redundant assurance MSHA requires that the voltage will not exceed 8.6 volts, and that Figure 44 indicates as an intrinsically safe level.
- Remove C3.
- Shunt C1, C2, C4, and C9 each with a 7.5-volt 5-watt (1N5343) zener diode, or decrease their size to 15 uf.
- Leave F2 fuse 3/4 amp, as shown.

The resulting schematic will be as shown in Figure 47. The output is TBI-5 and TBI-4, and this 0- to 1-volt signal is intrinsically safe.



PARTS

P1 POWER SUPPLY - GLOBE BATTERY GRC 18060 CDF (60MA OUTPUT)
BATTERIES - GLOBE BATTERY GC410 TYPE 1 GEL/CELL (4 VOLT 9 AH) 4 REQ

R1 RESISTOR - SINGLE LAYER WIREWOUND (150 Ω 5 WATT) DALE RH-5

D1 ZENER DIODE 1N5352 15 VOLT, 5 WATT

Figure 42 POWER SUPPLY SCHEMATIC, -15VDC, INTRINSICALLY SAFE OUTPUT

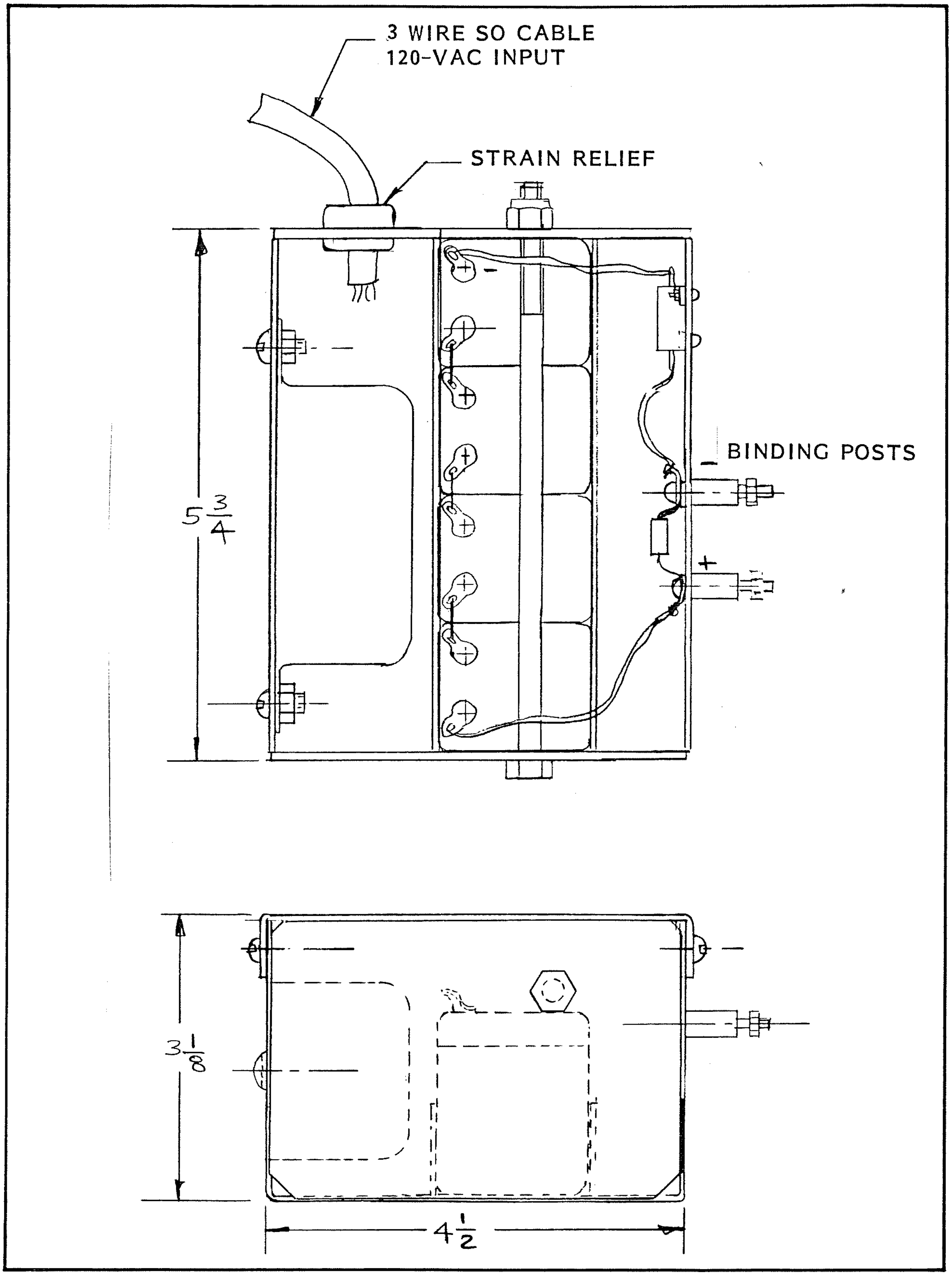
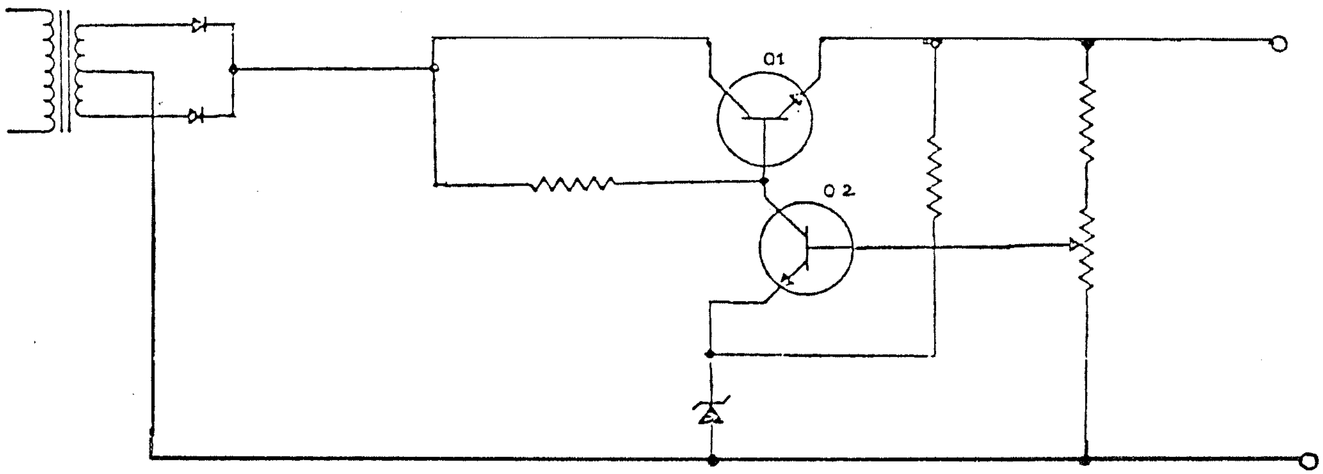


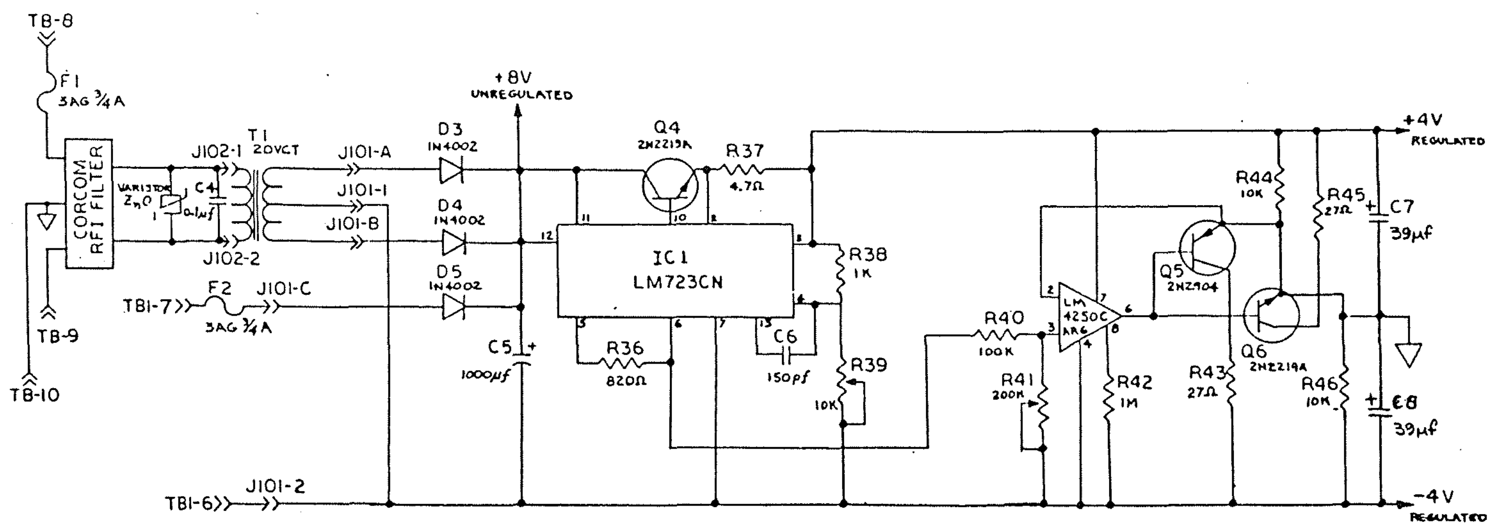
Figure 43 POWER SUPPLY, -15VDC, INTRINSICALLY SAFE OUTPUT



CHARGER IDENTIFICATION
CRC XX 060 CDF Battery System Voltage

CDF SERIES CHARGER SPECIFICATIONS	
1. Input	120 VAC ± 10% 50 to 60 HZ
2. Outputs available: Nominal Voltages Current	6, 8, 10, 12, 18 and 24 VDC 0 to 15 milliamperes for supervisory circuit and 60 to 45 milliamperes for battery charging.
3. Terminations Input: Output:	Two 10" yellow jacketed #20 stranded wires. 10" #20 stranded wire with red jacket (+) 10" #20 stranded wire with black jacket (—)
4. Case Material	Steel (gray finish)
5. Operating Temperature	—4° F. to +122° F.

Figure 44 BATTERY CHARGER



NOTE:-
1. SHEET 1 AND SHEET 2 ARE ON SAME CIRCUIT BOARD.
(B) 2. THIS DRAWING CANNOT BE CHANGED WITHOUT MESA APPROVAL.
3. THIS IS AN INTRINSICALLY SAFE CIRCUIT. WARNING: ANY CHANGES MADE ON THIS INSTRUMENT MAY RESULT IN AN UNSAFE OPERATING CONDITION.

Figure 45 ECOLYZER 4000 SERIES POWER SUPPLY SCHEMATIC

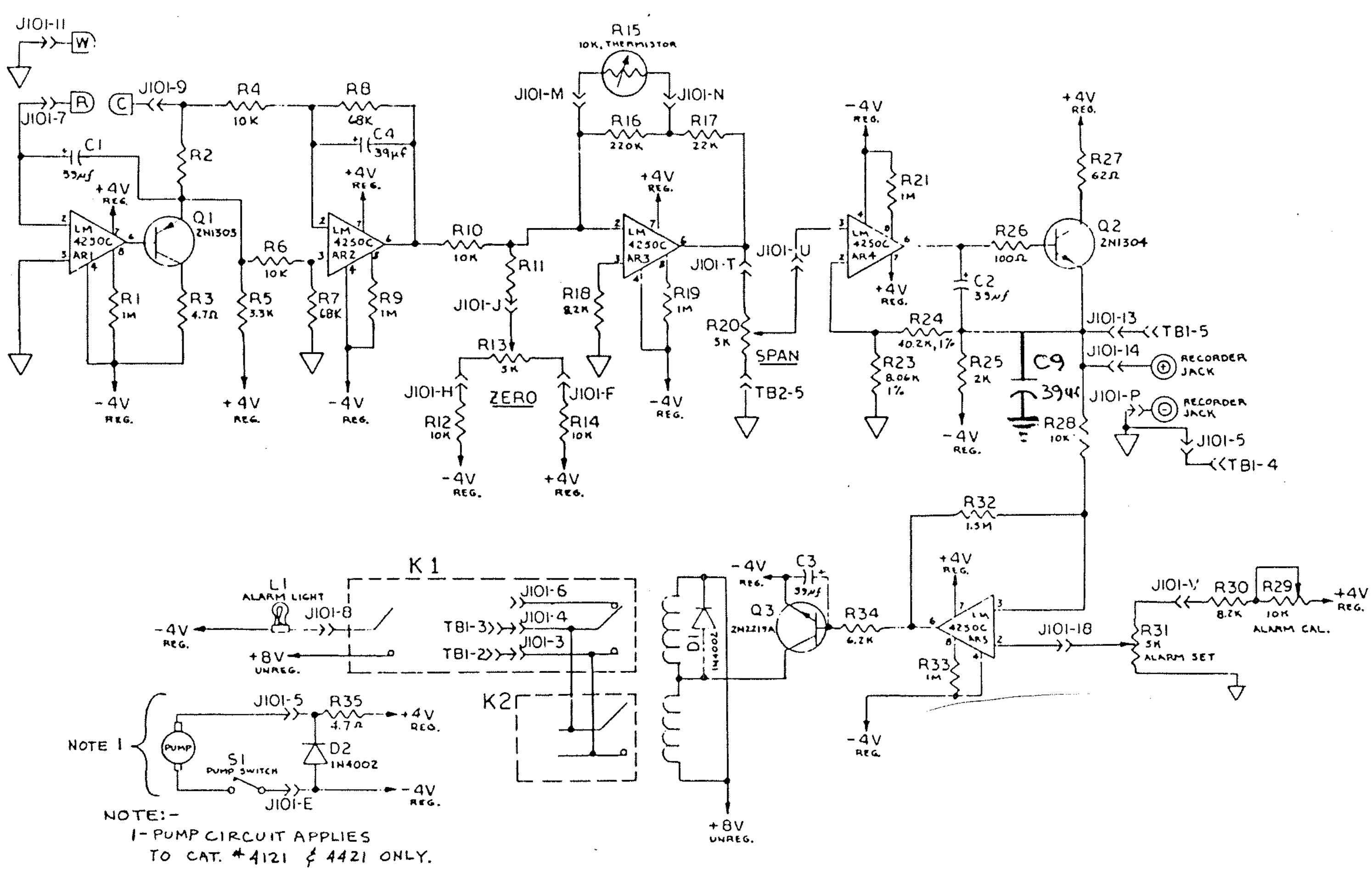


Figure 46 ECOLYZER 4000 SERIES SCHEMATIC (CO)

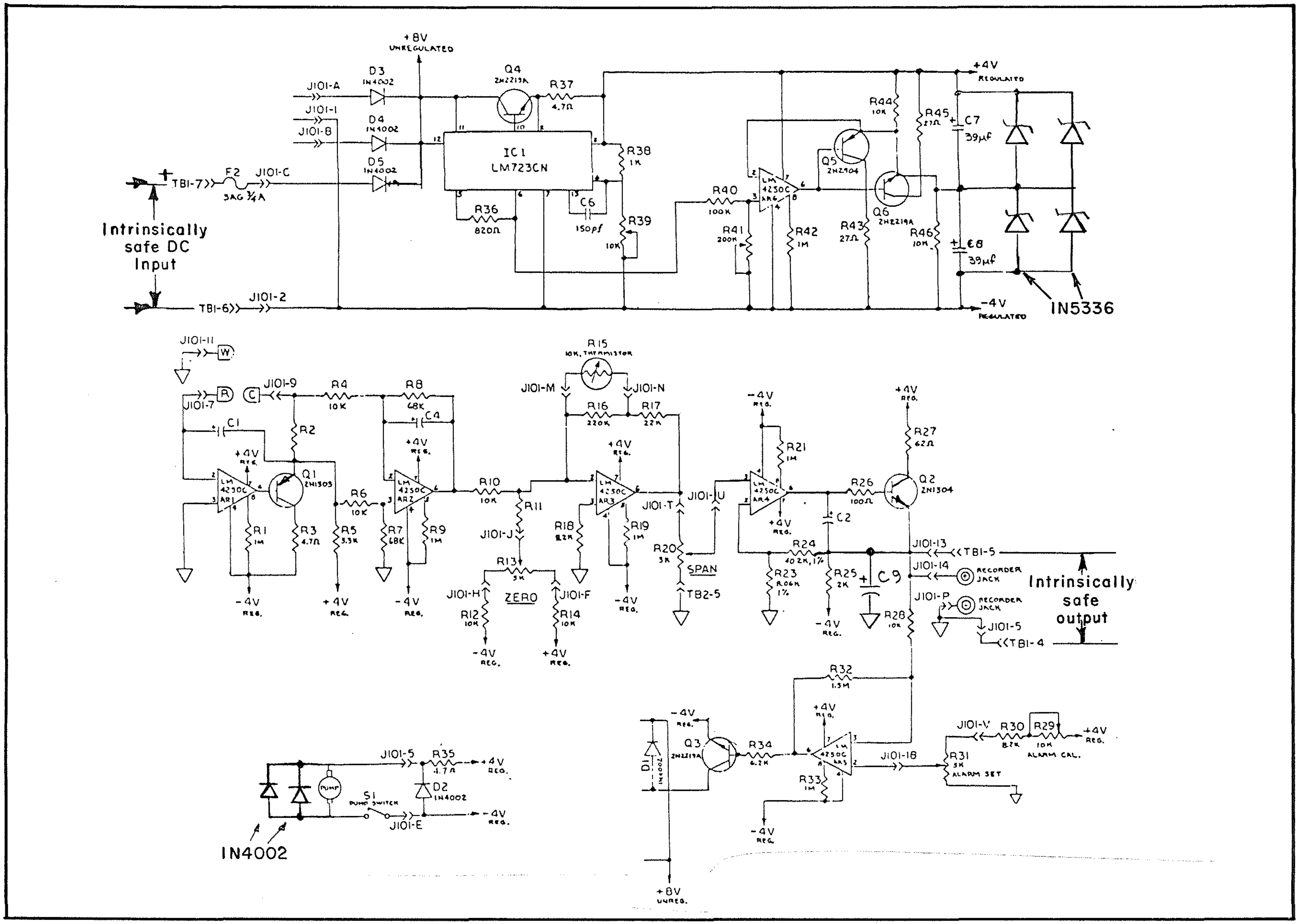


Figure 47 MODIFIED ECOLYZER 4125 CO DETECTOR FOR INTRINSIC SAFETY

This instrument may now be submitted to MSHA's Approval and Certification Center for sensor classification or intrinsic safety evaluation. The instrument uses less than 150 ma so, at 10VDC, it is easy to provide intrinsically safe power.

Figure 48 is the schematic of a power supply system that could be located in fresh air or neutral air to provide intrinsically safe power for the Ecolyzer as long as there is mine ventilation. It could also provide intrinsically safe power at all times if it is located on the surface. The power lead length is limited, however. Below is a table of tolerable power lead lengths between the Figure 48 power supply and the modified 4125 Ecolyzer:

Wire Pair	Lead Length
#24 AWG	700 feet
#23	900 feet
#22	1,000 feet
#21	1,400 feet
#20	1,800 feet
#19	2,200 feet
#18	2,800 feet

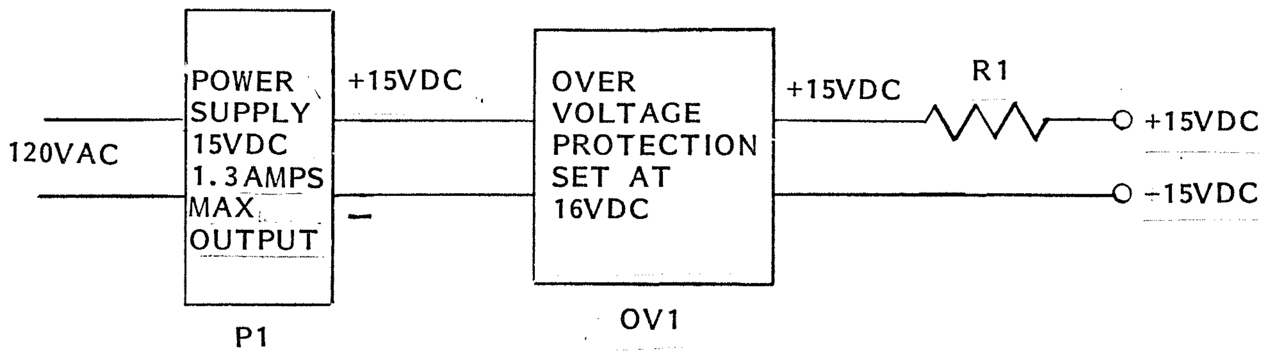
If the power supply potential is increased to 20 VDC, its power will still be intrinsically safe, and the power lead lengths in the above table can be doubled.

Figure 49 is the schematic of a power supply that can be located in fresh or neutral air to provide intrinsically safe power from batteries for up to 7 hours after mine power is lost. The supply has a capacitor that might remain charged and thus not be intrinsically safe. R2 and R3 are redundant paths to remove this charge. At the same time, they consume 5 watts (2-1/2 watts each) to provide heat to keep the box interior dry under damp mine conditions. D1 and D2 are redundant barriers to prevent the capacitor from being charged by the batteries. R1 is 50-watt size, so it will not burn open if the supply is dead-shorted. For a short time, the batteries and the power supply together would be capable of providing high current. Figure 50 shows a suggested power supply construction.

3.5.3.3 MSA Model 571 CO Detector

Figure 51 shows the schematic (excluding the AC power supply that converts 115 VAC or 230 VAC to the 12 VAC that this instrument uses). CO measurement is performed with the sensing head, which can be used 5,000 feet from the amplifier if Number 14 connecting wire is used (2,400 feet if Number 18 wire is used). This wire should be shielded.

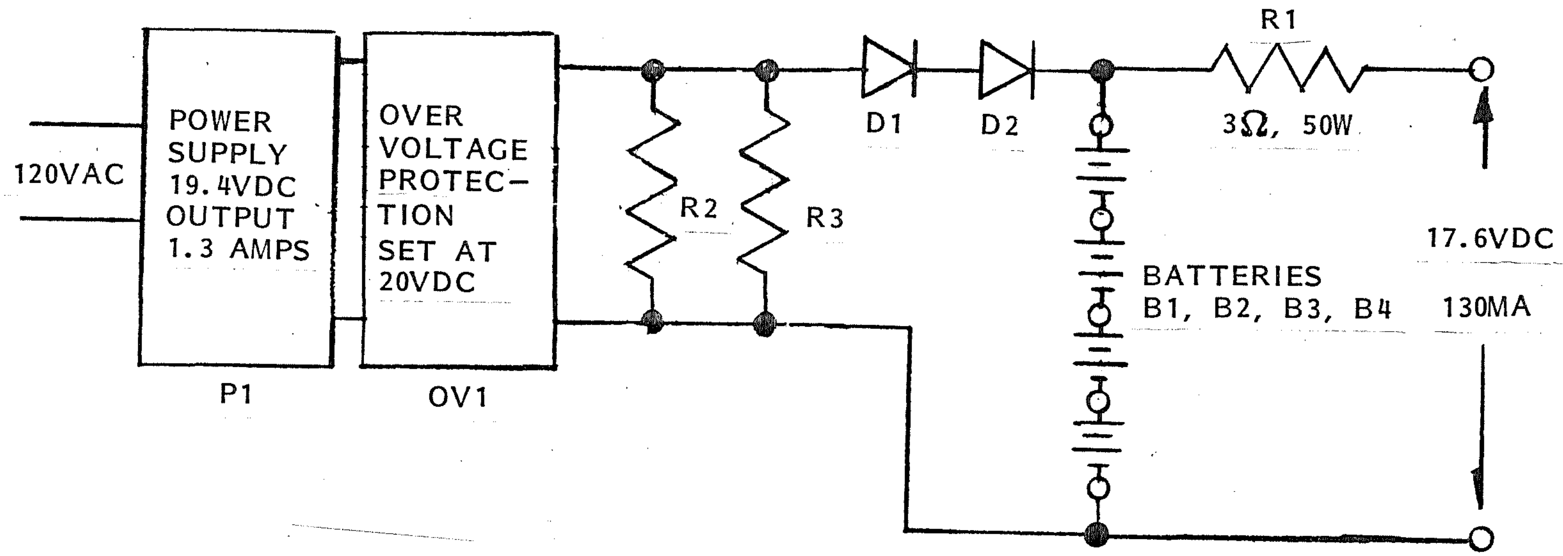
An examination of Figure 51 shows that the four leads connected to the sensing head feed into large resistances, so MSHA may decide that the sensing head circuitry is intrinsically safe as is. If it is not, it can be made intrinsically safe by inserting a 3-ohm wirewound resistor in each of the leads as it exits the amplifier (these would decrease the allowable length of the connecting wire to the head about 10 percent). The long amplifier/lead length will allow monitoring in return air so long as mine ventilation provides a safe atmosphere for the amplifier and its power supply. Also, this lead length allows the amplifier to be located on the surface with the head deep in the mine to provide monitoring at all times.



PARTS

P1 POWER SUPPLY - POWER/MATE CORP EM-15B, HACKENSACK, NJ
OV1 OVER VOLTAGE PROTECTION MODULE - POWER/MATE CORP. OVP-4
R1 RESISTOR - SINGLE LAYER WIREWOUND (3 Ω 10 WATT) DALE RH10

Figure 48 POWER SUPPLY WITH INTRINSICALLY SAFE OUTPUT



PARTS

P1 POWER SUPPLY - POWER/MATE CORP. EM-15B, HACKENSACK, NJ
OVI OVER VOLTAGE PROTECTION - POWER/MATE CORP. OVP-4
R1 RESISTOR - SINGLE LAYER WIREWOUND (3Ω, 50 WATT) DALE RH50
R2, R3 RESISTOR (150 Ω 10 WATT) DALE RH10
B1, B2, B3, B4 BATTERIES - GLOBE BATTERY CO GC410 TYPE A GEL/CELL (4 VOLT .9 AH)
D1, D2 DIODES - MOTOROLA MR750 (50PIV 6AMP)

Figure 49 POWER SUPPLY SCHEMATIC WITH INTRINSICALLY SAFE OUTPUT

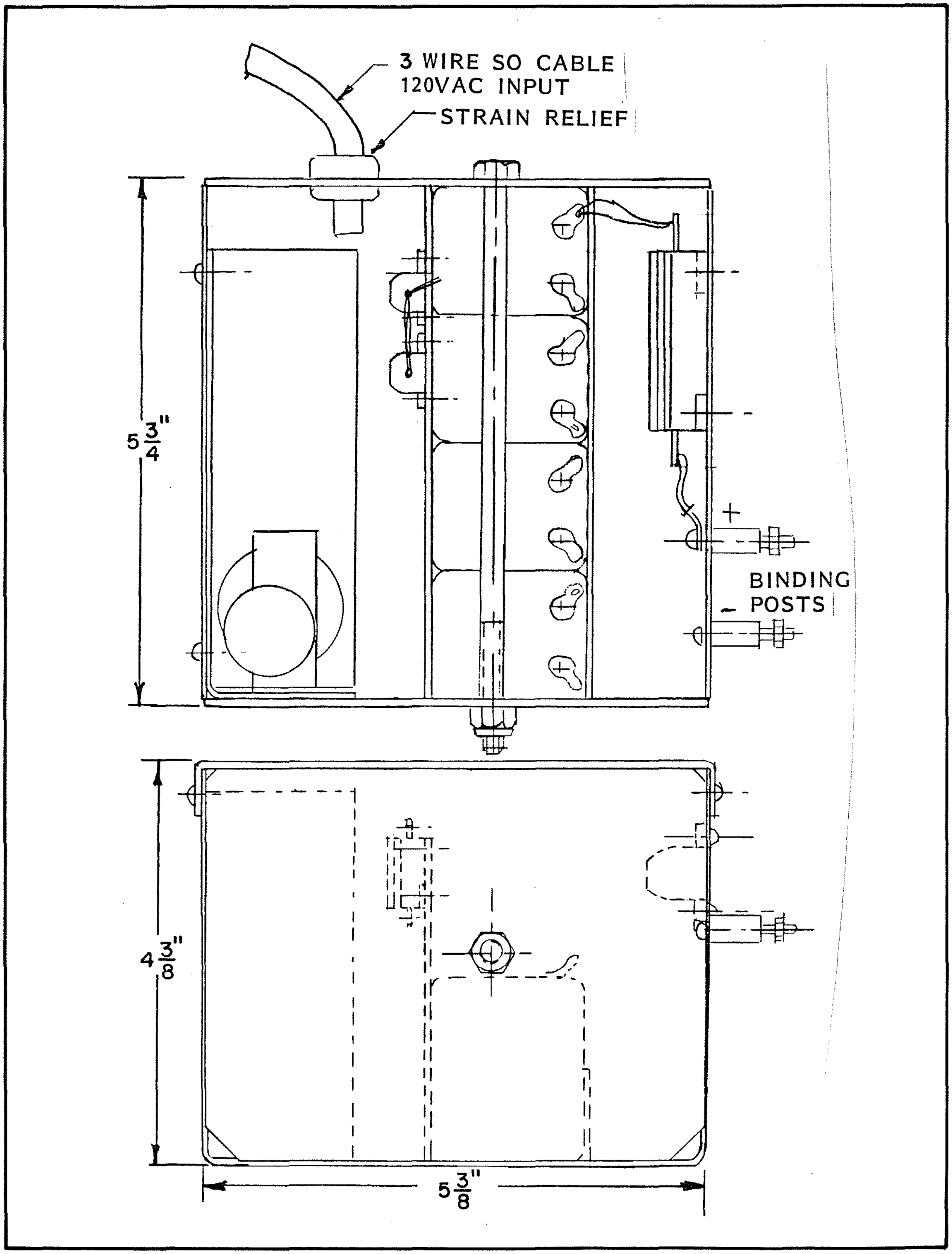
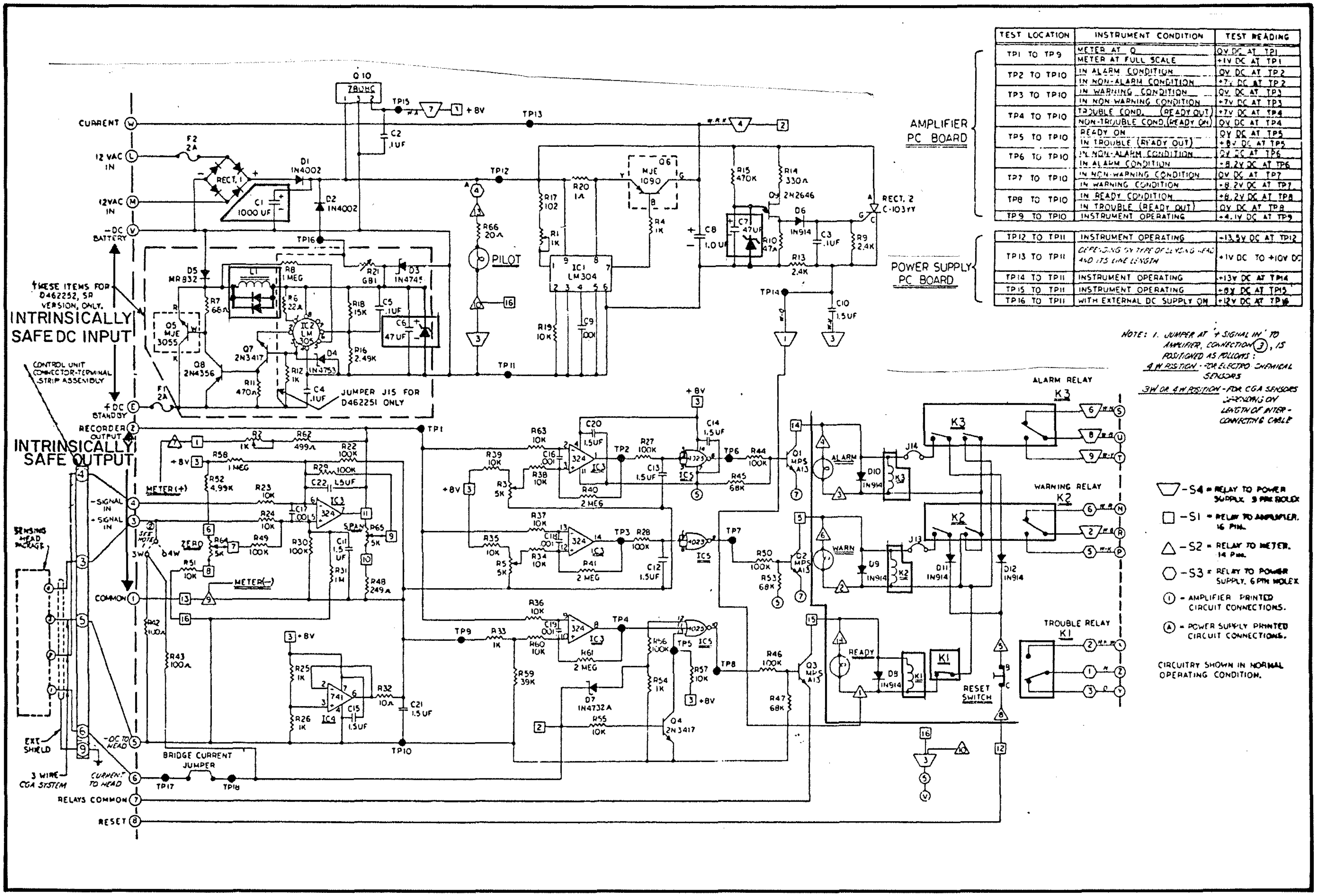


Figure 50 SUGGESTED POWER SUPPLY CONSTRUCTION -- INTRINSICALLY SAFE OUTPUT



	TEST LOCATION	INSTRUMENT CONDITION	TEST READING
AMPLIFIER PC BOARD	TP1 TO TP9	METER AT 0	0V DC AT TP1
		METER AT FULL SCALE	+1V DC AT TP1
	TP2 TO TP10	IN ALARM CONDITION	0V DC AT TP2
		IN NON-ALARM CONDITION	+7V DC AT TP2
	TP3 TO TP10	IN WARNING CONDITION	0V DC AT TP3
		IN NON-WARNING CONDITION	+7V DC AT TP3
	TP4 TO TP10	TROUBLE COND. (READY OUT)	+7V DC AT TP4
		NON-TROUBLE COND. (READY ON)	0V DC AT TP4
	TP5 TO TP10	READY ON	0V DC AT TP5
		IN TROUBLE (READY OUT)	+8V DC AT TP5
	TP6 TO TP10	IN NON-ALARM CONDITION	0V DC AT TP6
		IN ALARM CONDITION	+8.2V DC AT TP6
	TP7 TO TP10	IN NON-WARNING CONDITION	0V DC AT TP7
		IN WARNING CONDITION	+8.2V DC AT TP7
	TP8 TO TP10	IN READY CONDITION	+8.2V DC AT TP8
		IN TROUBLE (READY OUT)	0V DC AT TP8
	TP9 TO TP10	INSTRUMENT OPERATING	+4.1V DC AT TP9
POWER SUPPLY PC BOARD	TP12 TO TP11	INSTRUMENT OPERATING	+13.5V DC AT TP12
	TP13 TO TP11	DEPENDING ON TYPE OF SENSING HEAD AND ITS LINE LENGTH	+1V DC TO +10V DC
	TP14 TO TP11	INSTRUMENT OPERATING	+13V DC AT TP14
	TP15 TO TP11	INSTRUMENT OPERATING	+8V DC AT TP15
	TP16 TO TP11	WITH EXTERNAL DC SUPPLY ON	+12V DC AT TP16

Figure 51 MSA CO ANALYZER SCHEMATIC

The power supply and amplifier as shown in Figure 51 are not intrinsically safe, however, because of the following:

- o AC power supply
- o L1 inductor
- o C1 1,000-uf capacitor
- o Relay coils (the "lights" are light-emitting diodes)
- o Two 47-uf capacitors

It can likely be made into a battery-operated, intrinsically safe system if mine power is lost. To do this, the following must be performed:

- o Remove the AC power supply
- o Remove the relays
- o Remove the 1,000 uf C1 capacitor
- o Diode protect L1. It appears that this can be done with two 1N4002 fly-back diodes in parallel with L1.
- o Experiment with decreasing the size of C6 and C7 to limit their stored energy. Figure 40 indicates 3.3 uf would make it permissible. MSHA may also want assurance that malfunction of other circuitry will not allow this voltage to climb above 15 volts. This can be done by adding a zener diode such as 1N5352 (15 volts, 5 watts) in parallel with C6 and C7 so the capacitor potentials cannot exceed 15 volts. Making this CO analyzer permissible should be regarded as an engineering problem that will have to be resolved by experimentation with technical guidance from the manufacturer and MSHA.

The power supply with batteries shown in Figures 49 and 50 would likely be satisfactory for this unit. Without relays or lights, it takes 230 ma; .9-AH batteries would power it for just 4 hours.

3.5.3.4 Protectowire Line-Type Heat Detector

The passive sensor consists only of the desired length of sensing wire and a terminating resistor with a shunting pushbutton at the end (Figure 52). Since the sensor contains no power sources or energy storage components, it is inherently intrinsically safe, so the intrinsic safety of this system rests with the power supply and comparator.

The comparator contains two capacitors, neither of which can source damaging current to the sensor line, because it is protected by series resistors. The circuit as presently constructed is an effective barrier. The capacitors can, however, be reduced in value to 3.3 uf each, and resistor R1 can be increased to 100K ohms without affecting circuit design. Connecting a zener diode pair in parallel with each of these capacitors to limit their stored energy to amounts that Figure 40 shows as acceptable is a necessary precaution. The capacitor between COM and +15Vdc may be deleted altogether.

The 15VDC, intrinsically safe battery source of Figure 42 would provide the necessary power, with or without mine power. The power supply must be located in fresh or neutral air.

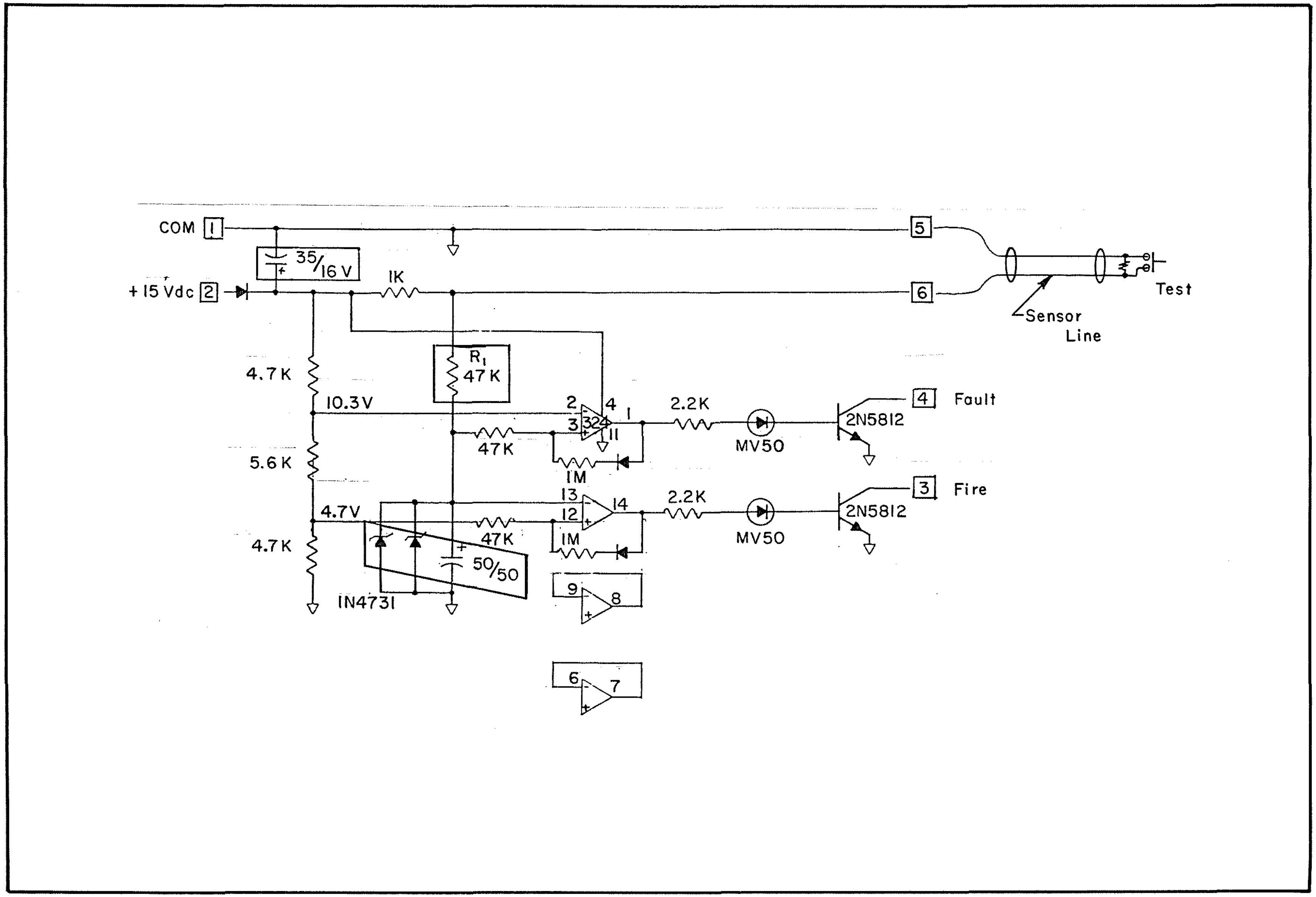


Figure 52 PROTECTOWIRE INTERFACE CIRCUIT WIRING DIAGRAM

3.5.3.5 Telemetry and Control

The following are comments made by Aquatrol in their assessment for modifying their telemetry and control system to make it intrinsically safe:

- Many capacitors would also have to be reduced in value or eliminated entirely. This would be a very time-consuming process, since the circuit design is affected.

- Many circuit boards within this cabinet have capacitors, which would fall outside the safe guidelines as an energy storage device.

These comments, plus MSHA comments that large systems require more manpower than is available for intrinsic safety evaluations, preclude the possibility of making the telemetry and control system intrinsically safe by modification.

It is thus recommended that the telemetry and control system be rendered permissible by means other than just intrinsic safety. Permissibility should be achieved by use of explosionproof boxes or by locating the telemetry and control equipment in fresh or neutral air. MSHA classified intrinsically safe barriers would be physically located with the telemetry and control circuits and would isolate potentially dangerous energy levels within the telemetry and control circuits from the signal leads to the MSHA classified sensors.

The maximum voltage the telemetry can generate is 6 VRMs at a source impedance of 600 ohms, or 0.01 ampere. These signals have energy levels far below that required to ignite methane. Since mine power would be turned off with loss of ventilation, intrinsically safe power from battery sources such as those described would remain on after mine power was turned off to continue the local mine sensing underground.

The inherent safety of this approach would eliminate the need for all power in an explosionproof box to be turned off if ventilation fails. The explosionproof box would have the sole purpose of rendering energy storage components harmless in a methane atmosphere. Barriers would assure this energy would be contained within the box under abnormal conditions.

3.5.4 MSHA Investigation Procedure Guidelines

Almost all of the available permissibility investigative routes may be pursued to gain permissibility approval for the mine shaft fire protection system.

Even if the Aquatrol telemetry and control system is located in neutral air, the need to continue monitoring when mine fans are turned off will mandate that the Aquatrol telemetry and control system be located on the surface. Explosionproof boxes will thus be investigated for certification, and sensors will be investigated for intrinsic safety. Finally, a mine-wide monitoring system evaluation will be conducted.

3.5.4.1 Flow Chart

Figure 53 shows the procedural steps to be taken to obtain MSHA permissibility investigations.

The requestor is asked to assign a six-digit number to the application which is mentioned in the introductory top letter. MSHA has labeled this number the "Company Application Code Number" and provides a space in their application and correspondence forms for it.

After receiving the application, MSHA assigns their number to the project which is used in all future correspondence. As a matter of practice, MSHA returns a form letter immediately to announce receipt of the application and to inform the requestor when the technical review will begin. However, the form letter may perform the function of informing the requestor of deficiencies in the application, if such is the case.

After the technical review begins, the requestor can expect to provide further information through correspondence. Deficiencies in design will probably be pointed out by MSHA and will have to be corrected before MSHA finishes the review. After everything is satisfactory to MSHA, a number will be assigned, and a letter will be sent to the requestor.

3.5.4.2 Forms and Agency Contacts

MSHA has application forms for each of their investigations. Figure 54 gives a list of application forms.

The Becon particle sensor, Ecolyzer CO analyzer, MSA CO analyzer, Protectowire line-type heat detector, and the intrinsic safety barriers will be handled via the intrinsic safety evaluation or sensor/barrier classification route. The explosion proof boxes will be handled by the enclosure certification route. The whole system will be investigated via the mine-wide monitoring system evaluation.

Samples of filled-out forms are included as Appendix L for further understanding of the details involved in preparing these forms.

All correspondence with MSHA is directed through the Chief of the Approval and Certification Center.

MSHA's address is:

> Chief, Approval and Certification Center
> RR #1, Box 201B
> Industrial Park Blvd.
> Triadelphia, WV 26059

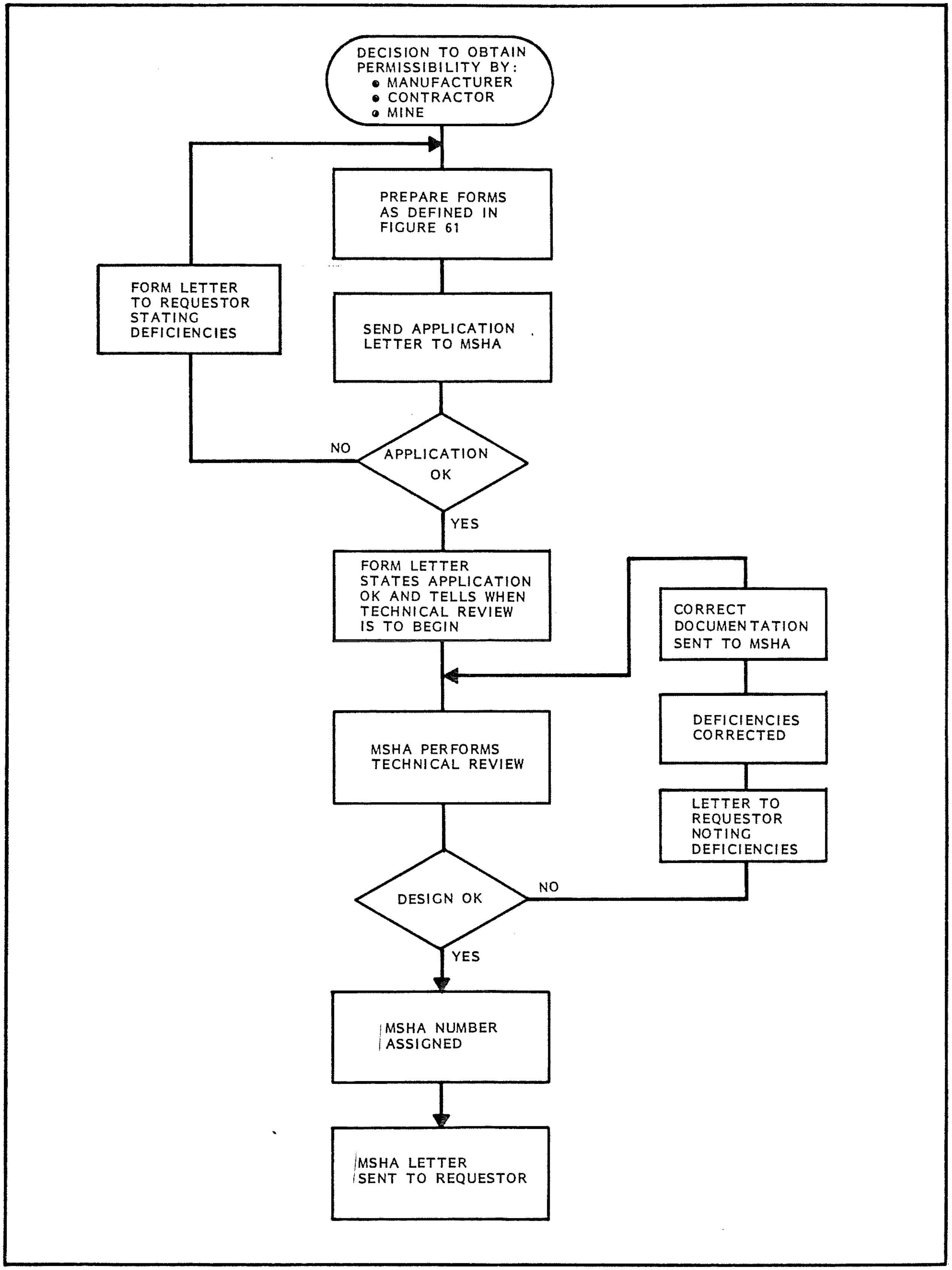


Figure 53 PROCEDURES FOR MSHA APPROVAL

TYPE OF INVESTIGATION

EXPLOSIONPROOF ENCLOSURE OR EXTENSION OF CERTIFICATION	MINE-WIDE MONITORING SYSTEM EVALUATION	INSTRUMENT OR EXTENSION OF APPROVAL	INTRINSIC SAFETY OR EXTENSION OF EVALUATION
FORMS			
• NEW CERTIFICATION APPLICATION LETTER	• MINE-WIDE MONITORING SYSTEM EVALUATION APPLICATION (NO FORM)	• INSTRUMENT APPROVAL APPLICATION LETTER	• INTRINSIC SAFETY EVALUATION APPLICATION LETTER
OR		OR	OR
• EXTENSION OF CERTIFICATION APPLICATION LETTER	• BARRIER CLASSIFICATION APPLICATION LETTER	• EXTENSION OF INSTRUMENT APPROVAL APPLICATION LETTER	• EXTENSION OF INTRINSIC SAFETY EVALUATION APPLICATION LETTER
• DRAWING LIST	• SENSOR CLASSIFICATION APPLICATION LETTER	• DRAWING LIST	• DRAWING LIST
• CHECKLIST	• ACTIVE CHEMICAL/ HOT FILAMENT/MSHA PRE-ACCEPTED SENSOR CLASSIFICATION APPLICATION LETTER	• CHECKLIST	• CHECKLIST

Figure 54 MSHA INVESTIGATION APPLICATION FORMS

IV. DOCUMENTATION

4.1 MOVIE FILM AND PHOTOGRAPHY

Goals for filming the final demonstration at Peabody Mine were to describe each element of the mine shaft fire and smoke protection system in such a manner that the USBM or other agency could compile a series of documentary film and photos to show the complete system operation. The end product was not designed to be a documentation of an individual application or single test.

Mr. Jim Siemens, an employee of television station WANO in Decatur, Illinois, privately subcontracted to perform documentation on 16-mm film, 35-mm slides, and photos during the March 12-13 demonstration. Mr. Siemens exhibited strong interest in the program and in continuing this type of activity within the mining industry. In February 1981, photograph and movie tests were conducted at the Peabody Mine at all areas where the final demonstration tests were to occur. Mr. Siemens assessed at that time that additional lighting was necessary for underground scenes.

During the demonstration, overall pictures of the mine complex and the individual areas were taken, as well as close-up details of each component or element of the system. Mine personnel participated in describing the process of USBM/contractor involvement and office visits, mine personnel discussion, and activities such as hands-on operation of the control system and fire and smoke sensors were filmed.

A scenario of a mine fire was filmed, in which the hoist operator observed the alarm, left his position and tested the system, telephoned the mine superintendent, opened the master unit, and obtained the graphic details of the alarm. The following story line was used for filming the simulated fire condition:

a. fire starts with flames and smoke visible

b. fire detected by system sensor(s)

c. underground sensor(s) transmit(s) alarm signal to the surface control panel via multiplex telemetry

d. alarm signal(s) appear(s) on graphic panel and sounds audible alarm (close-up)

e. operator acknowledges alarm(s) and turns thumb wheel to proper sensor station (close-up)

f. operator unlocks and opens panel door and swings out printer

g. operator uses key to unlock function switches and depresses "24-hour summary" button (close-up)

h. printer makes 24-hour graph of sensor(s) output (close-up)

i. operator depresses ALERT button (close-up), then moves to telephone, picks up receiver, and dials

j. red flashing light appears on remote unit.

Mine personnel assisted throughout filming by carrying portable lights, batteries, and camera equipment and by stimulating sensors with smoke candles, calibrating the sensors, and operating the master control unit.

All photos, slides, and 16-mm motion pictures were processed and submitted, accompanied by a draft story line, for Peabody personnel review. In April 1981, the following were sent by Mr. Siemens to ESD:

1,350 feet of original film

1,250 feet of work print

3 boxes of 35-mm film (36 shots/box).

These items had been reviewed and approved by Peabody Mine officials.

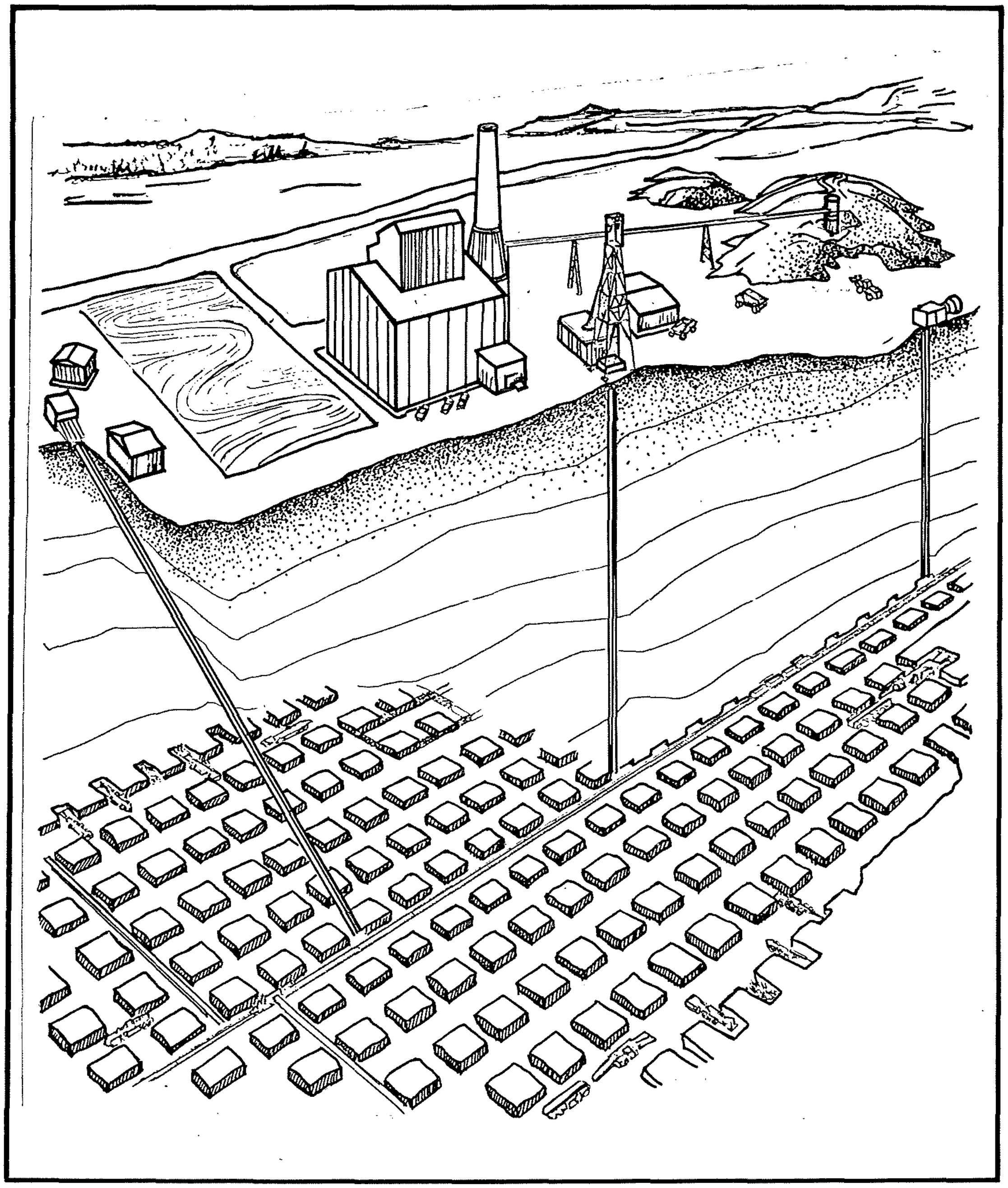
4.2 SELECTION AND USE MANUAL

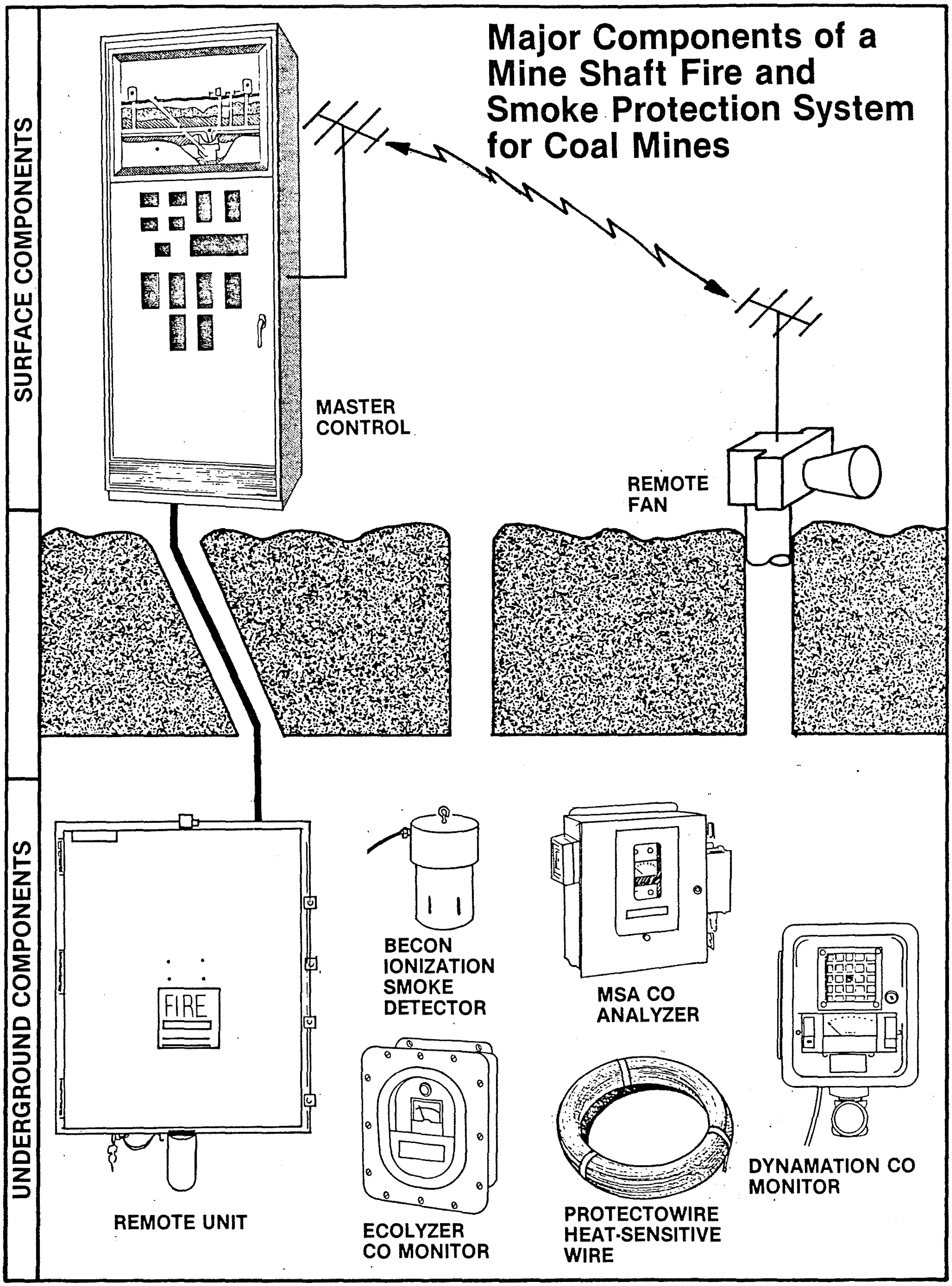
A Selection and Use Manual has been prepared to familiarize potential users with the mine shaft fire and smoke protection system. Alternative systems are discussed to meet a variety of mine profiles (e.g., size, depth, number of entries). Features of the system developed and tested under this contract are highlighted, including the following:

- Introduction
- Decision Criteria for Selecting Mine Shaft Fire and Smoke Protection Systems
- Types of Remote Data Collection Systems in Use Within the Mining Industry
- Systems Developed Under USBM Contract H0100017
- In-Mine Tests

SELECTION AND USE MANUAL FOR

COAL MINE SHAFT
FIRE AND SMOKE PROTECTION SYSTEMS




Major Components of a Mine Shaft Fire and Smoke Protection System for Coal Mines
SURFACE COMPONENTS
UNDERGROUND COMPONENTS
MASTER CONTROL
REMOTE FAN
REMOTE UNIT
FIRE
BECON IONIZATION SMOKE DETECTOR
MSA CO ANALYZER
DYNAMATION CO MONITOR
ECOLYZER CO MONITOR
PROTECTOWIRE HEAT-SENSITIVE WIRE

INTRODUCTION

One of the most significant hazards confronting underground mine workers is the potential of fires and the resulting contamination from carbon monoxide and other toxic fumes. Any time persons are caught "inby" a mine fire, chances of successful escape are threatened. Mine shaft and slope areas appear to be some of the most hazardous zones in the event of a fire, partly because any blockage of these primary travel routes hinders evacuation efforts. Data indicates that fire and smoke conditions which have occurred in or caused contamination of mine shafts have accounted for a significant number of injuries and deaths, and that fires resulting in fatalities are three times more likely to occur in shafts or slopes.[6]

These hazardous conditions gave rise to the Bureau of Mines Contract H0242016 (Mine Shaft Fire and Smoke Protection System for Metal and Nonmetal Mines - June 1974 to September 1976) and Contract H0100017 (Demonstration of a Mine Shaft Fire and Smoke Protection System for Coal Mines - September 1979 to July 1983). During the earlier contract, mine shaft fire and smoke hazards were evaluated, and major goals for effective protection against these hazards were outlined. A time-division, multiplexed, microprocessor-based control system and early-warning fire and smoke sensors were briefly tested in a deep Idaho silver mine and California tungsten mine. The results of these efforts were published in a two-part report,[6] and a guide to the selection of mine shaft fire and smoke protection systems[7] (featured on the inside back cover of this manual) was also released.

The objectives of the recent USBM contract, H0100017, were to continue the evaluation of the underground mine shaft fire and smoke hazard as it relates to coal mines, develop performance requirements for a state-of-the-art prototype system to reduce this hazard with reasonably priced, reliable hardware, and demonstrate (via a long-term, cost-sharing, in-mine demonstration) the prototype mine shaft fire and smoke protection system that would apply to a majority of coal mine shafts (including inclines), especially in deep mines.

This manual presents the significant findings of the four-phase program to assist mine personnel in identifying the specific fire protection needs of their particular mine and selecting a mine shaft fire and smoke protection system that can reasonably satisfy those needs.

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6. Volume I - NTIS PB-263577, July 1975
   Volume II - NTIS PB-284166, September 1976.
7. NTIS PB-268088, September 1976.

DECISION CRITERIA FOR SELECTING MINE SHAFT FIRE AND SMOKE PROTECTION SYSTEMS

The selection of a mine shaft fire and smoke protection system requires the same kind of care, analysis, and evaluation given to planning a new mine development. The geographic location of coal reserves, coal type, current and long-range market, environmental constraints, anticipated operating duration, mine methods, equipment options and reliability, ventilation needs, financial base, labor conditions, and various legal constraints are all factors that must be considered when selecting a system. These factors, or decision criteria, can be grouped into four categories:

- MINE PROFILE AND HISTORY define the basic needs of a fire and smoke protection system. Mine size and depth determine the magnitude of the system being considered. Deeper mines may have longer wait periods at the shaft bottom for cage access, resulting in longer evacuation times. Entry type, construction, and quantity determine alternative escape routes. Wood-lined or older shafts with grease or oil accumulation are more hazardous than newer concrete and steel shafts. Hoppers located near a shaft or slope bottom may act as heated areas for spontaneous combustion. Gas ignition and self-ignition of coal piles are more common in some mining districts than others. The mine's fire history provides further evidence of safety needs. Fire-conscious mine management have already implemented a variety of prevention measures. Other factors to consider are the age and estimated close date of the mine, location of remote equipment, mining and haulage system types, work force size, training, and skills, distance of work force from egress shaft and mine downtime.

- SYSTEM COST AND AVAILABILITY vary with mine complexity. Manual labor savings can be realized with fixed-location sensors and remote control of such devices as fans, pumps, air regulators, ventilation doors, or fire extinguisher systems. The acceptable installation, maintenance, calibration, and operation cost of the system must be considered.

- PERFORMANCE AND RELIABILITY of the system components within particular mine conditions must also be considered. Humidity, dust, and temperature and voltage fluctuations affect the system equipment. System equipment should operate without maintenance for a minimum of six months.

- COMPONENT TRADEOFFS may be necessary if there are budgetary or time constraints and may entail decisions concerning automatic versus manual devices, type and number of functions, and location and use of devices.

TYPES OF REMOTE DATA COLLECTION SYSTEMS IN USE WITHIN THE MINING INDUSTRY

Visits to underground mines to evaluate existing mine shaft fire and smoke protection measures and remote data collection systems revealed that production monitoring was most important and that remote reporting fire safety systems were limited in scope. Only a token representation of mine shaft fire and smoke protection systems was found, although it was evident that the addition of safety components would be readily acceptable to mines if other direct benefits could be realized from production-oriented activities coupled with a new safety system. The existing fire protection systems consisted mostly of the observations and actions of personnel in the immediate vicinity. The following types of remote data collection systems were found during the mine visits:

- CONVEYOR BELT FIRE PROTECTION SYSTEMS are the most common in underground coal mines, because they are mandatory by legislation. Several such systems exist, including the tone telemetry system with underground remote station monitors which transmit specific frequency-shift audio tones to a central station, the resistance telemetry system which utilizes changes in the line-resistance measurements to locate the area for investigation, the diode system in which a full-wave alternating current indicates fire, and the voice-announcing system with a specific recorded message (in a remote panel on each belt) which indicates the location rather than the event.

- THE PRODUCTION REPORTING SYSTEM, designed for reporting production operations and inventory, has certain capabilities to extend into a mine safety system. At one of 14 mines visited, shift supervisors call a central operator every 2 hours to relate all problems, delays, and needs. This information is typed into a local computer system which serves CRT's on the surface, in mine offices, and at underground locations.

- OTHER REPORTING SYSTEMS include air sampling systems with remote units which monitor air velocity, methane; CO analysis in conveyor belt-ways; smoke-actuated door closure with ionization smoke sensors and self-closing doors; radio data reporting systems to check and control remotely located ventilation fans; a USBM tube bundle gas analysis system which monitors CO and particles of combustion; and a USBM prototype spontaneous combustion protection system with remotely-located sensors for CO_2, CO, O_2, smoke or temperature.

Sixty-six percent of the 221,000 coal mine workers in the United States are employed in underground coal mines. Of these workers, 47.9 percent are employed in shaft or slope mines. From 1950 through 1977, workers were exposed to a total of 1,014 underground coal mine fires (excluding fires resulting from explosions or ignitions of gas/dust). Methane control, ventilation recording, and belt fire systems are very important in terms of mine safety laws and production. Few early warning gas detector systems exist, however; most gas analysis is performed with portable electronic devices or color stain tubes. Although mines recognize the validity of checking the quality of air entering the shaft or slope, only one of 14 was found to have remote reporting sensors at the collar. The location of underground transformer stations, maintenance shops, and storage/assembly areas near the shaft bottom clearly affects fire dangers.

SYSTEMS DEVELOPED
UNDER USBM CONTRACT H0100017

Four different systems were developed to satisfy the criteria of a mine shaft fire and smoke protection system. These systems vary in size and component selection, depending on four mine profiles. The optimum system was designed for large operations with the greater magnitude of hazards. A remote station transmits analog input data from three CO analyzers, three particle analyzers, and two heat sensors (one in the slope belt and one over the hopper). Analog data is also received by a ventilation regulator positioner, a combustible gas sensor in the transformer area and from an air flow indicator near the regulator.

Alternate I, the recommended system within the guidelines of H0100017, was also designed for large mines, but gave consideration to selecting readily available, field-proven equipment. This system has three remote stations. Unit 200 is the slope bottom, hopper area and exhaust shaft. Analog data is received and transmitted to a surface master station from three CO analyzers, three particle sensors, and two heat sensors (one in the slope belt and one over the hopper). Unit 300 at the slope collar transmits analog signals of a CO analyzer and particle sensors to monitor intake air. Unit 400 is the remote fan. This area is coupled to the surface controller by radio telemetry that eliminates long underground wiring. Analog data from one CO analyzer and a particle sensor, and switch signals of a fan-run indicator, heat sensor, fire-pull, and power fail are sent via radio approximately 5 miles to the surface control center. The surface control is the same as that in the optimum system, but without the CRT and terminal input capabilities. A graph of each analog signal received is printed for the last 24 hours of service, and a graphic display identifies all remote locations and recording devices.

Alternate II system concept was designed for mines with reduced needs. It has two remote stations, one at the slope or shaft bottom and the other at the slope or shaft top.

The Alternate III system concept was designed for the minimum mine profile. It is a basic system for slope bottom and single-shaft area protection only, with one remote controller which sends analog data of three CO analyzers and three particle analyzers. Since there is no printer or graphic display, manual data logging of events is required.

Each system described uses multiplex telemetry, is hardwired or coupled by radio, and is easily expanded without additional wiring. Trade-off analysis of the systems and their different mine profiles is included in the Contract H0100017 final report.

IN-MINE TESTS

Underground tests were conducted by a large midwest coal mine between August 1980 and July 1983 and followed by additional long-term analysis by the production mine personnel.

- INSTALLATION of the surface control station (master unit 100), slope bottom station (remote unit 200), slope top station (remote unit 300), and the radio coupled remote shaft station (remote unit 400) utilized multiconductor, twisted pair, shielded, burial-type phone cable routed between the sensors and their remote units. An existing, dedicated phone pair was then used to route to interconnect the remote units and route to the surface unit.

- OPERATION features of the control unit were easily understood by mine personnel, and audible and visual alarms on the mine graphic panel readily identified the signal source. Time of occurrence and the specific sensor and concentration (if analog) was printed (if in alarm) or memorized for 24 hours.

- DEMONSTRATION TESTING was performed by stimulating the 10 analog and 15 digital sensors and producing legible and meaningful data on the surface control printer. The most significant testing was performed at times other than when planned by the contract. Four notable events occurred that describe the equipment performance and response by operating mine personnel.

  - Carbon Monoxide In Intake Air

    Exhaust fumes from a truck parked near the slope intake-air caused the CO analyzer to alarm. Repeated alarms and investigation by the hoist operator confirmed the condition and cause. Intermittent parking of trucks near the slope collar was not considered a deterrent to health and safety, but was an example of mine intake air being effectively monitored.

  - Overheated Motor

    A 150-horsepower belt-drive motor overheated, causing smoke to alarm the Becon particle sensor in the hopper-top area. Although the motor was 15 crosscuts away, in neutral air, smoke particles consistently caused alarms which the hoist operator reported to the mine superintendent, who investigated and found the smoking motor.

  - Heating Coal Pile

    Residual coal remaining in the hopper during the coal strike in May 1981 became sufficiently self-heated to alarm the Becon particle sensor. Although local underground power was occasionally off, the Becon has telemetry line power and remained on during the strike. The hoist operator observed the continuous increase in concentration and notified personnel who removed the heating pile.

- Mine Fire

  A smoldering fire from a worked-out section of the mine was undetected by the mine shaft fire and smoke protection system, although the exhaust was vented over a Becon and CO analyzer. Mine air was routed to the sensors through a flame arrestor protected draw-tube leading from the exhaust-fan housing to the sensor assemblies. The draw-tube was blocked with condensed water, and the contaminated air did not reach the sensors.

o EQUIPMENT PERFORMANCE demonstrated the variety of problems that exist with underground mine operations: electrical noise, power fluctuations, high and low temperatures, dust, and humidity contributed to the greater-than-anticipated maintenance of several sensors and complete failure of others.

  - One of three different types of CO analyzers continues to perform reliably, but its mechanical pump requires added maintenance. The diffusion collection electrochemical cell unit and the semiconductor (TGS) CO analyzers did not demonstrate long-term accuracy desired.

  - The four particle sensors required the least maintenance of any device and were within tolerance after 2 years of service. One unit above the hopper top was subjected to heavy dust and water spray that required frequent blow-out. Sensors at two fan locations were sampling return mine air through flame arrestor protected tubes which plugged often.

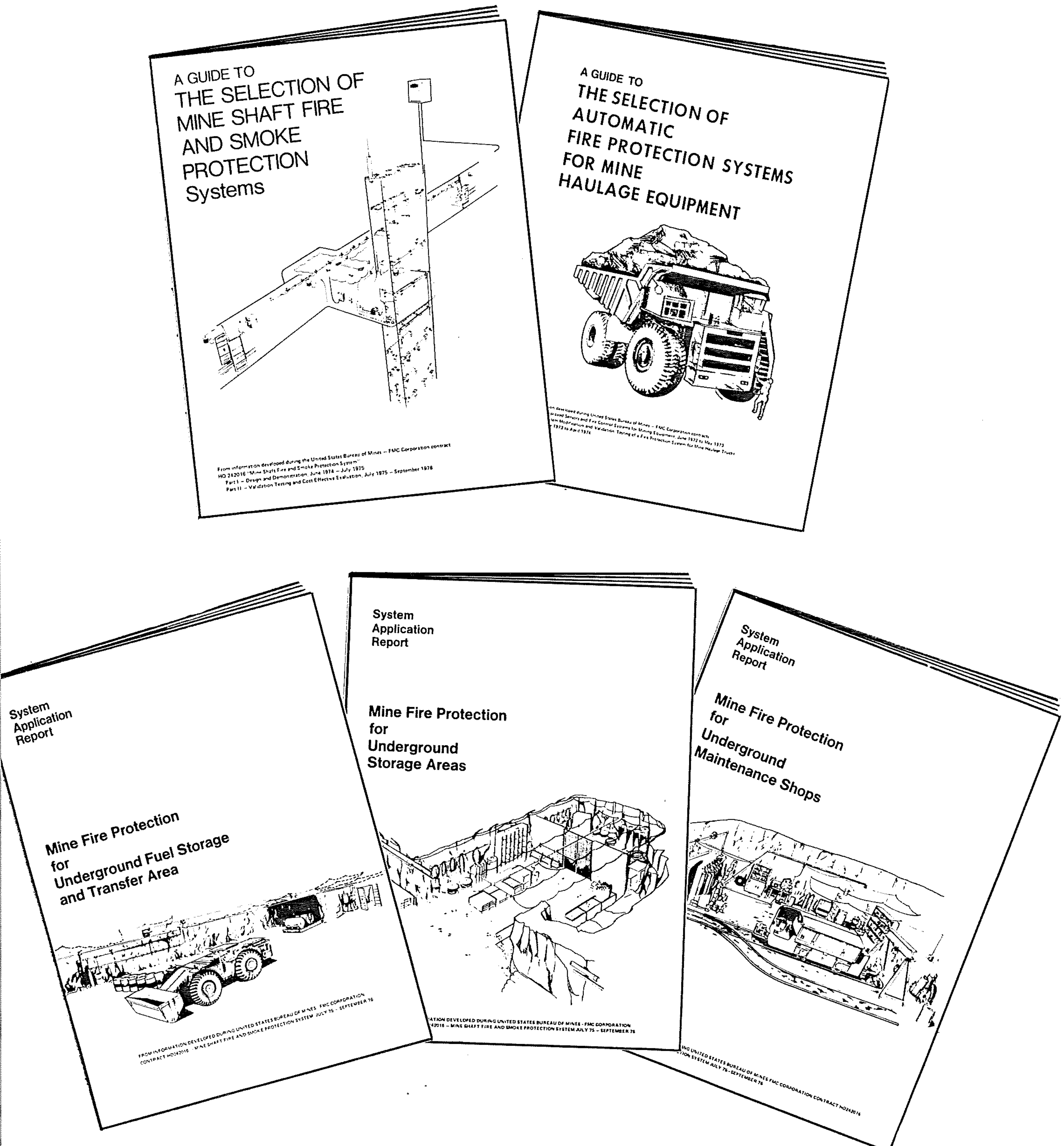
  - The passive, heat-sensitive wire was also very reliable, as expected.

  - Control functions provided acceptable performance throughout the program. Recommended improvement are to reduce the auto-print rate and further eliminate needless and excessive printouts. The 24-hour memory and graph capabilities was proven useful during several tests, as was the graphic display and adjustable alarm setpoint features.

  - The necessary MSHA variance approvals and FCC and NRC licenses were obtained for the draw-tube, radio link, and particle sensors, respectively, but presented no problems.

Fire Protection Reports for Other Mine Applications

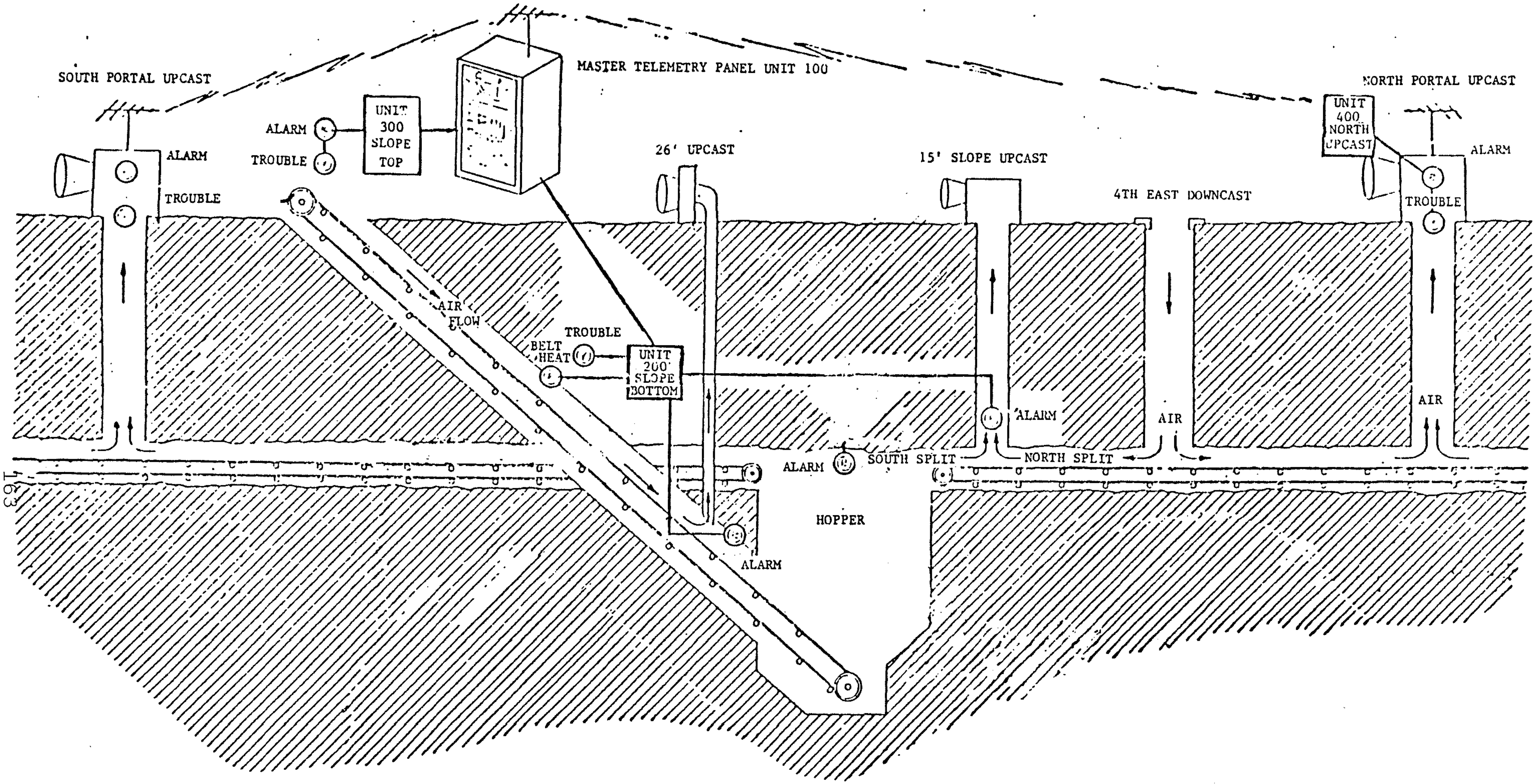
To Move Research Results Into Industrial Practice



Copies of these reports may be obtained from the
United States Bureau of Mines
Twin Cities Research Center
Minneapolis, Minn.

Appendix A

GENERAL ARRANGEMENT DIAGRAM



The system you are observing is part of a U. S. Bureau of Mines safety research effort. The components are designed to quickly locate and determine the hazard levels of possible fire and smoke conditions.

Gas concentrations, smoke levels and overheat conditions are part of the information transmitted by wire or radio from this location to a Master Panel in the slope hoist room.

This system is a prototype design and therefore subject to periodic adjustments and corrections.

Prime Contractor:
ESD Corporation
Engineered Systems Development
San Jose, California

Subcontractor:
Aquatrol Corporation
St. Paul, Minnesota

U.S.B.M.
Twin Cities Research Center
Minneapolis, Minnesota

Appendix B

TOPICS ADDRESSED IN DATA ACQUISITION PROCESS

DATA TO BE ACQUIRED AND PRESENTED

The data collection effort will concentrate on the following:

- o Evaluation of the coal mine shaft/shaft station fire and smoke hazard
- o Developing design concepts (including performance requirements) for a reasonably priced, reliable fire and smoke protection system.

1. Fire and Smoke Hazard Analysis

Charts, graphs, and tables will present hazard data collected in response to the following questions:

- o How many fires have occurred in your underground coal mines?
- o What were the causes?
- o Where did they occur?
- o What is the potential of fires in other areas?
- o What is the potential consequence of fires in other areas?

Similar data relating to fire accident and injury data will be presented from responses to the following questions:

- o What injuries or fatalities have occurred as a result of fires?
- o What other losses have occurred?
- o Where did any injuries, fatalities, and losses occur?
- o What potential exists for other injuries, fatalities, and losses to occur, and where are their locations?

Additional charts, graphs, and tables providing information on contributions to the mine shaft fire and smoke hazard will be constructed based on responses to the following questions:

- o How many workers are employed in your underground coal mines?
- o What are shift sizes?
- o Where are the workers located in relation to the shafts?
- o What are normal or alternate escape places, evacuation lines, and how is evacuation accomplished (walking, man-trips, etc.)?
- o What is mine depth, cage size, hoist speed?
- o What is shaft construction and combustible loading?
- o What other contributors to shaft or mine contamination exists from combustible loading in or near the intake, shaft bottom, etc.?
- o What are ventilation characteristics in the mine and shafts or slopes?

- o What potential exists for ventilation changes during production, maintenance, holidays, or during fire situations and what are the results of such changes?

2. Design and Effectiveness of Protection Systems

Information on design, application, and effectiveness of mine fire and smoke protection systems (including mine monitoring systems) will be collected from coal and noncoal mining companies from the following questions:

- o What is the configuration of the installed systems?
- o What ventilation characteristics or considerations are related to the systems?
- o What is the system description and where is it located?
- o What description of the system operation, its limits, and performance characteristics can be provided?
- o What was the mine company's incentive for procurement and installation of the system?
- o What capacity or ability does the system have to sense and/or extinguish fires and/or control smoke?
- o What is the response time of the system to operate or warn miners of a hazard and its location?
- o What is the original and current purchase cost, installation cost, maintenance and operating cost?
- o What is the reliability as installed and as modified by mine conditions, time, corrosion, component failures, repair delays, etc.?
- o What is the overall performance history of the system, including success or failure during actual events?
- o Would the mine company endorse, install, or reject additional systems?
- o What suggestions are offered?

Appendix C

MINE POPULATION FOR STUDY

MINE POPULATION FOR STUDY

The population of all coal mines falling within the scope of the contract for demonstration of a Mine Shaft Fire and Smoke Protection System was developed from the 1978 Coal Mine Directory published by the Keystone Coal Industry Manual. Mines selected for inclusion were underground and had at least 25 employees. Mines listed as actively operating were included as well as mines which were listed as being under construction, since there is a minimum of a two-year lag between the gathering of data and its publishing in the directory. The use of these factors will assure that the mine visits provide a representative sample of the total population.

The following list shows the number of coal mines by state selected for this population.

State and Abbreviation	Quantity
Alabama (AL)	15
Arkansas (AR)	2
Colorado (CO)	15
Illinois (IL)	28
Iowa (IA)	2
Kentucky (KY)	126
New Mexico (NM)	1
Ohio (OH)	19
Pennsylvania (PA)	91
Tennessee (TN)	24
Utah (UT)	18
Virginia (VA)	31
West Virginia (WV)	164
Wyoming (WY)	2
Canada (CN)	6
Total	544

Appendix D

EXCERPTS OF 20 MINE FIRE REPORTS FOR SLOPE OR SHAFT MINE LOCATIONS

EXCERPTS OF 20 OF THE 1014 MINE FIRE REPORTS DESIGNATED SLOPE OR SHAFT (ALLEN REPORT)

Report No. 4 Date: 5/19/50 Cause: Spontaneous

Description:

Fire started in portal of an abandoned slope into the No. 11 mine. A wooden stopping was built 60' inby, the slope was caved (by blasting) for 50' from the portal and a rock barrier 10' inby the end of the caved area was built. This did not stop the fire so caved material was removed and coal stripped from sides for a considerable distance. Work was completed on May 27. Williams, M.L., MESA Denver, 2 pp.

Report No. 114 Date: 5/25/55 Cause: Lightning

Description:

Fire was discovered in the entrance of 2nd hill, lightning had struck the wire and entered lightning arrestor blowing it up. This ignited the timbers, arrestor was mounted on. Fire was immediately put out and area cleaned and rock dusted. HSAC Denver, 1 pp.

Report No. 120 Date: 9/5/55 Cause: Fan for cooling compressor broke severing oil line, spraying oil on heated machine and drive pulley igniting same.

Report No. 120 (con't)

Description:

Section foreman on pre-shift started compressor in slope and went to other sections. Upon return, he encountered dense smoke. He went for help. Superintendent and Manager brought other certified employees who fought the fire with water and rock dust. Roof bolter destroyed. Reay, T.T., HSAC Denver, 4 pp.

Report No. 132 Date: 11/5/55 Cause: Poor blasting safety

Description:

Two shots fired with black powder 11/5. No check for fire and fire was discovered 11/6. Materials obtained 11/7 and slope sealed. Bradford, R.D., HSAC Denver, 2 pp.

Report No. 214 Date: 6/11/55 Cause: Short from leaking batteries during charge

Description:

Fire occurred at charging station at bottom of belt slope in charging jeep because of short in leaking battery. Hughes, F.E., HSAC Denver, 4 pp.

Report No. 364 Date: 2/5/60 Cause: Possibly bad bottom roller

Description:

Fire discovered at 2:00 A.M. by 3rd shift workman. It extended 20 feet up the slope portal to the tipple. Three fire trucks

Report No. 364 (con't)

called out. The belt burned in two and rolled 300' down the slope where two maintenance men put the fire out with water and CO_2. Dona, B.J., HSAC Denver, 1 pp.

Report No. 514 Date: 9/3/62 Cause: Unknown

Description:

Fire of unknown origin discovered by hunters near the mine. It is believed that the fire started on the surface and spread to mine portal via the belt conveyor. Fire department called and fire extinguished. Fire destroyed coal storage bin, 150 tons of coal, two supply storage buildings, head drive and 200 ft. of belt conveyor, mine props, chain conveyor unit, and several electric motors. Freeman, Joe, 5 pp.

Report No. 520 Date: 10/16/62 Cause: Sparks thrown by welding operations ignited dry timbers

Discription:

Sparks thrown by the welding operation ignited dry timbers along the slope causing a fire. It was extinguished by water. Wilson, H.F., Fulmer, J.A., MESA Hazard, 8 pp.

Report No. 690 Date: 11/22/65 Cause: Spontaneous

Description:

Smoke was discovered about 70' inby the portal during an examination to clear reopening this mine. The fire was in an inaccessible abandoned area and evidently started spontaneously when neighboring strip mine operation broke through draining the fire area of water. The mine was sealed with earth. Callahan, J.T., HSAC Denver, 5 pp.

Report No. 774 Date: 9/23/67 Cause: Leaking gas cylinder ignited by airborne sparks

Description:

Cylinder fire occurred below the underground rotary dump on the feeder floor at the slope bottom. Valve was leaking and airborne sparks evidently ignited the gas. One man tried to smother the flames with his gloves but fuse plugs ruptured and flame-up occurred. Water was sprayed until fire burnt out. Breedon, J.D., HSAC Denver, 4 pp.

Report No. 790 Date: 2/5/68 Cause: Spontaneous combustion

Description:

Fire discovered in wood cribbing material installed over steel arches. Fire kindled spontaneously in a wooden bar encased in urethane foam. Foam was being used to plug a cavity over the arches at the entrance to the slope. About 12 feet of foam was removed and water applied to fire and extinguished. Croyle, G.W., Lester, C.E., HSAC Denver, 5 pp.

Report No. 22 Date: 6/1/52 Cause: Possibly a light socket burst permitting hot metals to fall on floor onto combustible materials

Description:

Smoke was observed rising from the man-and-material shaft. Rock dust was applied unsuccessfully. Water was then applied to the fire and extinguished. Possibly a light socket burst permitting hot metals to fall on the floor onto combustible materials. Perz, Frank, MESA Vincennes, 5 pp.

Report No. 63 | Date: 4/20/54 | Cause: Sparks from acetylene torch ignited oil spillage

Description:

Fire occurred in abandoned fan house and spread to wood-lined return air shaft and man shaft. Metal on surface structures was being removed for scrap. Scrap company employee received permission to cut shaft out of abandoned steam-driven shaft with stipulation that hole between hole and shaft be blocked. This was not done and sparks ignited oil on floor of house. Callahan, J.T., MESA Denver HSAC, 4 pp.

Report No. 141 | Date: 1/23/56 | Cause: Probably smoldering hot material left from welding and cutting 32 hrs. previous, though inspection made; perhaps short in lighting cable

Description:

Maintenance shift (15 men) entered mine at 12:00 midnight. Three went to S.E. main North until 2:15 A.M. Upon returning to 4 South, they encountered smoke in intake. They crossed over to return and went back to bottom finding fire near the hopper which had been welded up 32 hours previous. Burning belt pulled burning several air locks, then broke, spewing hot material. Air locks prevented spread. Belt, Loren A., HSAC Denver, 4 pp.

Report No. 389 Date: 5/5/60 Cause: Sparks from torch used to cut bolts from a fan installation landed on wooden lining of shaft and ignited it

Description:

Fire discovered 12:40 P.M. in No. 4 shaft by contractor employee who had been dismantling fan installation. Two explosions occurred when water applied to hot metal and 2 men hurt, 1 in each explosion. Clay and water dumped in shaft extinguished the blaze. McDonald, T.J., Turner, Everett, HSAC Denver, 7 pp.

Report No. 658 Date: 5/15/65 Cause: Hot spark or molten slag from material being burned with torch ignited grease

Description:

Sparks or molten metal from oxyacetylene torch being used to make repairs to canopy ignited grease on wooden shaft guide. Flames traveled along the grease on the guides and terminated near the skip-dumping platform. Fire extinguished quickly. Barr, Richard E., HSAC Denver, 5 pp.

Report No. 714 Date: 7/21/66 Cause: (Believed) Sparks from acetylene torch ignited timbers & plank lines at top of air shaft

Report No. 714 (cont)

Description:

Outside foreman told welder to repair gate lock on screen cover of air shaft. He put plate beneath work and wetted timbers below when done. Area was checked from 1 side several times. Truck driver drove by shaft when ball of fire shot up. Other fan pulled smoke into the mine and 34 men suffered from inhalation on their way out. Fire companies pumped water, but due to roof falls, shaft was finally slushed. Wilson, H.F., Menta, E., Ward, T.J., HSAC Denver, 19 pp.

Report No. 901 Date: 5/15/70 Cause: Fire shot or series of shots which were overburdened and/ or underburdened ignited gas emitting from feeders

Description:

Fire occurred in coalbed after 40 charged boreholes were fired simultaneously. Fire was extinguished by flooding the bottom of the shaft and 10 tons of rock dust also dropped into the shaft. Fanok, P.N., McManus, M.W. MESA Morgantown, 5pp.

Report No. 953 Date: 1/13/73 Cause: Hot metal fell and ignited combustible material at shaft bottom

Description:

Fire occurred at the bottom of hoist shaft when hot metal from cutting operations fell and ignited dust, oil and grease. The fire was extinguished in 15 minutes with water and extinguishers. One man received 1st degree burns. Small fire had been found earlier and extinguished. Adams, C., Sakovich, M., Wolfe, M., Itoman, J., HSAC Denver, 6 pp.

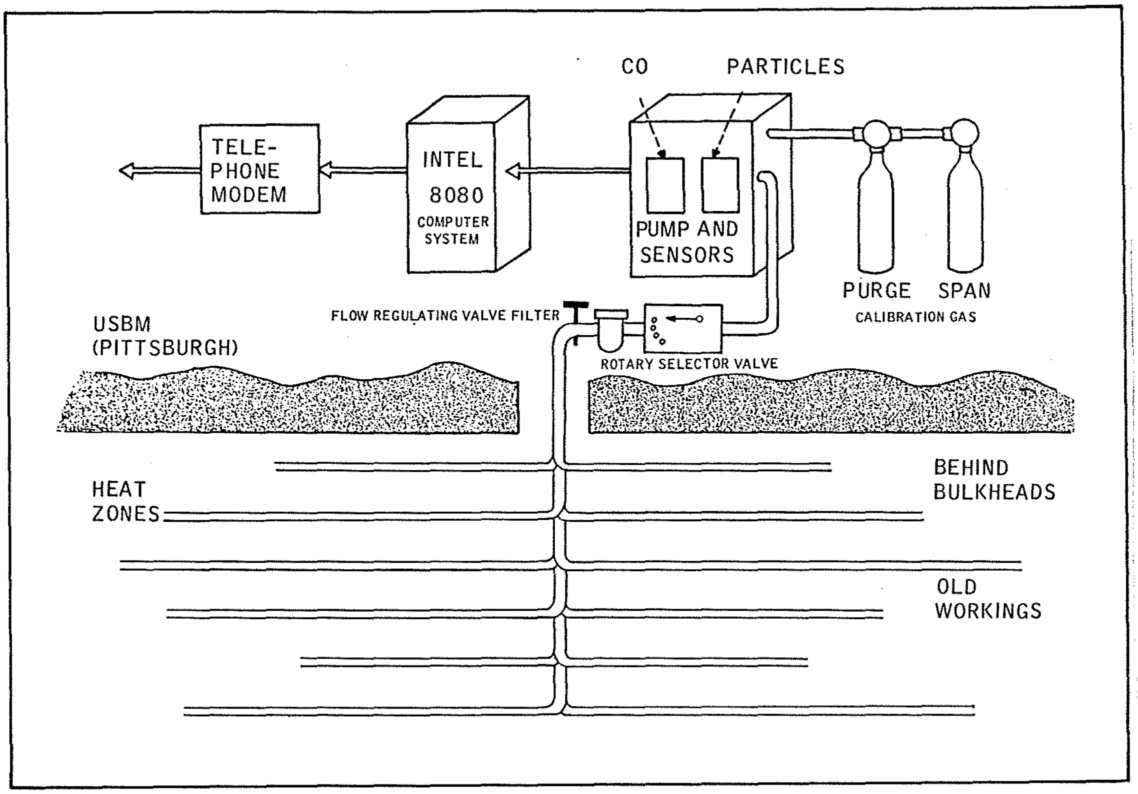
Report No. 958 Date: 8/7/73 Cause: UNK - consensus that it started from short circuited electrical cable or sparks or hot metal

Description:

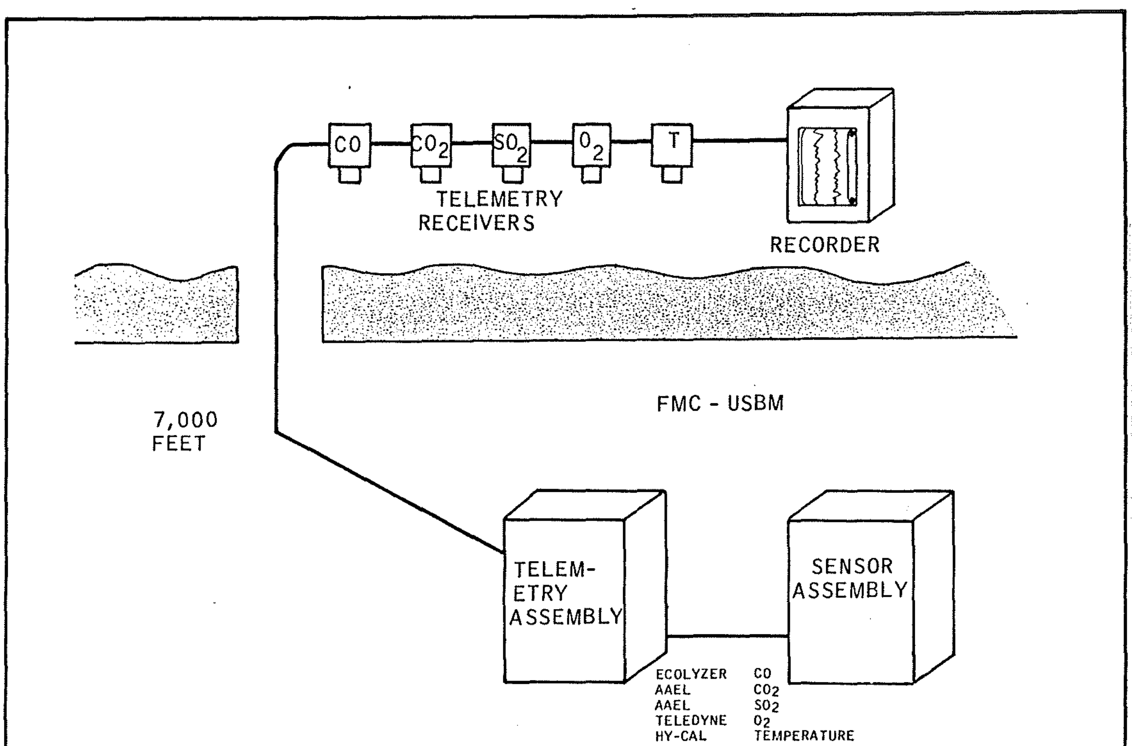
A fire originated in the timbers and cribbing and spread to the coal ribs at the bottom of the intake air shaft. Attempts to fight the fire by direct means were unsuccessful due to the intense smoke and heat. It was elected to earth fill the shaft and seal the fire area. Soreel, Hudson, Brag, L.E., MESA Madisonville, 9 pp.

Appendix E

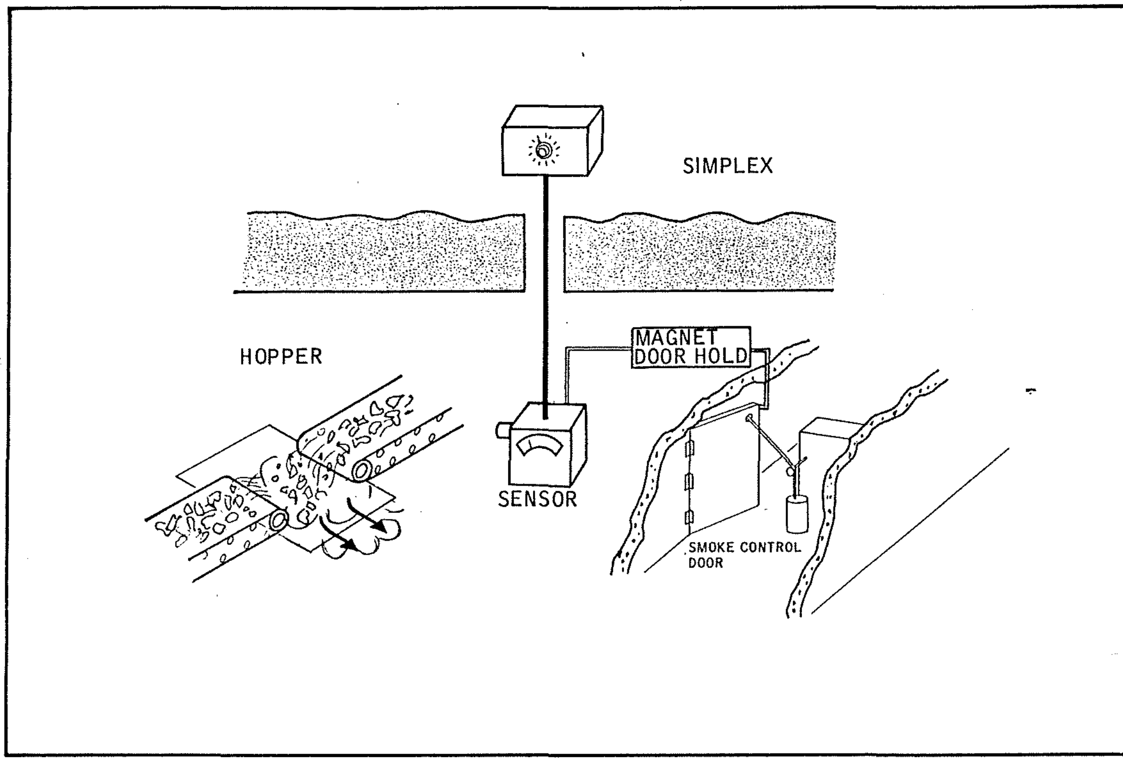
SENSORS FOUND IN UNDERGROUND MINES



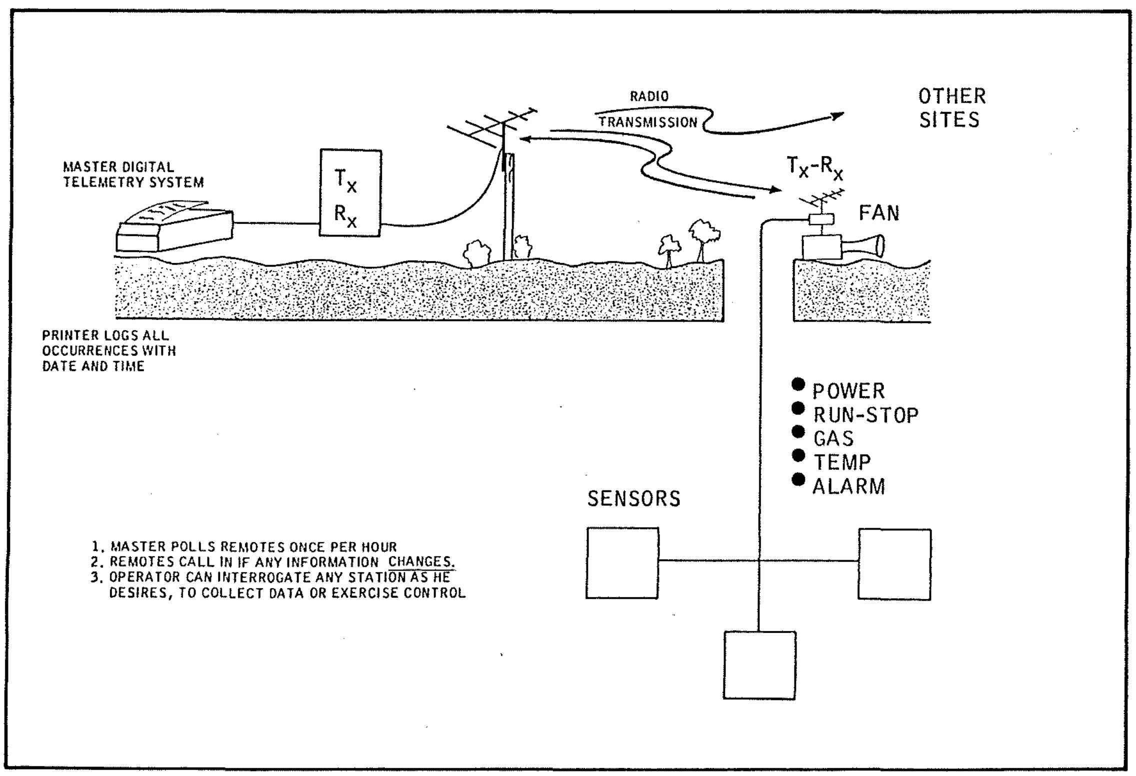
USBM TUBE BUNDLE SYSTEM



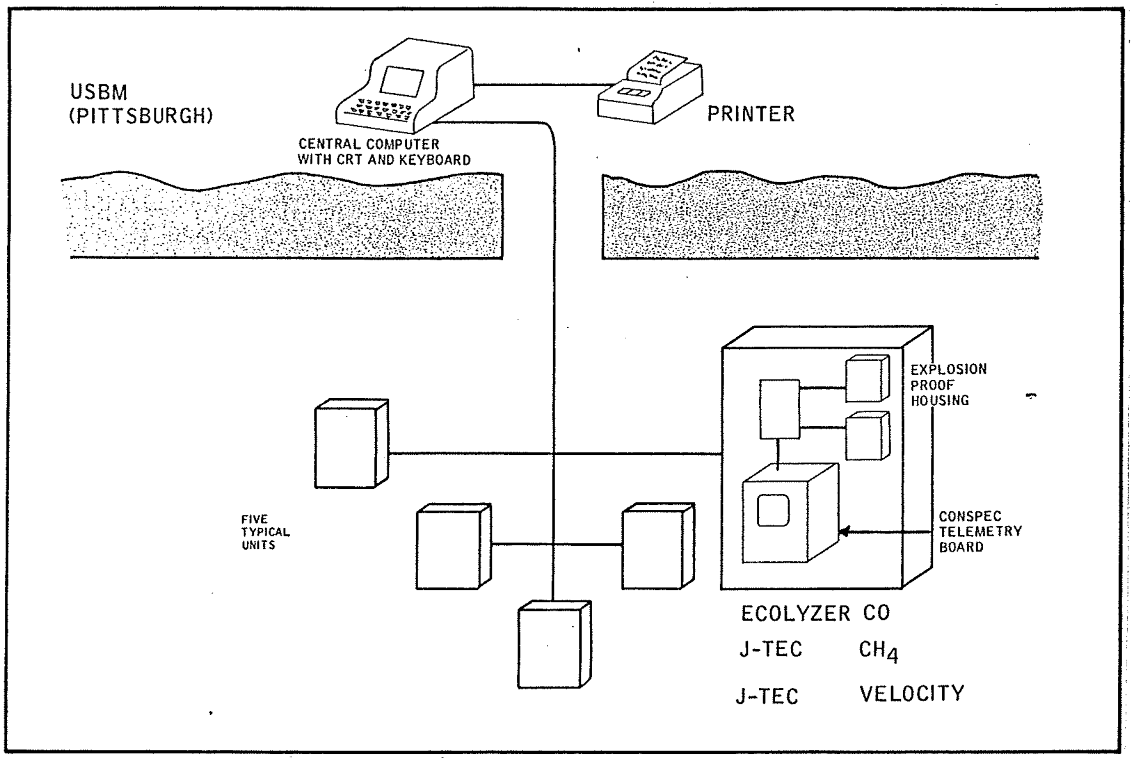
FMC/USBM SPONTANEOUS COMBUSTION PROTECTION SYSTEM



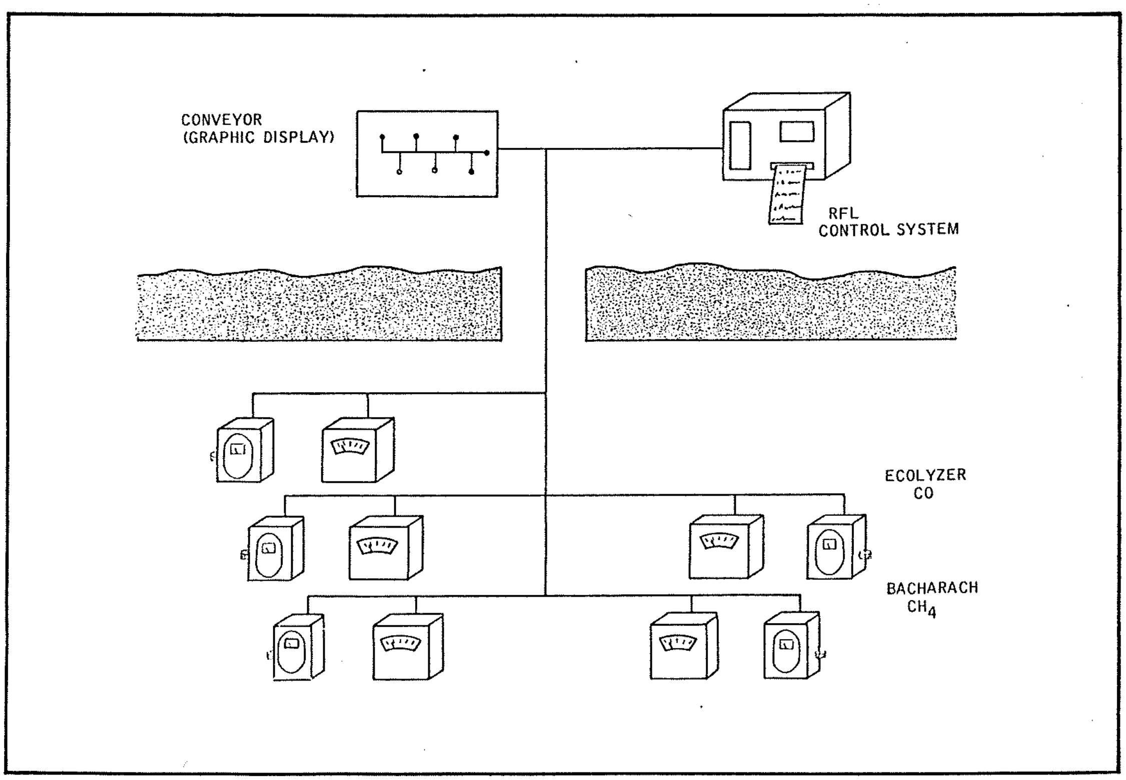
SMOKE-ACTUATED VENTILATION CONTROL SYSTEM



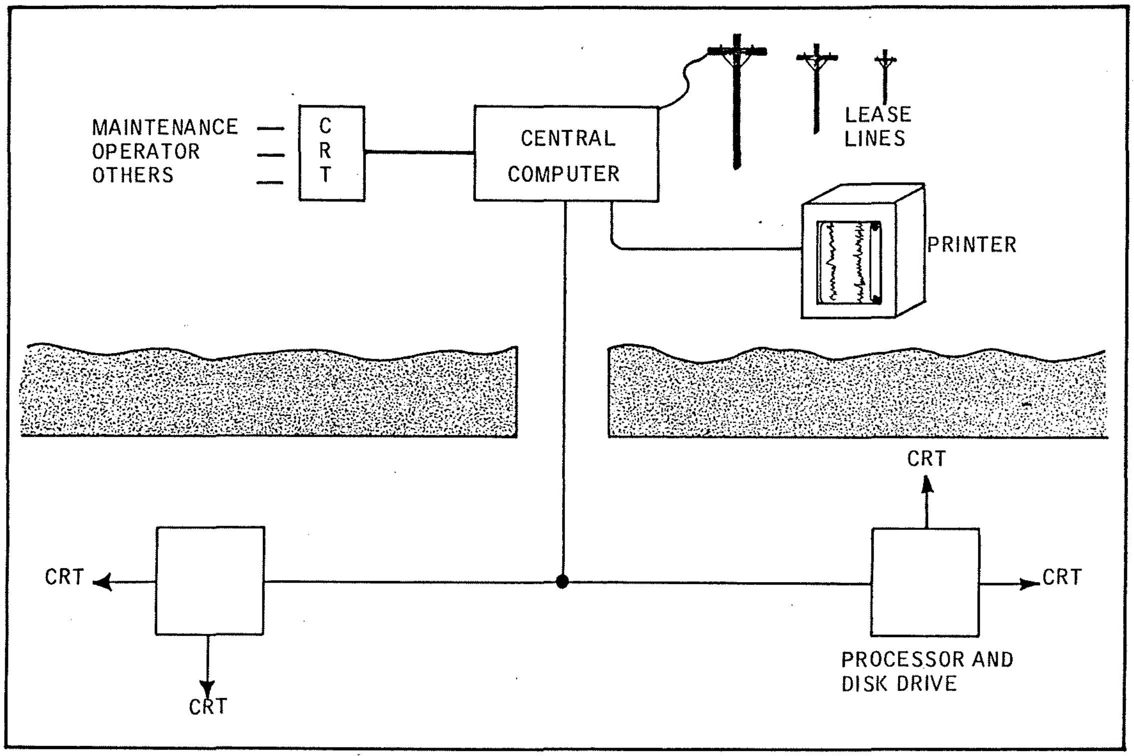
RADIO CONTROL SYSTEM FOR REMOTE FANS



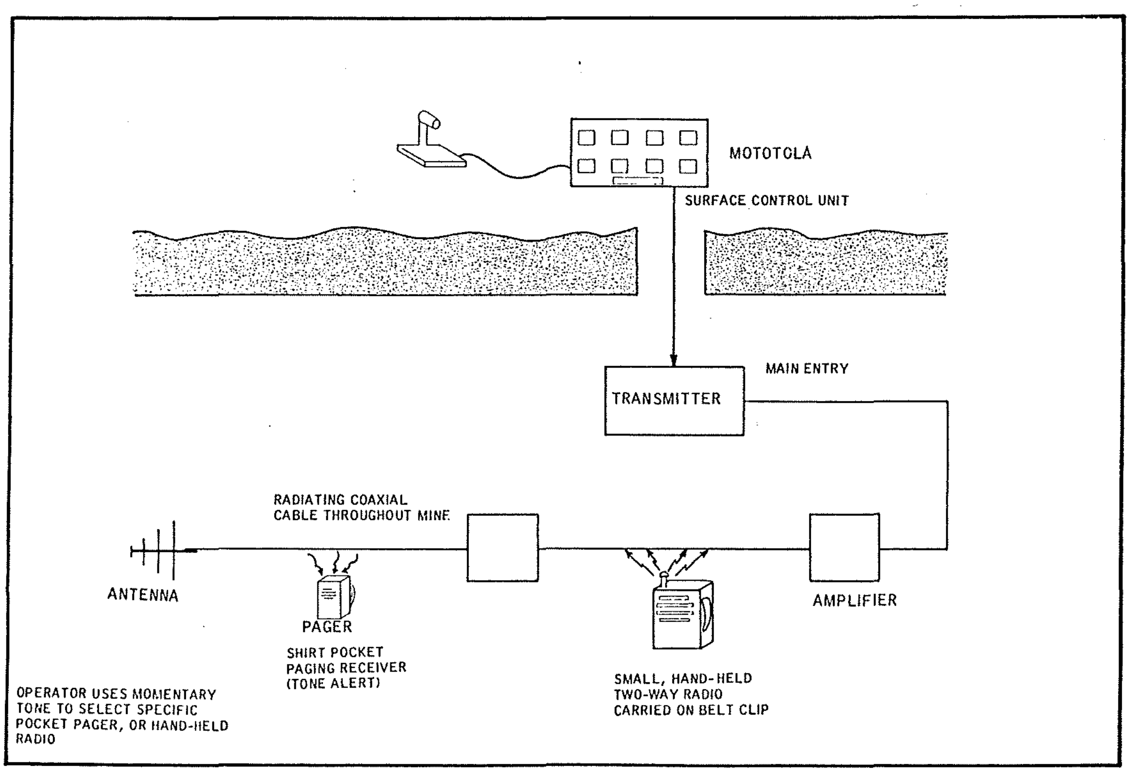
USBM MINE ENVIRONMENT DATA COLLECTION SYSTEM



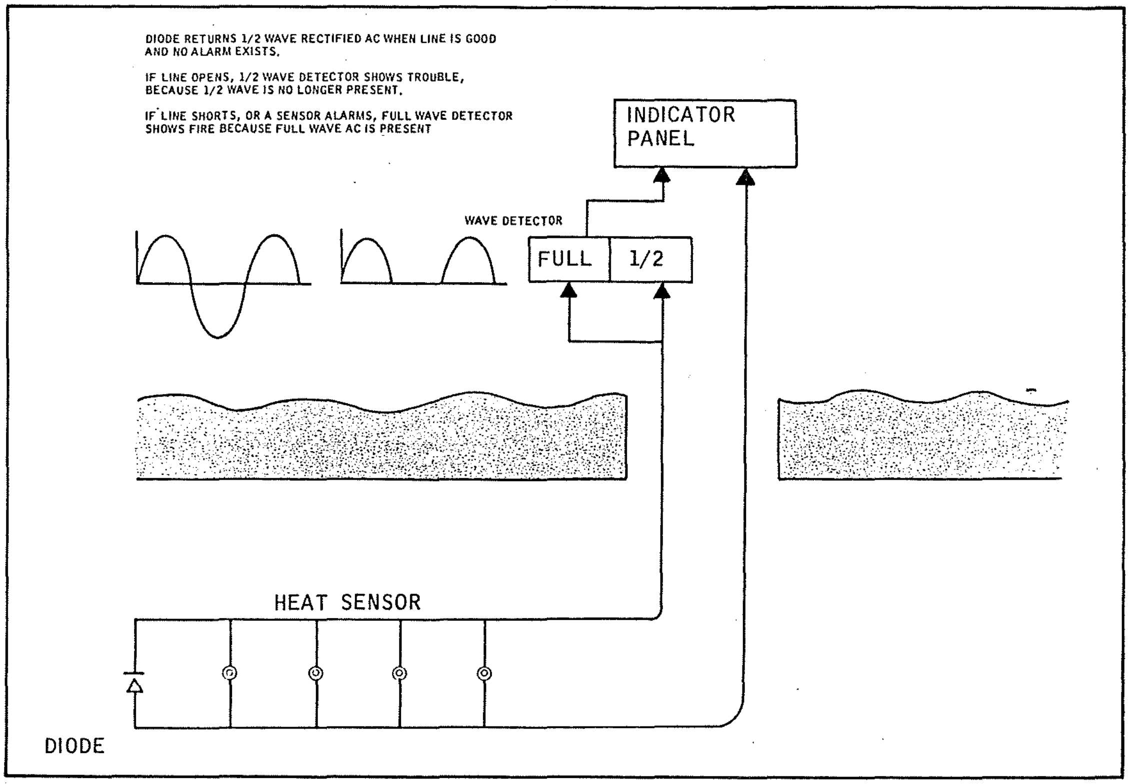
CONVEYOR BELT GAS TELEMETRY SYSTEM



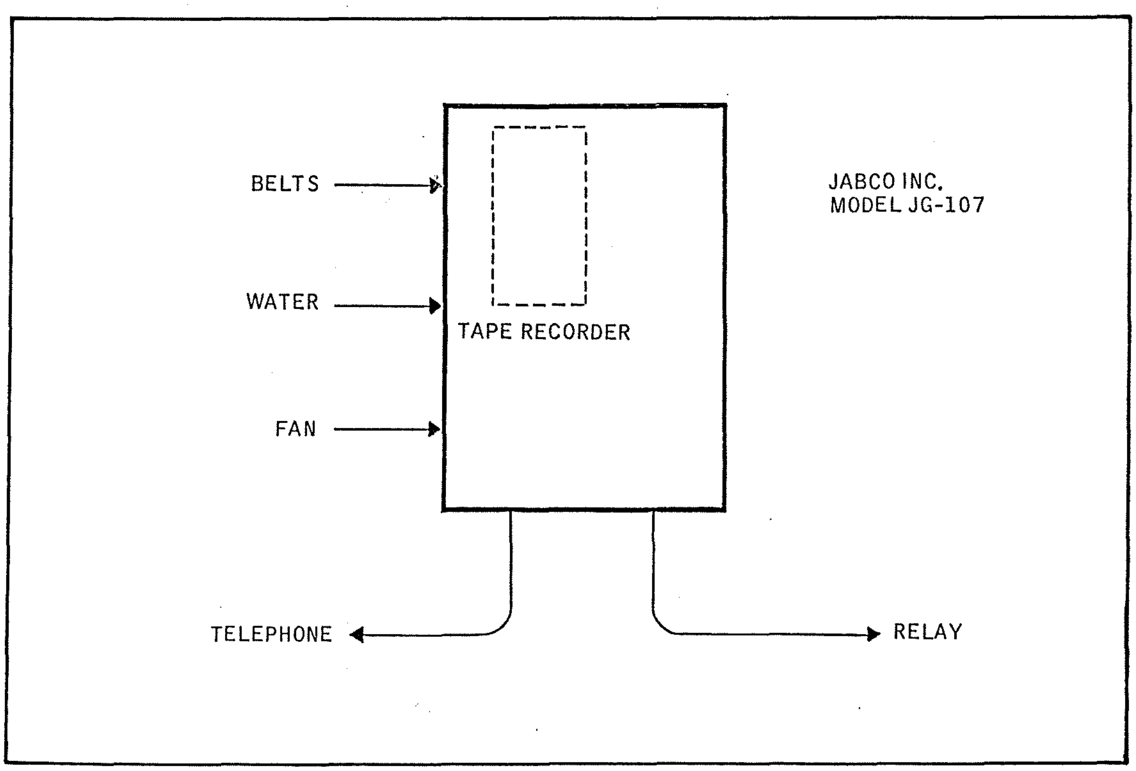
PRODUCTION REPORTING TELEMETRY SYSTEM



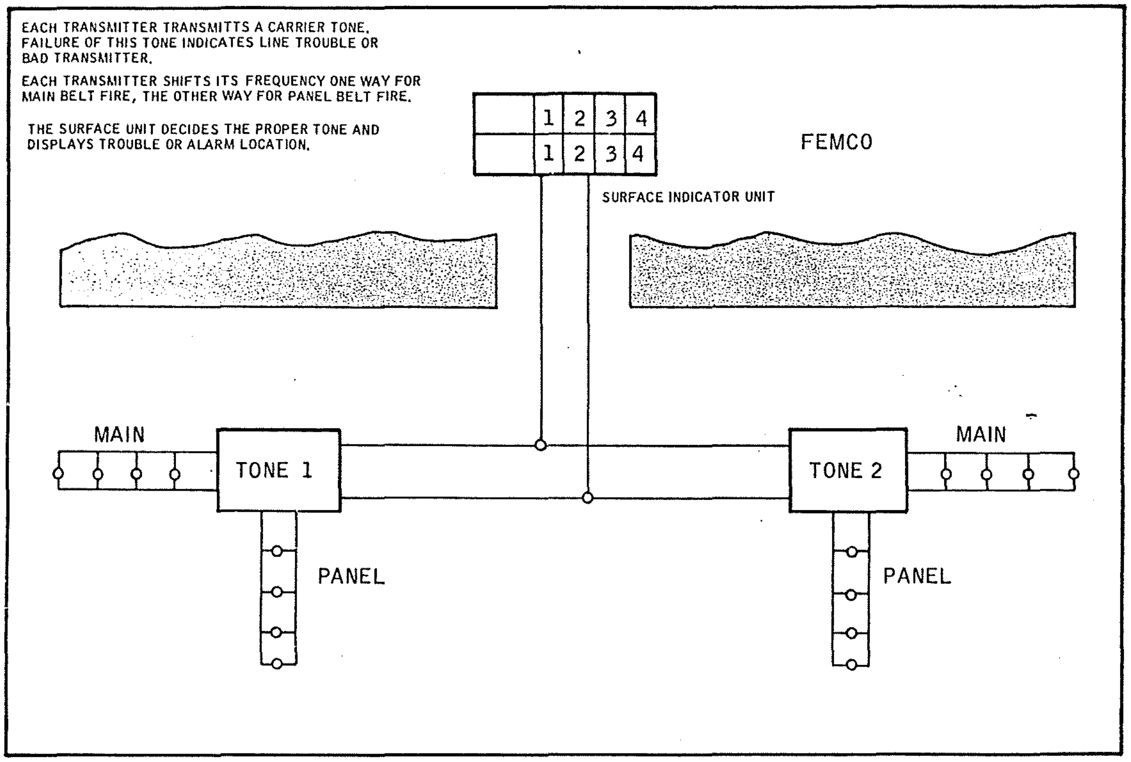
RADIO VOICE COMMUNICATION TELEMETRY SYSTEM



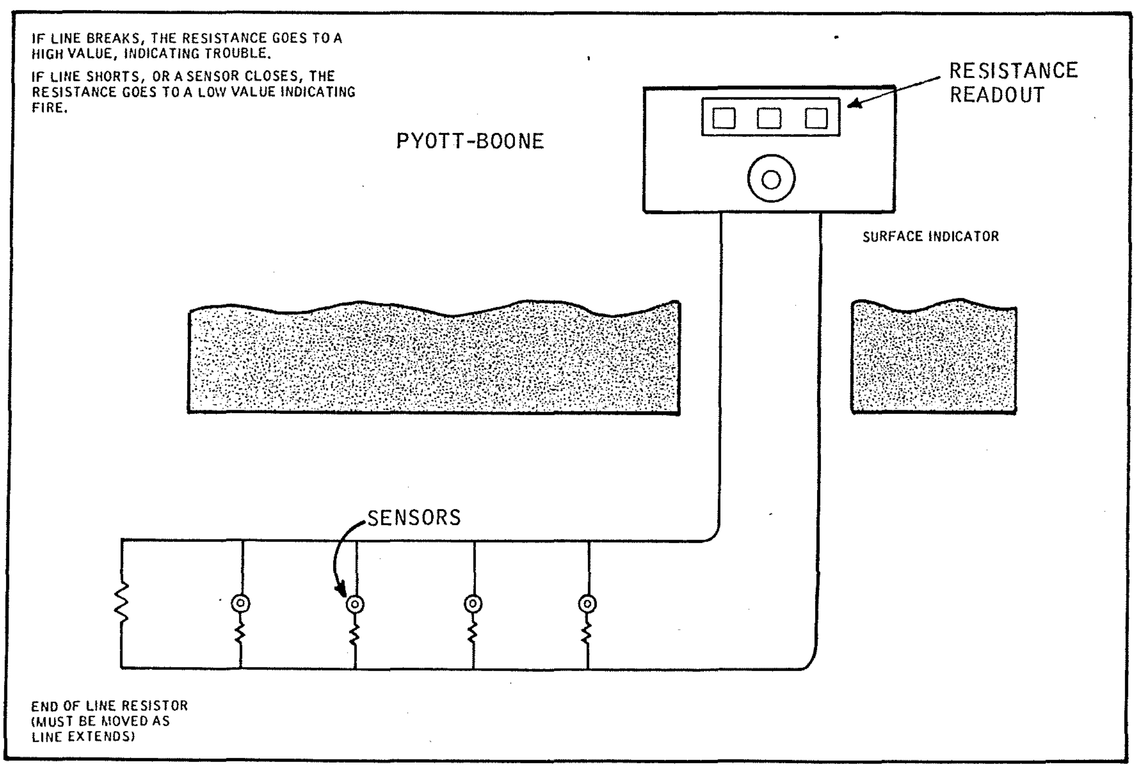
CONVEYOR BELT DIODE TELEMETRY FIRE DETECTION SYSTEM



PRE-RECORDED VOICE TELEMETRY REPORTING SYSTEM



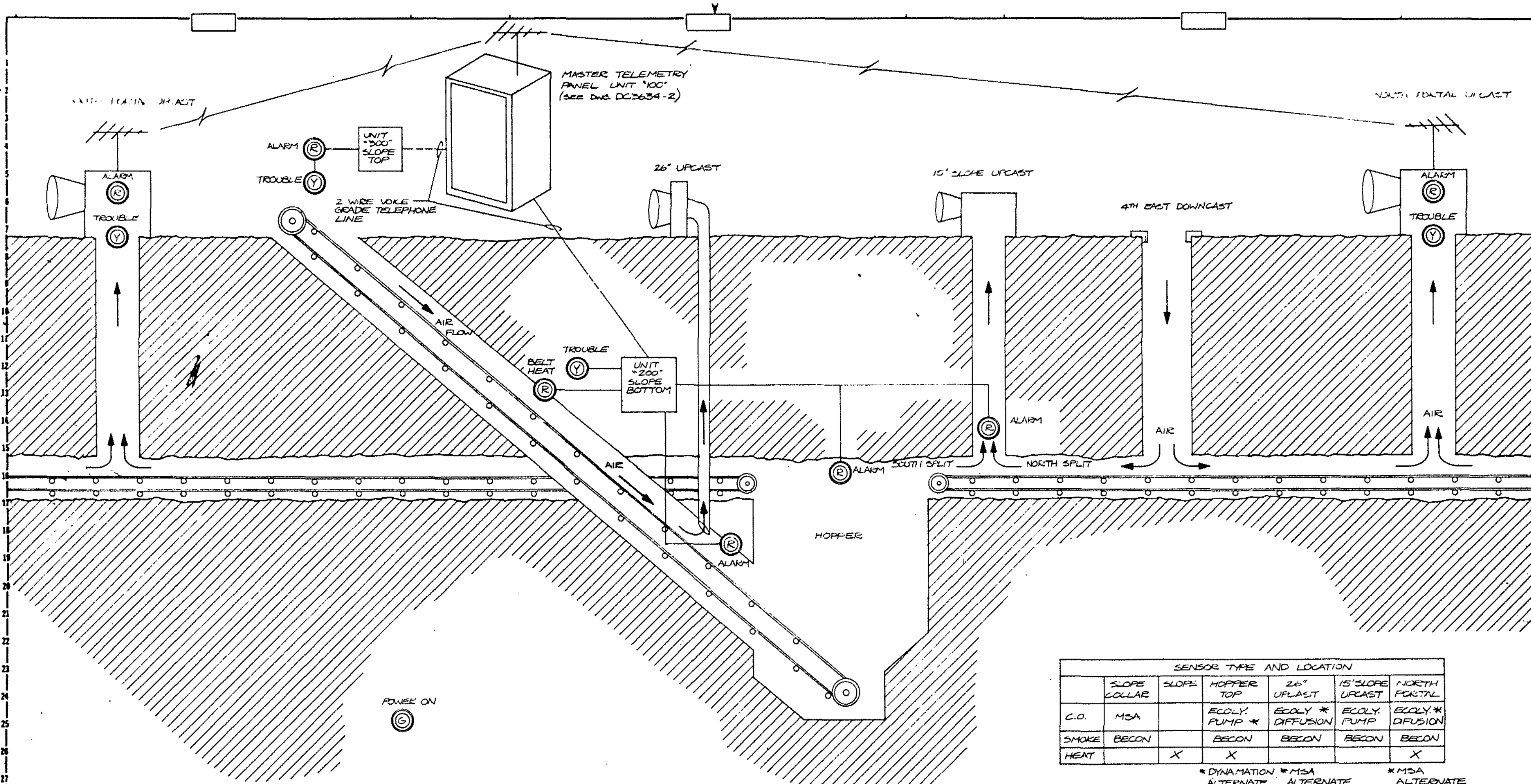
CONVEYOR BELT TONE TELEMETRY FIRE DETECTION SYSTEM



CONVEYOR BELT RESISTANCE TELEMETRY FIRE DETECTION SYSTEM

Appendix F

DRAWINGS



SENSOR TYPE AND LOCATION						
	SLOPE COLLAR	SLOPE	HOPPER TOP	26" UPCAST	15' SLOPE UPCAST	NORTH PORTAL
C.O.	MSA		ECOLY. PUMP *	ECOLY * DIFFUSION	ECOLY. PUMP	ECOLY. * DIFUSION
SMOKE	BECON		BECON	BECON	BECON	BECON
HEAT		X	X			X

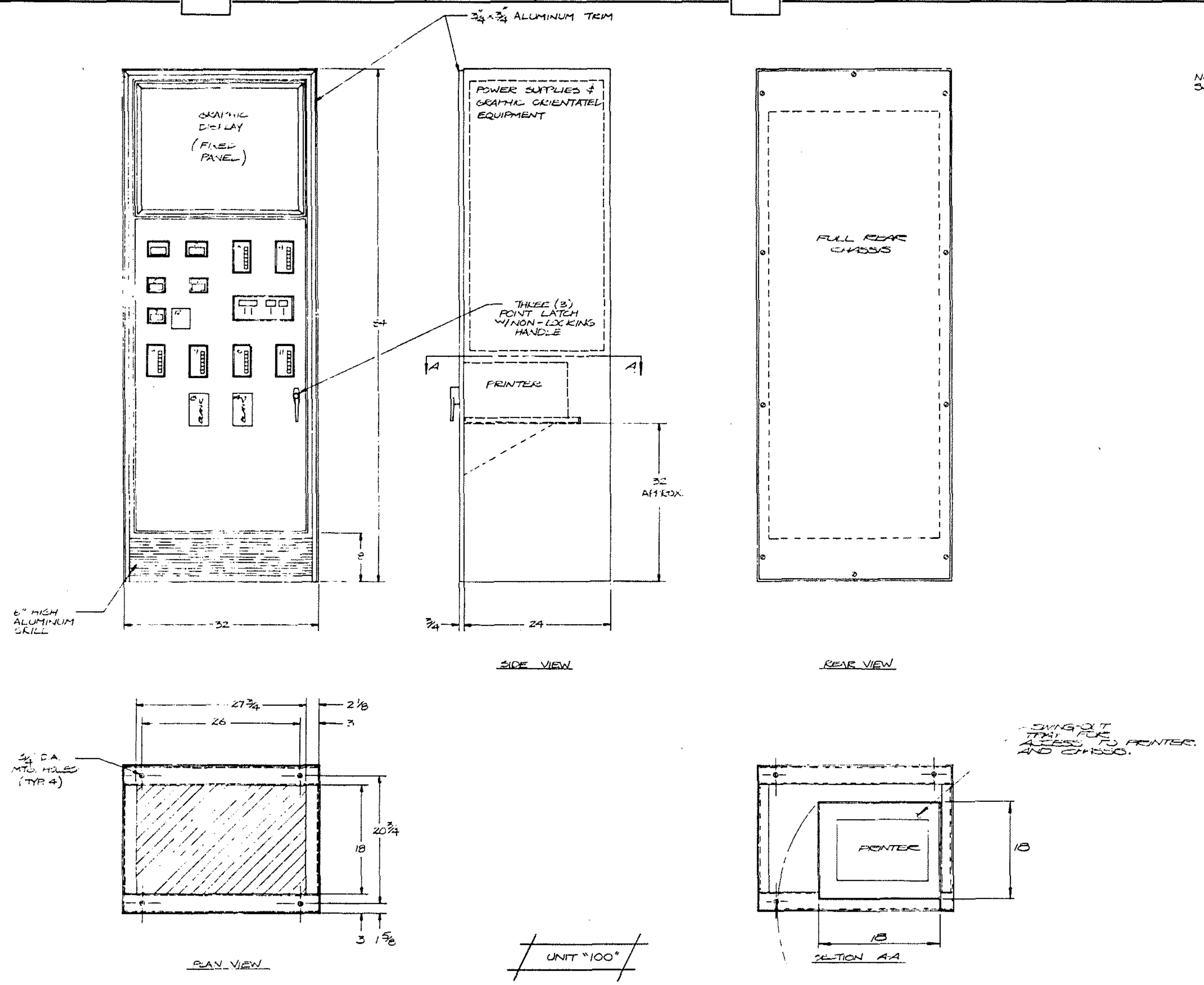
* DYNAMATION ALTERNATE * MSA ALTERNATE * MSA ALTERNATE

CIRCLES DENOTE LAMPS ON GRAPHIC PANEL. THE ALARM LAMPS INDICATE C.O. SMOKE OR HEAT. MAINTENANCE TYPE CONDITIONS, POWER FAIL & DATA FAIL HAVE SEPERATE LAMPS TO ALERT PERSONNEL TO CORRECT AREA. ALL ALARMS HAVE INDIVIDUAL ANNUNCIATORS ON THE CONTROL PANEL, IN ADDITION TO THE GRAPHIC LAMPS.

REVISIONS: A AS PER SUBMITTAL 6-6-80; AS BUILT 9-27-81

NOTES:

AQUATROL CORPORATION TOTAL CONTROL — ST. PAUL MINNESOTA
PROJECT: PEABODY MINE #10
DATE: 6-16-80 DATE: 6-17-80 DATE: 6-11-81
TITLE: SYSTEM LAYOUT
DWG NO. DC3634-1 B
5154162



NAMEPLATE SCHEDULE:

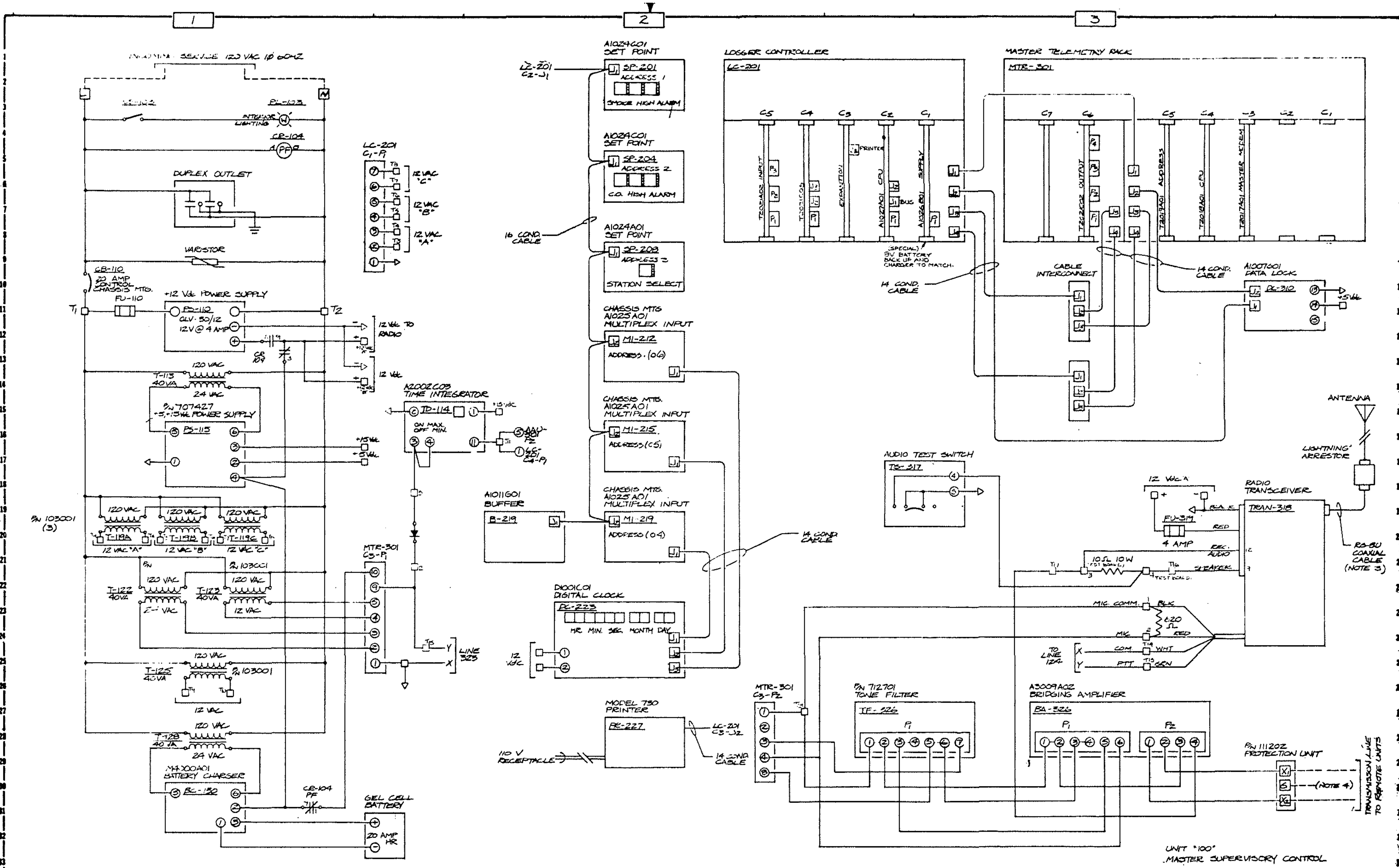
1. SMOKE
2. C.O. PPM
3. ENTER SMOKE SETPOINTS
   ENTER C.O. SETPOINTS
   (BLANK)
4. ALERT
   PRINT SET POINTS
   24 HR. SUMMARY
   (BLANK)
   (BLANK)
   LAMP TEST
5. HIGH ALARM SMOKE
6. HIGH ALARM C.O. PPM
7. STATION SELECT
8. SMOKE SENSORS
   SLOPE TOP
   25" UPCAST
   HOPPER TOP
   15' SLOPE UPCAST
   NORTH UPCAST
   SOUTH UPCAST
9. C.O. SENSORS
   SLOPE TOP
   25" UPCAST
   HOPPER TOP
   15' SLOPE UPCAST
   NORTH UPCAST
   SOUTH UPCAST
10. SLOPE TOP FIRE PULL
    HOPPER FIRE PULL
    NORTH PORTAL FIRE PULL
    SLOPE BELT HEAT
    HOPPER TOP HEAT
    NORTH PORTAL HEAT
11. DATA FAIL
    POWER FAIL
    MASTER TELEMETRY FAIL
    NORTH FAN OFF
    SOUTH FAN OFF
    HEAT SENSOR FAIL
12. STATION SELECT LEGEND:
    1. SLOPE TOP
    2. 25" UPCAST
    3. HOPPER TOP
    4. 15' SLOPE UPCAST
    5. NORTH UPCAST
    6. SOUTH UPCAST
13. BLANK
14. BLANK

UNIT "100"
MULTIPLEX SUPERVISORY CONTROL

REVISIONS:
A

NOTES:
1. MATERIAL: 12 GA. CRS. W/ ALUMINUM TRIM.
2. FINISH: LAVAX SAFETY YELLOW ENAMEL.
3. ENCLOSURE NEMA 1A GASKETED.
4. WIRING DIAGRAMS PER DWGS. PC3034-3 thru 5.
5. SHADED AREA REPRESENTS AVAILABLE CONDUIT SPACE

AQUATROL CORPORATION — TOTAL CONTROL — ST. PAUL, MINNESOTA
PROJECT: PEABODY MINE # 3
TITLE: PANEL LAYOUT



REVISIONS:

A	AS PER INSTALL	2-11-80
B	AS BUILT	8-27-80
C	AS INSTALLED	11-3-80

NOTES:

1. ELECTRICAL AND HYDRAULIC SYMBOLS AS PER 10-2000.
2. PANEL LAYOUT AS PER DWG. DC3634-2.
3. ANTENNA AND CABLE BY AQUATROL FOR INSTALLATION BY OTHERS.
4. #10 WIRE TO GROUND SYSTEM

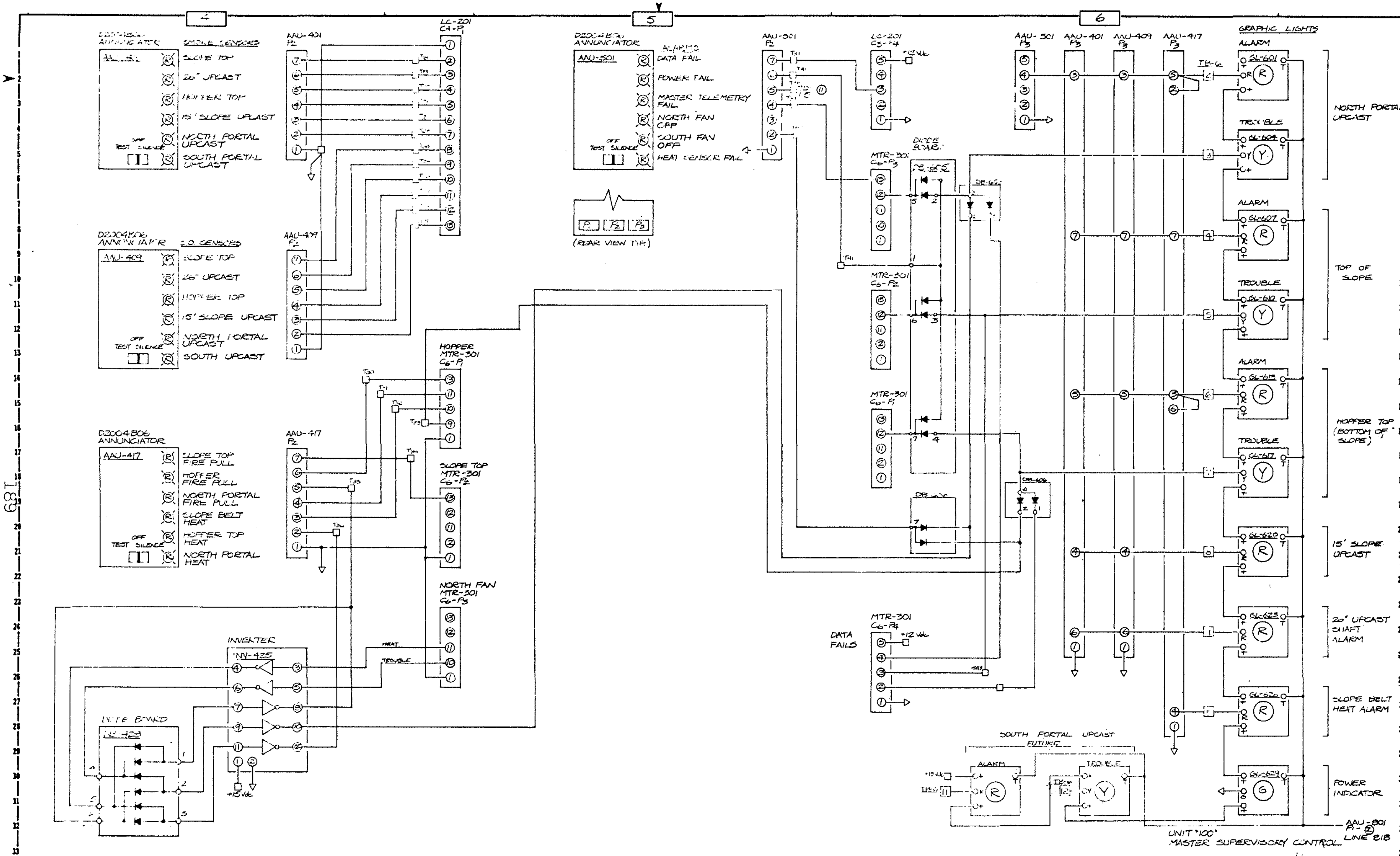
AQUATROL CORPORATION — TOTAL CONTROL — ST. PAUL MINNESOTA

PROJECT: PEABODY MINE #10

TITLE: WIRING DIAGRAM

DWG. NO. DC3634-3

5154164



REVISIONS:

NOTES:

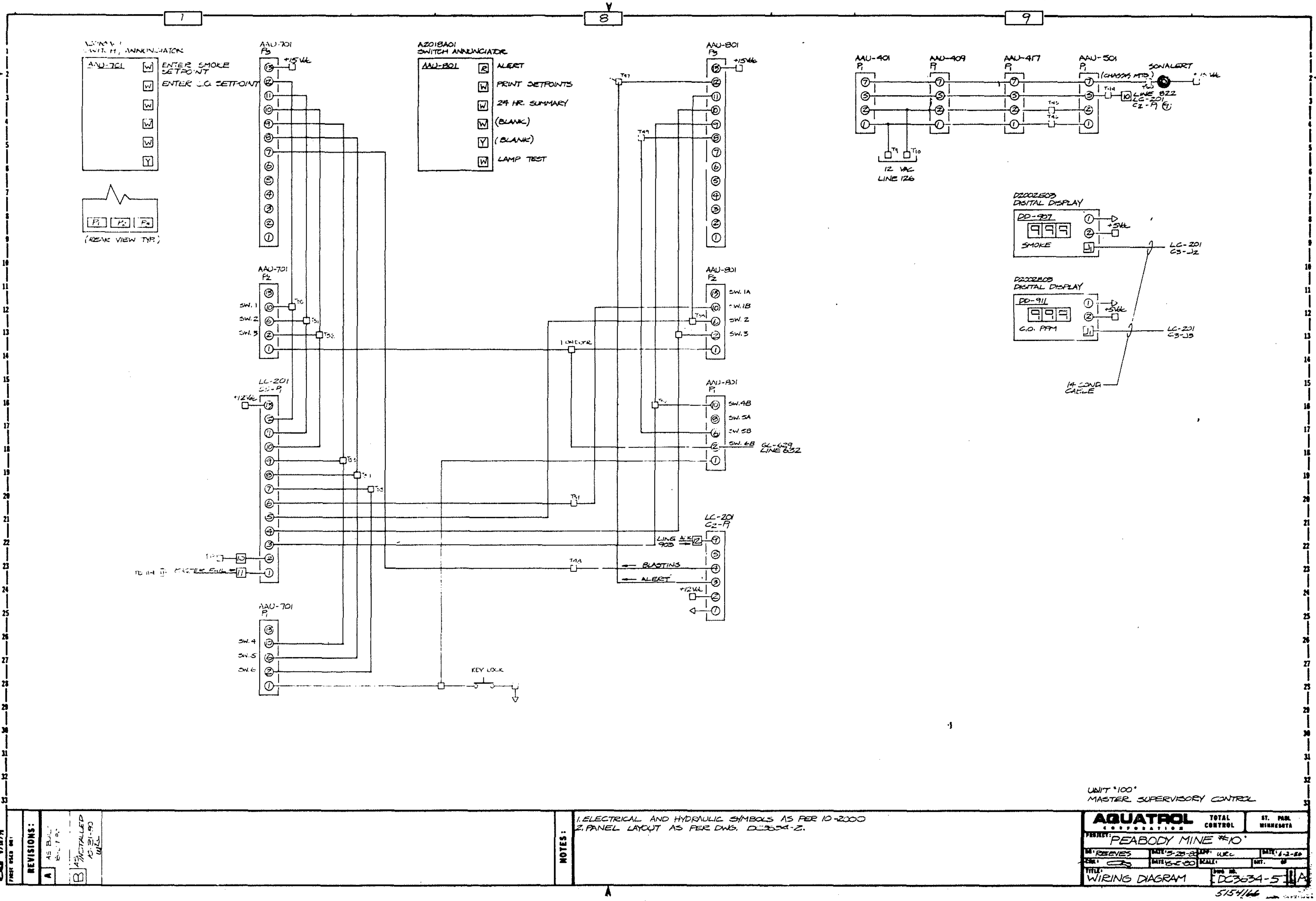
1. ELECTRICAL AND HYDRAULIC SYMBOLS AS PER 10-2000.
2. PANEL LAYOUT AS PER DWG. DC3634-Z.

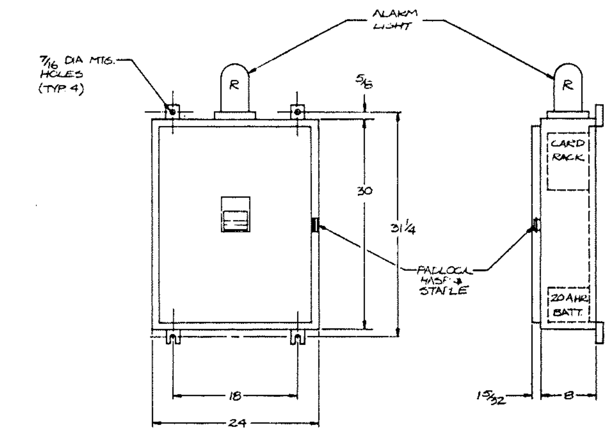
AQUATROL CORPORATION — TOTAL CONTROL — ST. PAUL, MINNESOTA

PROJECT: PEABODY MINE #10

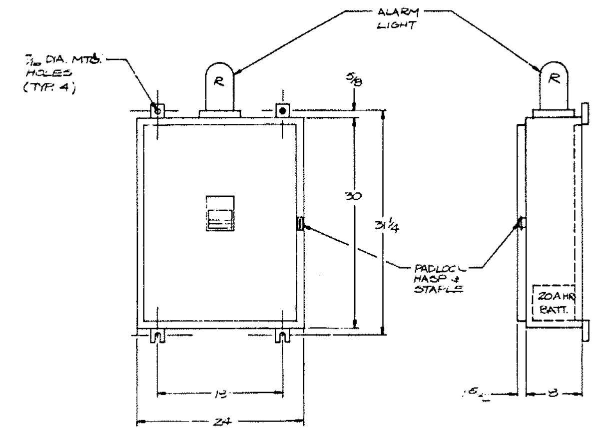
DR: REEVES DATE: 5-28-80

TITLE: WIRING DIAGRAM DC3634-4 C

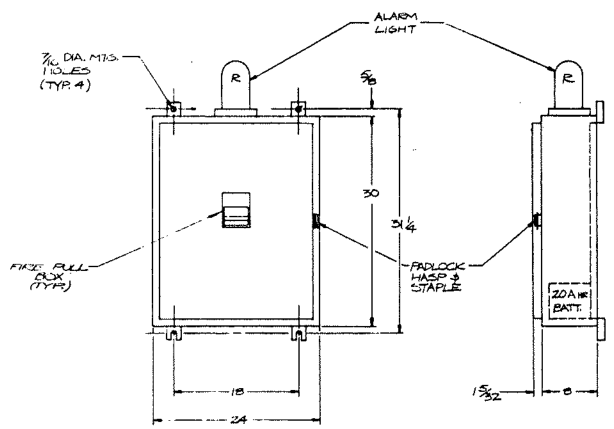

7
8
9
SWITCH ANNUNCIATOR
AAU-701
ENTER SMOKE SETPOINT
ENTER C.O. SETPOINT
(REAR VIEW TYP.)
AAU-701 P3
+15 VDC
AZ018A01 SWITCH ANNUNCIATOR
AAU-801
ALERT
PRINT SETPOINTS
24 HR. SUMMARY
(BLANK)
(BLANK)
LAMP TEST
AAU-801 P3
AAU-401 P1
AAU-409 P1
AAU-417 P1
AAU-501 P1
SONALERT
(CHASSIS MTD.)
LINE 822
LC-201 C2-P1
12 VAC LINE 126
DZ002503 DIGITAL DISPLAY
DD-907
SMOKE
LC-201 C3-J2
DZ002503 DIGITAL DISPLAY
DD-911
C.O. PPM
LC-201 C3-J3
14 COND. CABLE
AAU-701 P2
SW. 1
SW. 2
SW. 3
AAU-801 P2
SW. 1A
SW. 1B
SW. 2
SW. 3
LC-201 C3-P1
+12 VDC
AAU-801 P1
SW. 4B
SW. 5A
SW. 5B
SW. 6B
LC-629 LINE 832
LC-201 C2-P1
LINE 905
BLASTING
ALERT
+12 VDC
MASTER FAIL
AAU-701 P1
SW. 4
SW. 5
SW. 6
KEY LOCK
UNIT "100"
MASTER SUPERVISORY CONTROL
REVISIONS:
A AS BUILT
B AS INSTALLED 10-31-80 WLL
NOTES:
1. ELECTRICAL AND HYDRAULIC SYMBOLS AS PER 10-2000
2. PANEL LAYOUT AS PER DWG. DC3634-2.
AQUATROL CORPORATION
TOTAL CONTROL
ST. PAUL MINNESOTA
PROJECT: PEABODY MINE #10
DR: REEVES
DATE: 5-28-80
TITLE: WIRING DIAGRAM
DC3634-5
A
5154/66



UNIT "200"



UNIT "300"



UNIT "400"

UNITS "200", "300", "400"

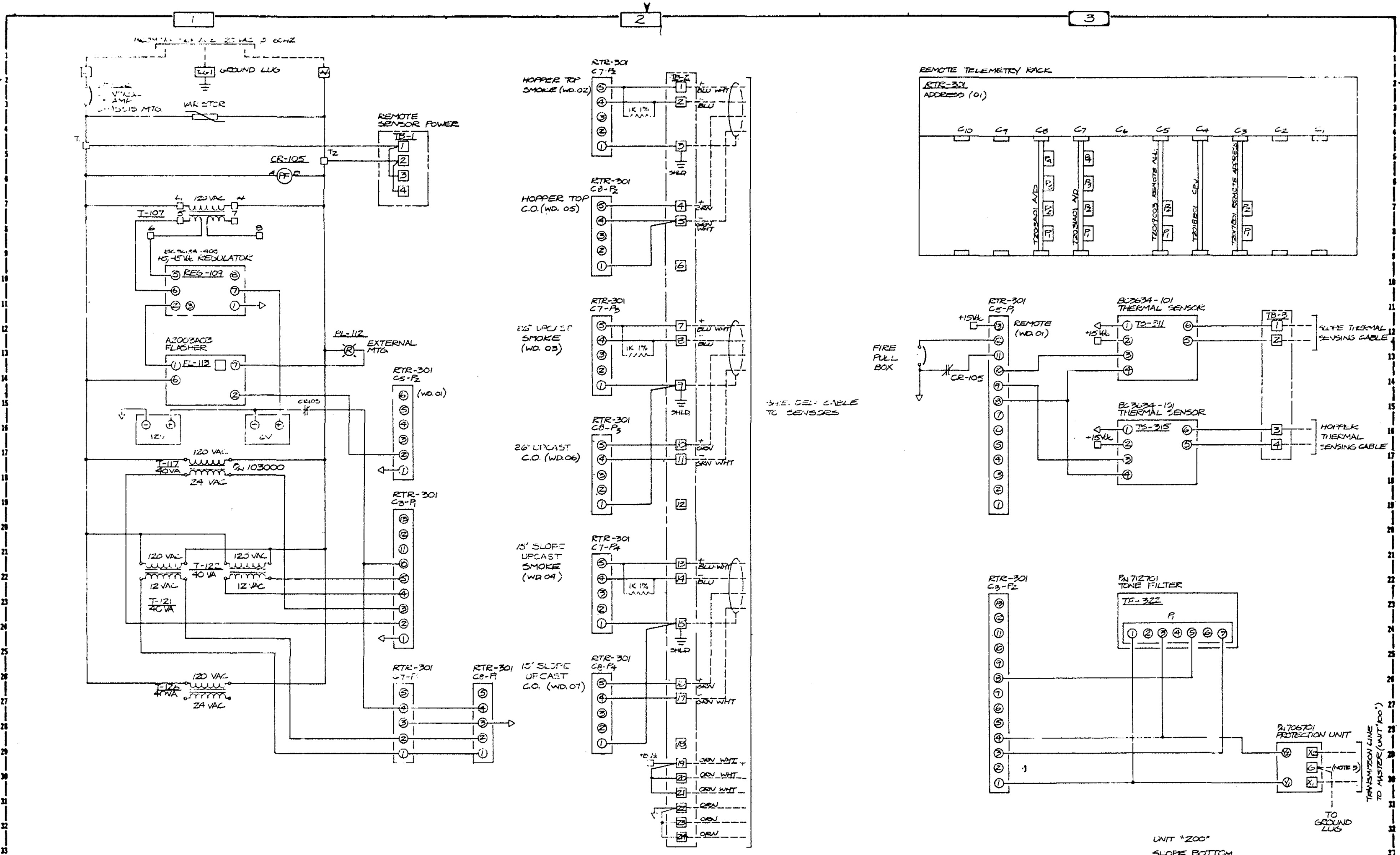
REVISIONS:

A

NOTES:

1. ENCLOSURE: NEMA 4.
2. MATERIAL: 14 GA. CRS.
3. FINISH: LAVAX SAFETY YELLOW ENAMEL 23-780.
4. WIRING DIAGRAM AS PER DWG. DC3634-7, 8, & 9.

AQUATROL CORPORATION		TOTAL CONTROL	ST. PAUL MINNESOTA
PROJECT: PEABODY MINE #10			
DR: REEVES	DATE: 6-2-80	APP: WRC	DATE: 6-2-80
CHK:	DATE:	SCALE:	SHT:
TITLE: PANEL LAYOUT		DWG NO: DC3634-6	



REVISIONS:
A AS PER ... 6-11-80
B AS BUILT
C AS INSTALLED 12-31-80

NOTES:
1. ELECTRICAL AND HYDRAULIC SYMBOLS AS PER 10-2000.
2. PANEL LAYOUT AS PER DWG. DC3634-6.
3. #10 WIRE TO GROUND SYSTEM.

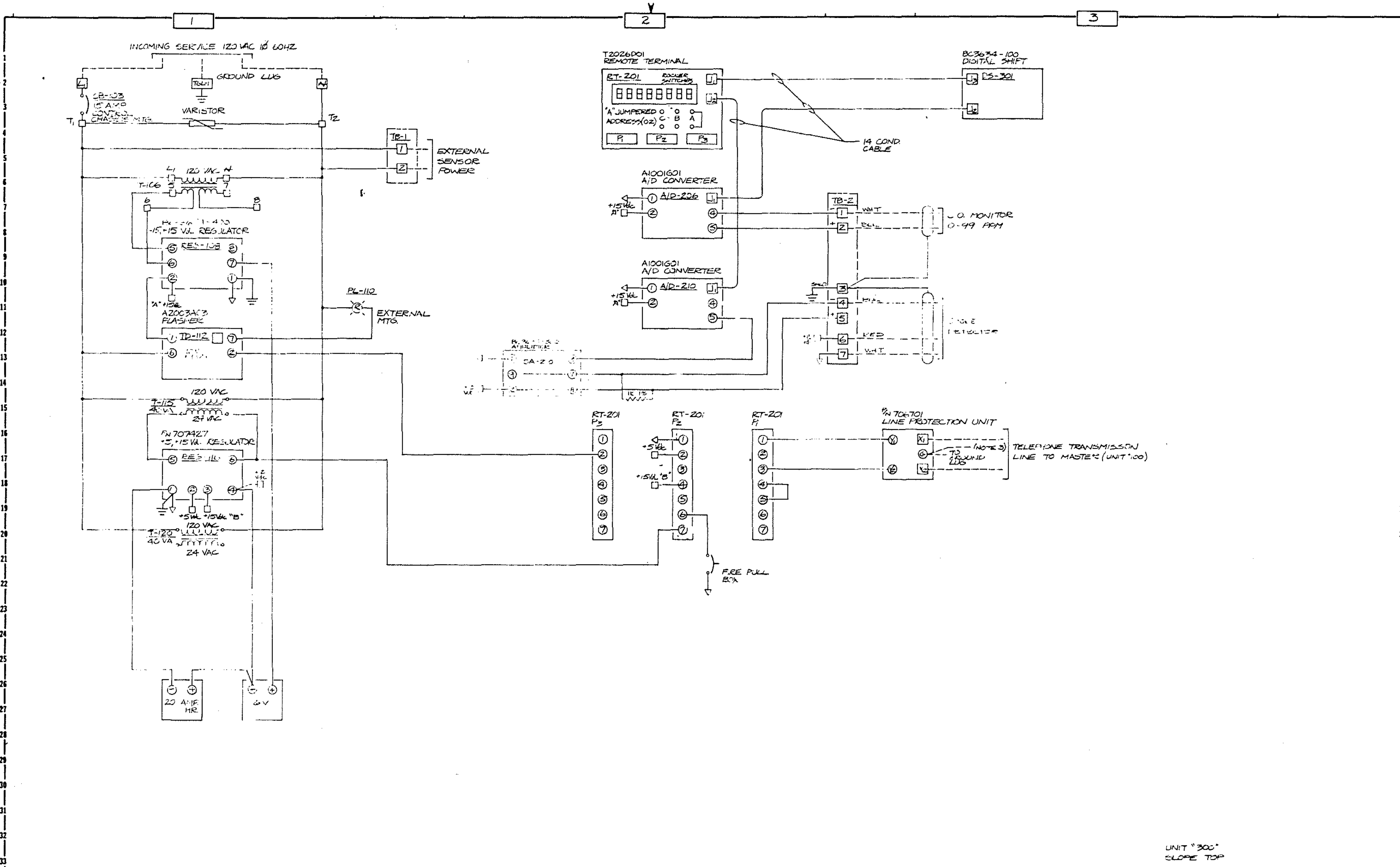
AQUATROL CORPORATION — TOTAL CONTROL — ST. PAUL MINNESOTA

PROJECT: PEABODY MINE #10

TITLE: WIRING DIAGRAM

DWG NO. DC3634-7 C

5154168



REVISIONS:

A AS PER SUBMITTAL 6-13-80

C AS INSTALLED

NOTES:

1. ELECTRICAL AND HYDRAULIC SYMBOLS AS PER 10-2000.
2. PANEL LAYOUT AS PER DWG DC3634-6.
3. #10 WIRE TO GROUND SYSTEM.

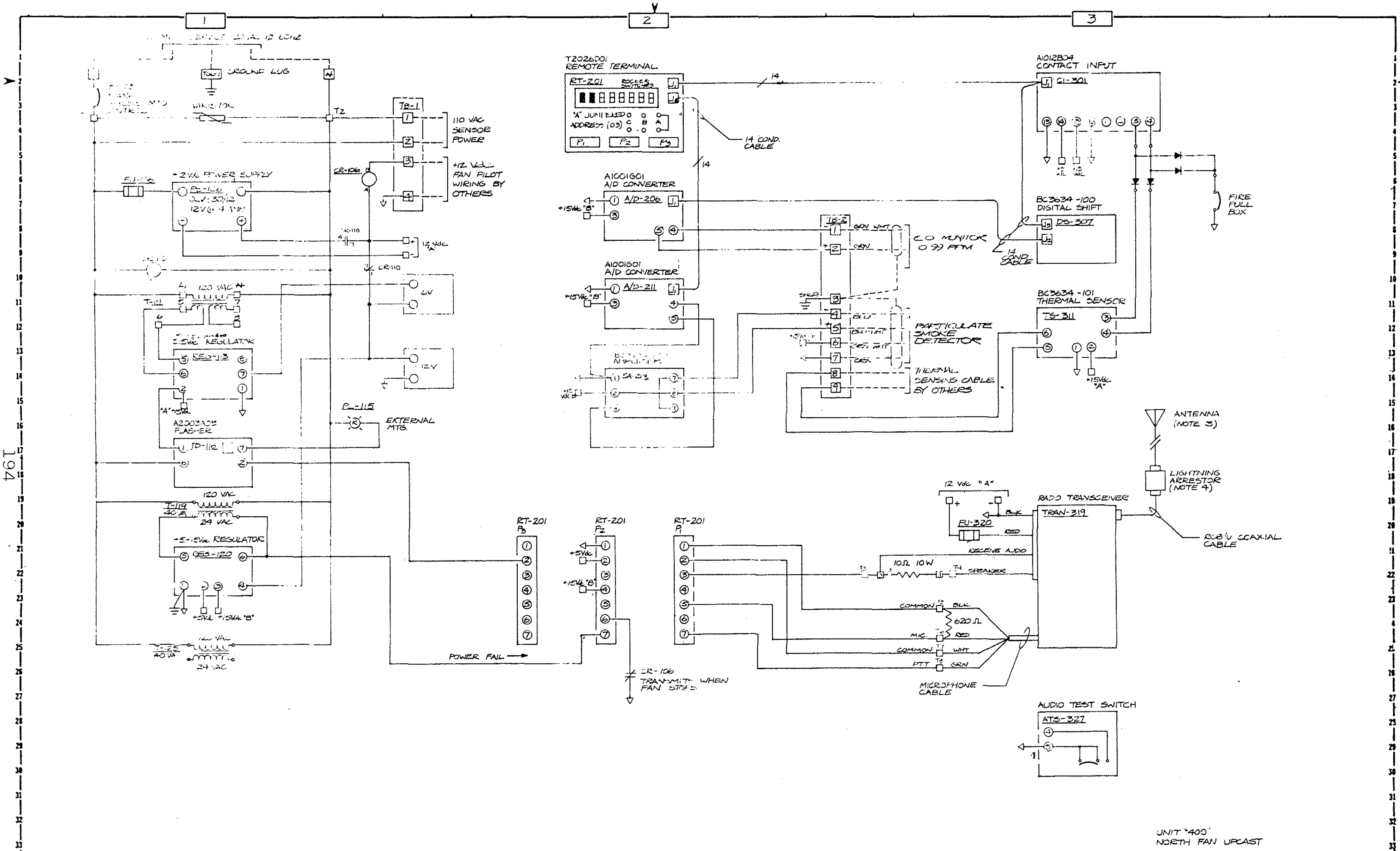
AQUATROL CORPORATION — TOTAL CONTROL — ST. PAUL, MINNESOTA

PROJECT: PEABODY MINE #10

TITLE: WIRING DIAGRAM

DWG NO. DC3634-8 C

5154169



NOTES:

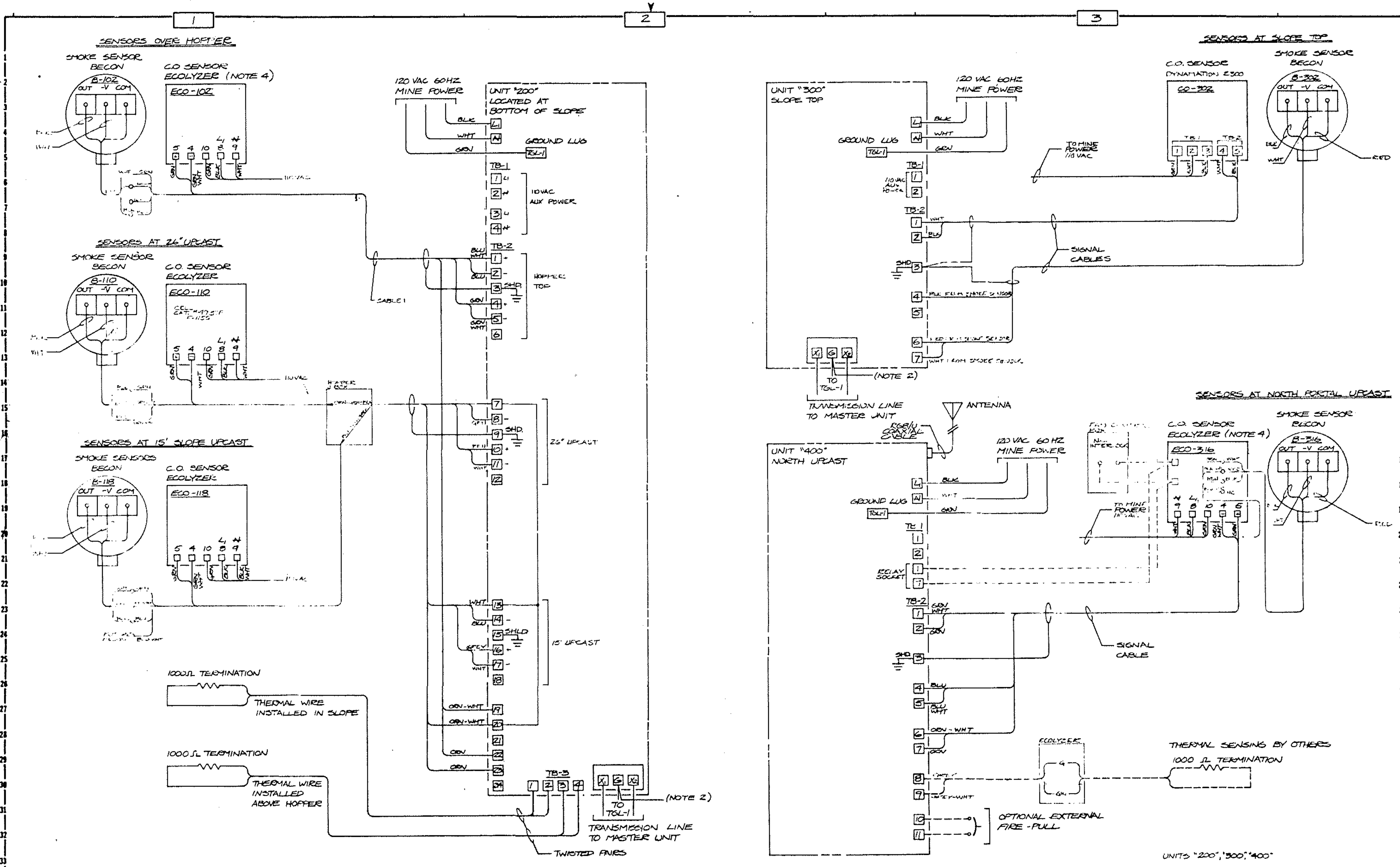
1. ELECTRICAL AND HYDRAULIC SYMBOLS AS PER 10-2000
2. PANEL LAYOUT AS PER DWG. DC3634-6.
3. ANTENNA AND CABLE BY AQUATROL FOR INSTALLATION BY OTHERS.
4. #10 WIRE TO GROUND SYSTEM.

REVISIONS:

A	ISSUED SUBMITTAL 6-13-80
B	
C	10-21-80

AQUATROL CORPORATION	TOTAL CONTROL — ST. PAUL, MINNESOTA
PROJECT:	PEABODY MINE #10
DR: REEVES	DATE: 6-21-80
CHK:	DATE: 6-2-80
APP: WRL	DATE: 6-2-80
TITLE:	WIRING DIAGRAM
DWG NO.	DC3634-9
REV	C

5154170



REVISIONS:

NOTES:

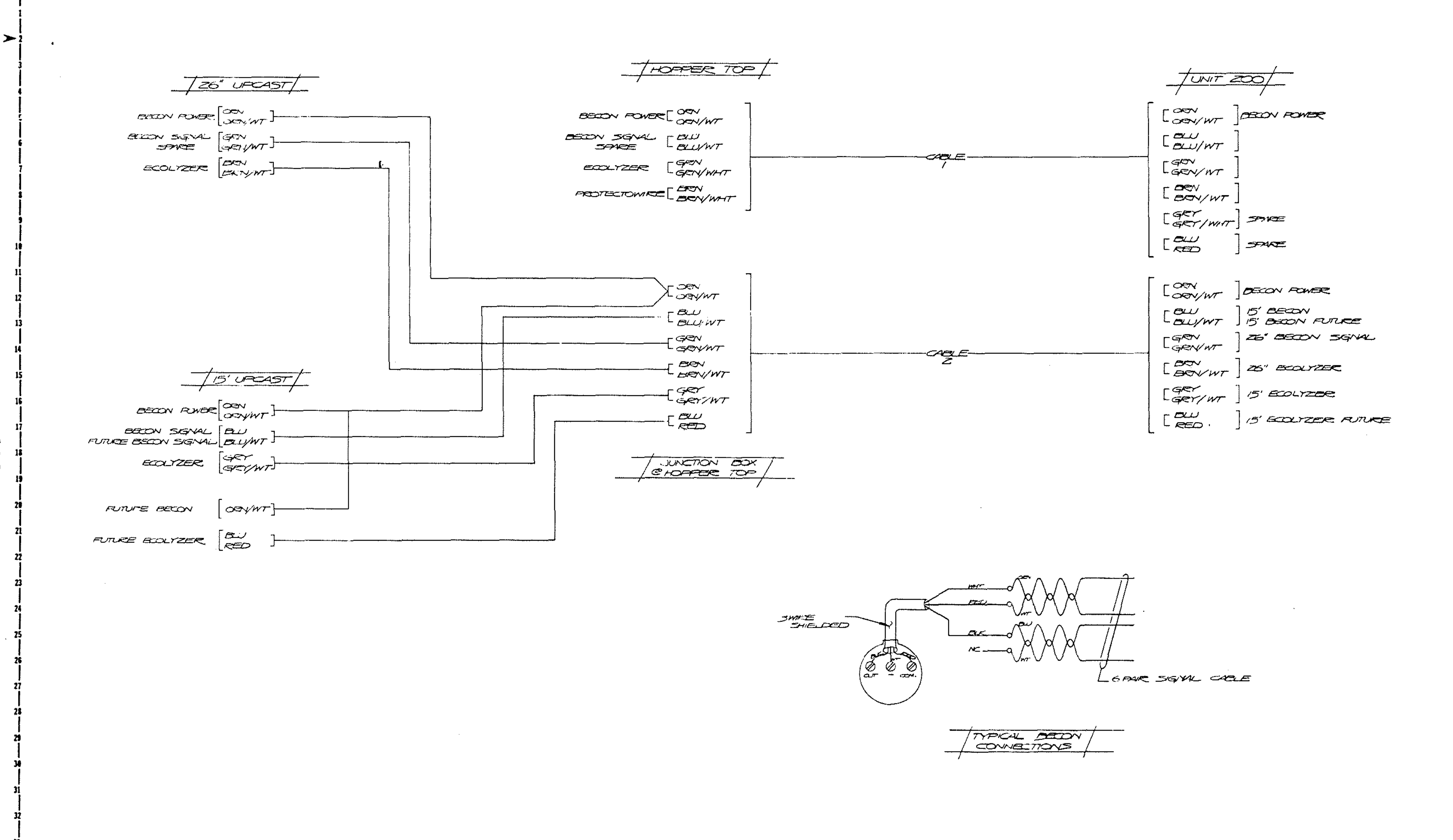
1. ELECTRICAL AND HYDRAULIC SYMBOLS AS PER 10-2000.
2. #10. WIRE TO GROUND SYSTEM.
3. IDENTIFY CABLE PAIRS CAREFULLY.
4. SEE DC3634-11 FOR ALTERNATE SENSOR WIRING.

AQUATROL CORPORATION — TOTAL CONTROL — ST. PAUL MINNESOTA

PROJECT: PEABODY MINE #10

TITLE: INSTALLATION DWG.

DC3634-10



REVISIONS:

A

NOTES:

1. ELECTRICAL AND HYDRAULIC SYMBOLS AS PER 10-2000.
2. PANEL LAYOUT AS PER DWG. DC3654-2 AND 6.

AQUATROL CORPORATION — TOTAL CONTROL — ST. PAUL MINNESOTA

PROJECT: PEABODY MINE #10

TITLE: INSTALLATION CABLE DRAWING

Appendix G

FCC LICENSE

50' 9: 9 CIS3: 2275'55 0

UNITED STATES OF AMERICA
FEDERAL COMMUNICATIONS COMMISSION

AUTHORIZATION

SERVICE:SPECIAL INDUSTRIAL
CLASS: OPERATIONAL FIXED

RADIO STATION LICENSE

CALL SIGN: WEK97
FREQUENCY: 173.39625MH
LICENSE NO: CIS8:252

LICENSEE NAME: PEABODY COAL MINE COMPANY INC.
PEABODY MINE #1.

ID NO: 57614
SYSTEM NO:

TRANSMIT LOCN: 3 MI E & 2 MI N

LAT: 39-37-3
LONG: 89-31-

CITY: PAWNEE,ILL CNTY: CHRISTIAN

GROUND: 596 FT AM
SUPP STRUCT: 40 FT
ANTENNA: 50 FT
TELEPHONE

CONTROL POINTS
SAME AS TRANSMITTER

PEABODY COAL MINE CO INC
PEABODY MINE #1
ATTN ROBERT DANKO
P O BOX 158
PAWNEE IL 62558

POWER	E.R.P.	NO OF UNITS	EMISSION DESIGNATORS
18.000W	83.0W	1	16F3

SPECIAL CONDITIONS:
NONE

PAINTING/LIGHTING SPECS:
NONE

THIS IS A COPY. THE ORIGINAL CERTIFICATE IS AVAILABLE FOR INSPECTION AT F.S.O. MINE #10.

Subject to the provisions of the Communications Act of 1934, subsequent acts, and treaties, and all regulations heretofore or hereafter made by this Commission, and further subject to the conditions and requirements set forth in this license, the licensee hereof is hereby authorized to use and operate the radio transmitting facilities herein described for radio communication.

This license is issued on the licensee's representation that the statements contained in licensee's application are true and that the undertakings therein contained, so far as they are consistent herewith, will be carried out in good faith. The licensee shall, during the term of this license, render such service as will serve public interest, convenience, or necessity to the full extent of the privileges herein conferred.

This license shall not vest in the licensee any right to operate the station nor any right in the use of the frequencies designated in the license beyond the term hereof, nor in any other manner than authorized herein. Neither the license nor the right granted hereunder shall be assigned or otherwise transferred in violation of the Communications Act of 1934. This license is subject to the right of use or control by the Government of the United States conferred by Section 606 of the Communications Act of 1934.

This authorization effective SEPT 9,1980, and will expire 3.00 A.M. EST SEPT 9,1985

RECEIVED
SEP 15 1980
MINE 10

FEDERAL COMMUNICATIONS COMMISSION

FCC FORM 470 COPY

Appendix H

NRC LICENSE FOR BECON SENSOR

NRC-374 (7-78)

U. S. NUCLEAR REGULATORY COMMISSION
MATERIALS LICENSE

This Copy Is For Your Files

Pursuant to the Atomic Energy Act of 1954, as amended, the Energy Reorganization Act of 1974 (Public Law 93-438), and Title 10, Code of Federal Regulations, Chapter 1, Parts 30, 31, 32, 33, 34, 35, 36, 40 and 70, and in reliance on statements and representations heretofore made by the licensee, a license is hereby issued authorizing the licensee to receive, acquire, possess, and transfer byproduct, source, and special nuclear material designated below; to use such material for the purpose(s) and at the place(s) designated below; to deliver or transfer such material to persons authorized to receive it in accordance with the regulations of the applicable Part(s); and to import such byproduct and source material. This license shall be deemed to contain the conditions specified in Section 183 of the Atomic Energy Act of 1954, as amended, and is subject to all applicable rules, regulations and orders of the Nuclear Regulatory Commission now or hereafter in effect and to any conditions specified below.

Licensee	
Peabody Coal Company P. O. Box 530 Taylorville, Illinois 62568	3. License number 12-19558-01
	4. Expiration date January 28, 1986
	5. Docket or Reference No.

6. Byproduct, source, and/or special nuclear material	7. Chemical and/or physical form	8. Maximum amount that licensee may possess at any one time under this license
Krypton 85	A. Sealed source (Gas)	A. 30 millicuries

9. Authorized use

A. For use in custom made smoke detectors.

CONDITIONS

10. Licensed material shall be used only at Peabody Coal Company, Mine No. 10, Pawnee, Illinois.

11. The licensee shall comply with the provisions of Title 10, Chapter 1, Code of Federal Regulations, Part 19, "Notices, Instructions and Reports to Workers; Inspections" and Part 20, "Standards for Protection Against Radiation."

12. Licensed material shall be used by, or under the supervision of, Gary Smothers, Ervin L. Shimjus, Alan V. Perks, or John Robert Danko.

FORM NRC-374A (5-76)

U. S. NUCLEAR REGULATORY COMMISSION
MATERIALS LICENSE
Supplementary Sheet
CONDITIONS

License Number 12-19558-01

Docket or
Reference No. ______

(continued)

13. Installation, initial radiation survey of devices, relocation, maintenance, repair, and removal from service of the devices containing licensed material and installation, replacement, and disposal of sealed sources containing licensed material used in the devices shall be performed only by the FMC Corporation or by other persons specifically authorized by the Commission or an Agreement State to perform such services.

14. Except as specifically provided otherwise by this license, the licensee shall possess and use licensed material described in Items 6, 7, and 8 of this license in accordance with statements, representations, and procedures contained in application dated August 28, 1980. The Nuclear Regulatory Commission's regulations shall govern the licensee's statements in applications or letters, unless the statements are more restrictive than the regulations.

FEB 24 1981

For the U. S. Nuclear Regulatory Commission

Paul R. Guinn

Material Licensing Branch

Appendix I

OPERATION AND MAINTENANCE OF MASTER CONTROL PANEL

MASTER CONTROL PANEL
MINE SHAFT FIRE AND SMOKE PROTECTION

1 SMOKE LEVEL
Digital display indicates 0-999 concentration. Smoke baseline zero is 100 and tolerence of 25-50 is normal. Display updates every 6-seconds.

2 CO PPM LEVEL
Digital display indicates 0-999 PPM carbon monoxide. CO baseline zero is 10, and display updates every 6 seconds. (Display of 15 interprets to 5 PPM).

3 ENTER SMOKE SETPOINT
ENTER CO SETPOINT
(See Note 1) Changes sensor alarm limits. Value and location based on thumbwheel position of HIGH ALARM SMOKE or CO and STATION SELECT.

4 Function buttons to command, record, and test the system (see Note 1).

ALERT (red button) activates red light at each remote location.

PRINT SETPOINTS will provide list of alarm levels of all analog sensors (see Note 5).

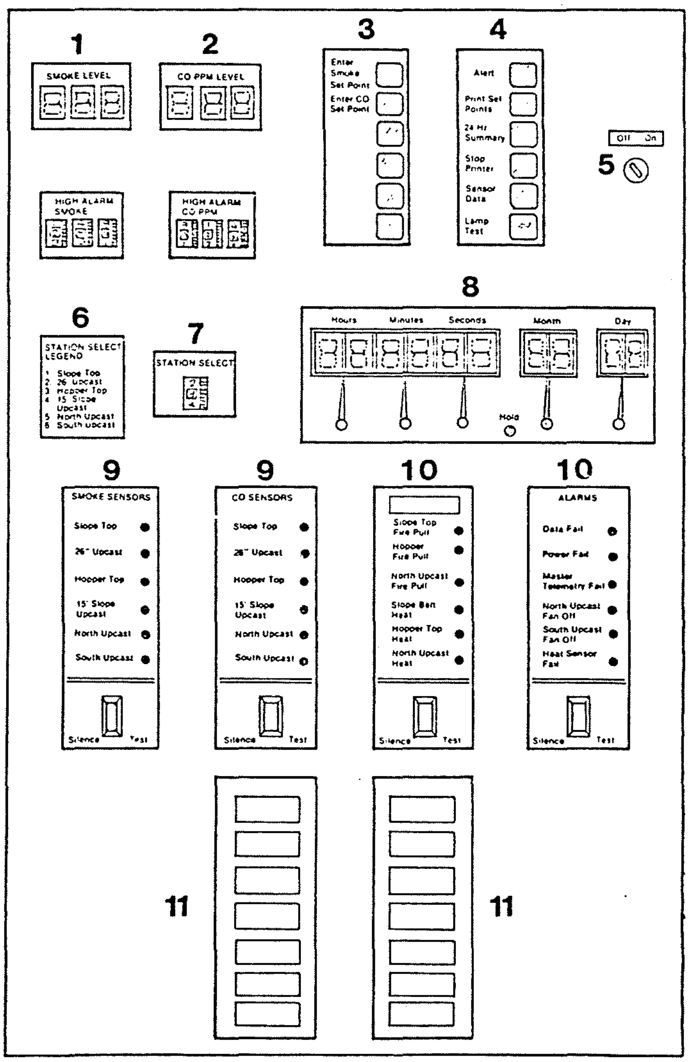
24-HR. SUMMARY produces a graph of smoke and CO sensors as indicated on station select thumbwheel position (see Note 5).

STOP PRINTER button stops and resets the printer for the next print function.

SENSOR DATA gives list of present analog values of smoke and CO sensors (see Notes 5 and 6).

LAMP TEST causes all indicator lamps on mine graphic display and within 12 buttons to illuminate.

5 KEY SWITCH will lock out or activate the function buttons.



6 HIGH ALARM SMOKE and HIGH ALARM CO PPM
Digital setpoint controllers: Three thumbwheels allow 0-999 adjustment. Smoke baseline is 100 and CO is 10. Indication of 15 on CO digital display equals 5 PPM at source.

7 STATION SELECT LEGEND
Thumbwheel identifies location of smoke and CO sensors. Thumbwheel setting used to observe values on digital display and adjust alarm points.

8 CLOCK and DATE is connected to the printer to identify time and date of each printed event. Individual buttons advance or hold the timing cycle.

9 SMOKE SENSORS and CO SENSORS indicate which sensor has exceeded it's present alarm point. The lights are interconnected to the mine graphic display and flash when in alarm condition. Pressing the lower switch toward the left silences the audible alarm and changes the flashing light to steady. Movement to the right causes all lights on the panel to flash. The steady light is removed when the sensor returns below the alarm setpoint level (see Note 2).

10 ALARM panels identify location and alarm condition of fire pulls, heat sensors, and north or south fans off. Trouble indicators identify problems on data fail, power fail, master telemetry fail and heat sensor fail. (See Note 6).

11 SPARE PANELS installed for future additions to system.

GENERAL NOTES

1. Key switch must be ON to activate all function buttons. Leave switch in OFF position during normal standby conditions.

2. All events are recorded on internal printer to identify time, date, and concentration level (if analog signal).

3. The recorder automatically prints a 24-hour summary of daily analog sensor data by providing the high value, low value and mean value. This summary is not the same as generated when button marked 24-HR SUMMARY is depressed (see below).

4. The recorder speed automatically increases during any SMOKE or CO alarm. Normal print rate is once per hour per analog signal whereas the alarm rate is every 10 minutes. This is evident only when opening the cabinet door, turning the key switch ON, depressing the 24-HR SUMMARY button and observing the graph generated by the printer.

5. Unlock and open the cabinet door to observe and confirm printer information.

6. The recorder automatically prints NO ALARM sensor data and ALARM CONDITION sensor data. Print rates of each are variable.

Appendix J

OPERATION AND MAINTENANCE INSTRUCTIONS

I. NORMAL OPERATION AND MAINTENANCE (No Alarms)

The following notes assume the unit is connected to and receiving 110-volt AC power (green power light illuminated) as well as having a functional wire pair and/or radio system interconnecting all remote units to the master unit.

A. OPERATION

1. The smoke and carbon monoxide sensors have been "baseline zero" calibrated. This means that zero parts per million CO at the sensor is actually producing 0.1 volt output, yet the analog meter at the detector has been mechanically set back to 0 ppm. Consequently, the master unit CO PPM LEVEL digital display will always indicate 10 units above actual background CO ppm (display of 15 interprets to 5 ppm). Hence, any zero drift at the sensor or telemetry remote unit will indicate a corresponding change from the CO baseline zero of 10 at the CO PPM LEVEL digital display. Similarly, no smoke at the sensor actually produces 0.9 milliampere output. Consequently, the master unit SMOKE LEVEL digital display will always indicate 100 units above actual background smoke. Hence, any zero drift at the sensor or telemetry remote unit will indicate a corresponding change from the smoke baseline zero of 100 at the SMOKE LEVEL digital display yet tolerance of ±25-50 is to be expected normally.

2. Enter lowest possible HIGH ALARM SMOKE and CO setpoints at each of five station locations identified on STATION SELECT LEGEND. Station 6, south upcast, is a planned future expansion and Stations 7 through 9 are nonexistent. (It is suggested to start with 25 ppm for all CO sensors and 250 ppm for all smoke sensors.) Adjustment is based on alarm frequency. Enter as follows:

   - o Turn key switch to ON position.
   - o Adjust thumbwheels of HIGH ALARM SMOKE to 250 and HIGH ALARM CO PPM to 025.
   - o While holding ENTER SMOKE SETPOINT button depressed, turn STATION SELECT thumbwheel from 1 to 5.
   - o After releasing ENTER SMOKE SETPOINT button, depress and hold ENTER CO SETPOINT button and turn STATION SELECT thumbwheel from 5 to 1.

3. Check setpoint entries by unlocking cabinet door and depressing PRINT SETPOINTS button. Observe printer output. Station 6 does not have sensors, but all recording functions are built into the control system for planned future expansion. For this reason, enter 999 for HIGH ALARM SMOKE and for CO. Turn thumbwheel to Station 6, depress ENTER SMOKE SETPOINT button, and then ENTER CO SETPOINT button. Close and lock cabinet door, turn key to OFF position, and secure keys.

NOTE

The 999 indication on the smoke sensor will inform an observer of three possible conditions: disconnected signal lines, power fail at the detector, or a saturated smoke detector. If the number 000 appears for the smoke sensor, the sensor or telemetry line may be shorted. The 000 indication on a CO sensor will inform an observer of two possible conditions: disconnected signal line or a power fail at the detector. If the numbers 99 appear for CO, the sensor may be saturated, or it may have a high voltage induced onto the line.

4. No lights should appear on mine graphic display panel or at the function indicators except for green POWER light.

5. The printer within the cabinet automatically prints SENSOR DATA at a preset time interval that is internally adjusted from 1 to 60 minutes. Concentration of smoke and CO gas from 10 sensors is recorded. Another internal adjustment of 1 to 60 minutes will allow faster print rate of SENSOR DATA whenever one of the sensors is in an alarm condition (i.e., exceeding the HIGH LEVEL setpoints).

6. At midnight, the printer automatically prints a 24-hour summary of daily highs, lows, and mean values of analog signals from smoke and CO sensors.

B. MAINTENANCE REQUIREMENTS

1. Daily

Observe that the 24-hour clock and date is correct and adjust as necessary. The clock-adjust controls are not locked out with the key. Advance by depressing buttons under digital display or stop by depressing the HOLD button. Move toggle switches on four lower indicator panels to test individual lights.

2. Weekly

Terminate printer paper and review for possible changes to the system. Perform as follows:

- Turn key switch to ON position.
- Depress SENSOR DATA. Allow printer operating within cabinet to stop.
- Depress PRINT SETPOINTS.
- Unlock and open cabinet; then swing out printer to observe recorded data. Advance printer paper and tear off used portion.
- Depress PRINT SETPOINTS and then SENSOR DATA buttons.
- Swing printer back to stored position.
- Close and lock cabinet door, depress LAMP TEST to check lights within two rows of buttons, turn key switch to OFF position, and secure keys.

3. Monthly or As Required

Replace the printer paper within the cabinet. See owner's manual located inside cabinet for installtion notes of Centronics Model 730-1 printer.

Emergency standby batteries within the master unit should be checked for functional service by one of the following methods:

- o Disconnecting the AC power cord.
- o Turning off the circuit breaker of the primary power source.

When the master control panel is operating on DC power only, a yellow power light will illuminate, the smoke and CO visual alarms and digital displays will operate normally, and the clock will stay functional. The observer should contact the mine electrical/instrumentation personnel to correct the cause of AC power failure.

NOTE

Automatic data logging discontinues when AC power is lost. Manual observation of sensor values is required. The function buttons, audible alarm, and printer do not operate on DC power.

4. Problems or Malfunctions

Contact mine electrical maintenance or instrumentation personnel for repair and service. This equipment is a new prototype design by USBM, ESD Corporation, and Aquatrol Corporation. Occasional repair and other design changes are anticipated. Cooperation to keep daily, weekly, and monthly observation and service is appreciated.

II. OPERATION AND MAINTENANCE (Alarm Condition)

The following notes assume that the audible horn is sounding, and lights are flashing on the mine graphic display and at the indicator panels on the Master Control Unit.

A. Observe the mine graphic drawing for a flashing light. This light relates to the general mine area and type of alarm:

- o A YELLOW LIGHT indicates a system problem or malfunction such as DATA FAIL (line broken or inoperative remote), POWER FAIL (loss of power at a remote), MASTER TELEMETRY FAIL (computer malfunction), or HEAT SENSOR FAIL (broken wire).
- o A RED LIGHT indicates a more serious situation such as SMOKE or CO (exceeded alarm setpoint values), FIRE PULL (manually activated), HEAT (overheat condition) or FAN OFF (fan at remote shaft has stopped).

B. Observe the lower alarm panels for another flashing red light to identify the specific problem and where it is located. Once located press that panel toggle switch to the left to SILENCE THE AUDIBLE ALARM. All lights will stop flashing, but remain on if the sensor remains in alarm.

C. If smoke or CO sensor lights were flashing and remained steady after silencing the audible alarm, move STATION SELECT thumbwheel to the station in alarm and observe the digital displays for SMOKE LEVEL and CO PPM LEVEL. The observer can watch the present value and rate of change occurring at the sensor. The display values are updated every 6 seconds.

- o If, after observing the display for a couple of minutes, the smoke is above 300 and steady or rising or CO is above 30 ppm and steady or rising, telephone the location area.

NOTE

These values are selected based on startup alarm setpoints of 250 for smoke and 25 for CO. Because of variable mine environments, alarm setpoints may change.

- o Telephone the shift superintendent if the smoke is above 300 or the CO is above 30 ppm, and either is increasing at a rate of approximately 1.0 percent per digital display cycle (i.e., smoke increases 3.0 and CO increases 0.3 ppm every 6 seconds).
- o Unlock and open the cabinet door, swing out the printer, turn key switch to ON, and depress PRINT SETPOINTS and then the 24 HOUR SUMMARY.
- o On the printout paper, observe and circle the alarm setpoint value of the sensor in alarm and review the graph of that sensor in alarm. Interpretation of the graph may be easier if all SMOKE (+ symbols) are connected, and all CO (* symbols) are connected to show two curves. Remember that a zero (0) symbol means that both the smoke and CO values are the same.
- o Determine if alarm was caused by a sharp rise in concentration over a short time or if rise was gradual over several hours.

CAUTION

A sharp rise indicates a local source condition that could be quickly growing. A slow rise indicates the source is at a greater distance away from the sensor or growth is slow. Spontaneous combustion exhibits slow increase in CO and smoke particles. However, a failing sensor head or a sensor drifting because of environmental contamination could also cause slow increases. A fast growing, flaming fire condition exhibits high smoke particle count but low carbon monoxide. However, arcing, welding, and other energy sources will exhibit high particles and low CO.

- o Write the cause for alarm (if determined) onto the graph.
- o Swing the printer back to its stored position.
- o Close and lock the door, and turn the key switch to OFF position.
- o Secure the keys.

D. FIRE PULL alarms are manually activated. The observer should telephone the area and inquire if the handle has actually been pulled or if a problem exists. Report any system malfunction to the program coordinator or mine electrical/instrumentation personnel.

HEAT alarms are caused either intentionally by test (person depressing test button on end-of-line resistor), accidentally from damage, or by an actual overheat condition. This alarm will stay on until the shorted-wire condition is repaired. The observer should telephone the area and determine the cause of the alarm. Report any system malfunction to the program coordinator or mine electrical/instrumentation personnel.

FAN OFF indications provide printed records (date and time) of each occurrence. Safeguards and backup devices built into the fan systems will start auxiliary diesel engines to power the fans and activate alarm devices to inform nearby personnel. A weekly record may be required by the program coordinator of all FAN OFF indications.

HEAT SENSOR FAIL is the result of an open-wire condition such as possible during a poor connection, roof falls, or accidental damage. Telephone the area identified and report the incident to the program coordinator or mine electrical/instrumentation personnel. The open-wire condition must be traced and repaired to remove the alarm.

DATA FAIL alarm means information is not being received by the master unit either as a result of the remote unit being disabled or the interconnecting wire being broken. Contact the program coordinator or mine electrical/instrumentation personnel.

POWER FAIL alarm indicates a loss of 110-volt AC power at any of the remote units or on the mster control unit. All units will continue to operate on standby 24-volt DC batteries for 10 hours; however, the printer will not function to record events, and the function buttons do not operate. Contact the program coordinator or mine electrical/instrumentation personnel.

This equipment is a new prototype design by USBM, ESD Corporation, and Aquatrol Corporation. Occasional repair and other design changes are anticipated. Cooperation to follow the above guidelines and procedures is appreciated.

- U.S. Department of the Interior
  Bureau of Mines
  Twin Cities Research Center
  5629 Minnehaha Avenue South
  Minneapolis, Minnesota 55417
  (612) 725-4500
  Mr. Steven J. Sampson

- ESD Corporation
  Engineered Systems Development
  600 Meridian Avenue
  San Jose, California 95126
  (408) 280-5000
  Mr. Ralph B. Stevens

- Aquatrol Corporation
  2258 Terminal Road
  St. Paul, Minnesota 55113
  (612) 636-3950
  Mr. William R. Cross

Appendix K

OPERATION AND MAINTENANCE MANUAL
SUMMARY

OPERATOR'S MANUAL
Coal Mine Shaft Fire and Smoke Protection System

CONTENTS

SECTION

SECTION	DESCRIPTION
I.	Blank sheets were provided to record set-up and calibration procedures adopted regarding the fire and smoke protection system.
II.	The Aquatrol Corporation telemetry control system summary and component data sheets included detailed explanations for system operation and option selection. The functional description provides information about the radio coupled remote shaft station, slope top station, slope bottom station, surface master control station, and the printer.
III.	The Becon C121B is a single-chamber combustion particle detector. It consists of a single shielded ionization chamber, a radioactive source, an ion-collecting electrode, and a current amplifier. It is manufactured by Wormald International.
IV.	The Dynamation 2301 carbon monoxide analyzer uses a solid state Tagushi Gas Sensor. It has a detection range of 0 to 300 parts per million.
V.	The Ecolyzer 4125 carbon monoxide analyzer uses an electrochemical cell with mechanical pump. Made by Energetics Science, a Division of Becton Dickinson and Company, this unit has a range of 0 to 50 parts per million.
VI.	The Ecolyzer 5100 carbon monoxide analyzer is a new design for an electrochemical cell which eliminates the need for a pump.
VII.	The MSA 571 carbon monoxide analyzer uses an electrochemical cell that does not use a pump. It is manufactured by Mine Safety Appliance Company.
VIII.	The Protectowire WPP-155 heat sensor is a continuous line-type thermal fire detector. It detects fire when heat over 155° F melts the insulation over the conductors strung throughout the fire hazard area. Consequently, the conductors "short out" which indicates the presence of fire.
IX.	Vendor drawings and schematics can be kept here.

Appendix L

SAMPLE FORMS FOR REQUESTING MSHA INVESTIGATIONS

UPDATED APPLICATIONS PROCEDURES FOR APPROVALS, CERTIFICATIONS, INTRINSIC SAFETY APPROVALS, AND INTRINSIC SAFETY EVALUATIONS UNDER PART 18, 30 CFR

Approval and Certification Center
Division of Electrical Safety
November 13, 1979
Revised January 31, 1980

APPLICATION PROCEDURES FOR
APPROVAL AND CERTIFICATION ACTIONS
Part 18, 30 CFR

The increasing number of applications for approval and certification actions, dictates that we reduce the time spent processing these actions. One area of major concern is the inadequacy and incompleteness of the submitted applications. Considerable time can be saved if the applications include all the required information necessary to ascertain compliance with Title 30 Mineral Resources, Code of Federal Regulations (30 CFR), Part 18.

A copy of 30 CFR can be purchased from:

Superintendent of Documents
U.S. Government Printing Office
Washington, D.C. 20402
Telephone No. (202) 7833238

Before making application for approval or certification, Part 18 of 30 CFR should be reviewed carefully.

Effective February 1, 1980 applications must include the following:

1. The appropriate application form (See enclosures A-1 through A-4). These forms are basically self-explanatory. However, it should be noted that the company application code number is a number containing six (6) or fewer numeric characters assigned by the applicant to identify the subject application (See enclosure A-5). The person to contact, referenced at the end of the application form, is the applicants' representative responsible for answering any questions regarding the subject application.

2. A drawing list in the proper format (See enclosures A-6 through A-8). The drawing list is a complete list of drawings, bills of material, and specifications which show the details of design and construction of the equipment as related to the applicable requirements of 30 CFR, Part 18.

3. The appropriate check list, completed and signed (See enclosures A-9 and 1((Note: The original should be submitted, not a copy.) The check list is a list of basic information needed to evaluate the subject application with regards to the applicable requirements of 30 CFR, Part 18. All items appearing on the check list(s) must be properly documented on/with drawings and specifications. When acceptance of an electrical enclosure(s) that has not been previously certified or accepted, is necessary to process an approval action, a check list (Enclosure A-9) must be completed for each enclosure and must be submitted along with the machine check list.

   It should be noted that all requirements of 30 CFR, Part 18 pertaining to each enclosure/machine may not be included on the check list and additional information therefore may be required.

The portion of the check lists labeled "administrative" will be given a preliminary review when the application package is received. If any deficiencies are noted, the applicant will receive a form letter (See Enclosure A-13) indicating the areas where the deficiencies were noted. If the subject discrepancies are not corrected and resubmitted before the technical review is initiated, the application will be cancelled and the entire package will be returned to the applicant.

4. All new and/or revised drawings, bills of material and specifications. The drawings shall be adequate in number and detail to identify fully the complete assembly, component parts, and subassemblies for both approval and certification applications. In addition, for certification applications, the assembly drawing of the electrical enclosure should include: a) locations and identification by drawing number all component parts, b) sections to depict flame arresting paths where necessary, c) cable entrances, d) other pertinent details.

NOTE:

Fees are not to be submitted with the application. (See enclosure A-11).

In order to facilitate the processing of an application, it is essential that all the information requested be furnished. Assistance through technical consultations is available by appointment. Incomplete applications will result in unnecessary delay and possible cancellation of the application request.

NEW CERTIFICATION APPLICATION LETTER

Director, Approval and
Certification Center
RR #1, Box 201B
Industrial Park Blvd.
Triadelphia, WV 26059

Company and Address: ____________
____
____

Date: __________________________

Subject: New Certification of the ______________________________,
(Model or Type)

______________________, ______________________________,
(Electrical Rating) (Enclosure)

Company Application Code No.: ______________________

Gentlemen:

We are requesting certification of the subject enclosure built according to ____.
(Assembly, Bill of Material, etc.)

Choose one:

_________ This is a new design and a prototype will be available for inspection and explosion tests.* Please advise us in advance of the assigned testing date.

_________ This is a new design, however, we would like the inspection and explosion tests* waived, based on its similarity to the __________________________ inspected and tested under
(Model or Type) (Enclosure)
Inv. MR-________________, Certification No. __________-____(ext.)
letter dated __________________.

* For non-explosion proof enclosures only inspection applies.

(Brief description of design features and unusual areas).
(If more space is needed use additional sheet).

(Enclosure A-1)
(Sht.1)

Enclosed are all the new and/or revised drawings and specifications pertinent to this application.

If there are any questions, please contact ______________________
(Mr./Ms.)

at ______________________.
(Telephone No.)

Sincerely yours,

(Enclosure A-1) (Sht. 2)

NEW CERTIFICATION APPLICATION LETTER

Sample

Director, Approval and
Certification Center
RR #1, Box 201B
Industrial Park Blvd.
Triadelphia, WV 26059

Company and Address: XYZ Company
Box 123
Pittsburgh, PA 15298

Date: March 23, 1979

Subject: New Certification of the Model 5000 (Model or Type), 250 volt D.C. (Electrical Rating), Starter (Enclosure),

Company Application Code No.: 100001

Gentlemen:

We are requesting certification of the subject enclosure built according to Assembly Drawing D-5000 (Assembly, Bill of Material, etc.).

Choose one:

______ This is a new design and a prototype will be available for inspection and explosion tests.* Please advise us in advance of the assigned testing date.

X This is a new design, however, we would like the inspection and explosion tests* waived, based on its similarity to the Model 4000 Starter (Model or Type) (Enclosure) inspected and tested under Inv. MR-9800, Certification No. X/P-6002 - 0 (ext.) letter dated January 30, 1979.

* For non-explosion proof enclosures only inspection applies.

(Brief description of design features and unusual areas).
(If more space is needed use additional sheet).

The subject enclosure has the same basic design and configuration of the Model 4000 enclosure, however, it is two inches shorter in length and three inches shorter in width, resulting in a 10% decrease in internal volume. In addition, the case is machined to accommodate four packing gland assemblies, instead of six.

(Enclosure A-1)
(Sht. 3)

Enclosed are all the new and/or revised drawings and specifications pertinent to this application.

If there are any questions, please contact Mr. John R. Smith
(Mr./Ms.)

at (412) 366-2000. .
(Telephone No.)

Sincerely yours,

(Enclosure A-1) (Sht. 4)

EXTENSION OF CERTIFICATION APPLICATION LETTER

Director, Approval and
Certification Center
RR #1, Box 201B
Industrial Park Blvd.
Triadelphia, WV 26059

Company and Address: ____________

____

____

Date: __________________________

Subject: Extension of Certification No. X/P-________, Inv. MR-________,
________________________, ________________________,
(Model or Type) (Electrical Rating)
________________________.
(Enclosure)

Company Application Code No: ____________________

Gentlemen:

We are requesting an extension of certification of the subject enclosure built according to ______________________________.
(Assembly, Bill of Material, etc.)

This enclosure is similar to the ______________________________
(Model or Type) (Enclosure)
built according to ______________________________ and
(Assembly, Bill of Material, etc.)
certified under Inv. MR-____________, Certification No. ______-____(ext.),
letter dated ________________, except as follows (Itemize):
(If more space is needed, use additional sheet)

Enclosed are all the new and/or revised drawings and specifications pertinent to this application.

If there are any questions, please contact ______________________
(Mr./Ms.)
at ____________________.
(Telephone No.)

Sincerely yours,

(Enclosure A-2)
(Sht. 1)

EXTENSION OF CERTIFICATION APPLICATION LETTER

Sample

Director, Approval and
Certification Center
RR #1, Box 201B
Industrial Park Blvd.
Triadelphia, WV 26059

Company and Address: XYZ Company
Box 123
Pittsburgh, PA 15298

Date: March 23, 1979

Subject: Extension of Certification No. X/P- 6002 , Inv. MR- 8920 ,
Frame 365 (Model or Type), 40 HP, 440-Volt, 3-Phase, 60 Hertz, AC (Electrical Rating)
Motor (Enclosure).

Company Application Code No: 100002

Gentlemen:

We are requesting an extension of certification of the subject enclosure built according to Bill of Material M-365 (Assembly, Bill of Material, etc.).

This enclosure is similar to the Frame 365 A-C Motor (Model or Type) (Enclosure) built according to Bill of Material M-365A (Assembly, Bill of Material, etc.) and certified under Inv. MR- 8920 , Certification No X/P-6000- 5 (ext.), letter dated February 13, 1979 , except as follows (Itemize):
(If more space is needed, use additional sheet)

1. A D-flange bracket replaces the standard bracket at the Back End.

2. A new bearing cap is used at the Back End to accomodate a No. 310 bearing instead of a No. 308.

3. A new shaft is used to accommodate the No. 310 bearing.

Enclosed are all the new and/or revised drawings and specifications pertinent to this application.

If there are any questions, please contact Mr. Joe Brown (Mr./Ms.)
at (412) 366-0001 (Telephone No.).

Sincerely yours,

(Enclosure A-2)
(Sht. 2)

APPROVAL APPLICATION LETTER

Director, Approval and
Certification Center
RR #1, Box 201B
Industrial Park Blvd.
Triadelphia, WV 26059

Company and Address: ____________

____

____

Date: ______________________

Subject: New Approval of the ______________________________,
(Model or Type)

______________________, ______________________________.
(Electrical Rating) (Machine)

Company Application Code No.: ______________________

Gentlemen:

We are requesting approval of the subject machine built according to
____.
(Layout, Bill of Material, Assembly)

The subject machine consists of: (Brief description of machine)
(If more space is needed use additional sheet.)

It is unusual in the following area(s), (Itemize):

(Choose one):

____ This is a new design and a prototype will be completely assembled and available for inspection on ____________ (Date), at ____________ (Location).

____ This is a new design, however, we would like the factory inspection waived due to its similarity to the ____________ (Model or Type), __________ (Machine), inspected under Approval No. ____________, Inv. MR-____________ letter dated ______________.

(Enclosure A-3)
(Sht.1)

Enclosed are all the new or revised drawings pertinent to this application. If there are any questions, please contact ______________________ at
(Mr./Ms.)

______________________.
(Telephone No.)

Sincerely,

APPROVAL APPLICATION LETTER

Sample

Director, Approval and
Certification Center
RR #1, Box 201B
Industrial Park Blvd.
Triadelphia, WV 26059

Company and Address: XYZ Company
Box 123
Pittsburgh, PA 15298

Date: March 23, 1979

Subject: New Approval of the Model 100 (Model or Type), 950 Volt, 3 Ph, 60 Hz, AC (Electrical Rating) Roof Bolter (Machine).

Company Application Code No.: 200001

Gentlemen:

We are requesting approval of the subject machine built according to Electrical Layout and Bill of Material 100 (Layout, Bill of Material, Assembly).

The subject machine consists of: (Brief description of machine)
(If more space is needed use additional sheet.)

(2) 125 HP, 950 V, AC Motors, (1) 950 V AC Starter, (3) Pushbutton Stations, and (1) #2/0 Trailing Cable.

The above enclosures have all been previously certified.

It is unusual in the following area(s), (Itemize):

N/A

(Choose one):

X This is a new design and a prototype will be completely assembled and available for inspection on May 10, 1979 (Date), at our plant in Pgh. (Location).

____ This is a new design, however, we would like the factory inspection waived due to its similarity to the ________ (Model or Type), ________ (Machine), inspected under Approval No. ________, Inv. MR-________ letter dated ________.

(Enclosure A-3)
(Sht. 3)

Enclosed are all the new or revised drawings pertinent to this application. If there are any questions, please contact Mr. John Smith (Mr./Ms.) at (412) 366-0001 (Telephone No.).

Sincerely,

(Enclosure A-3)
(Sht. 4)

EXTENSION OF APPROVAL

Director, Approval and
Certification Center
RR #1, Box 201B
Industrial Park Blvd.
Triadelphia, WV 26059

Company and Address: ____________

____

____

Date: ____________________

Subject: Extension of Approval, No. 2G-____________, Inv. MR-________;
________________________, ________________________,
(Model or Type) (Electrical Rating)
________________________.
(Machine)

Company Application Code No.: ____________________

Gentlemen:

We are requesting extension of approval of the subject machine built according to ____.
(Layout, Bill of Material, Assembly)

This machine is similar to the ____
(Model or Type) (Machine)
built according to ____,
(Assembly, Bill of Material, Layout)
Approval No. 2G-__________-_____(ext.), Inv. MR-________________,
letter dated ______________, except as follows:
(If more space is needed, use additional sheet.)

Enclosed are all the new or revised drawings and specifications pertinent to this application.

If there are any questions, please contact ______________________ at
(Mr./Ms.)
________________________.
(Telephone No.)

Sincerely yours,

(Enclosure A-4)

(Sht. 1)

EXTENSION OF APPROVAL

Director, Approval and
Certification Center
RR #1, Box 201B
Industrial Park Blvd.
Triadelphia, WV 26059

Company and Address: XYZ Company
Box 123
Pittsburgh, PA 15298

Date: March 23, 1979

Subject: Extension of Approval, No. 2G- 7201, Inv. MR- 9899;
Type 440 AC (Model or Type), 440 Volt, 3 Phase, 60 Hertz, A-C (Electrical Rating),
Pump Assembly (Machine).

Company Application Code No.: 200002

Gentlemen:

We are requesting extension of approval of the subject machine built according to Bill of Material and Assembly D-440 AC (Layout, Bill of Material, Assembly).

This machine is similar to the Type 575A Pump Assembly (Model or Type) (Machine) built according to Bill of Material and Assembly D-575 AC (Assembly, Bill of Material, Layout), Approval No. 2G- 7201 - 0 (ext.), Inv. MR- 9899, letter dated February 14, 1979 except as follows:
(If more space is needed, use additional sheet.)

1. Different voltage rating, (From 550 to 440 volt A-C).

2. Lower horsepower rating, (From 50 Hp. to 50 Hp).

Enclosed are all the new or revised drawings and specifications pertinent to this application.

If there are any questions, please contact Mr. John Smith (Mr./Ms.) at (312) 366-9688) (Telephone No.).

Sincerely yours,

(Enclosure A-4)
(Sht. 2)

U.S. DEPARTMENT OF LABOR
MINE SAFETY AND HEALTH ADMINISTRATION
APPROVAL AND CERTIFICATION CENTER
R. R. 1, Box 201B
Industrial Park Blvd.
Triadelphia, West Virginia 26059

MEMORANDUM FOR: ALL INTERESTED PARTIES

Steve Sawyer

FROM: STEPHEN G. SAWYER
Director, Approval and Certification Center

SUBJECT: Company Assigned Application Number

Because all Approval and Certification actions have been computerized, we need your cooperation in identifying your request. Each application to the Approval and Certification Center shall be identified by a Company Assigned Application Number. That number shall contain six(6) or fewer numeric characters and shall appear on the initial application and on all subsequent correspondence. Any application that is received without an identifying number will be returned to the sender without further action by the Approval and Certification Center.

(Enclosure A-5)

DRAWING LIST FORMAT FOR
ENCLOSURE CERTIFICATION OR EXTENSION OF CERTIFICATION

Investigation MR-__________

Drawing List

(Company Name) (Type or Model)
(Electrical Rating) (Kind of Enclosure)
Built According to (Bill of Material,
Assembly Drawing No., Parts List, etc.)
(Extension of) Certification No. _______

EXAMPLE:

Investigation MR-9800

Drawing List

XYZ Co. Model 5000, 240-volt D.C. Starter Enclosure
Built According to Assembly Drawing D-5000
Certification No. X/P-_____

Title	Drawing No.	Part, Item Group, etc. No.	Revision No. Engineering Change No. Revision Date etc.
Bill of Material			
Assembly Drawing			
Case (Machining)			
Case Weldment			
Details			
Shaft Assy. (2)			
Bushing			
Shaft			
Pushbutton Assy. (4)			
Cover (Machining)			
Cover Plate			
Shaft Assy. (2)			
Pushbutton Assy. (2)			

(Enclosure A-6)(Sht.1)

Title	Drawing No.	Part, Item Group, etc. No.	Revision No. Engineering Change No. Revision Date etc.
Bushing	____	____	____
Push Rod	____	____	____
Lens Assy. (5)	____	____	____
Mounting Flange (Opt.)	____	____	____
Receptacle Assy. (Opt.)	____	____	____
Handhole Cover	____	____	____
Panel Board	____	____	____
Certification Plate	____	____	____
Cable (1.062"-1.302" O.D.) Gland Assy. (2)			
Packing Gland Assy.	____	____	____
Nipple	____	____	____
Bushing	____	____	____
Gland Nut	____	____	____
Packing 3/8"			
Cable Gland-Plugged			
Nipple	____	____	____
Plug (Tackwelded)	____	____	____
(Alt.) Cable (1.390"-1.536" O.D.) Gland Assy. (3)			
Nipple	____	____	____
Bushing	____	____	____
Gland Nut Assy.	____	____	____
Gland Nut	____	____	____
Hose Tube	____	____	____
Packing 1/4"			

(Enclosure A-6)(Sht.2)

DRAWING LIST FORMAT FOR
MOTOR CERTIFICATION OR EXTENSION OF CERTIFICATION

Investigation MR-______

Drawing List

(Company Name) (Type or Model)
(Electrical Rating) (Kind of Enclosure)
Built According to (Bill of Material,
Assembly Drawing No., Parts List etc.)
(Extension of) Certification No. X/P-______

EXAMPLE:

Investigation MR-______

Drawing List

XYZ Co. Frame 365, 40 HP, 440 Volt, 3 Phase,
60 Hertz, 53 amps. FLA, A-C Motor
Built According to Bill of Material M-365A
Certification No. X/P-______

Title	Drawing No.	Part, Item Group, etc. No.	Revision No. Engineering Change No. Revision Date, etc.
Bill of Material	______	______	______
Assembly Drawing	______	______	______
Frame Machining	______	______	______
Frame Weldment	______	______	______
Front End Bracket	______	______	______
Bracket Casting	______	______	______
Back End Bracket	______	______	______
Bracket Casting	______	______	______
Front End Bearing Cap	______	______	______
Rear End Bearing Cap	______	______	______
Bearing Cap Casting	______	______	______
Shaft	______	______	______
Main Pole Assy. (D.C. only)	______	______	______

(Enclosure A-7)(Sht.1)

Title	Drawing No.	Part, Item Group, etc. No.	Revision No. Engineering Change No. Revision Date, etc.
Inter Pole Assy. (D.C. only)			
Handhole Cover (2)			
Fan Outer			
Certification Plate			
Pipe Nipple-Cond. Box			
Conduit Box Machining			
Conduit Box			
Conduit Box Cover			
Cable (1.062"-1.302" O.D.) Gland Assy.			
Gland Adapter			
Bushing			
Gland Nut			

Packing - 3/8"
(Ref.) Motor Cable, 3/C-#6, PCG, 1.18" O.D.)

NOTE:

Since these are drawing lists for specific enclosures and are only offered as examples of the format to be used, the drawings listed may not be representative of your enclosure, and should be modified accordingly.

The drawing list you submit should contain the basic drawing number in its designated column, the part, item, group, etc. number if applicable in its designated column, if not applicable a dash in this column will be acceptable; and the latest revision number or date, or engineering change, etc. in its designated column.

You will note in the title column some titles are indented under others. If there is a need to specify a drawing that is referenced on another drawing it should be indented under the drawing that references it. In addition the quantity (if more than one) of the item listed should follow the title of the item in the title column.

EXAMPLE: Handhole Cover (2)

If the item is an alternate (meaning an item used in place of a previously specified item) or optional (meaning an item which may or may not be used) it should be so designated.

DRAWING LIST FORMAT FOR
MACHINE APPROVAL OR EXTENSION OF APPROVAL

Investigation MR-_____

Drawing List

(Company Name) (Type or Model No. of Machine)
(Electrical Rating) (Kind of Machine)
Built According to (Bill of Material
and/or Assembly Drawing No.)
Maximum Tramming Speed - (______)
(Extension of) Approval No. 2G-_____

EXAMPLE:

Investigation MR-_____

Drawing List

XYZ Company Model 100, 950 V.
3 Ph., 60 Hz., AC Roof Bolter
Built According to Assembly Drawing D100
Maximum Tramming Speed - 1 MPH
Approval No. 2G-______

Title	Drawing No.	Part, Item Group, etc. No.	Revision No. Engineering Change No. Revision Date etc.
Assembly Drawing	______	______	______
Bill of Material	______	______	______
Wiring Diagram	______	______	______
Schematic Diagram	______	______	______
Cable Reel Guide Assembly	______	______	______
Cable Guide	______	______	______
Cable Guide Insulator	______	______	______
Cable Reel Spooling Device Assembly	______	______	______
Roller (2)	______	______	______
Trailing Cable Strain Clamp	______	______	______

(Enclosure A-8) (Sht. 1)

Title	Drawing No.	Part, Item Group, etc. No.	Revision No. Engineering Change No. Revision Date etc.
Insulator Block (2)			
(Alternate) Trailing Cable Strain Clamp			
Insulator Block (2)			
(Optional) Headlight Guard (2)			
Caution Statement			
Factory Inspection Form			

NOTE:

The preceding portion of the drawing list can be termed the general portion. It should contain all drawings pertinent to schedule requirements that are not listed with a specific electrical enclosure. Since this list is only offered as an example of the format to be used the items listed in the general portion may not be representative of your machine and should be modified accordingly.

The drawing list you submit should contain the basic drawing number in its designated column; the part, item, group, etc. number if applicable in its designated column, if not applicable a dash in this column will be acceptable; and the latest revision number or date, or engineering change, etc. in its designated column.

You will note in the title column some titles are indented under others. If there is a need to specify a drawing that is referenced on another drawing it should be indented under the drawing that references it. In addition the quantity (if more than one) of the item listed should follow the title of the item in the title column.

EXAMPLE: Insulator Block (2)

If the item is an alternate (meaning an item used in place of a previously specified item) or optional (meaning an item which may not be used) it should be so designated. These practices should be followed throughout your drawing list where applicable.

NOTE:

The following format should be used when identifying the electrical enclosures on the machine.

Electrical Enclosures

(Company Name) (Type or Model No. of Enclosure) (Electrical Rating) (Kind of Enclosure) (Quantity)

Drawing list the same as listed for the (original issuance) (or) (No. of Extension) of Certification No. X/P-(__________) letter of certification dated (________________).

EXAMPLE:

XYZ Company, Model 201, 950 V., 3 Ph., 60 Hz., AC Starter (2)

Drawing list the same as listed for the 1st extension of Certification No. X/P-9001, letter of certification dated January 30, 1979.

NOTE:

If an enclosure is being accepted as part of the approval action and not an independent certification action, it should be listed in a format similar to the one for a standard controller which follows.

(Company Name) (Type or Model No. of Enclosure) (Electrical Rating) (Kind of Enclosure) (Quantity)

EXAMPLE:

XYZ Company, Type 5-3-1 950 V, AC, 3 Ph, 60 Hz, AC Starter (1)

Title	Drawing No.	Part, Item Group, etc. No.	Revision No. Engineering Change No. Revision Date etc.
Assembly Drawing			
Bill of Material			
Case (Machined)			
Case (Weldment)			
Support Detail			
Panel Board			
Case Cover			
Pushbutton Assembly (4)			
Pushbutton Shaft			
Inspection Cover (2)			
(Alternate) Inspection Cover (2)			
Breather Assembly			
Breather Details			
Gland Assembly (For Reel Cable)(Cable Range-)			
Gland Nut			
Gland Assembly (2) (For Tram Motor Cable)(Cable Range-)			
Gland Nut			
(Alternate) Gland Assembly (2) (For Tram Motor Cable) (Cable Range-)			

Title	Drawing No.	Part, Item Group, etc. No.	Revision No. Engineering Change No. Revision Date etc.
Gland Assembly (For Headlight Cord) (Cable Range-)			
Gland Nut			
(Optional) Gland Assembly (For Pushbutton Cord)(Cable Range-)			
Gland Nut			

Reel Cable - (No. of Conductors) (Size of Conductors) (Type of Cable) (Outer Diameter)

(2) Motor Cable - (Same information as for reel cable)

(Alternate) (2) Motor Cable - (Same information as for reel cable)

Headlight Cord - (Same information as for reel cable)

(Optional) Pushbutton Cord - (Same information as for reel cable)

NOTE:

Any optional or alternate items should be listed either directly after each standard item or altogether after the standard items.

The trailing cable information should be listed at the end of the drawing list and should include its size, type, electrical rating, maximum length, overload protection, conductor temperature rating, type of insulation, and the fact it is flame-resistant.

EXAMPLE:

Trailing cable - 500 feet maximum length 3C #2 Type "G-GC" Round 2KV Volt, Flame-resistant (1.55" O.D.) 60o, neoprene; protected by an instantaneous trip circuit breaker set at 800 amp.

CERTIFICATION/EXTENSION OF CERTIFICATION CHECK LIST

Complete the following; leave no blanks. If a particular item does not apply, use the designation N/A.

Administrative

_____ 1. Is the appropriate application form properly completed?

_____ 2. Is a drawing list in the proper format included in the application package?

_____ 3. Are all correspondence, specifications and lettering on drawings in English? (Sec. 18.6, (l))

_____ 4. Are all drawings and Bills of Material titled, numbered, dated and legible? (Sec. 18.6, (e))

_____ 5. Are there any pencil or ink notations on the drawings and Bills of Materials? (Note: Pencil and ink notations are unacceptable for specifications).

_____ 6. Do all documents include a note "Do not change without approval of MSHA" on each page or sheet? (Sec. 18.6 (e)) (See Enclosure A-12)

Investigative

_____ 7. Do all revised drawings and Bills of Material show the latest revision and/or date? (Sec. 18.6 (e))

_____ 8. Is the internal free volume specified on the enclosure assembly drawing? (Sec. 18.31)

_____ 9. Is the factory inspection form, which is used to maintain quality control at the place of manufacture, included with the application? (Sec. 18.6 (k))

_____ 10. Is the certification plate design included with the application and the method of attachment specified? (Sec. 18.13)

_____ 11. Do all machining and casting drawings specify tolerances? (Sec. 18.6 (e))

_____ 12. Do all machining and casting drawings specify the material? (Sec. 18.6 (e))

_____ 13. Do all weldment drawings include specifications for the size and type of welds and the statement "All welds made in accordance with American Welding Society Standards"? (Sec. 18.31 (a) (2))

_____ 14. Do all surfaces, plane and cylindrical, comprising flame-arresting paths on machining drawings include surface finish and maximum deviation (planarity) specifications? (Sec. 18.33)

_____ 15. Are all purchased parts identified by the manufacturers name, drawing number, and rating if applicable? (Sec. 18.6 (e))

_____ 16. Does the notation "Do Not Drill Through" or equivalent appear on all drawings with the specifications for all blind holes? (Sec. 18.6 (e))

_____ 17. Are all standard hardware and miscellaneous parts, such as insulating pieces, specified with respect to size and kind of material? (Sec. 18.6 (e))

_____ 18. Are the size, type and grade of bolts for fastening flame-arresting path parts specified? (Sec. 18.32)

_____ 19. Are the size and thickness of lockwashers used under fastening bolts specified? (Sec. 18.32)

_____ 20. Do all drawings which specify holes for fastening bolts include the method of removing burrs or projections that affect the planarity of the surface forming a flame arresting path? (Sec. 18.31)

_____ 21. Are cable ranges or cables including tolerances specified for all packing gland assemblies?

_____ 22. Are all packing gland nuts and stuffing boxes secured against loosening? (Sec. 18.37 (c))

_____ 23. Are all unused lead entrances plugged and tackwelded accordingly? (Sec. 18.29 (c))

_____ 24. Are all drawings of component parts submitted to MSHA identical to those used in the manufacture of the parts? (Sec. 18.6 (e))

NOTE: Items 25 thru 31 apply to battery boxes and batteries (exceeding 12 volts) only.

_____ 25. Are all material thicknesses specified including: cover, tray, covers/vents and receptacle compartment? (Sec. 18.44 (a))

_____ 26. Are the battery box covers lined with a flame-resistant insulating material?

_____ Does the material meet the flame-resistant requirements of 30 CFR, 18.65? (Sec. 18.44 (b))

_____ Is the MSHA I.D. number specified? (If applicable)

_____ 27. Are the battery box covers provided with a means for securing them in a closed position? (Sec. 18.44 (c))

(Enclosure A-9)(Sht.2)

_____ 28. Are drainage holes provided in the bottom of each battery box? (Sec. 18.44 (f))

_____ 29. Are the cables secured and are they positioned to guard against abrasion? (Sec. 18.44 (i))

_____ 30. If the connector is not mounted on the tray, is the length of cable from the tray to the connector specified? (Sec. 18.44 (j))

_____ 31. Is the total weight of the battery and tray, charged and ready for service, listed on the assembly drawing? (Sec. 18.44 (a))

____
(Signature)

_______________________ _______________________
(Title) (Date)

(Enclosure A- 9 (Sht. 3)

APPROVAL/EXTENSION OF APPROVAL CHECKLIST

Complete the following; leave no blanks. If a particular item does not apply, use the designation N/A.

Administrative

_____ 1. Is the appropriate application form properly completed?

_____ 2. Is a drawing list in the proper format included in the application package?

_____ 3. Are all correspondence, specifications and lettering on drawings in English? (Sec. 18.6, (l))

_____ 4. Are all drawings and Bills of Material titled, numbered, dated and legible? (Sec. 18.6 (e))

_____ 5. Are there any pencil or ink notations on the drawings and Bills of Material? (Note: Pencil and ink notations are unacceptable for specifications).

_____ 6. Do all documents include a note "Do not change without approval of MSHA" on each page or sheet? (Sec. 18.6 (e)) (See Enclosure A-12)

Investigative

_____ 7. Do all revised drawings and Bills of Material show the latest revision and/or date? (Sec. 18.6 (e))

_____ 8. Do all wiring diagrams showing intrinsically safe circuits include a warning statement that any change(s) in the intrinsically safe circuitry or components may result in an unsafe condition? (Sec. 18.6 (e))

_____ 9. Is the maximum tramming speed specified?

10. Does the assembly drawing include:

_____ a. The overall dimensions;

_____ b. Location and/or position of all electrical enclosures and;

_____ c. Cable and hose routing (including clamping)? (Sec. 18.6 (e))

11. Is each electrical enclosure fully identified either on the assembly drawing or on a separate Bill of Material as to

_____ a. Manufacturer;

_____ b. Model Number and type of enclosure;

_____ c. Electrical rating;

_____ d. Certification number or the approval number under which it was accepted and,

_____ e. Quantity. (Sec. 18.6 (e))

(Enclosure A-10)

_____ 12. Is guarding for moving parts shown? (Sec. 18.20 (c))

13. If the maximum tramming speed of the machine is greater than 2.5 mph:

_____ a. Is an audible warning device specified? (Sec. 18.20 (e))

_____ b. Are headlight and red light-reflecting material specified for both front and rear of the machine? (Sec. 18.20 (g))

_____ c. Is a cable reel provided if the machine is powered with a trailing cable? (Sec. 18.45 (a))

_____ 14. If the machine is mobile, is red light-reflecting material specified for each end of the machine? (Sec. 18.20 (g))

_____ 15. If the machine is wheel mounted, does the design of the driving mechanism preclude accidental movement when parked? If not,
_____ are parking brakes specified? (Sec. 18.20 (f))

_____ 16. If the machine is equipped with a powered dust collector is the 25B Approval Number (for the dust collector) specified? (Sec. 18.21)

_____ 17. If the machine is a boring type continuous miner, is a view shown depicting the 200 square inch cross-sectional area for auxiliary face ventilation? (Sec. 18.22)

_____ 18. Is it specified that all V-Belts are "static conducting" as as per RMA Bulletin No. 3, Edition 2, approved 1972, Power Transmission Belt Technical Bulletin? (Sec. 18.26)

_____ 19. Is strain relief specified for the trailing cable(s) and any remote cables/cords? (Sec. 18.40)

20. Is the following information specified for the trailing cable? (Sec. 18.35)

_____ a. Conductor size.

_____ b. Number of Conductors.

_____ c. Type.

_____ d. Electrical rating.

_____ e. Outer diameter.

_____ f. Statement that the cable is flame-resistant.

_____ g. The outby short circuit protection.

_____ h. Conductor temperature rating.

_____ i. Type of insulation.

_____ j. Maximum length.

_____ 21. If the maximum length of the trailing cable exceeds 500 feet, is the maximum inrush current specified? (Sec. 18.35 (a-5))

22. Is the following information specified for all intercomponent cables/cords? (Sec. 18.36)

_____ a. Conductor size.

_____ b. Number of conductors.

_____ c. Type.

_____ d. Electrical rating.

_____ e. Outer diameter.

_____ f. Statement that the cable/cord is either flame-resistant or enclosed in flame-resistant hose conduit.

23. Does the wiring/schematic diagram include the following:

_____ a. All short circuit protection (including ratings and settings) (Sec. 18.51)

_____ b. All overcurrent protection (including ratings and settings) (Sec. 18.51)

_____ c. Identification of all intrinsically safe circuits by manufacturer, model number, investigation number and date?

_____ d. The Peak Inverse Voltage and forward current ratings (for diode grounding).

_____ e. Primary and secondary transformer voltages.

_____ f. Voltage rating.

_____ 24. Are the placement and method of attachment of the approval plate specified? (Sec. 18.11 (b))

_____ 25. Are a complete factory inspection form and caution statement specified and included in the application package (if not previously accepted)? (18.6 (j&k))

_____ 26. Are all purchased parts identified by the manufacturer's name, drawing number, and rating if applicable? (Sec. 18.6 (e))

____
(Signature)

____
(Title)

____
(Date)

(Enclosure A-10)(Sht.3)

U.S. DEPARTMENT OF LABOR
MINE SAFETY AND HEALTH ADMINISTRATION
APPROVAL AND CERTIFICATION CENTER
R. R. 1, Box 201B
Industrial Park Blvd.
Triadelphia, West Virginia 26059.

Applicants for Approvals, Certifications, or Acceptances:

The Mining Safety and Health Administration, Approval and Certification Center is in the process of revising the Schedules of Fees charged for conducting approval, certification, and acceptance investigations, and for changing the procedures by which those fees are collected. Until the Schedules of Fees can be changed, some interim administrative procedures will be implemented to improve the Center's operating efficiency.

EFFECTIVE IMMEDIATELY CHECKS ARE NO LONGER REQUIRED TO BE SUBMITTED WITH AN APPLICATION. ANY CHECKS RECEIVED WITH AN APPLICATION WILL BE RETURNED.

MSHA will notify the applicant at the completion of the investigation. Included with the notification (approval letter, extension, rejection, or cancellation acknowledgement etc.) will be a fees disposition page. This page will state the total amount of the fee charged for conducting the investigation. Upon receipt of the fee disposition page the applicant credited to the proper account, the company assigned application number and the Approval and Certification Center assigned PAR number must appear on the check.

This check should be made payable to MSHA and sent to the Mining Safety and Health Administration, Branch of Finance, Denver Federal Center, P.O. Box 25367, Denver, Colorado 80225.

There will be no change to the amount of fees charged for conducting an investigation.

Please direct questions concerning these procedures to Mr. Daniel Dancu at 304-547-0400, extension 72.

Sincerely,

Stephen G. Sawyer, Ph.D.
Director, Approval and Certification Center

(Enclosure A-11)

U.S. DEPARTMENT OF LABOR
MINE SAFETY AND HEALTH ADMINISTRATION
APPROVAL AND CERTIFICATION CENTER
Box 201B, Route 1
Industrial Park Road
Triadelphia, West Virginia 26059

April 6, 1978

MEMORANDUM FOR: All Interested Parties

FROM: STEPHEN G. SAWYER
Chief, Approval and Certification Center

SUBJECT: Change in Approval, Certification, and Acceptance Labels or Markings

As per the Federal Register, Vol. 43, No. 58 - Friday, March 24, 1978, Part 1 of Title 30, Code of Federal Regulations, has been amended to reflect the Mining Enforcement and Safety Administration's (MESA's) transfer from the Department of Interior to the Department of Labor as the Mine Safety and Health Administration (MSHA). A salient effect of said amendment is that all approval, certification and acceptance labels or markings issued or permitted by the Approval and Certification Center must henceforth reflect said change. Present labels or markings can be updated by the following changes where applicable: replace "MESA" with "MSHA"; replace "Department of Interior" with "Department of Labor"; replace "Mining Enforcement and Safety Administration" with "Mine Safety and Health Administration"; replace the MESA logo with the MSHA logo. The MSHA logo is shown below.

All components, equipment, instruments, products, etc., for which an approval, certification, acceptance, or extension thereto, has been or will be issued by the Approval and Certification Center, shall have labels and markings that reflect MSHA, Department of Labor.

Present inventories of "old" labels or markings can be used until exhausted, but not after March 9, 1979, the one year birthday of MSHA. Components, equipment, instruments, products, etc., already in the field do not have to be recalled for updated labeling. If you have any questions feel free to contact Mr. Frank Lee, Principal Electrical Engineer, (304) 547-0400, ext. 60. Thank you.

United States Department of Labor
MSHA
Mine Safety and Health Administration

(Enclosure A-12)

U.S. DEPARTMENT OF LABOR
MINE SAFETY AND HEALTH ADMINISTRATION
APPROVAL AND CERTIFICATION CENTER
R. R. 1, Box 201B
Industrial Park Blvd.
Triadelphia, West Virginia 26059

Reply to Attn of:
MSHA:A&CC

____

Attn:__________________

____

____

Gentlemen:

Referring to your application dated______________, Co. Code__________,
requesting__________________of the __________________________,
(action) (Model/type, enclosure/machine)
an administrative review of your application has been completed and the following comments apply:

( ) Application form not included/incomplete/not in proper format.
( ) Drawing list not included/not in proper format.
( ) Correspondence, specifications and lettering on drawings not in English.
( ) Drawings not titled/numbered/dated/legible.
( ) Pencil/ink notations appear on drawings/bills of material.
( ) All documents do not include a note "Do not change without approval of MSHA".

If the above discrepancies are not corrected and resubmitted before the technical review is initiated, the application will be cancelled and the entire package returned. The technical review will begin in approximately ______________________.

( ) No discrepancies exist. The technical review will begin approximately ______________________.

( ) Other____

____

____

____

(Enclosure A-13) (Sht. 1)

This was an administrative review only; no technical evaluation was made.

If you have any questions concerning the above comments, contact ____________________ at (304) 547-0400, Extension__________.

Sincerely,

(Enclosure A-13) (Sht. 2)

APPLICATION PROCEDURES FOR
APPROVAL OR INTRINSIC SAFETY EVALUATIONS
OF INTRINSICALLY SAFE INSTRUMENTS AND CONTROL CIRCUITS
PART 18, 30 CFR

The increasing number of applications for approval and intrinsic safety evaluation dictates that we reduce the time spent processing these actions. One area of major concern is the inadequacy and incompleteness of many of the submitted applications. Considerable time can be saved if the applications include all the required information necessary to ascertain compliance with Title 30 Mineral Resources, Code of Federal Regulations (30 CFR), Part 18.

A copy of 30 CFR can be purchased from:

Superintendent of Documents
U.S. Government Printing Office
Washington, D.C. 20402
Telephone No. (202) 783-3238

Before making application for approval or intrinsic safety evaluations, Part 18 of 30 CFR should be reviewed carefully.

Effective February 1, 1980, applications must include the following:

1. The appropriate application form (see enclosures B-1 through B-4). These forms are basically self-explanatory. However, it should be noted that the company application code number is a number containing six (6) or fewer numeric characters assigned by the applicant to identify the subject application (see enclosure A-5). The person to contact, referenced at the end of the application form, is the applicants' representative responsible for answering any questions regarding the subject application.

2. A drawing list in the proper format (see enclosure B-5). The drawing list is a complete list of drawings, bills of material, and specifications which show the details of design and construction of the equipment as related to the applicable requirements of 30 CFR, Part 18.

3. The appropriate check list, completed and signed (see enclosure B-6). (Note: The original should be submitted, not a copy). The check list is a list of <u>basic</u> information needed to evaluate the subject application with regards to the applicable requirements of 30 CFR, Part 18. All items appearing on the check list(s) must be properly documented on/with drawings and specifications.

   It should be noted that all requirements of 30 CFR, Part 18 pertaining to each instrument circuit may not be included on the check list and additional information therefore may be required.

The portion of the check lists labeled "administrative" will be given a preliminary review when the application package is received. If any deficiencies are noted, the applicant will receive a form letter (See Enclosure A-13) indicating the areas where the deficiencies were noted. If the subject discrepancies are not corrected and resubmitted before the technical review is initiated, the application will be cancelled and the entire package will be returned to the applicant.

4. All new and/or revised drawings, bills of material, and specifications. The drawings shall be titled, numbered, and dated, in English, and show the latest revision. They shall be adequate in number and detail to identify fully the complete assembly, component parts, and subassemblies. In addition, an assembly drawing of each electrical enclosure showing locations and identifying by drawing number all component parts and other pertinent details is required. The minimum amount of documentation required will include:

   A. An overall assembly drawing showing the physical construction of the instrument and identifying the major components.

   B. Schematic diagrams.

   C. Electrical parts lists which include detailed specifications or separate specification sheets of all energy storage components.

      a. Batteries: Type, Voltage, Capacity, and Manufacturer's name and part number or NEDA number.

      b. Transformers: Manufacturer's name and part number, inductance (nominal and tolerance) and d.c. resistance (nominal and tolerance), or; specifications showing the physical construction of the transformer to include, core, type, insulation, size of wire, number of turns, physical dimensions, and spacing (clearances) of terminals. For power transformers, voltage and current ratings of all windings should be listed, along with high potential or dielectric strength specifications.

      c. Inductors: Manufacturer's name and part number or; inductance (nominal and tolerance), and d.c. coil resistance (nominal and tolerance) or; specifications of the core type, size of wire, insulation, and number of turns.

      d. Mechanical relays: Manufacturer's name and part number, coil inductance (nominal and tolerance), coil resistance (nominal and tolerance), and physical separation (clearances) between coil terminals and switching contacts or contact leads.

e. Capacitors: Type, capacitance (nominal and tolerance), and working voltage. If the capacitors are used as protective components to provide intrinsic safety isolation, the maximum dielectric test voltage must be specified.

f. Current Limiting Resistors: Resistance (nominal and tolerance), type of construction (single layer wirewound or metal film), wattage, manufacturer, and manufacturer's part number.

g. Optical Isolators and Solid State Relays: Maximum voltage and current ratings, dielectric strength, and spacing (clearances) between input and output.

h. Instrument Motors: Manufacturer's name and part number, inductance (nominal and tolerance), and d.c. resistance (nominal and tolerance).

i. Zener Diodes: Zener voltage (nominal and tolerance), wattage, and JEDEC number.

j. Incandescent Lamps and Fluorescent Lamps: Manufacturer's type number, voltage, current, and wattage rating.

k. Solid State Voltage and Current Limiting Devices: Manufacturer's name and part number, input and output voltage and current ratings, and power dissipation rating.

l. Heat Sinks: Manufacturer's name and part number or details of the physical dimensions and materials used.

m. Other Non-Energy Storage Components: JEDEC number, generic number of integrated circuits, nominal resistance, etc., whichever is applicable.

D. Layout drawings showing the physical location of parts on printed circuit boards.

E. Printed circuit board artwork drawings (for circuits where spacings must be maintained to preserve intrinsic safety).

F. A block diagram showing the major components of the circuit.

G. A technical description of circuit operation.

5. Where parts of circuits being evaluated for intrinsic safety are housed in explosion-proof enclosures which are supplied with the circuits, the enclosure must be identified by manufacturer's name and part number, MSHA certification number, extension of certification and letter date. If the explosion-proof enclosures are supplied by the user, detailed installation instructions must be provided.

6. In general, the equipment required for inspection and test will include:

   A. One complete instrument.

   B. Three of each inductive component rated over 100 microhenries; e.g., motors, relays, speakers, transformers, inductors, etc.

   C. Three of each capacitor, rated one microfarad or more.

   D. Three sets of batteries.

   E. Ten samples of each current limiting resistor.

   F. Thirty samples of each incandescent or fluorescent lamp.

   If any of these components are normally potted or encapsulated, please submit unencapsulated units. Encapsulated units may also be required if a dielectric strength test is needed to determine the sufficiency of the encapsulating material. In any case, photographs of the encapsulated versions will be required for the final records.

7. The following information should also be supplied (if available) to aid in the instrument evaluation:

   A. Copies of test reports of other approval agencies.

   B. Photographs (8" x 10") of the instrument components.

NOTE: Fees are not to be submitted with the application. (See enclosure A-11).

In order to facilitate the processing of an application, it is essential that all the information requested be furnished. Incomplete applications will result in unnecessary delay and possible cancellation of the application request.

Technical assistance is available through consultations with MSHA personnel. Consultations can be arranged by appointment.

To expedite extensions of instrument approvals or changes to circuits covered by an intrinsic safety evaluation, two copies of each revised drawing should be submitted. On one of the copies, the changes made since the drawing was approved should be outlined or circled in green.

INSTRUMENT APPROVAL APPLICATION LETTER

COMPANY NAME AND ADDRESS:

____

____

____

Director, Approval and
Certification Center
RR #1, Box 201B
Industrial Park Boulevard
Triadelphia, West Virginia 26059

DATE: ____________________

SUBJECT: New Approval of the ____,
(Model)

_______________________, ________________________________.
(Voltage) (Type of Instrument)

Company Application Code No.: _________________________

Gentlemen:

We are requesting approval of the subject instrument which consists of the following major components:

(Brief description of the function of the instrument).
(If more space is needed, use additional sheets).

(Choose one):

_____ This is a new design and an instrument or prototype will be available for inspection and testing on __________________.
(Date)

_____ This design is similar to the ________________________________,
(Model)

______________________________ inspected and tested under
(Type of Instrument)

Investigation __________, Approval No. _________, letter

dated __________________.

Enclosed are all the new and/or revised drawings pertinent to this application. If there are any questions, please contact ________________ at
(Mr./Ms.)

________________________.
(Telephone No.)

Sincerely,

(Enclosure B-1, Sheet 2 of 4)

INSTRUMENT APPROVAL APPLICATION LETTER

Sample COMPANY NAME AND ADDRESS:

XYZ Company

Box 123

Pittsburgh, PA 15298

DATE: June 22, 1979

Director, Approval and
Certification Center
RR #1, Box 201B
Industrial Park Boulevard
Triadelphia, West Virginia 26059

SUBJECT: New Approval of the Model SLM225 ________,
(Model)

9 volt, Sound Level Meter.
(Voltage) (Type of Instrument)

Company Application Code No.: 062279

Gentlemen:

We are requesting approval of the subject instrument which consists of the following major components:

1. Sound Level Meter SLM225 Processor and Readout Unit.

2. Battery Pack SLM226.

3. Microphone MIC227.

(Brief description of the function of the instrument).
(If more space is needed, use additional sheets).

The SLM225 Sound Level Meter is a portable battery powered instrument used to measure the noise level in the work areas of underground coal mines. A technical description of the circuit operation is enclosed.

(Choose one):

_X_ This is a new design and an instrument or prototype will be available for inspection and testing on August 15, 1979.
(Date)

_____ This design is similar to the ________________________,
(Model)

________________________ inspected and tested under
(Type of Instrument)

Investigation __________, Approval No. __________, letter

dated __________________.

(Enclosure B-1, Sheet 3 of 4)

Enclosed are all the new and/or revised drawings pertinent to this application. If there are any questions, please contact Mr. John R. Smith at
(Mr./Ms.)

(412) 555-2000, Ext. 156.
(Telephone No.)

Sincerely,

John R. Smith

(Enclosure B-1, Sheet 4 of 4)

EXTENSION OF INSTRUMENT APPROVAL APPLICATION LETTER

COMPANY NAME AND ADDRESS:

____

____

____

Director, Approval and
Certification Center
RR #1, Box 201B
Industrial Park Boulevard
Triadelphia, West Virginia 26059

DATE: ____________________

SUBJECT: Extension of Approval No. 2G-____________,

Investigation No. IA-____, ______________________________ (model),

_________________________ (voltage), ____________________________ (type of instrument).

Company Application Code No. ______________.

Gentlemen:

We are requesting an extension of approval of the subject instrument which consists of the following major components:

This instrument is similar to the ___________________________ (model),

_________________________________ (type of instrument), Approval No. 2G-________-_______ (ext.),

Investigation No. IA-______________, letter dated __________________,

except as follows: (f more space is needed, use an additional sheet)

(Enclosure B-2, Sheet 1 of 4)

Enclosed are all new and/or revised drawings, a revised drawing list, and a revised approval checklist.

If there are any questions, please contact ______________________________,
(Mr/Ms.)

at _________________________.
(telephone No.)

Sincerely yours,

EXTENSION OF INSTRUMENT APPROVAL APPLICATION LETTER

Sample

COMPANY NAME AND ADDRESS:

Director, Approval and
Certification Center
RR #1, Box 201B
Industrial Park Boulevard
Triadelphia, West Virginia 26059

XYZ Company

Box 123

Pittsburgh, PA 15298

DATE: March 23, 1979

SUBJECT: Extension of Approval No. 2G- 9999 ,

Investigation No. IA- 999, Model SLM225 (model),

9 volt (voltage), Sound Level Meter (type of instrument).

Company Application Code No. 032379 .

Gentlemen:

We are requesting an extension of approval of the subject instrument which consists of the following major components:

1. Sound Level Meter SLM225 Processor and Readout Unit;

2. Battery Pack SLM228.

3. Microphone MIC229.

This instrument is similar to the Model SLM225 (model),

Sound Level Meter (type of instrument), Approval No. 2G-9999 - 0 (ext.),

Investigation No. IA- 999 , letter dated April 2, 1977 ,

except as follows: (If more space is needed, use an additional sheet)

1. A 1.2 ohm, 5 watt, wirewound resistor was added to battery pack SLM226 to make battery pack SLM228.

2. Microphone MIC229 has been substituted for Microphone MIC227.

3. L1, L2, and L3 on Schematic 22502 have been changed from 5mH to 2mH.

(Enclosure B-2, Sheet 3 of 4)

Enclosed are all new and/or revised drawings, a revised drawing list, and a revised approval checklist.

If there are any questions, please contact Mr. John R. Smith,
(Mr/Ms.)

at (412) 555-2000, Ext. 156.
(telephone No.)

Sincerely yours,

John R. Smith

(Enclosure B-2, Sheet 4 of 4)

INTRINSIC SAFETY EVALUATION APPLICATION LETTER

COMPANY NAME AND ADDRESS:

____

____

____

Director, Approval and
Certification Center
RR #1, Box 201B
Industrial Park Boulevard
Triadelphia, West Virginia 26059

DATE: ____________________

SUBJECT: Intrinsic Safety Evaluation of the ______________________,
(Model)

______________________, ______________________________,
(Voltage) (Type of Circuit)

Company Application Code No.: ______________

Gentlemen:

We are requesting an intrinsic safety evaluation of the subject circuit which consists of the following major components:

1.

(Brief description of design approach to provide intrinsic safety). (If more space is needed, use additional sheets).

(Choose one):

_____ This is a new design and a circuit or prototype will be available for inspection and testing on ______________.
(Date)

_____ This design is similar to the ____________________________,
(Model)

____________________ inspected and tested under Investigation
(Type of Circuit)

______________, letter dated ______________.

(Enclosure B-3, Sheet 1 of 4)

Enclosed are all the new and/or revised drawings pertinent to this application. If there are any questions, please contact ____________________
(Mr./Ms.)

at ______________________.
(Telephone No.)

Sincerely,

(Enclosure B-3, Sheet 2 of 4)

INTRINSIC SAFETY EVALUATION APPLICATION LETTER

Sample

COMPANY NAME AND ADDRESS:

XYZ Company

Box 892

Pittsburgh, PA 15298

Director, Approval and
Certification Center
RR #1, Box 201B
Industrial Park Boulevard
Triadelphia, West Virginia 26059

DATE: March 21, 1978

SUBJECT: Intrinsic Safety Evaluation of the Model 89276 (Model),

440 VAC/6 VDC (Voltage), Valve Control Circuit (Type of Circuit),

Company Application Code No.: 032176

Gentlemen:

We are requesting an intrinsic safety evaluation of the subject circuit which consists of the following major components:

1. A 440 VAC/6 VDC Power Supply, P/N 89277, designed to be mounted in an explosion-proof box.

2. Intrinsically safe valve amplifier circuits, P/N 89278.

3. Hydraulic valves, P/N 89279.

(Brief description of design approach to provide intrinsic safety). (If more space is needed, use additional sheets).
This valve control system is powered by a P/N 89277 power supply which must be located in a certified explosion-proof box. The 12 volt output is maintained at an intrinsically safe level by a series of zener diodes and current limiting resistors as shown on schematic drawing No. 27768, Rev. A. The valves and amplifier circuits are intrinsically safe.
(Choose one):

__X_ This is a new design and a circuit or prototype will be available for inspection and testing on April 19, 1978 (Date).

_____ This design is similar to the ________________ (Model),

________________ (Type of Circuit) inspected and tested under Investigation

____________, letter dated ____________.

(Enclosure B-3, Sheet 3 of 4)

Enclosed are all the new and/or revised drawings pertinent to this application. If there are any questions, please contact Mr. John R. Smith (Mr./Ms.) at (412) 555-2000, Ext. 156. (Telephone No.)

Sincerely,

John R. Smith

(Enclosure B-3, Sheet 4 of 4)

EXTENSION OF INTRINSIC SAFETY EVALUATION APPLICATION LETTER

COMPANY NAME AND ADDRESS:

____

____

____

Director, Approval and
Certification Center
RR #1, Box 201B
Industrial Park Boulevard
Triadelphia, West Virginia

DATE: ______________

SUBJECT: Extension of Intrinsic Safety Evaluation,

Investigation IA-________, ______________________________,
(model)

______________________________, ______________________________.
(voltage) (type of circuit)

Company Application Code No. ________________________.

Gentlemen:

We are requesting an extension of intrinsic safety evaluation of the subject circuit which consists of the following major components:

This design is similar to the ______________, ____________________
(model) (type of circuit)

inspected and tested under Investigation IA-__________, letter dated

________________, except as follows: (If more space is needed, use additional sheets).

Enclosed are all new and/or revised drawings, a revised drawing list, and a revised intrinsic safety evaluation checklist.

If there are any questions, please contact ______________________________,
(Mr./Ms.)

at ________________________.
(telephone No.)

Sincerely yours,

(Enclosure B-4, Sheet 2 of 4)

EXTENSION OF INTRINSIC SAFETY EVALUATION APPLICATION LETTER

Sample

COMPANY NAME AND ADDRESS:

XYZ Company

Box 892

Pittsburgh, PA 15298

DATE: March 29, 1979

Director, Approval and
Certification Center
RR #1, Box 201B
Industrial Park Boulevard
Triadelphia, West Virginia

SUBJECT: Extension of Intrinsic Safety Evaluation,

Investigation IA- 998, Model 89276 (model),

40 VAC/6 VDC (voltage), Valve Control Circuit (type of circuit).

Company Application Code No. 032979.

Gentlemen:

We are requesting an extension of intrinsic safety evaluation of the subject circuit which consists of the following major components:

1. A 440 VAC/6 VDC Power Supply, P/N 89277, designed to be mounted in an explosion-proof box.

2. Intrinsically safe valve amplifier circuits, P/N 89278.

3. Hydraulic valves, P/N 89976.

This design is similar to the Model 89276 (model), Valve Control Circuit (type of circuit) inspected and tested under Investigation IA- 998, letter dated April 20, 1978, except as follows: (If more space is needed, use additional sheets).

1. On Power Supply Schematic Drawing 25768, Rev. C, R1 was changed from 50 ohms to 600 ohms, Q5 was 2N4982 and is now 2N5673.

2. Hydraulic Valves P/N 89976 are being substituted for valves P/N 89279.

(Enclosure B-4, Sheet 3 of 4)

Enclosed are all new and/or revised drawings, a revised drawing list, and a revised intrinsic safety evaluation checklist.

If there are any questions, please contact Mr. John R. Smith,
(Mr./Ms.)

at (412) 555-2000, Ext. 156.
(telephone No.)

Sincerely yours,

John F. Smith

(Enclosure B-4, Sheet 4 of 4)

DRAWING LIST FORMAT FOR

INSTRUMENT APPROVALS OR INTRINSIC SAFETY EVALUATIONS

The drawing lists shown on Sheets 2 and 3 of Enclosure B-5 are offered for example only and may not represent your particular instrument.

In general, the drawing list should begin with the overall assembly drawing and then list schematics, parts layout drawings, artwork drawings, parts lists, caution statements, and warning label drawings. If a drawing is referenced on another drawing, it should be indented and listed below the referencing drawing. Where more than one of a component is used, the quantity should be listed after the drawing title:

EXAMPLE: Battery (3)

If an item is an alternate (used in place of a previously listed item) or optional (may or may not be used) it should be so designated.

DRAWING LIST FORMAT FOR
INSTRUMENT APPROVAL OR EXTENSION OF APPROVAL

Investigation IA- (Leave blank for New Approvals)

Drawing List

(Company Name)
(Model Number) (Type of Instrument)
(_____ Extension of) Approval No. 2G-____ (Leave blank for New Approvals)

EXAMPLE:

Investigation IA-____

Drawing List

XYZ Company
Model 376 Sound Level Meter
Approval No. 2G-____

Title	Drawing No.	Revision
SLM Assembly Drawing	________	______
P.C. Board Component Layout	________	______
P.C. Artwork	________	______
SLM Schematic	________	______
Microphone Specification	________	______
Meter Specification	________	______
Battery Pack	________	______
Current Limiting Resistor Spec.	________	______
Final Inspection Form	________	______
Warning Label	________	______

(Enclosure B-5, Sheet 2 of 3)

DRAWING LIST FORMAT FOR
INTRINSIC SAFETY EVALUATION

Investigation IA-____ (Leave Blank)

Drawing List

(Company Name)
(Model Number) (Type of Circuit)

EXAMPLE:

Investigation IA-____

Drawing List

XYZ Company
Model 123 Valve Control Circuit
Intrinsic Safety Evaluation

Title	Drawing No.	Revision
Valve Control Circuit Assembly	________	______
Power Supply Assembly	________	______
Component Layout	________	______
P.C. Artwork	________	______
Power Supply Schematic	________	______
Transformer Spec.	________	______
Current Limiting Components	________	______
Valve Amplifier Assembly	________	______
Component Layout	________	______
P.C. Artwork	________	______
Valve Amplifier Schematic	________	______
Valve Coil Assembly	________	______
Valve Coil Schematic	________	______
Final Inspection Form	________	______
Intrinsic Safety Labels	________	______

(Enclosure B-5, Sheet 3 of 3)

INSTRUMENT APPROVAL, EXTENSION OF APPROVAL, OR
INTRINSIC SAFETY EVALUATION CHECKLIST

Complete the following; leave no blanks. If a particular item does not apply, use the designation N/A.

Administrative

_____ 1. Is the appropriate application form properly completed?

_____ 2. Is a drawing list in the proper format included in the application package?

_____ 3. Are all correspondence, specifications, and lettering on drawings in English? (Sec. 18.6 (1))

_____ 4. Are all drawings and Bills of Material titled, numbered, dated, and legible? (Sec. 18.6 (e))

_____ 5. Are there any pencil or ink notations on the drawings and Bills of Material? (Note: Pencil and ink notations are unacceptable.)

_____ 6. Do all documents include a note "Do not change without approval of MSHA" on each page or sheet? (Sec. 18.6 (e)) (See Enclosure A-12)

Investigative

_____ 7. Do all revised drawings and Bills of Material show the latest revision and/or date? (Sec. 18.6 (e))

_____ 8. Do all wiring diagrams showing intrinsically safe circuits include a warning statement that any change(s) in the intrinsically safe circuitry or components may result in an unsafe condition? (Sec. 18.6 (e))

_____ 9. Does the overall assembly drawing show the location of major components?

_____10. Are all schematic drawings included?

_____11. Are the batteries identified by: Type, Voltage, Capacity, and Manufacturer's name and part number or NEDA number?

_____12. Are transformers identified by: Manufacturer's name and part number or; inductance (nominal and tolerance) and d.c. resistance (nominal and tolerance), or; specifications showing the physical construction of the transformer to include, core type, insulation, size of wire, number of turns, physical dimensions, and spacing (clearances) of terminals?

_____ 13. Are voltage and current ratings listed for all windings of power transformers?

_____ 14. Are inductors identified by: Manufacturer's name and part number or; inductance (nominal and tolerance) and d.c. resistance (nominal and tolerance) or; specifications of the core type, size of wire, insulation, and number of turns?

_____ 15. Are mechanical relays identified by: Manufacturer's name and part number or; coil inductance (nominal and tolerance), coil resistance (nominal and tolerance), and physical separation (clearances) between coil terminals and switching contacts or contact leads?

_____ 16. Are capacitors identified by: Capacitance (nominal and tolerance), and working voltage?

_____ 17. Is the dielectric test voltage specified for capacitors used as protective components?

_____ 18. Are current limiting resistors identified by: Resistance (nominal and tolerance), type of construction (single layer wirewound or metal film), wattage, manufacturer, and manufacturer's part number?

_____ 19. Are optical isolators and solid state relays identified by: Manufacturer's name and part number or, maximum voltage and current ratings, dielectric strength, and spacing (clearances) between input and output?

_____ 20. Are instrument motors identified by: Manufacturer's name and part number or; inductance (nominal and tolerance) and d.c. resistance (nominal and tolerance)?

_____ 21. Are zener diodes identified by: Zener voltage (nominal and tolerance), wattage, and JEDEC number?

_____ 22. Are incandescent and fluorescent lamps identified by: Manufacturer's type number, voltage, current, and wattage rating?

_____ 23. Are solid state voltage and current limiting devices identified by: Manufacturer's name and part number, input and output voltage and current ratings?

_____ 24. Are heat sinks identified by: Manufacturer's name and part number or details of the physical dimensions and materials used?

_____ 25. Do the p.c. board layout drawings show the physical location of all electrical components?

_____ 26. Are p.c. board artwork drawings included?

_____ 27. Is a block diagram included?

_____ 28. Are the placement and method of attachment of the approval plate specified? (Sec. 18.11 (b))

_____ 29. Are a complete factory inspection form and caution statement specified and included in the application package (if not previously accepted)? (Sec. 18.6 (j&k)

_____ 30. For intrinsic safety evaluations: Do the schematic diagrams clearly show which circuits must be located in fresh air or housed in a certified explosion-proof enclosure?

____
(Signature)

______________________ ______________________
(Title) (Date)

(Enclosure B-6, Sheet 3 of 3)

U. S. Department of Labor

Mine Safety and Health Administration
Industrial Park Boulevard
RR 1, Box 201B
Triadelphia, West Virginia 26059

June 21, 1982

TO ALL INTERESTED PARTIES

SUBJECT: MINE-WIDE MONITORING SYSTEMS

Gentlemen:

The Mine Safety and Health Administration's Approval and Certification Center will accept applications for Mine-Wide Monitoring System (MWMS) Evaluations and Sensor Classifications and Barrier Classifications. This package contains application forms and instructions for the evaluation of MWMS, and for sensor and barrier classification for use on MWMS's. These evaluations or classifications are not applicable for use on other systems, approvals, acceptances or investigations. The enclosed application instructions are intended to provide a simple procedure whereby complex systems with performance specifications within recognized limits for safety can be expeditiously processed.

Applications for MWMS evaluation and sensor or barrier classification should contain the information itemized on the attached application instructions. Insufficient information will result in application cancellation.

MSHA reserves the right to require the submittal of additional information, such as detailed schematics and specifications, or actual equipment prior to the issuance of MWMS acceptance or a sensor or barrier classification.

For further information contact Ken Sproul at the Approval and Certification Center. Telephone No. (304) 547-0400.

APPLICATION INSTRUCTIONS FOR MINE WIDE MONITORING SYSTEM EVALUATION

An application letter for a Mine Wide Monitoring Systems Evaluation should contain the following information.

1. The company name, address, telephone number and the name of the company representative.

2. A company assigned code number - an arbitrary six-digit numerical code assigned by the submitting company for company identification purposes.

3. The date.

4. The functional block diagram and/or specification(s) of the Mine Wide Monitoring System including drawing number(s) and revisions. The functional block diagram should contain the necessary interconnection information to insure compliance with the conditions as outlined on the MWMS drawing(s) and specification(s) requirements.

5. The installation and maintenance - inspection manual used by the installer and maintained at the installation site, to insure that each MWMS is installed and maintained in accordance with the conditions stipulated in the application. The installation and maintenance inspection manual should contain as a minimum the following information:

    1. Form Number/Date.
    2. Characteristics to be inspected and/or tested, with limits.
    3. Method of testing or inspection.
    4. Results of testing or inspection.
    5. Signature/Date.

6. Sign the application letter.

MINE WIDE MONITORING SYSTEM

Drawing and Specification Requirements for
use of Simplified Processing Procedures

Drawing(s) and specification(s) submitted for a Mine Wide Monitoring System should indicate that:

A. All interfaces to any data transmission line contain circuitry limiting the Data Transmission Line voltage to a maximum of 60 volts per conductor to ground.

B. All outstations are either blue or red in color and are located in intake air.

*Blue outstations may monitor sensors located in areas where equipment is required to be permissible.

*Red outstations are not connected to any circuits entering or located within areas where equipment is required to be permissible.

C. All blue outstations have MSHA power circuit (P.C.) classified input barriers installed in the data transmission line and that the barrier voltage classification is greater than or equal to the highest power circuit voltage being monitored.

D. All blue outstation inputs from power circuits or sensors requiring external power for operation have an MSHA classified power circuit (P.C.) barrier whose voltage classification is greater than or equal to the maximum voltage of the circuit monitored, or supplied to the barrier, or being supplied to the sensor for operation.

E. All outputs of power circuit (P.C.) barriers (inputs to blue outstations) are 120 volts/or less.

F. All sensors in areas where equipment is required to be permissible have a MSHA classification label. (The classification label shall designate an alphabetical classification for the sensor and the label shall be attached to the sensor or, when necessary for inspection purposes, in close proximity to the sensor. i.e. An oil level sensor label could be on the oil tank at the point of cable entry.)

G. Cables from MSHA classified sensors terminate in a MSHA classified barrier of the same classification. MSHA classified barriers are located at a blue outstation(s).

H. Cables from MSHA classified barriers that terminate in explosion-proof enclosures located in areas where equipment is required to be permissible, comply with the following conditions:

(1). The modification of existing permissible electrical equipment and circuitry within the permissible electrical equipment shall be documented by the operator under an acceptable Field Modification Application.

(2). Cable termination (data transmission line from a blue outstation) within MSHA certified enclosures are to a barrier with a classification that matches the classification of the barrier at the blue outstation. A P.C. barrier with a voltage rating greater than or equal to the voltage input to the enclosure is required when power circuits are monitored or power is obtained from within the MSHA certified enclosure.

(3). All cables leaving an MSHA certified enclosure and terminating in a sensor must meet the following conditions:

A. The sensor has a classification label.

B. The cable is shielded and the shield grounded at the MSHA certified enclosure.

C. The sensor classification has the same letter classification as a barrier located within the MSHA certified enclosure and connected to each individual sensor cable. A barrier classification label shall be located on the exterior of the MSHA certified enclosure and in close proximity to each and every barrier cable entrance.

D. Connections to the data transmission line shall be between the data transmission line classified barrier and the P.C. barrier when a P.C. barrier is required.

(4). Physical isolation is provided within an MSHA certified enclosure by means of an insulated or grounded metallic shield around all barriers and cables.

I. All sensors whose cable passes through an area where permissible equipment is required, have a MSHA classification label and interface with a blue outstation through a MSHA classified barrier of the same classification.

J. Barriers or barrier enclosures are attached to the blue outstation and are so labeled that barrier outputs identify the type of sensor to which the barrier cable is connected, i.e., CO sensor, CH_4 Sensor, Anemometer.

K. All cables entering blue outstations from the P.C. barriers, and all cables connecting a classified barrier with a classified sensor, and all cables connecting the blue outstation with non-classified sensors are shielded with the shield connected to ground at the outstation.

L. Grounding techniques for outstations and barriers are employed using no less capacity than a No. 12AWG Wire.

M. All blue outstations shall contain a MSHA evaluation label with the conditions of use as specified by MSHA.

N. MWMS components and circuits (except under the conditions outlined in (O)) underground automatically deenergize upon loss of mine ventilation. Manual deenergization from a centralized surface control area is acceptable. Manual reenergization of each individual underground outstation is required.

O. Fire detection circuits that monitor conveyor belts or conveyor belt entries meet the conditions specified by 30 CFR, Part 75.1103, including the capability to monitor for 4 hours upon loss of mine power. Exception: circuits shall deenergize either manually or automatically upon loss of mine ventilation, unless the power supply and circuits have been accepted by MSHA as intrinsically safe. Such circuits must be manually reenergized at each individual underground outstation.

P. Detailed installation and maintenance instructions are supplied to all purchasers or users of these systems, installation inspection checklist(s) must be included.

Q. Restrictions of use and modification of the system are explained to purchasers or users of these systems.

APPLICATION INSTRUCTIONS FOR BARRIER VOLTAGE (P.C.) OR ALPHABETICAL CLASSIFICATION

Complete the application for barrier evaluation form (MSHA - 15) as follows: (See sample Enclosure No. 1.)

1. Enter the company name and return address in the spaces provided. Include the name of the representative to be contacted if additional information is needed.

2. Enter the telephone number of the company representative, including area code, in the space designated "Telephone No.".

3. Enter the company assigned code number in the space designated "Company Assigned Code No." (Arbitrary six-digit numerical code assigned by the submitting company for company identification purposes.)

4. Enter the date in the space designated "Date."

5. Enter the manufacturer's descriptive name for the barrier in the space designated "Nomenclature."

6. Enter the name of the company that manufactures the barrier in the space designated "Manufacturer."

7. Enter the manufacturer's assigned part number or model number of the barrier in the space designated "Part/Model No."

8. Enter the barrier classification requested (See Table 1 for alphabetical classification or enter the P.C. Voltage classification requested) in the space designated "Class Requested."

9. Enter the highest voltage level (Nominal plus tolerances) that will be available at the output terminals of the barrier in the space designated "Maximum Output Voltage."

10. Enter the highest current value (Nominal plus tolerances) that will be available at the output terminals of the barrier in the space designated "Maximum Output Current."

11. Enter the barrier rated voltage. Barrier rated voltage shall meet or exceed 250 volts.

12. If applicable, enter the approval agency and the referenced published standard under which the device has been evaluated, in the space designated "Approval Agency." Applications referencing approval agencies should include a copy of the applicable standard, the address of the approval agency, and a copy of the test report.

13. Draw the electrical schematic of the basic barrier design in the space designated "Electrical Schematic or Drawing Reference(s)."

14. The statement shall be completed by having an authorized representative sign in the space labeled "Original Signature" and filling in the title and company name in the appropriate spaces on the application. The individual signing the application shall be an authorized representative of the company, who can bind the company to the conditions stipulated in the application letter.

The Barrier Classification Application Letter (MSHA - 15) shall be submitted in duplicate for each type barrier being evaluated. If applicable, a copy of the test report of the approval agency which previously evaluated the subject barrier is to be submitted with the application letter. Any drawing or specification sheet being submitted as documentation for the barrier classification shall comply with the following:

a. All drawings(s) have a title block, a title, a number assigned, a date, and be legible.

b. Pencil or ink notations not appear on drawings being submitted for documentation.

c. Drawings show the date of the latest revision.

d. All drawings include a note "Do Not Change Without Approval of MSHA" which is included on all drawings reproduced by the applicant.

e. All drawings be in English.

15. All applications for barrier classification shall be submitted with a barrier. The barrier will be returned by MSHA upon completion of the investigation.

TABLE 1

CLASS	VOLTS (Output)	CURRENT (Max)	CAPACITANCE (Max)	INDUCTANCE (Max)
A	5V	3A	5 mf	100 uh
B	5V	1A	5 mf	1 mh
C	10V	3A	60 uf	100 uh
D	10V	1A	60 uf	1 mh
E	12V	3A	30 uf	100 uh
F	12V	1A	30 uf	1 mh
G	15V	1.25A	15 uf	300 uh
H	20V	0.7A	7 uf	1 mh
I	20V/10V	0.7A/0.1A	1 uf	800 uh
J	25V	0.3A	3 uf	10 mh

APPLICATION LETTER
Barrier Classification for use on Mine Wide Monitoring Systems

Chief, Approval and Certification Center
Industrial Park Boulevard
RR #1, Box 201B
Triadelphia, West Virginia 26059

COMPANY NAME & ADDRESS

____

Attn: ______________________________

____

____

DATE ______________________________

TELEPHONE NO. ______________

Company Assigned Code No. ______________________

GENTLEMEN:

We are requesting an evaluation of a barrier to be used on Mine Wide Monitoring Systems.

BARRIER SPECIFICATIONS

1. Nomenclature ______________________
2. Manufacturer ______________________
3. Part/Model No. ______________________
4. Class Requested ______________________
5. Maximum Output Voltage ______________
6. Maximum Output Current ______________
7. Barrier Input Voltage Rating ______________
8. Approval Agency ______________________

FOR MSHA USE ONLY

ELECTRICAL SCHEMATIC OR DRAWING REFERENCE(S):

I ______________________ (Original Signature), ______________________ (Title) attest that

______________________ (Company) will maintain signed inspection records

traceable to each unit on which we affix a classification label, to insure that it meets all the safety requirements listed above.

APPLICATION INSTRUCTIONS FOR SENSOR CLASSIFICATION

A. Complete the application for sensor evaluation form (MSHA-16) as follows: (See sample Enclosure No. 2.)

1. Enter the company name and return address in the spaces provided. Include the name of the representative to be contacted if additional information is needed.

2. Enter the telephone number of the company representative, including area code, in the space designated "Telephone Number."

3. Enter the assigned company code number in the space designated "Company Assigned Code No." (Arbitrary six-digit numerical code assigned by the submitting company for company identification purposes.)

4. Enter the date in the space designated "Date."

5. An authorized representative of the company shall sign in the appropriate space labeled "Original Signature." The individual signing the application shall be an authorized representative of the company who can bind the company to the conditions stipulated in the application letter.

6. Enter the manufacturer's descriptive name for the sensor in the space designated "Nomenclature."

7. Enter the name of the company that manufactures the barrier in the space designated "Manufacturer."

8. Enter the manufacturer's assigned model number of the sensor in the space designated "Model No."

9. Enter the sensor classification(s) requested in the space designated "Class Requested." Sensor classification(s) should be consistent with the specifications of the barrier classification(s) to which it will be connected. (See Table 1.)

10. Enter the sum total of all the capacitance (nominal values plus tolerances) contained in the sensor in the space designated "Maximum Total Capacitance." If the sensor has no capacitance, indicate with "N/A" or "None."

11. Enter the sum total of all the inductance (nominal values plus tolerances) contained in the sensor in the space designated "Maximum Total Inductance." If the sensor has no inductance, indicate with "N/A" or "None."

12. Enter the ohmic value of the lowest rated resistor (nominal value less tolerance) of the sensor circuitry in the space designated as "Minimum Resistor Ohmage."

13. Enter the wattage rating of the lowest wattage rated resistor (nominal value less tolerance) of the sensor circuitry in the space designated as "Minimum Resistor Wattage."

14. Enter a brief description of the basic sensor design (i.e., manufacturer's specifications, circuit design, internal components, etc.) in the space designated "Brief Description of Design." If electrical schematic, layout design, or parts lists are necessary, the drawing number(s) shall be referenced under the "Brief Description of Design."

15. The application letter shall be completed by having an authorized representative sign in the space provided for original signature and filling in the title and company name in the appropriate spaces. The individual signing the application shall be an authorized representative of the company who can bind the company to the conditions stipulated in the application letter.

B. Complete the application for Active Chemical/Hot Filament/or MSHA Pre-Accepted Sensor evaluation form (MSHA - 17) as follows: (See sample Enclosure No. 3.)

1. Enter the company name and return address in the spaces provided. Include the name of the representative to be contacted if additional information is needed.

2. Enter the telephone number of the company representative, including area code, in the space designated "Telephone No."

3. Enter the assigned company code number in the space designated "Company Assigned Code No." (Arbitrary six-digit numerical code assigned by the submitting company for company identification purposes.)

4. Enter the date in the space designated "Date."

5. An authorized representative of the company shall sign the appropriate space labeled "Original Signature." The individual signing the application shall be an authorized representative of the company who can bind the company to the conditions stipulated in the application letter.

6. Enter the manufacturer's descriptive name for the sensor in the space designated "Nomenclature."

7. Enter the name of the company that manufactures the sensor in the space designated "Manufacturer."

8. Enter the manufacturer's assigned model number of the sensor in the space designated "Model No."

9. Enter the sensor classification(s) requested in the space designated "Class Requested." Sensor classification(s) should be consistent with the specifications of the barrier classification(s) to which it will be connected. (See Table 1.)

10. Enter the sum total of all the capacitance (nominal values plus tolerances) contained in the sensor in the space designated "Maximum Total Capacitance." If the sensor has no capacitance, indicate with "N/A" or "None."

11. Enter the sum total of all the inductance (nominal values plus tolerances) contained in the sensor in the space designated "Maximum Total Inductance." If the sensor has no inductance, indicate with "N/A" or "None."

12. Enter the ohmic value of the lowest rated resistor (nominal value less tolerance) of the sensor circuitry in the space designated as "Minimum Resistor Ohmage."

13. Enter the wattage rating of the lowest wattage rated resistor (nominal value less tolerance) of the sensor circuitry in the space designated as "Minimum Resistor Wattage."

14. Enter the MSHA assigned investigation number (IA, MM, etc.) where the sensor was previously accepted by MSHA. If the sensor was not previously accepted by MSHA, enter "N/A" or "No" in the space designated previously evaluated.

15. Enter a brief description of the basic sensor design i.e., manufacturer specifications, circuit design, internal components, etc. in the space designated "Brief Description of Design." If the sensor was previously evaluated, explain any modification to the previously evaluated design.

16. The application letter shall be completed by having an authorized representative sign in the space provided for original signature and filling in the title and company name in the appropriate spaces. The individual signing the application shall be an authorized representative of the company who can bind the company to the conditions stipulated in the application letter.

C. The sensor evaluation application letter (MSHA - 16 or MSHA - 17) shall be submitted in duplicate for each type sensor being evaluated. Any drawing being submitted as documentation for the sensor evaluation shall comply with the following:

1. All drawing(s) have a title block, a title, a number assigned, a date, and be legible.

2. Pencil or ink notations not appear on drawings being submitted for documentation.

3. Drawings show the date of the latest revision.

4. All drawings include a note "Do not Change without Approval of MSHA" which is included on all drawings reproduced by the applicant.

5. All drawings be in English.

D. All applications for sensor classification must be submitted with a typical sensor. The sensor will be returned by MSHA upon completion of the investigation.

for use on
Mine Wide Monitoring Systems

COMPANY NAME & ADDRESS

____

Attn: ______________________

____

____

TELEPHONE No. ______________

Chief, Approval and Certfication Center
Industrial Park Boulevard
RR #1, Box 201 B
Triadelphia, West Virginia 26059

DATE: ______________________
Company Assigned Code No. ______________

GENTLEMEN:

We are requesting an evaluation of a Sensor Assembly to be used on Mine Wide Monitoring Systems.

I ______________________, attest to the following:
(Original Signature)

1. No power source is connected to or within the sensor, except through the MSHA Classified Barrier.
2. Chemical or hot filament components do not exist in this sensor.
3. All motors are brushless type.
4. Light-emitting diodes are the only illuminating devices.

SENSOR SPECIFICATIONS

1. Nomenclature ______________________
2. Manufacturer ______________________
3. Model NO. ______________________
4. Class Requested ______________________
5. Maximum Total Capacitance ______________
6. Maximum Total Inductance ______________
7. Minimum Resistor Ohmage ______________
8. Minimum Resistor Wattage ______________

FOR MSHA USE ONLY

BRIEF DESCRIPTION OF THE DESIGN: ______________________

____

____

I ______________________, ______________________ attest that
(Original Signature) (Title)

______________________ will maintain signed inspection records trace-
(Company)
able to each unit on which we affix a classification label, to insure that it meets all the safety requirements listed above.

APPLICATION LETTER
Active Chemical/Hot Filament/or MSHA Pre-Accepted Sensor Classification
for use on
Mine Wide Monitoring Systems

COMPANY NAME & ADDRESS
____

ATTN: ___________________

____

____

TELEPHONE No. __________

Chief, Approval and Certification Center
Industrial Park Boulevard
RR #1, Box 201B
Triadelphia, West Virginia 26059

DATE: __________________
Company Assigned Code No. ____________________

GENTLEMEN:

We are requesting an evaluation of an Active Chemical/Hot Filament Sensor to be used c
Mine Wide Monitoring System.

I ______________________________, attest to the following:
(Original Signature)

1. No power source is connected to or within the sensor, except through the MSHA Classified Barrier.
2. All motors are brushless type.
3. Light-emitting diodes are the only illumination devices.

SENSOR SPECIFICATIONS

1. Nomenclature ____________________
2. Manufacturer ____________________
3. Model Number ____________________
4. Barrier Class Requested ____________________
5. Maximum Total Capacitance ____________________
6. Maximum Total Inductance ____________________
7. Minimum Resistor Ohmage ____________________
8. Minimum Resistor Wattage ____________________
9. Previously Evaluated ____________________

FOR MSHA USE ONLY

BRIEF DESCRIPTION OF THE DESIGN: ____

____

I ______________________________, ______________________________ attest t
(Original Signature) (Title)

______________________________, will maintain signed inspection records tra
(Company)

able to each unit on which we affix a classification label, to insure that it meets al

the safety requirements listed above.

Enclosure

APPLICATION LETTER
Barrier Classification
for use on
Mine Wide Monitoring Systems

Chief, Approval and Certification Center
Industrial Park Boulevard
RR #1, Box 201B
Triadelphia, West Virginia 26059

COMPANY NAME & ADDRESS
DLM Inc.
Attn: Ms. Bonnie Lee
228 Victor Street
Scotch Plains N.J. 07076

DATE 4-22-83
Company Assigned Code No. 000001

TELEPHONE NO. 201-233-6823

GENTLEMEN:

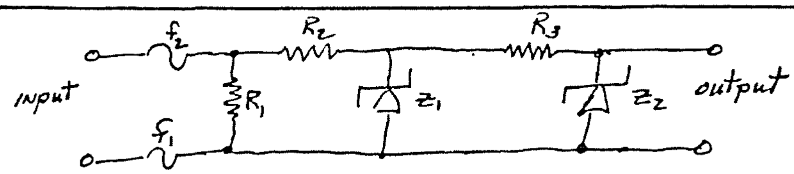
We are requesting an evaluation of a barrier to be used on Mine Wide Monitoring Systems.

BARRIER SPECIFICATIONS

1. Nomeclature IS. BARRIER
2. Manufacturer STANZ Ltd.
3. Part/Model No. 30-6193-001
4. Class Requested D
5. Maximum Output Voltage 10.0 volts
6. Maximum Output Current 945.0 ma.
7. Barrier Input Voltage Rating 400 volts
8. Approval Agency Int. Testing Labs.

FOR MSHA USE ONLY

ELECTRICAL SCHEMATIC OR DRAWING REFERENCE(S):



$F_1 + F_2$ — .945 ma @
R_1 — 50 ohms ½ watt
$R_2 + R_3$ — 100 ohms, ½ watt @
$Z_1 + Z_2$ — 10 volt, 10 watt, 500volt Zener, @

I Ms. Bonnie Lee (Original Signature), Vice Pres. Eng. (Title) attest that DLM Inc. (Company) will maintain signed inspection records traceable to each unit on which we affix a classification label, to insure that it meets all the safety requirements listed above.

APPLICATION LETTER
Sensor Classification
for use on
Mine Wide Monitoring Systems

Chief, Approval and Certfication Center
Industrial Park Boulevard
RR #1, Box 201 B
Triadelphia, West Virginia 26059

COMPANY NAME & ADDRESS
Wherle Industry
Attn: Ken Wherle
202 Cooks Ave
Scotch Plains, N.J. 07076
TELEPHONE No. 900-579-0477

DATE: May 28, 1982
Company Assigned Code No. 000471

GENTLEMEN:

We are requesting an evaluation of a Sensor Assembly to be used on Mine Wide Monitoring Systems.

I Ken Wherle (Original Signature), attest to the following:

1. No power source is connected to or within the sensor, except through the MSHA Classified Barrier.
2. Chemical or hot filament components do not exist in this sensor.
3. All motors are brushless type.
4. Light-emitting diodes are the only illuminating devices.

SENSOR SPECIFICATIONS

1. Nomenclature Liquid Level Detector
2. Manufacturer Wherle Industry.
3. Model NO. CK-172
4. Class Requested A, B, C
5. Maximum Total Capacitance N/A
6. Maximum Total Inductance N/A
7. Minimum Resistor Ohmage 1,000 ohms
8. Minimum Resistor Wattage 2 watts

FOR MSHA USE ONLY

BRIEF DESCRIPTION OF THE DESIGN: Output signal proportional to center arm of pot and position relative to the common leg. Center arm position adjusted by positive bouyancy float.

I Ken Wherle (Original Signature), Vice Pres. Eng. (Title) attest that Wherle Industry (Company) will maintain signed inspection records traceable to each unit on which we affix a classification label, to insure that it meets all the safety requirements listed above.

Enclosure No. —

MSHA-17

APPLICATION LETTER
Active Chemical/Hot Filament/or MSHA Pre-Accepted Sensor Classification
for use on
Mine Wide Monitoring Systems

Chief, Approval and Certification Center
Industrial Park Boulevard
RR #1, Box 201B
Triadelphia, West Virginia 26059

COMPANY NAME & ADDRESS
Leonard Monitoring Inc.
ATTN: Mr Sam Leonard
1968 East Orange Ave.
Beach Haven West, N.J. 0707?
TELEPHONE No. 201-233-6723

DATE: May 29, 1982
Company Assigned Code No. 000055

GENTLEMEN:

We are requesting an evaluation of an Active Chemical/Hot Filament Sensor to be used on Mine Wide Monitoring System.

I Sam Leonard, attest to the following:
(Original Signature)

1. No power source is connected to or within the sensor, except through the MSHA Classified Barrier.
2. All motors are brushless type.
3. Light-emitting diodes are the only illumination devices.

SENSOR SPECIFICATIONS

1. Nomenclature Methane Monitor
2. Manufacturer Finn Inc
3. Model Number Silver Edge-316
4. Barrier Class Requested C
5. Maximum Total Capacitance .45 μF
6. Maximum Total Inductance N/A
7. Minimum Resistor Ohmage 150 ohms
8. Minimum Resistor Wattage 1 watt
9. Previously Evaluated MM-1886

FOR MSHA USE ONLY

BRIEF DESCRIPTION OF THE DESIGN: MM-1886 Design Modified to Allow 2 No 18 wires Tapped off pins M1 + M2 for connection to "C" Barrier.

I Sam Leonard, Vice Pres Sales attest that
(Original Signature) (Title)

Leonard Monitoring Inc., will maintain signed inspection records trace-
(Company)

able to each unit on which we affix a classification label, to insure that it meets all the safety requirements listed above.