FINAL REPORT

VOLUME I

System Description

DEVELOP, ASSEMBLE AND INSTALL A PERMISSIBLE
SURVEILLANCE AND COMMUNICATION SYSTEM IN THE
BUREAU OF MINES MINING AND SAFETY RESEARCH
CENTER COAL MINE AT BRUCETON, PENNSYLVANIA

Contract No. H0110845

May 31, 1973

MINE SAFETY APPLIANCES COMPANY

201 NORTH BRADDOCK AVENUE

AREA CODE 412 – PHONE. 241-3900   **PITTSBURGH 8, PA.**   CABLE "MINSAF" PITTSBURGH

Contract No. HO110845

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USBM CONTRACT FINAL REPORT (Contract No. HO110845)

Volume I

Systems Development

DEPARTMENT OF THE INTERIOR
BUREAU OF MINES
WASHINGTON, D. C.

FOREWORD

This report was prepared by Mine Safety Appliances Company, Research and Engineering Division, 100 N. Braddock Avenue, Pittsburgh, Pa., under USBM Contract No. H0110845. The contract was initiated under the Coal Mine Health and Safety Research Program. It was administered under the technical direction of the Pittsburgh Mining and Safety Research Center with Mr. John N. Murphy acting as the technical project officer. Mr. Joseph A. Herickes was the contract administrator for the Bureau of Mines.

This report is a summary of the work recently completed as part of this contract during the period June 15, 1971, to March 31, 1973. This report was submitted by the authors on May 31, 1973.

This technical report has been reviewed and approved.

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LIST OF ILLUSTRATIONS

I.   INTRODUCTION

The purpose of this report is to describe the work accomplished by Mine Safety Appliances Company under Contract No. HO110845. This contract required the design, installation and testing of a permissible mine surveillance and communication system for the USBM Bruceton experimental mine facility.

While much of the design and operational detail of this system can be drawn from the instruction manuals delivered with the equipment, some of it will be repeated here in Volume I for the sake of clarity, but the principal objective will be to report on overall system and subsystem performance and to suggest design alternatives for future consideration.

Details of the overall system design will be found in Volume II of this report.

II. GENERAL DESCRIPTION AND PURPOSE

The system installed at the USBM Bruceton Research Center consists of an aboveground central computer control facility (or surface monitor station) and ten mine monitor stations at selected locations within the mine. Each station provides local measurement and display of several environmental parameters which have been judged critical to safety in mining operations. These include smoke, noise, carbon monoxide, methane, hydrogen, temperature, rate of temperature rise and ventilation rate. The system is designed to demonstrate that continuous monitoring of these parameters can provide early recognition of a potentially dangerous condition so that corrective action can be taken before a disaster occurs.

A data communications link established by an FSK telemetry polling system provides remote readout and alarms at the surface monitor station and the capability of remote control of certain mine station operational functions and system checks. In addition, a voice communications system has also been installed to permit party line phone conversation between any of the mine stations and/or the surface station.

One of the primary objectives of this contract effort was to provide a highly productive tool for mine safety research. For this reason, the surface monitor station includes not only parameter display and alarm systems but a very flexible and functional data handling and storage system whose central processing unit is a GE-PAC 30-2E computer.

An open view of one mine monitor station is shown in Photo No. 1. The sensor probes are shown atop the sensor module, but each probe is extendable up to at least ten feet from the station. Also atop the station is a paging speaker and central alarm system. The station chassis contains ten sliding trays. Nine of these house electronics for the eight selected sensors and one optional sensor. The tenth tray houses the communication electronics. Below the trays is another submodule containing the telemetry electronics. The flameproof housing at the bottom contains the power-supply system which provides intrinsically safe power to the sensor module. Another view as installed underground is shown in Photo No. 2.

A preengineered building was constructed adjacent to the existing instrument building at the Bruceton Research Center to house the surface monitor station equipment. The building is shown in Photo No. 3.

Photo No. 4 is an interior view of the building. The equipment shown, from left to right, includes an operator's console with its status display panel, a matrix control panel and cathode ray tube display with hard copy unit, a data communication

printer and paper tape system, and the GE-PAC 30-2E mini-computer with its magnetic tape data storage unit.
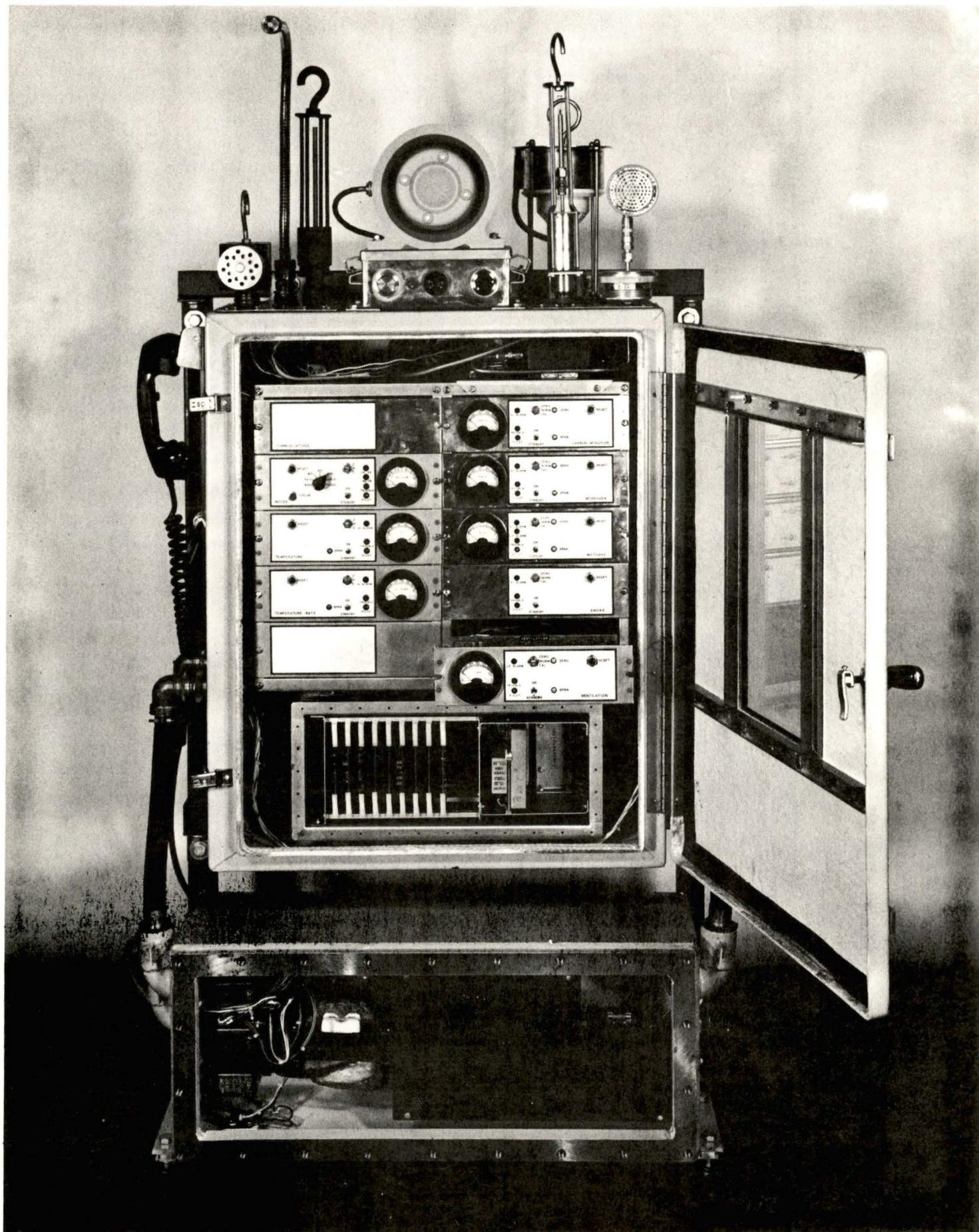
MINE MONITOR STATION — OPEN VIEW

MINE MONITOR STATION INSTALLATION
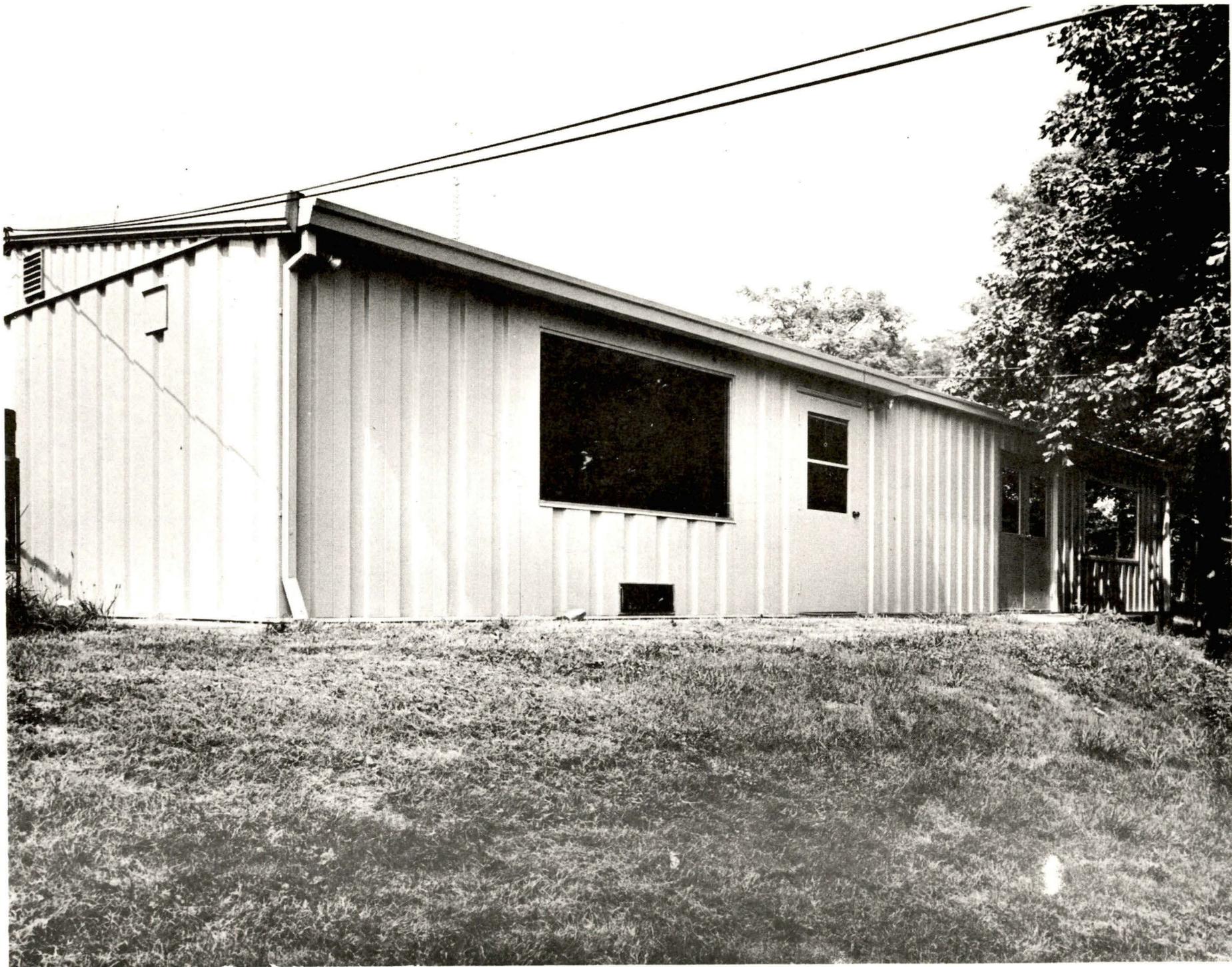
SURFACE MONITOR STATION BUILDING
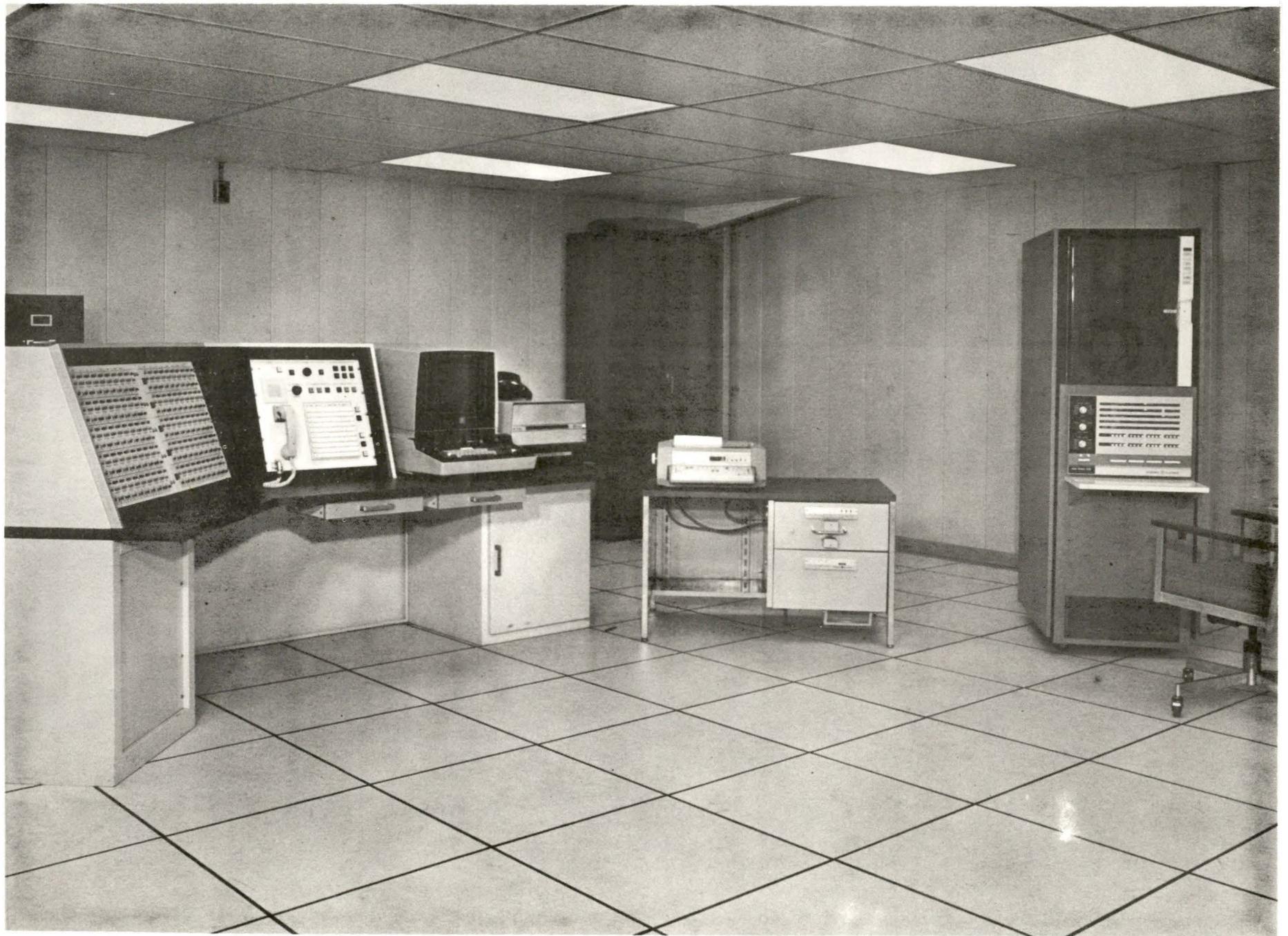
INTERIOR VIEW OF SURFACE MONITOR STATION

III. SCOPE OF WORK

The manuscript of pages 9 through 32 was originally presented at the conference on Mine Electrotechnology at West Virginia University, August 2-4, 1972. It is reproduced herein to describe the scope of this contract effort.

SURVEILLANCE AND COMMUNICATIONS SYSTEM FOR THE

USBM RESEARCH COAL MINE AT BRUCETON, PENNSYLVANIA

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ABSTRACT

A surveillance and communications system has been installed in the Research Coal Mine of the United States Bureau of Mines at Bruceton, Pa. The system provides for continuous local and remote monitoring of 10 selected sites in the mine for methane, carbon monoxide, hydrogen, smoke, temperature, rate of temperature rise, ventilation rate and noise. In addition to local readout and alarm capability at each underground site, all data is transmitted to a surface station via scanning telemetry over a single pair of wires which also serve as the voice communication link between all stations and the surface. A computer on the surface provides automatic station polling, data storage, recall, display and analysis functions. In addition, an operator control panel and CRT display makes possible very flexible operation for research purposes without interrupting routine surveillance. Redundant power and telemetry cables with automatic line status test and switchover assures continued functioning of the system even though portions of the system are damaged.

INTRODUCTION

The mine surveillance and communication system described provides continuous local and remote monitoring of several parameters critical to normal mine operation at each of ten underground sites in the Bruceton Research Coal Mine of the United States Bureau of Mines.

The system design permits surveillance of methane, carbon monoxide, hydrogen, smoke, temperature, rate of temperature rise, ventilation rate and noise level at each of ten underground sites. Two-way voice communication is provided between the ten locations and between any mine station and the surface monitor station. All underground equipment is designed to meet USBM permissibility requirements.

Each mine monitor station is designed as a totally integrated package with its own local readout and status indicators. The data from each mine monitor station, in selected sequence, is transmitted via scanning telemetry to a surface monitor station over a single pair of wires. The voice communication link is provided over this same pair. A

separately routed redundant pair is provided to allow continuous monitoring in event of an incident should the first pair be shorted or opened. The cabling system is provided with automatic switchover upon such a line fault. A similar redundant cabling system is provided for 240 volt a-c power with routing from two sources in opposite directions.

The surface monitor station functions as a central control for the entire system and provides for continuous display of all data and status indications, long term data storage and computer processing of such data through appropriate software.

The equipment includes a GE-PAC 30-2 computer with 32K core storage, a Terminet 300 Teleprinter for operator-computer communication, and an operator's console. The console includes status and display panels for all sensors, a CRT display, a hard copy unit and an operator's control panel for independent operation of the CRT display modes.

MINE MONITOR STATION

The mine monitor station shown in Fig. 1 is designed to include two major interconnected modules; a power module and the sensor module. This separation into two modules is done to insure compliance with permissibility requirements and to make the sensor module more readily transportable.

The sensor module is packaged in a fiberglass reinforced polyester plastic enclosure which is 30" high by 24-1/2" wide by 12" deep. Inside the enclosure is a stainless steel "egg-crate" rack designed to house the individual sensor trays and provide additional structural strength. The case also encloses the telemetry package and voice communications electronics tray. The case is provided with a hinged door with a window for viewing of the meter and status readouts.

In addition to connector mountings for individual sensors, the top surface of the sensor module case is used for mounting a central alarm unit and paging speaker system. Each sensor tray incorporates its own visual alarm status lights (LEDS). No audible alarm is provided at the individual sensor trays. Instead, the central alarm system has been designed to provide both a large, easily seen, red visual alarm and loud (120 db at 2900 Hz) pulsating audible alarm if any sensor should indicate an alarm status. The only exception to this is the elimination of the audible alarm for the noise sensor.

For the sake of maintenance and calibration procedures, an audible alarm disable switch is provided. A large white lamp is used as a pilot light. If the alarm disable switch is thrown, the white lamp flashes to warn the maintenance man that the audible alarm is disabled and to remind him to return the switch after he finishes working on the unit.

The sensor module has been designed to use only intrinsically safe power levels and circuitry. Since the primary power source in the
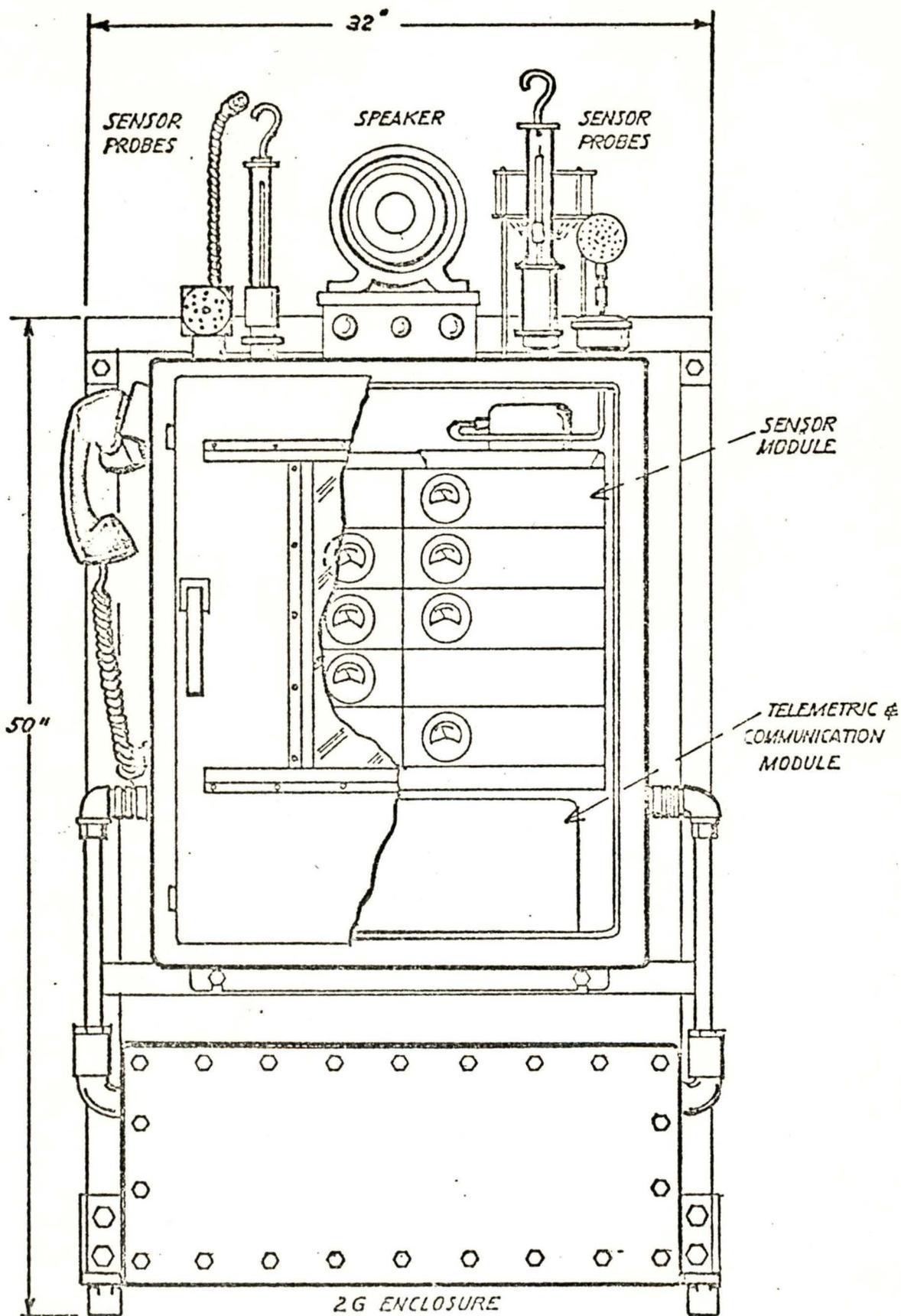
MINE MONITOR STATION
FIG. 1

mine to these stations is 240 volts a-c, this level must be reduced to appropriate d-c voltages for the various circuit elements of the sensor module. This reduction to several limited current, low voltage d-c power systems is incorporated in a permissible housing which meets USBM Schedule 2G. These intrinsically safe circuits are brought up to the sensor module (which mounts atop the power module) through two 37 conductor cables.

SENSOR ASSEMBLIES

The electronics for each sensor have been mounted in identical size tray assemblies which nest into the stainless steel egg crate rack. Including the spare sensor electronics, there are nine sensor systems, Table 1. The tenth tray space is used to house the electronics for the voice communications system.

To avoid extra design effort and to minimize the number of separate component parts, the tray assembly design has been kept as uniform as possible from one sensor to another with regard to physical layout for printed circuit cards, connectors and panel mounted components. Interconnections between sensor electronics (usually one printed circuit card) and detector interface (one card) are made through a mother board arrangement in the tray. P.C. electronics are plug-in type for easy replacement. Printed circuit board layouts for sensor electronics and interface have been kept as uniform as feasible. Thus it is possible, in some cases, to interchange a circuit card for one sensor type to another sensor electronics drawer and maintain operability. All meter movements are 0 to 5 V. d-c, 1 ma, although each is scaled in the required engineering units for that particular sensor.

METHANE

The methane sensor system is based on catalytic combustion of methane in air. The Pellement (trademark of Mine Safety Appliances Co.) sensing element is a small wire helix encapsulated in a ceramic bead which has been impregnated with a highly active catalyst which promotes the combustion of methane at relatively low surface temperatures. The increase in temperature due to combustion is translated into an increase in filament resistance which, in turn, produces a d-c voltage output when the sensor element is used in a Wheatstone bridge circuit. A second element without catalyst impregnation is used as the reference leg of the bridge to provide good stability and compensation for extraneous effects (temperature, thermal conductivity, etc.).

Except for packaging, the sensor head is identical to that used in the Methane Monitoring System, Model VI, which is currently in use in many mines. The unit requires no transport of sample since it operates by diffusion through a fritted metal disc in close proximity to the sensing element mounted behind the frit.

While the sensor head is normally intended to be mounted on the mine monitor station enclosure directly through mating electrical connectors, an extension cable may be employed for more remote location

TABLE 1 – SENSOR COMPLEMENT

SENSOR	RANGE	ACCURACY	SENSITIVITY	RESOLUTION	RESPONSE
VENTILATION	0-600 FPM	$\pm$ 3%	1.0 FPM	10 FPM	<1 sec.
TEMPERATURE	30°-80°F	$\pm$ 1°F	—	1°F	< 20 sec.
TEMPERATURE	0-60°F/Min.	$\pm$ 3°F	—	3°F	< 1 sec.
SMOKE	0.01 to 0.1 micron	—	.006 g/cf	—	5 sec.
NOISE	60-130 db	$\pm$ 3 db	(1)	1 db	ANSI S1.4-1971 slow
METHANE	0-5%	$\pm$ 1%	.1% CH_4	0.1%	3 sec.
CARBON MONOXIDE	0-500 ppm	$\pm$ 1%	10 ppm	10 ppm	90%< 50 sec.
HYDROGEN	0-500 ppm	$\pm$ 1%	10 ppm	10 ppm	90%< 50 sec.

(1) approx. 70 db re 1V/μ Bar, 20 Hz to 10K Hz

and a hook mount has been provided for such use. The diffusion disc of this assembly has been protected from dust and water by a baffle plate assembly.

The front panel of the methane monitor is typical of all the analog type sensors and its description in a general sense may be applied to the other sensor tray assemblies.

The local readout is a 0 to 5 V. d-c, 1 ma, ruggedized meter, scaled from 0 to 5 percent methane. Immediately to the right of the meter is a vertical row of status indicators; red LED's for HIGH and LOW alarm, a clear LED for sensor failure (trouble) and the methane module pilot light (green LED). To the upper right of the LED row is a three-position screwdriver actuated switch, labeled ZERO, NORM, CAL. This switch is used to set the electronics module in either normal operation, an electrical zero check mode (where the analog signal at the output of the bridge circuit is shorted) or a calibrate mode (where a synthetic signal is introduced into the detector amplifier input). Other components on the front panel are screwdriver adjustable pots for spanning and zeroing the sensor, a reset button for the alarm and trouble LED circuits, and an On/Standby switch. In the standby mode, a telemetry signal indicating failure is sent to the surface, indicating to the computer that valid data is not available from the sensor. In the standby mode, the local alarm is disabled, enabling the instrument technician to troubleshoot, calibrate or maintain the instrument without setting off local alarms.

The Wheatstone bridge circuit, bridge power failure sensing circuitry, and relay circuits for zero and calibrate modes are all mounted on a single printed circuit card in the module drawer.

Input and output signals from this card (both analog and digital) are connected through a "mother board" to a detector/telemetry interface card, Fig. 2. The interface card performs a variety of analog signal conditioning and amplification functions as well as logic procedures to determine status conditions and effect telemetry commands.

Circuit check and trouble signals appropriate to each sensor are provided.

CARBON MONOXIDE

As shown in Fig. 3, the carbon monoxide and hydrogen sensors share a common thermostatted sensor cell block and flow system. In addition, the basic principle of operation of each is identical so that the description of the carbon monoxide sensor, with the exception of the specific catalyst, serves also to describe the hydrogen sensor. The two sensors are the only ones incorporated within the mine monitor station itself.

The CO sensor portion of the cell block consists of two wells interconnected in series flow path. Each well contains a thermistor sensing element mounted on a Kovar header. One of these elements is
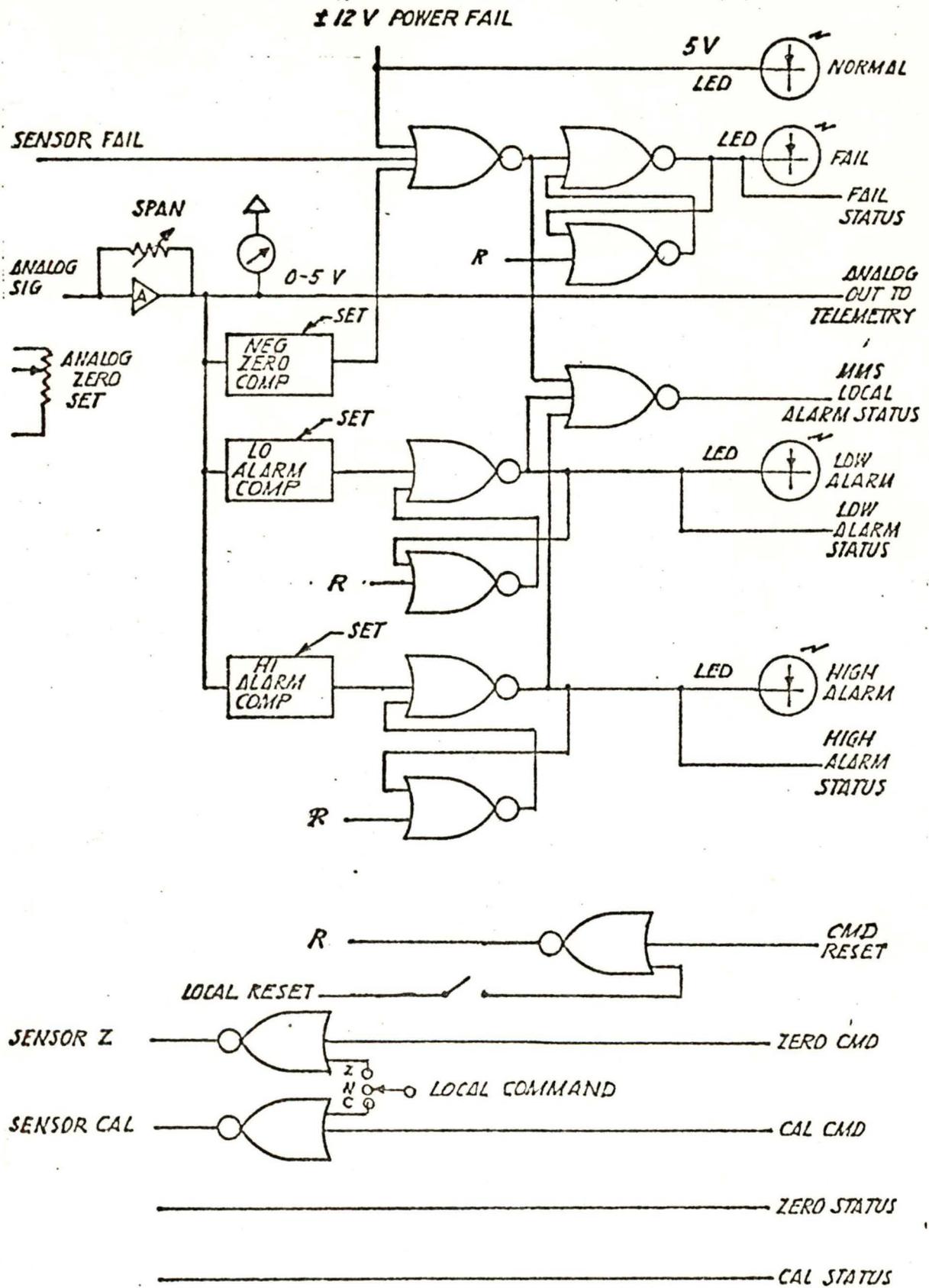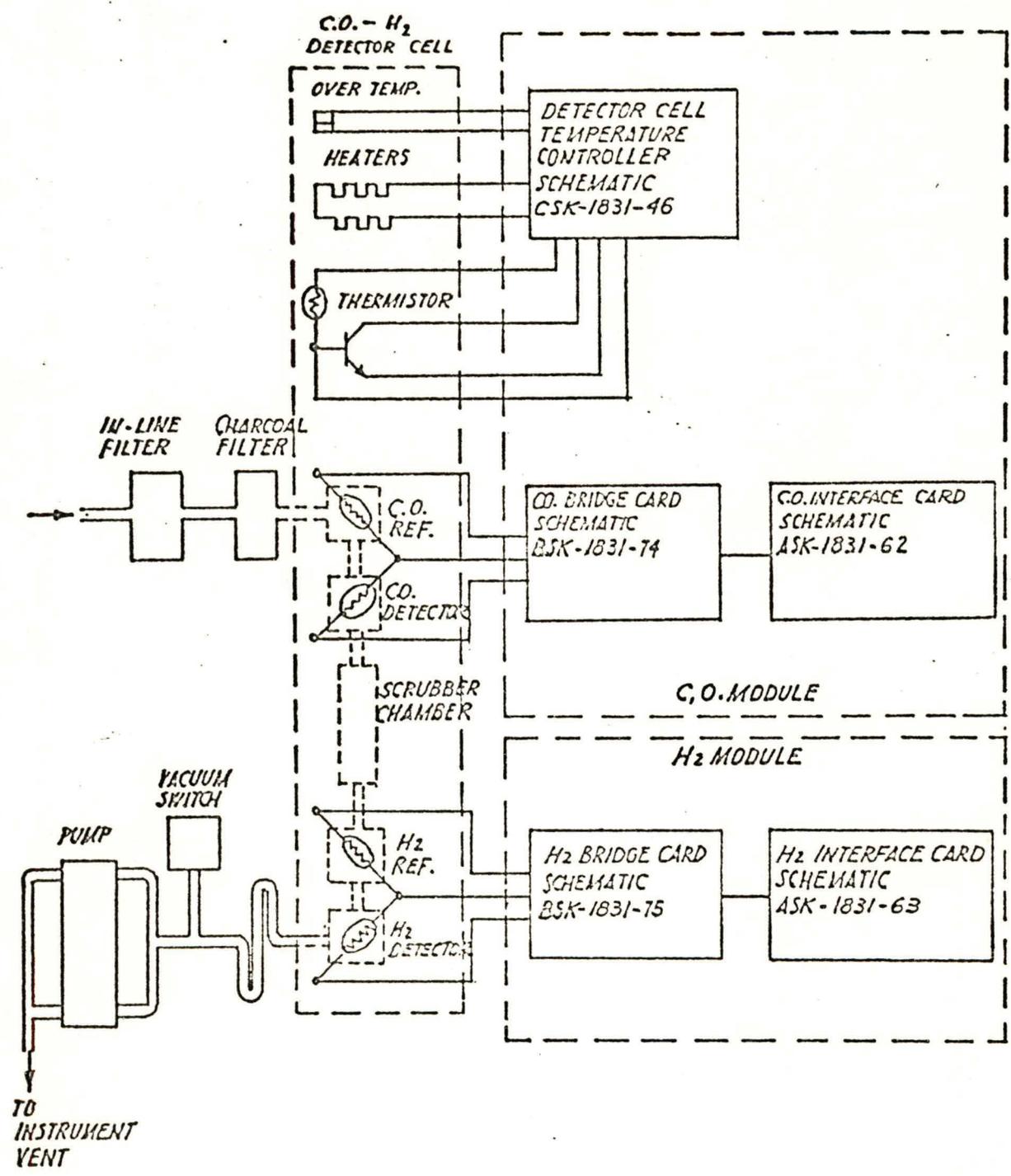
FIG. 2

INTERFACE FUNCTION DIAGRAM

FIG. 3

FUNCTIONAL SCHEMATIC
C.O. & H₂ MODULES

used as a reference element and is imbedded in a coarse mesh grade of diatomaceous earth. The second element well contains a bed of Hopcalite[R] catalyst (in intimate contact with the thermistor) which acts as a specific oxidizer for carbon monoxide in air. The two thermistor beads are electrically arranged in a Wheatstone bridge completed by two precision resistors in the electronics module, and powered by a highly regulated d-c power supply. The thermistors in practice act therefore as a differential thermometer, sensing any slight change in temperature between the two wells. This temperature change is induced when a concentration of carbon monoxide in air flows through the cell. The reference bed temperature always remains at the temperature setting of a proportional temperature controller and the resistance of the reference thermistor is therefore constant. The catalyst (Hopcalite) in the sensing well, however, combusts the carbon monoxide to carbon dioxide (with an efficiency of approximately 80%) and thus increases the temperature of that bed, lowering the resistance of the thermistor sensor and unbalancing the Wheatstone bridge. This unbalance is directly proportional to the concentration of carbon monoxide and is reflected in a d-c voltage signal. This signal is then conditioned and amplified to provide relatively high level (0 to 5 V. d-c) inputs to a local meter readout on the tray assembly panel, to an alarm circuit, and to the telemetry system.

The cell block, Fig. 4, is thermostatted at approximately 112°C. The air sample is pulled through the cell assembly with a brushless d-c dual head pump. It first passes through a high capacity end-of-line particulate filter provided with a quick-disconnect feature for accommodating various lengths of sample line easily and then through a chemical type filter (charcoal) which is mounted externally on the mine monitor station enclosure. Both filters are therefore easily and quickly replaceable during routine maintenance. The sample enters the cell block through a tempering path to equilibrate the gas to cell temperature, through the reference side of the CO sensor, and then to the sensing or detector well of the CO cell where any carbon monoxide is oxidized and detected. The sample then passes through a Hopcalite scrubber section through the reference and sensing wells of the hydrogen detector and exits through the pump assembly to vent.

HYDROGEN

The hydrogen sensor is identical in almost every respect to the carbon monoxide sensor, and the only significant difference is the catalyst bed. In this case, the catalyst is palladium on alumina which selectively combusts hydrogen.

VENTILATION

The ventilation monitor incorporates compensated metal clad thermoanemometer probe to monitor air velocity over the range of 0 to 600 feet per minute.
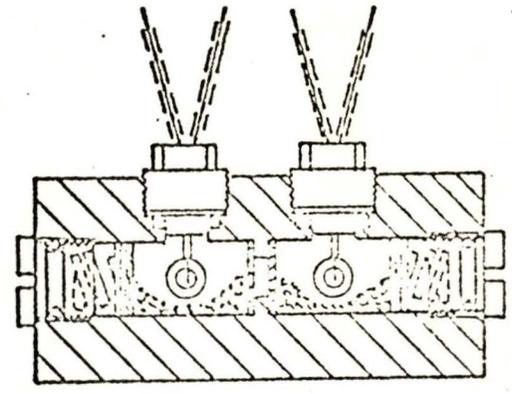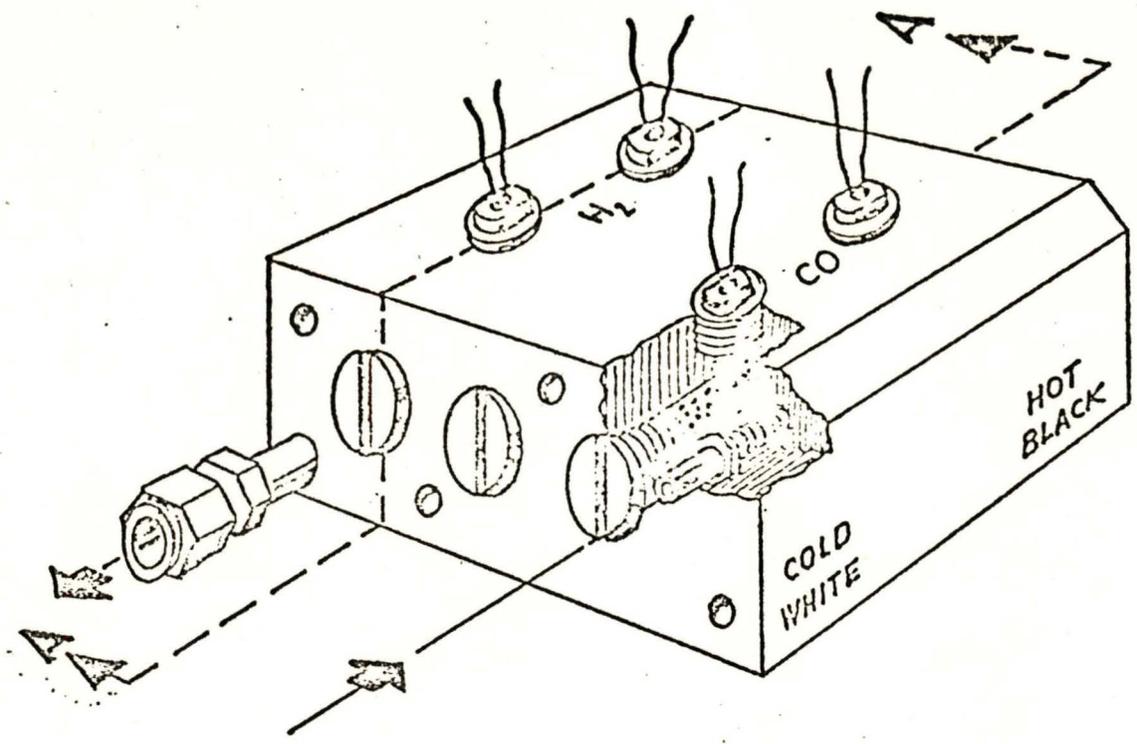
SECTION "A-A"

FIG. 4

The connector end of this probe contains the entire circuit for a normal nonlinear output thermoanemometer, including temperature compensation and amplification.

The output signal from the anemometer probe is taken through a linearization circuit before the interface circuit to provide a final output signal linearly proportional to air velocity.

An inverter is used after the alarm comparator to enable the alarm below set point rather than above. The analog amplifier is omitted since the output from the linearization card is already at 0 to 5 V. d-c over the range of 0 to 600 fpm.

TEMPERATURE

The temperature monitor which covers the range of 30 to 80°F, employs three-wire type, 100 ohm platinum wire resistance temperature detector, RTD. The probe is 5-1/2" long by 3/16" O.D., stainless steel clad and shock mounted at the connector end. The probe connector and extension cable connectors have been provided with redundant contacts for maximum reliability and freedom from contact resistance errors.

The RTD forms one leg of a Wheatstone bridge completed by fixed resistors and a zeroing potentiometer. The bridge circuit is powered by a regulated 3 volt d-c supply and the bridge output is then amplified to the required 0 to 5 V. d-c range by a two-stage IC amplifier circuit.

Included in the 10 foot harness and the probe itself are extra connector contacts which can be used for a continuity check of the cable and sensor system.

TEMPERATURE RATE OF RISE

The Temperature Rate Monitor is designed to measure rates of increase in ambient air temperature over the ranges of 0 to 60°F per minute. To accomplish this, it uses the same amplified RTD sensor output as the temperature monitor readout through a module connector system between the two tray assemblies.

The 0 to 5 V. temperature signal is routed through a module connector to a RC signal differentiator circuit. The output of this circuit is proportional to the product of the resistance-capacitance time constant (about one-half second) times the change in input voltage per second. The signal output level of the differentiator is inherently low and a IC amplifier is used to amplify the signal level before routing to the interface board.

SMOKE

The smoke monitor incorporates an ionization detector which responds to the extremely small particles associated with the early stages of a fire. Unlike the other sensors thus far described, this device has no analog output, but indicates an alarm condition in the presence of smoke in a sensing ionization chamber. A second chamber is used as a reference to obviate the effects of humidity, temperature and pressure. A high impedance amplifier-switching circuit establishes alarm status.

The sensor unit has been modified to include a mounting hook and an internal relay card circuit board for trouble and alarm functions. Since no analog value is transmitted, the tray assembly does not include a meter. The interface board has no analog amplification or alarm comparators since no analog signal is transmitted.

NOISE

The noise monitor is designed to function as a general purpose sound level meter with local readout and as an integrating noise exposure device with Walsh-Healey weighting for telemetry transmission.

As a sound level meter, the unit will cover a range of 60 to 130 db in 10 db increments selected by a seven position panel mounted switch. The local readout meter is graduated from -10 to 0 to +10 dbA in an exponential fashion that provides good resolution for the 0 to + dbA portion of the scale. The device provides "A" curve weighting and slow response. Alarm setting (high and low) correspond to 90 and 115 db.

As a Walsh-Healey type monitor, the unit will accumulate noise signals over a one-minute period, process, and provide an analog output to telemetry which is proportional to the noise exposure dosage. This exposure value will be transmitted by telemetry only when the local selector switch is set at 100 db, so in normal operation the switch is left in this position. The other positions are used only when it is desired to operate the device as a local noise survey meter. The pushbutton switch labeled "+ 10 db" is used to change the range by 10 db without operating the selector switch. At 100 db on the selector switch, the 90 db alarm function may be observed (-10 db on meter scale), but the 115 db alarm is out of meter range. By using the + 10 db switch, the 115 db alarm may be observed (at the + 5 db mark of the meter scale) without disturbing Walsh-Healey dosage to telemetry.

The sensor itself is a B&K Instruments, Inc., Model 4117, ceramic microphone with wind screen mounted on an 18 inch gooseneck. The microphone may be detached from the mine monitor station and located remotely through a ten-foot extension cable.

SURFACE MONITOR STATION

The Surface Monitor Station which consists of the control console, computer and its associated peripherals, will provide the central control, command, recording and display functions of the system. Fig. 5 is a block diagram of this equipment installed in the Instrumentation Building addition at the Bruceton facility. Automatic control of the system will be provided by the computer and its associated operational software under general direction of the station operator. Data is collected from the mine stations in any one of three modes of operation as commanded from either the control panel or the keyboards of the video or typewriter terminals. In the normal mode of operation, commands generated by the computer will sequentially interrogate each of the Mine Stations. Data will be received from each of the Mine Stations at six-second intervals, resulting in the total system data being updated once each minute.

The data, including sensor data, alarm and status indicators, as received by the computer, will be checked for parity errors, analyzed, displayed as directed and recorded on magnetic tape along with date and time for the necessary historical record. The operational software programs provided will automatically perform this function and provide outputs to the status and display panels for indications of status, calibration or set point alarms as necessary for each of the sensors. In addition, in the event of an alarm or fault condition, the audible alarm will be sounded and the visual alarm light will flash. The typewriter will be commanded to print out the alarm message along with the appropriate time indication of the event to provide a documented record.

In addition to the normal mode of operation, the system can be placed into two other modes of operation. Fig. 6 is a timing diagram comparing these three modes. This provides the means to acquire data in any of the following three modes of operation:

1. "Normal" Mode - 10 station interrogations per minute evenly spaced throughout the minute; i.e., complete system once per minute.

2. "Rapid One" Mode - 20 additional interrogations per minute of any one selected station, once every 2.0 seconds interleaved with the normal interrogation cycle.

3. "Rapid All" Mode - Interrogate all stations sequentially, one station every 2.0 seconds continuously.

Through discrete buttons on the control panel, the data from any one through all of the sensors at any number of stations can be displayed on the video terminal with a copy prepared by the typewriter, if desired. In addition, hard copy of the video terminal's display can be made with a hard copy unit.

```
┌─────────────┐     ┌─────────────┐     ┌─────────────┐     ┌─────────────┐
│ MEMORY      │     │ SELECTOR    │     │ MAG TAPE    │     │ MAG TAPE    │
│ BUS         │─────│ CHANNEL     │─────│ CONTROLLER  │─────│ TRANSPORT   │
│ CONTROLLER  │     │             │     │ D3-301      │     │             │
│ D1-101      │     │ D1-102      │     │ D3-103      │     │ D3-202      │
└─────────────┘     └─────────────┘     └─────────────┘     └─────────────┘
```

MEMORY BUS

```
┌─────────────┐
│ GE PAC 30-2E│
│ 32K CORE    │
│ AS-103      │
└─────────────┘
```

```
┌─────────────┐
│ 60HZ CLOCK  │
│ F4-101      │
└─────────────┘
```

```
┌─────────────┐     ┌─────────────┐
│ TERMINET 300│     │ TERMINET 300│
│ INTERFACE   │─────│ ASR         │
│ E2-101      │     │ E2-201      │
└─────────────┘     └─────────────┘
```

```
┌─────────────┐     ┌─────────────┐     ┌─────────────┐
│ ASR 33      │     │ VIDEO       │     │ VIDEO       │
│ INTERFACE   │─────│ TERMINAL    │─────│ TERMINAL    │
│ E2          │     │ INTERFACE   │     │ T-4002A     │
│             │     │             │     │ 021-0034-00 │
└─────────────┘     └─────────────┘     └─────────────┘
                                              │
                                        ┌─────────────┐
                                        │ HARD COPY   │
                                        │ UNIT        │
                                        │ 4601        │
                                        └─────────────┘
```

I/O
MULTIPLEX
BUS

```
┌─────────────┐     ┌─────────────┐
│ 103 DATA SET│     │ DIGINET     │
│ ADAPTER     │─────│ 160         │──── DATA LINE
│ H2-101,H5-102│    │ MODEM       │
└─────────────┘     └─────────────┘
```

```
┌─────────────┐
│ DIGITAL I/O MUX│
│ CONTROLLER  │
│ F3-101      │
└─────────────┘
```

```
┌────────┐ ┌────────┐ ┌────────┐ ┌────────┐ ┌────────┐
│128 POINT│ │128 POINT│ │128 POINT│ │128 POINT│ │128 POINT│
│INPUT   │ │OUTPUT  │ │OUTPUT  │ │OUTPUT  │ │OUTPUT  │
│MODULE  │ │MODULE  │ │MODULE  │ │MODULE  │ │MODULE  │
│F3-102  │ │F3-103  │ │F3-103  │ │F3-103  │ │F3-103  │
└────────┘ └────────┘ └────────┘ └────────┘ └────────┘
```

```
┌─────────────┐     ┌──────────────────────────────────────┐
│ 8 LINE      │     │                                      │
│ INTERRUPT MODULE│ │        OPERATOR CONSOLE              │
│ F1-101      │     │                                      │
└─────────────┘     └──────────────────────────────────────┘
```

FIG. 5

SURFACE STATION
COMPUTER & PERIPHERAL CONFIGURATION

INTERROGATION TIME

"NORMAL" POLLING MODE

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

"RAPID ONE" POLLING MODE

| 1 | S | S | 2 | S | S | 3 | S | S | 4 | S | S | S | S | S | 6 | S | S | 7 | S | S | 8 | S | S | 9 | S | S | 10 | S | S |

"RAPID ALL" POLLING MODE (S = SELECTED STATION)

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

TIME-SECOND

| 0 | 10 | 20 | 30 | 40 | 50 | 60 |

FIG. 6

The operator can also request via the CRT or Terminet Keyboards, specific information to be recalled from the magnetic tape history and to be presented on the CRT, or Terminet. Tabulations or plots (CRT only) of the following can be provided:

a. Individual sensor data vs time history
b. Ratio of two sensors vs time history
c. Minimum, maximum or average sensor data vs time

The Surface Monitor Station serves as a communication center for all stations. The paging system for voice communications is available at the console.
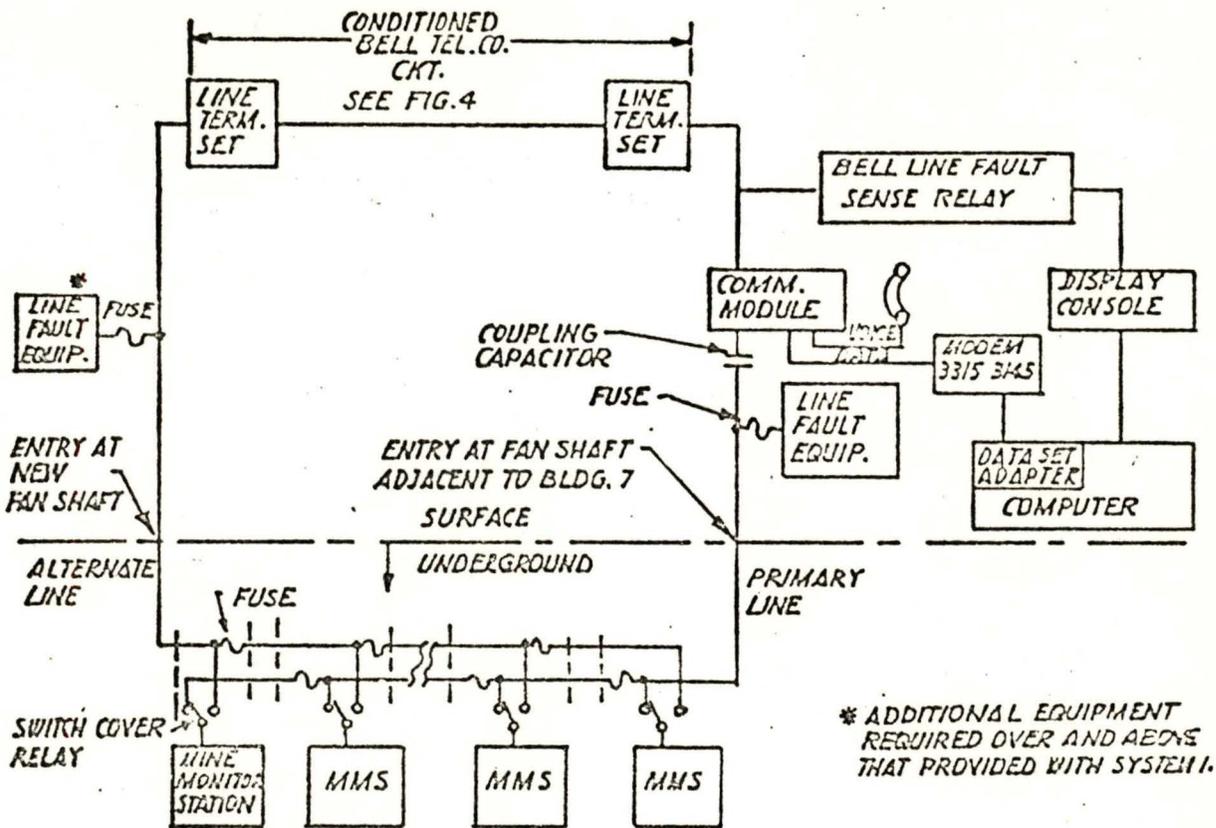
COMMUNICATION SYSTEM

The Surface Monitor Station (SMS) together with the ten underground Mine Monitor Stations (MMS) comprise a communications system. The system employs a single twisted pair of wires for the transmission media at any given time. A redundant alternate pair is also provided. The arrangement of these signal wires is shown in Fig. 7. The aboveground routing of the alternate signal pair is provided as a Bell Telephone Company circuit. Transmissions within the communication system are via the primary twisted pair. In the event of a failure occurring on this line, one or more of the MMS are automatically switched to an alternate line which allows for continued operation during line fault. Underground, the alternate line parallels the routing of the primary line but is run in the opposite direction from the SMS as shown in Fig. 7.

Simultaneous transmission of voice, data, keying and line monitor signals is accomplished by frequency diversity (speech-plus). Fig. 8 depicts the frequency allocations for these functions. Low voltage d-c is used for line monitoring and switching. The voice band starts at approximately 300 Hz and extends to 2700 Hz (L.P. filter cutoff). Two data channel frequencies are provided. The 3145 Hz band is used for mine monitor station telemetry transmission to the surface and the 3315 Hz band for interrogation and command transmission from the SMS to the MMS. The keying tone which activates the speakers in the paging system is 3600 Hz.

COMMUNICATION SET

Each Mine Monitor Station contains communication equipment for both voice and data. This equipment functions as a terminal for the voice system and for the FSK data signals. The conversion between digital data signals and FSK signals is provided by a conventional modem. The primary input/output device for the voice system is a telephone handset located on the left hand side of the sensor module housing. A paging speaker is also included as another output of the communication set. A block diagram of the communication set is shown in Fig. 9. This module provides the station with a balanced 2-wire connection to the communication line via a hybrid termination which is capacitively coupled to the line to prevent d-c current from flowing in the output

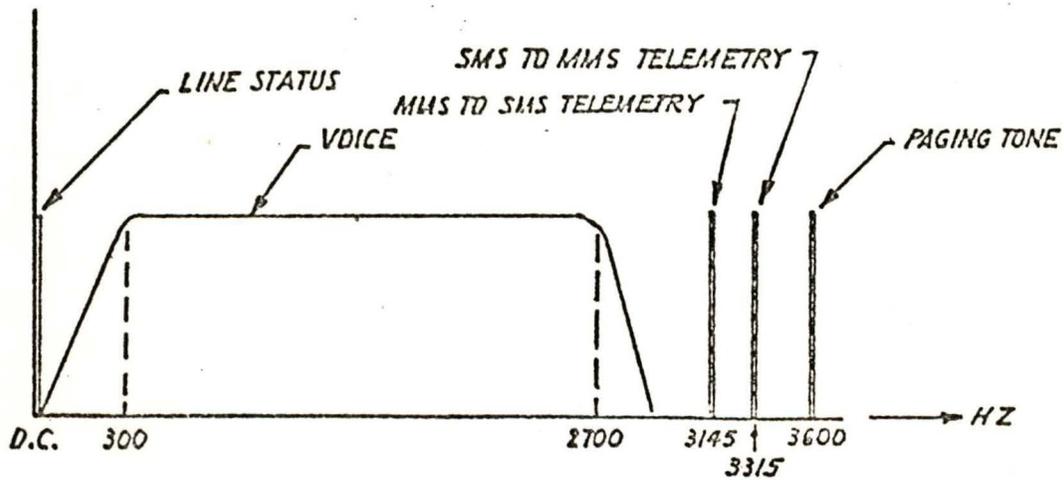CONDITIONED BELL TEL.CO. CKT. SEE FIG.4

SYSTEM 2 — Fig. 7

* ADDITIONAL EQUIPMENT REQUIRED OVER AND ABOVE THAT PROVIDED WITH SYSTEM 1.

Fig. 8
FREQUENCY ALLOCATION DIAGRAM

COMMUNICATION SET - Fig. 9

Fig. 10

SCHEMATIC, SPEAKER AMPLIFIER

transformer. This is necessary because of the d-c power on the lines used for line monitoring and switching circuitry. The hybrid termination provides a three-port device, consisting of a line port, receive port and transmit port. The "hybrid" provides the transition between the 2-wire line and the 4-wire connection in the communication module. Voltage gain is required both in the circuit which drives the transmit winding and that part of the circuit driven by the receive winding. With the hybrid it is possible to provide the required gains in both transmit and receive legs without the danger of entering a condition of oscillation.

Speech from the handset transmitter is coupled to the input of a limiter. An RCA CA3005 integrated circuit, designed for use as a limiter in communications equipment, is used. The output of this stage limits the speech signals to -16 db. The stage following the limiter is designed around an RCA CA3047 integrated circuit which is a high performance operational amplifier suited for this application as a buffer. This stage provides voltage gain. The output of the buffer drives a low pass filter. The cutoff frequency of the filter is 2.7 KHz. The characteristics of the filter are such that its response is down 60 db at 3.02 KHz. This effectively removes components of speech in the region where it could otherwise interfere with data transmission.

The line amplifier, also an RCA CA3047, is connected in a summary configuration and has three isolated inputs; data, speech and keying tone. Each incoming signal is coupled to the amplifier input through a separate isolation resistor, thus insuring that the relative levels of the three signals at the input are maintained. The amplifier provides a different amount of gain for each input. The stage gain for data is approximately 2, for voice it is approximately 3, and for "paging" tone it is approximately 1/2. The line amplifier drives the transmit winding of the "hybrid" transformer through a 604 ohm resistor to assure proper loading on the line.

The signals appearing at the line port are 0 dbm (peak) for voice - 10 dbm for data and - 10 dbm for keying tone.

The receive port of the hybrid passes the receive line signal to the receive amplifier (an RCA CA3047) which provides voltage gain and a low output impedance to drive three outputs. One output goes to the FSK modem receiver, another feeds the tone receiver used to key the paging speaker; the third output feeds through a low pass filter which removes the telemetry tones but passes the voice band. This filter is identical to the transmit filter previously described. The voice band output is delivered to the handset receiver and, if keyed, to the power amplifier and paging speaker. The schematic of the speaker amplifier is shown in Fig. 10. The speaker and amplifier are packaged as one unit in a cast metal horn assembly along with its volume control.

LINE STATUS AND SWITCHING

The redundant signal line system is implemented with an automatic switching method shown in Fig. 11. As long as the primary line is intact, it will operate the communications module. The plus and minus sides of the primary line (12 V. D.C.) are monitored by a hybrid solid-state reed relay device (Struthers-Dunn 16C2) termed VS_1 in the schematic. As long as signal is present, contacts VS1-1 are closed, thus energizing relay CR1 and closing contact sets CR1-1 and CR1-2 to the output to the communication module (terminals 13 and 14). CR3 is also energized to provide a closed relay contact (CR3-2) for primary line status indication. The alternate line is monitored with an identical hybrid device (VS2) and its status is taken directly from the VS2-1 contact set (closed when the alternate line signal is intact).

If the primary line input should open (as when a short blows fuses #2 and/or #3 in another station closer to the SMS) the contact VS1-2 will close, energizing CR2 and closing its contacts CR2-1 and 2 to connect the alternate line to the output.

TELEMETRY SYSTEM

General Description: The function of the telemetry system is to collect and transmit data signals from the sensors in the mine stations to the computer at the surface station. In addition to sensor data, the telemetry system collects and transmits from each of the mine station information concerning the status of the entire surveillance system such as telephone and power line integrity. The telemetry system also provides for transmission of control and command signals (interrogate, zero, cal, etc.) from the surface station to the individual mine stations. The communication link over which the telemetry system operates consists of the FSK modems and the "speech-plus" telephone system previously described. The telemetry system is controlled and the data is processed at the surface in accordance with the operating modes of the Surface Monitor Station and its associated computer. This section deals primarily with the overall functional design of the telemetry system and specifically to the design of the telemetry and command module located in each MMS. The corresponding hardware at the SMS is contained within the computer.

FUNCTIONAL DESIGN

All telemetered data is transmitted in digital form as pulse code modulation (PCM). In PCM a unique arrangement of serial pulses is assigned to each resolved signal value. Each pulse corresponds to one binary bit. Each complete message or train of pulses is organized into standard size words for identification and error detection. To minimize interface requirements, the word size of the telemetry system is the same as that of the computer, i.e., 8 bits. One bit position is assigned as a parity bit for error detection and odd parity is used to assure at least a one bit transition in each word. The remaining 7 bits/word are available for data. The code used for all analog values is straight binary to permit the full resolution capability of
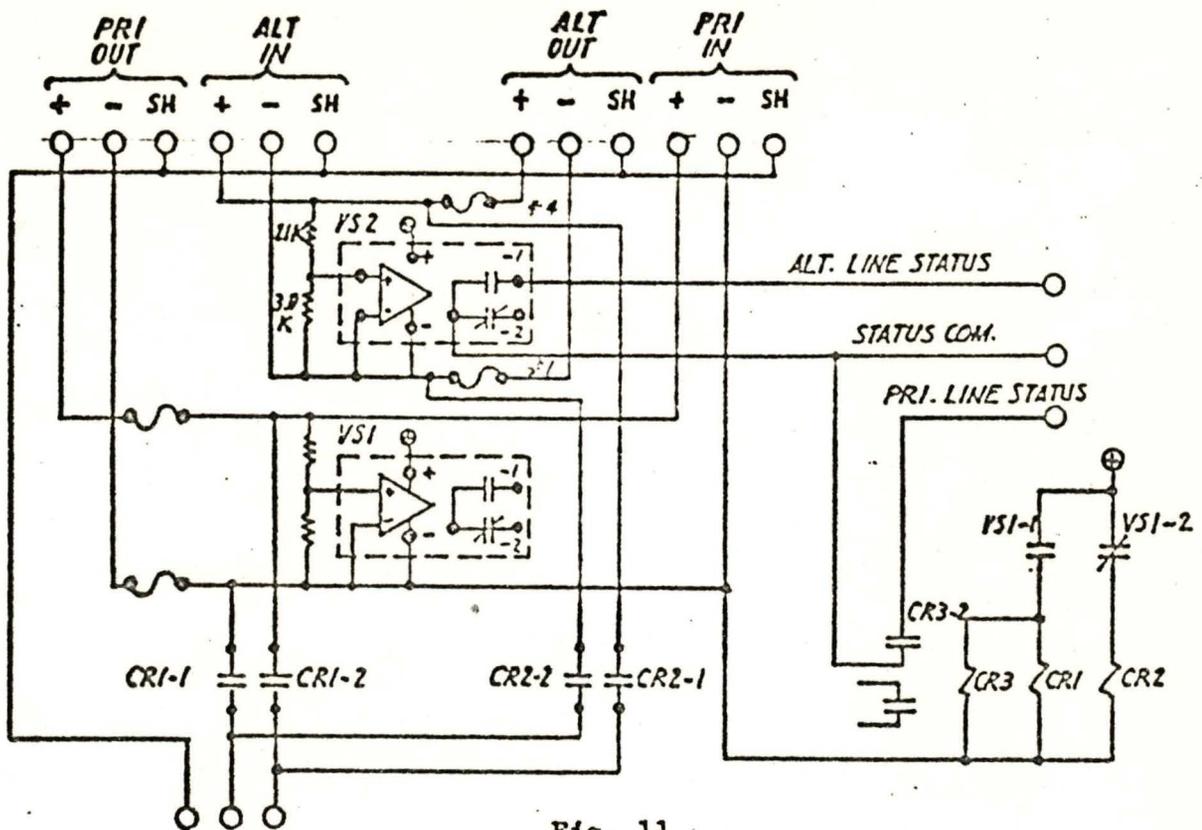
Fig. 11
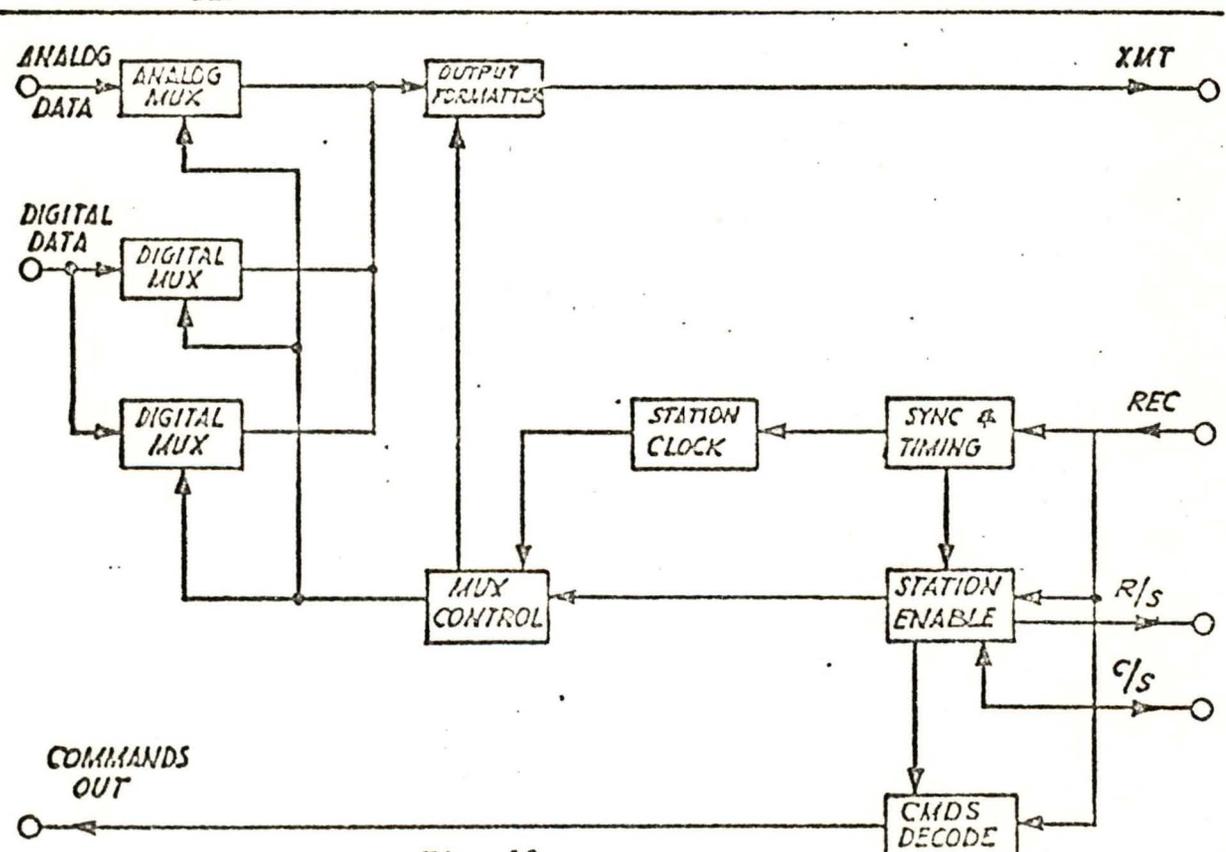SCHEMATIC
SIGNAL LINE STATUS & SWITCHING

Fig. 12
DATA TERMINAL

the telemetry system to be used. Digital type signals such as alarms and status indications are coded simply by assigning a word and bit position. The word list for the telemetry system is given in Table 2. A start and stop bit are added to each 8 bit data word, making each transmitted word 10 bits to permit asynchronous operation, thus relaxing bit rate stability requirements. A total of 16 ten bit words are used in each message from MMS to SMS with the following breakdown:

1. Fifty-seven bits for sensor values including one spare sensor

2. Eleven bits for set point alarms

3. Nine bits for sensor status (normal/failure)

4. Four bits for line status (normal/failure)

5. Eighteen bits for sensor command (zero/span/normal) indications

6. Eight spare bits

7. Sixteen parity bits

8. Thirty-two start, stop bits

9. Four bits for station address

Each station response message is initiated upon receipt of an interrogation command which consists of a single word containing the four bit station address from the SMS. The remaining three data bits in the interrogate word are assigned as commands. Eight possible commands may be sent to a station; only three (zero, span, normal) are implemented in the system. The frequency of interrogating a station is under software control by the SMS computer.

DATA TERMINAL

This module is designed to be intrinsically safe and is located within the MMS sensor housing, thus providing ready access. The T&C module is located on the lower shelf in the MMS housing, Fig. 1. The module is housed in a stainless steel case with all panel mounted components (connectors and switches) located in the sides so that the cover can be removed without electrically disconnecting any part of the circuitry. MMS telemetry equipment, exclusive of the modem, is constructed on 9 double sided circuit boards.

A block diagram of the MMS telemetry module is presented in Fig. 12. Upon receipt of an interrogate word (containing a station address and commands) from the modem, the Sync and Timing circuits are initiated and the Station Clock is synchronized. The address portion of the interrogate word is compared with the hard-wired address of the local station. If the address matches, the Station Enable initiates a station response by enabling the Mux Control. Simultaneously the command portion of the interrogate word is decoded in the Cmds Decode

WORD	BIT	PARAMETER	WORD	BIT	PARAMETER	WORD	BIT	PARAMETER
1	1	ST (START)	7	1	ST	13	1	ST
	2	ADDRESS		2	NOISE SENSOR (MSB)		2	H2 SENSOR (MSB)
	3	↕		3	↕		3	↕
	4			4			4	
	5	ADDRESS		5			5	
	6	DATA LINE 2 STATUS		6			6	
	7	DATA LINE 1 STATUS		7			7	
	8	SP (SPARE)		8	NOISE SENSOR		8	H2 SENSOR (LSB)
	9	PARITY		9	P		9	P
	10	STP (STOP)		10	STP		10	STP
2	1	ST	8	1	ST	14	1	ST
	2	CMD ZERO - VENT		2	SET PT VENT		2	TEMP SENSOR (MSB)
	3	CH4		3	NOISE SENSOR (LSB)		3	↕
	4	CO		4	SET PT CO		4	
	5	H2		5	H2		5	
	6	SMOKE		6	SMOKE		6	
	7	TEMP		7	TEMP		7	
	8	CMD ZERO ΔT		8	SET PT ΔT		8	TEMP. SENSOR
	9	P		9	P		9	P
	10	STP		10	STP		10	STP
3	1	ST	9	1	ST	15	1	ST
	2	CMD SPAN - VENT		2	VENT SENSOR (MSB)		2	ΔT SENSOR (MSB)
	3	CH4		3	↕		3	↕
	4	CO		4			4	
	5	H2		5			5	
	6	SMOKE		6			6	
	7	TEMP		7			7	
	8	CMD SPAN Δ TEMP		8	VENT SENSOR (LSB)		8	ΔT SENSOR (LSB)
	9	P		9	P		9	P
	10	STP		10	STP		10	STP
4	1	ST	10	1	ST	16	1	ST
	2	STATUS - VENT		2	UNUSED WORD		2	SPARE SENSOR (MSB)
	3	CH4		3	↕		3	↕
	4	CO		4			4	
	5	H2		5			5	
	6	SMOKE		6			6	
	7	TEMP		7			7	
	8	STATUS ΔT		8	UNUSED WORD		8	SPARE SENSOR (LSB)
	9	P		9	P		9	P
	10	STP		10	STP		10	STP
5	1	ST	11	1	ST			
	2	ST PT LO CH4		2	CH4 SENSOR (MSB)			
	3	ST PT HI CH4		3	↕			
	4	ST PT LO NOISE		4				
	5	ST PT HI NOISE		5				
	6	ST PT LO SPARE		6				
	7	ST PT HI SPARE		7				
	8	PWR LINE 1 STATUS		8	CH4 SENSOR (LSB)			
	9	P		9	P			
	10	STP		10	STP			
6	1	ST	12	1	ST			
	2	CMD ZERO-NOISE		2	CO SENSOR (MSB)			
	3	CMD ZERO-SPARE		3	↕			
	4	CMD SPAN-NOISE		4				
	5	CMD SPAN-SPARE		5				
	6	STATUS-NOISE		6				
	7	STATUS-SPARE		7				
	8	PWR LINE 2 STATUS		8	CO SENSOR (LSB)			
	9	P		9	P			
	10	STP		10	STP			

TELEMETRY FORMAT

TABLE 2

circuitry and the command is passed on to the sensors. The Mux Control provides word and bit control of the Analog Mux and the Digital Mux. Under this control, the analog data from the sensors is multiplexed to an analog to digital converter and presented as digitized data to the Output Formatter. The digital data from the sensors is also multiplexed and included. The Mux Control also provides parity and word control of the Output Formatter resulting in the serial train of pulses constituting the station telemetry message organized as previously described in Table 2.

POWER DISTRIBUTION

One of the prime design factors for the Mine Surveillance and Communication System is continuity of operation in the event of a disaster. It is, of course, quite possible that such a disaster may cause severe damage to portions of the mine monitor equipment or to the cabling system which interconnects the mine monitors and the surface control site.

In order to make it statistically highly improbable that a disaster would prevent all mine monitor communication with the surface, a redundant cabling system is employed. The redundant cabling system for power is similar to that previously described for communication in that relays are used to sense line failure and fuses are used to isolate short circuit faults.

SUMMARY

The surveillance and communications system described has been designed to use current sensor, telemetry and computer technology to provide continuous monitoring of parameters important to the safe operation of coal mines.

As part of the preinstallation testing, the ten mine monitor stations in Pittsburgh were linked with the control and computer portions of the system, surface monitor station, in Valley Forge by means of standard telephone lines. In this way, convenient and practical preliminary testing could be accomplished since it subjected the equipment to the necessity of operating over telephone grade lines.

Upon completion of the installation in the Research Coal Mine of the U. S. Bureau of Mines at Bruceton, Pa., operation of the system will provide a medium for testing and demonstrating the practicality of continuously monitoring vital parameters at many points in an operating mine and for doing studies on the effects of various mining practices on such parameters.

ACKNOWLEDGMENTS

IV. RESULTS AND RECOMMENDATIONS

4.1 Introduction

The Mine Surveillance and Communication System has been successfully installed and tested and has performed the tasks it was designed to do. Many of the features and techniques employed in this system which is designed as a research tool may not be as applicable in a normal working mine. It is the purpose of this section of the report to make an appraisal of the system and its sub-systems in view of current technology and normal mining practice.

4.2 Mine Monitor Station

4.2.1 Packaging and Construction

The reinforced plastic NEMA box with the stainless steel egg crate and the flameproof box provide sufficiently rugged construction with little or no corrosion to date. In some locations, water seepage through the cables into the flameproof box became a problem, but has been corrected with better sealing and by changing cable geometry. End of line filter assemblies were corroding, but replacement assemblies have been electroplated to prevent this in the future.

An overhead canopy was installed at four stations to keep excessive roof water from the sensor probes.

4.2.2 Sensors and Sensor Electronics

One problem with the carbon monoxide and hydrogen sensors has been the finite pump life. At least 5 pumps have failed. This is understandable since the manufacturer's specification shows a rating of 5000 hours maximum. Thought should be given to incorporation of a less expensive, permissible pump which would be replaced at least every six months. The CO sensors require at least weekly adjustment of zero controls.

No particular problems are presented by the temperature or methane monitors. The temperature rate of rise sensor, however, is particularly susceptible to transient pickup, especially when working on another sensor tray in the same station. For normal mine use, the more conventional rate of rise sensors such as the bellows actuated type

would be more applicable and less likely to produce false alarms. For research work, this type cannot, of course, yield analog values as does the RTD-Differentiator combination. On the other hand, rise data can be readily accumulated at the surface station by interpretation of the temperature values.

The smoke sensors appear to be quite adequate, but it must be pointed out that this basic sensor has been extensively modified by MSA for this purpose. This modification would greatly increase the price of this initially inexpensive sensor.

The ventilation sensor has required field modification to electronically slow its response time in order to average out the "noise" due to fast flow fluctuations, thus providing better average velocity values over the polling period. Meaningless alarms due to changes in turbulence are eliminated. While a metal clad type sensing element was chosen to prevent direct exposure to the environment, the probe is probably still too fragile for normal mine usage. Additional shielding around the sensor could be used if care is taken to properly orient the sensor with the flow path. A larger sensing element with slower response could have been readily used and would probably have been less costly. The methane sensors have presented no unusual problems.

The noise sensor design was strongly influenced by the need for a tool for safety research; consequently, this design is probably not appropriate as a noise monitor for an operating mine. For example, noise exposure is essentially associated with an individual and not an area; therefore, personal dosimeters are more appropriate than area monitors. The sensor design does provide a measure of the rate at which noise exposure in accordance with Walsh-Healey criteria is accumulated. Actual SPL is indicated at Mine Monitor Stations only since the telemetry system information rate is not adequate to transmit complete noise survey data to the Surface Monitor Station. Monitoring of noise hazards in an operating mine would most likely use personal dosimeters and portable sound level meters for noise surveys with audiometric measurements as backup.

CMOS electronics was used extensively in the MSA designed sensor trays and was coupled to TTL logic in the GE designed circuitry. The telemetry system in any future designs of this type could well use CMOS electronics for higher noise immunity and lower power consumption.

4.3   Surface Monitor Station

The computer control center has been designed with several input/output devices which perform essentially the same tasks. This degree of redundancy would be eliminated in future installations to cut costs. The present system, however, will enable the USBM to decide which of these devices are more reliable and useful. The complexity of the several modes of polling also increases the cost factor, and would not be provided in a more routine installation.

4.3.1   Software Techniques

The installed system has only 15 minutes of real time data storage during recall before overflow. Consideration should be given to a larger core. A magnetic tape cassette system could be used to avoid loss of data.

At present, the mag tape messages are numbers, with a given message for each number. The system uses real time data storage in 660 Byte blocks. Some space is left (less than 660 Bytes) and some or all of these messages could be expanded to English. Some consideration could also be given to dropping the RFTMOS punch, load routines and the memory print. Memory change should be retained as well as software backup of all the control panel functions.