26

AN EXPERIMENTAL VENTILATION CONTROL SYSTEM

M. Dayne Aldridge
Roy S. Nutter

West Virginia University
Department of Electrical Engineering
Morgantown, West Virginia

ABSTRACT

A description is given of an experimental ventilation control system designed, built, and tested by WVU under United States Bureau of Mines sponsorship. A description is given of the control system used and the mine-wide microcomputer-based venitlation monitoring system used with it. Test results of experiments conducted with this system at Eastern Associated Coal Corporation's Federal No. 2 underground coal mine are presented. In addition, a brief description is given of a new microprocessor based system presently being tested.

INTRODUCTION

Using funds supplied by the United States Bureau of Mines, under the Coal Mine Health and Safety Act of 1969, the West Virginia University (WVU) Department of Electrical Engineering established a research program in 1970 aimed at developing new technology for electronic communication and monitoring systems in coal mines. The original goal of this program was to develop practical and effective electronic systems for both operational and rescue mine communications and for monitoring conditions throughout the mine by displaying, at a central location, remotely measured parameters. Following extensive hardware and software development and testing of equipment on two operating sections of a commercial coal mine, a method for monitoring the total ventilation system in a mine was proposed by the WVU researchers. This led to a research project for evaluating mine-wide monitoring by constructing, installing and operating sensors throughout Eastern Associated Coal Corporation's Federal No. 2 mine. The objective of this program was to develop sufficient data and experience for government and industry to evaluate the mine-wide monitoring concept and establish desired design standards. Once completed, a remote control ventilation regulator was installed and tested.

BACKGROUND

The need for monitoring conditions in coal mines for safety purposes has been recognized for many years. A variety of instruments are used in coal mines today to insure the presence of a safe environment. Since the ventilation system plays the primary role in the control of methane and dust in normal mine activities and smoke and noxious gases during fires and explosions, the flow of air and the gases contained therein are the most important parameters that can be monitored for prevention of explosions and fires. Thus, the work described herein concentrates on ventilation monitoring with the following three objectives: 1) to provide early detection of problems well before human injury occurs, 2) to provide information on situations that develop beyond the incipient stages to aid the safe evacuation of personnel and control and elimination of the problem, and 3) to aid mine personnel in the day-to-day operation and maintenance of the mine system in minimizing hazards and maximizing efficiency.

Following a study of the candidate parameters for measurement and the availability of suitable sensors, the variables chosen for the WVU program were air velocity, differential pressure between airways, methane, carbon monoxide, temperature and relative humidity. Details of this study which was conducted under the U.S. Bureau of Mines Grant No. G0101702 are presented in previous reports.[1,2,3]

In order to most effectively monitor each variable it would be best to have sensors placed at each position where problems are most likely to occur. Obviously this is not practical. One solution is to place sensors at key positions so they can maintain surveillance over designated areas. In view of the way the air is supplied to each working section and fed back along nearby return airways, a natural location for the sensors is near the major splits of air. By properly choosing the splits to be monitored, the ventilation system can be effectively broken into zones or areas where all the air going into and out of each zone is under surveillance. Thus the occurrence of fire, abnormal methane liberation, ventilation disruption, etc., can be detected and the zone in which it is located determined.

Data from all the sensors discussed above must be converted to engineering units, checked and processed to determine the status of conditions in the mine, and displayed as required by operating personnel. As originally conceived, the research reported herein began with the hypothesis that the optimum arrangement was to locate all data processing and display equipment at one centralized location outside the mine. Early studies indicated that one of the major mine management problems during normal and emergency situations is the lack of an up-to-the-minute knowledge of conditions throughout the mine. Thus, it was concluded that the major thrust of the system design should be to accumulate as much useful data as possible at a central point and to process and display it in a useful and practical manner.

Because of the cost of digital processing equipment only a few years ago, the only practical solution to this problem was the centralized processing configuration. The recent advent of the microcomputer has made decentralized processing practical and thus requires that mine monitoring system architecture be reconsidered. It should be emphasized that the authors are not suggesting that the data processing should be totally decentralized. On the contrary, the major value of mine-wide monitoring is the accumulation of all data at one point for display, analysis and storage. Any system architecture must supply adequate centralized processing for these functions if historical surveys might become important to the user.

Maintenance of the ventilation system is one of the most critical jobs in deep coal mines. Although ventilation networks can be subjected to detailed mathematical analysis and computer simulation, every day operation of coal mine ventilation systems depends almost totally on experience and "cut-and-try" methods. The availability of mine-wide monitoring gives rise to the possibility of adjusting airflow regulators by electronic remote control.

This would permit changes in airflow distribution and quantity in a matter of minutes rather than over a period of several hours or days as now required. The value of such capability for mines with methane and dust control problems is obvious. In the case of explosion or fire, the ability to redistribute and control airflow would be extremely valuable in aiding the safe evacuation of men and in controlling the spread or propagation of fire. It should be recognized at the outset that remote control of mine ventilation must be coupled with a mine-wide monitoring capability. That is, the remote control capability is of little value unless its effect can be immediately measured throughout the mine.

There has been very little experimentation with remote control ventilation. The only other work known to the authors has been in Poland, the USSR and Belgium.[4,5,6] Extensive use of automatic ventilation control has been reported from the USSR,[7] but personal contacts indicate that remote control of ventilation regulators is used in only two mines. It is believed that the efforts reported here are the first attempts of regulator control in room-and-pillar mining.

SYSTEM DESCRIPTION

Initial tests of the basic concepts discussed above were carried out on a limited basis under U.S. Bureau of Mines Grant No. G0101702 as reported in reference [1].

Monitoring System

Beginning with the above objectives, a block diagram of the monitoring system that was installed and tested in Federal No. 2 mine is shown in Figure 1. The central computer system was located outside the mine in the engineering offices and 12 telemetry stations with sensors were located underground. Each of the major system components is briefly described in the discussion which follows.

The sensors used are listed in Table I.

TABLE I
TYPES OF SENSORS USED

Parameter	Sensor Type
Methane	Catalytic Hotwire
Carbon Monoxide	Solid State
Temperature	Thermistor
Relative Humidity	Solid State
Airflow	Vortex/Ultrasonic
Differential Pressure	Diaphragm/Magnetic Balance

The first four sensors in the above list are enclosed in a steel housing shown on the left side in Figure 2. A diaphragm pump pulls an air sample through an open faced filter which is fed to the sensors through a small airway manifold in two sensor mounting blocks. Voltage regulating and amplifying circuits are also enclosed in the housing. Electric power is fed to the package and the output signals are transmitted to nearby telemetry equipment by a cable containing 12 twisted pairs of No. 19 solid conductors.

The air flow sensor is enclosed in a separate housing as shown on the right side of Figure 2. This device senses air movement by measuring the rate of vortex formation in the wake of a generating rod. An ultrasonic method is used for detecting the vortices and is unaffected by normal dust and water spray.[8]

The digital telemetry units have a capacity for 20 analog channels and four on/off command channels for each monitoring station. The telemetry equipment along with the sensor power supply, intrinsically safe interface circuits and differential pressure transducers are housed in a steel enclosure mounted on skids. The housing is positioned in fresh air and does not require additional protection from possible roof falls or damage during transportation.

A block diagram of the central data processing and control center is at the top of Figure 1. All alarms and acknowledgments are simultaneously printed on

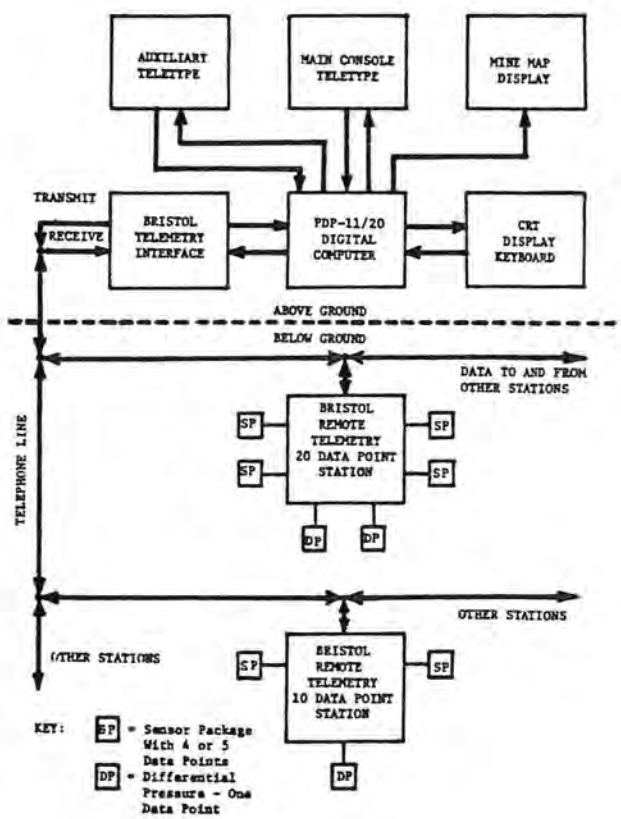

Figure 1. Block Diagram of the WVU Electronic Coal Mine Monitoring System

Figure 2. Sensor Package and Air Flow Sensor

one typewriter and stored on magnetic tape. The display panel shows the location of any alarm via a blinking red light on a mine map. The light blinks until the alarm is acknowledged then will continue on until the parameter falls back in acceptable limits. A green light is used for each mining section or return air station. Although the blinking red light indicates that at least one parameter is alarming in that area, the typewriter prints the location (station and airway), type of alarm (warning or danger), and a unique identification number for each parameter in the alarm. To acknowledge an alarm, the operator must use the identification number and his initials. A separate acknowledgment must be made for each alarm or an "acknowledge all" statement can be entered. All alarm and acknowledge data are printed on the system log typewriter.

Each sensor is queried once each minute, the data converted to engineering units and alarms levels checked. The data is stored in a disk memory and retained for one hour. Thus, at any given time all data for the immediate previous hour is available for quick retrieval. At the end of each hour a statistical analysis and summary of the previous hour's data is conducted and placed on magnetic tape. At any time desired by the operator he may call most any combination of data from the disk memory or hourly summary tape. This may be printed at high speed onto the CRT for rapid viewing or printed on the second typewriter for a permanent record. The output device is determined by the keyboard on which the command is typed.

The system was installed in Eastern Associated Coal Corporation's Federal No. 2 mine. The sensor packages were generally mounted on a timber in the flow of air of the entry being monitored. In return airways, packages were located near the top and center. In the case of intake airways where men and equipment move, the sensor package was located to the side near the corner of a cross cut as shown in Figure 3. The air flow sensor was located near the sensor package but in a position favorable to obtaining a reliable indication of the average air flow. In return airways this was usually on the same timber as the sensor package. However, the air flow sensors were usually hung from "spads" in the roof near the top center of intake airways.

The telemetry stations were located in cross cuts off of intake airways adjacent to return air, so that ventilation could be established over the telemetry equipment directly into return air. Power to the sensor packages and the returning signals were carried in cables consisting of 12 pair of No. 19 twisted copper wire.

The central computer was programmed in assembly language to perform several automatic and manual functions. The system would automatically scan each sensor output once each minute, convert the data to engineering units, check for alarms, type out alarm messages, activate alarm signals, record all data on disk memory for one hour, and conduct hourly summaries of data and record on magnetic tape. The operator could call for certain tasks to be performed when desired.

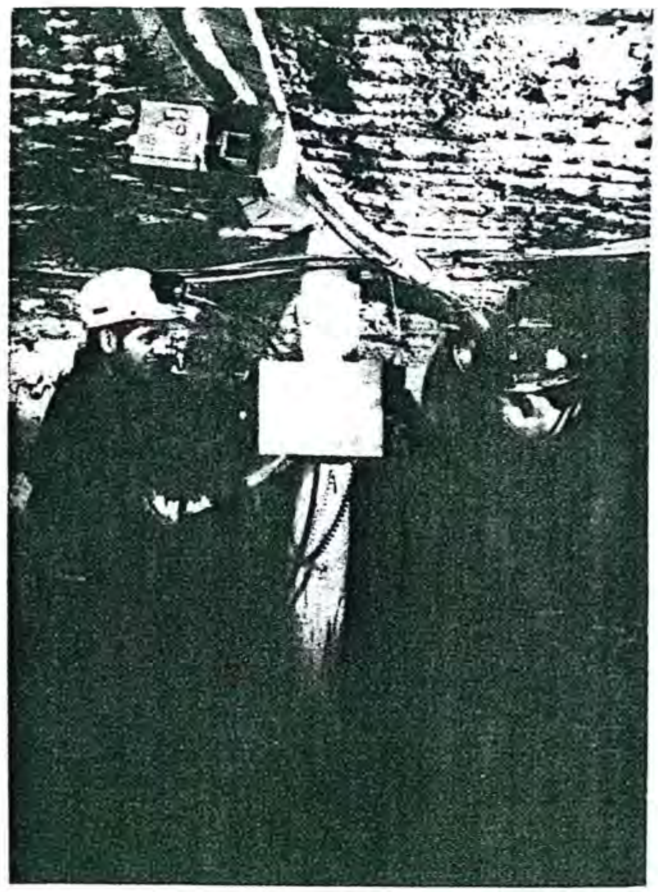

Figure 3. Typical Sensor Package Installation

The operator also has the ability to execute certain commands underground. These include turning on and off the sensor power supply and removing primary power from the telemetry station (which must be manually restored underground). These remote control features were not normally used.

Remotely Controlled Ventilation Regulators

The ability to control the distribution of airflow in a coal mine ventilation network is a problem that is as old as coal mining itself. In today's very large coal mines, adjustments in the distribution of airflow can be a very complicated and time consuming operation. Because of the non-linear nature of air distribution networks, adjustments must be handled on a "cut-and-try" basis. It is evident that use of mine ventilation regulators which can be operated by remote control from a central station on the mine surface could yield significant improvements in mine productivity and at the same time yield a safer operating environment in many mining situations. Experiments with such a remote control device require monitoring the flow of air to each operating section.

The WVU monitoring provided the capability of monitoring total airflow on each operating section and was the first opportunity to test and demonstrate a remote control mine ventilation regulator in a U.S. coal mine.

The project was established with the following three objectives:

1. construct and install two remote controlled ventilation regulators for use in the return airways of one room-and-pillar section,
2. conduct experiments to determine the suitability of the design used, and
3. provide a demonstration of the regulators for the mining industry.

The system consists of three major components as shown in Figure 4. Each regulator can be independently operated and the vanes set to any of 16 preprogrammed angular positions ranging from fully open to fully closed. A position sensor transmits the actual vane angle to the remote control for display. To change the opening of a regulator, a rotary switch is set to the desired position on the remote control unit. Buttons are pressed which initiate the control process. If signals are transmitted correctly, the regulator control is activated and the change is displayed at the remote control unit.

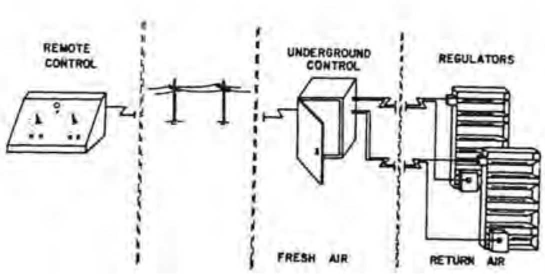

Figure 4. Remote Control Ventilation Regulator

Specifications

Following are some specifications of the final experimental equipment used in the mine tests described later.

Door Configuration. Table II gives the regulator specifications as used in the experimental set up.

TABLE II
REGULATOR SPECIFICATION AS USED

2 Sections	0.762m V x 1.016m H (30"V x 40"H) each
Horizontally Opposed Blades	
Operating Temperature	-40°C to 93.3°C (-40°F to 200°F)
Max Pressure Differential	0.154m (6") water column
Max Approach Velocity	1212m (4000 feet) per min.

These regulators have the advantage of being available from many heating and air-conditioning manufacturers. A distinct advantage is that they may be obtained for almost any size opening. Sizes start at 0.203m (8-inch) (nominal) vertical and horizontal dimensions and go up in 0.050m (2-inch) increments to 1.22m (48 inches) vertical and horizontal dimensions. Sizes larger than 1.22m (48 inches) can be made up of standard damper sections connected together vertically or horizontally. This method of ganging sections together was used in the experimental set up to obtain a 1.53m (60-inch) height overall. These may be ganged either vertically or horizontally.

Actuator. The actuator chosen was an electric gear-motor whose specifications are given in Table III. This type of gear-motor is available from many suppliers. The Honeywell motor used lends itself particularly well to operation of the regulator with a ratchet lever for manually operating the vanes of the regulator. This motor contains limit switches that must be removed in order for the regulator to be operated with the lever. This motor can then operate over 360° and allow the remote controller to recover operation after power has been reinstated underground. As installed in the experimental set up, the ratchet lever was not used. So the limit switches were left in the motors and simply readjusted for use with the regulator.

TABLE III
ELECTRIC ACTUATOR SPECIFICATION

120 Volts	
13 Watts	
16 Volt-Amps	
Torque Running	86.4 kg-m (75 pound-inches)
30 Seconds Limit Switch to Limit Switch	
Operating Temperature	-40°C to 51.7°C (-40°F to 125°F)
Explosion Proof Housing	Crouse-Hinds DHE-94

The explosion-proof housing was provided by Crouse Hinds, Inc., especially for the Honeywell motor used. Use of this housing was approved by MSHA under experimental permit No. 355. Cabling for the actuators was double-insulated SO cable as required by Schedule 2G.

Position Encoder. The position encoder used was one of the lowest cost versions available. It allows 6-bit accuracy in 90° rotation which is the capability of the ventilation doors. This gives 64 possible readout positions for the vanes. Since this was thought to be extreme positioning accuracy for the vanes, 16 of the possible 64 were chosen. Any 16 of the 64 could be used depending upon how one wanted to plot linearity on the surface control readout. A Read Only Memory (ROM) is used to encode these 64 positions into 16 readout positions. This ROM is located on the underground controller board.

INSTALLATION AND TESTING

The two regulators were installed in series with normal regulators in the return airways on the 1 West Left Side section as shown in Figure 5. Figure 6 shows one of the regulators as finally installed. The regulators were normally left fully open with all electrical circuits to the actuator motors disconnected. Tests were conducted on Sunday morning, July 24, 1977.

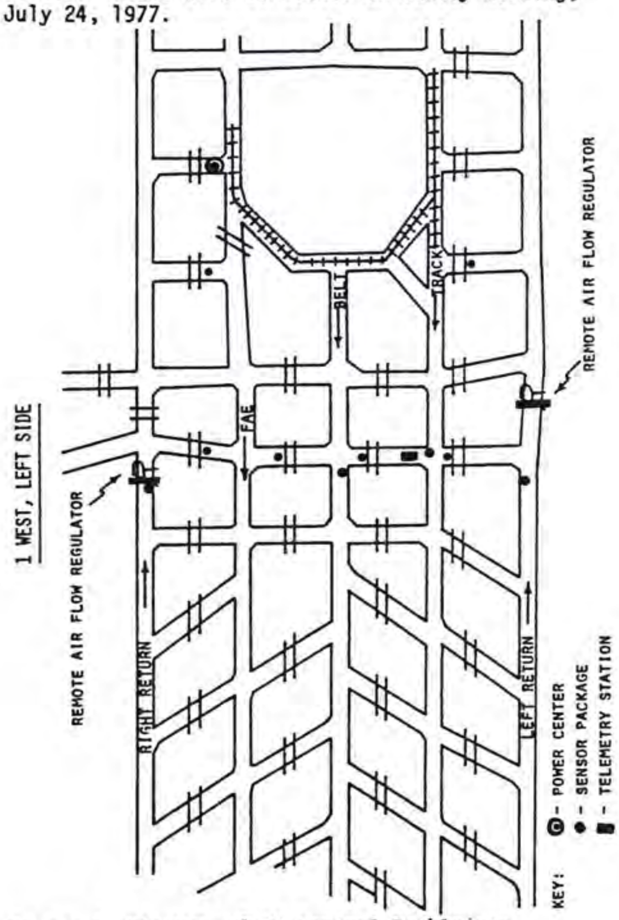

Figure 5. Diagram of RC Control Regulators

Tests were conducted with the following procedure. The Remote Control (RC) regulators in both returns were closed to position 10. The manual regulators were opened in an attempt to return to the normal conditions. Although this was quickly achieved in the left return, it was not possible to raise the flow in the right return above one-half the normal level. Since there was a limited amount of time available to conduct the tests, the decision was made to proceed on that basis.

The original plan was to modulate both the left and right return flows above and below their normal values and to measure effects in all four instrumented airways and in an adjacent section. When the experiment began, the regulators would not reopen beyond position 10, but would close to a smaller number and return to position 9 or 10. After some

Figure 6. Actual Regulator Installation at Federal No. 2 Mine

experimentation, it was found that the motors did not have sufficient torque to move the vanes of the regulators beyond position 9 or 10 without external help. This was found later to be the result of rust on the motor shaft and in the bushing through the explosion-proof enclosure. After this was discovered the tests progressed but with insufficient time to gather data from a large number of settings of the RC regulators.

Data was obtained from the airways of 1 West Left Side (location of the regulators) and 1 West Right Side as shown in Figure 5. One of these installations is shown in Figure 6. Since more data was obtained than can be conveniently included here, the following observations will be made followed by a presentation and discussion of the most important data. No effects were measured on the adjacent section 1 West Right Side. This is not surprising since these sections are located near a fan and operate at a fairly high pressure. No changes were noted in the methane in the return airways on the section under test. No long transient effects were noted in the changing flows or pressures. That is, after the one minute polling cycle of the monitoring system the flows and pressures had settled to their new values.

The flow and pressure data resulting from the tests are shown in Table IV. Except for two settings the flow in the track entry was below the airflow sensor threshold. Since the beltway was not monitored, the most important data was the flows in the two returns and differential pressures. A portable differential pressure gauge was also used to measure the pressure around the RC regulator in the left return.

Modulation of the right return was not productive since that dropped the right return flow below the threshold of the airflow sensor. Also the differential pressure on the right side was not determined which was later found to be an intermittent problem with the telemetry multiplexer. Since the problem with motor torque had not been identified at this point, attention was focused on the left return. Data was obtained for three different positions in the sequence 10, 8, 9, 10 yielding four sets of data to analyze. It was during this sequence that the torque problem was found. However, the time for conducting these tests had already expired. In addition, the ventilation had to be returned to normal.

TABLE IV(A)
REMOTELY CONTROLLED REGULATOR TEST DATA

Regulator Position			Velocities Meters/Minute				Differential Pressure (mmW)	
Left	Right	Differential Pressure Across Left Regulator (mW)	Left Return	Track	Escapeway	Right Return	Left Return	Right Return
Initial Condition			104	38	72	126	36	843
10	9		105	30	59	56	31	21
10	8		99	*	46	*	30	
10	9	0.102	102	*	66	49	31	30
8	9	0.109	48	*	63	55	13	24
9	9	0.102	90	*	57	53	26	25
10	9	0.096	153	44	71	55	49	27

TABLE IV(B)
REMOTELY CONTROLLED REGULATOR TEST DATA

Regulator Position			Velocities Feet/Minute				Differential Pressure (IW)	
Left	Right	Differential Pressure Across Left Regulator (IW)	Left Return	Track	Escapeway	Right Return	Left Return	Right Return
Initial Condition			341	124	237	414	.141	3.32
10	9		345	100	192	182	.123	.087
10	8		325	*	152	*	.119	
10	9	4	334	*	218	161	.123	.114
8	9	4.3	158	*	206	180	.051	.096
9	9	4.0	294	*	187	173	.104	.099
10	9	3.75	502	144	232	181	.194	.105

Inspection of the data yielded some interesting observations. Taking the ratio of pressure to velocity and velocity squared yields the data in Table V.

TABLE V
COMPARISON OF PRESSURE AND FLOW

Position	$\Delta P_L/V_L$	% from Mean	$\Delta P_L/V_L^2$	% from Mean
10	3.68×10^{-4}	3.1	1.102×10^{-6}	-13.7
8	3.22×10^{-4}	-9.8	2.04×10^{-6}	59.6
9	3.54×10^{-4}	-0.9	1.20×10^{-6}	- 6.1
10	3.86×10^{-4}	8.1	0.77×10^{-6}	-39.7

This data shows a more linear than quadratic relationship between flow and differential pressure. It should also be noted that the flow in the right return was virtually unaffected by the modulation of the left return flow. Small pressure changes were indicated on the right side but were too small to be conclusive. Similarly, modulation of the right return showed only a very slight change in the left return.

Since four sets of data were obtained for the left side, an attempt was made to model the airway resistances of the left return and total intake. That is, it was assumed that the equation

$$V_L^2 AR_L + V_I^2 AR_I = \Delta P_L$$

was assumed to relate the pressure and flows where

- V_L = air velocity in left return
- V_I = sum of air velocities in left and right returns (i.e., intake air velocity)
- A = area of airway
- ΔP_L = differential pressure between intake and left return
- R_L and R_I = resistances of left return and intake respectively.

Placing the flow and pressure data for first position 10 and position 8 gives two equations in two unknowns, which can be solved to yield

$$AR_L = 2.347 \times 10^{-7}$$

$$AR_I = 3.95 \times 10^{-7}$$

If these values are then used with the flow data for position 9 a calculated pressure of 2.69mm (0.106 inches) of water is found whereas 2.64 (0.104) was measured. Similarly for the second position 10 the calculated pressure is 6.17mm (0.243 inches) of water compared to a measured value of 4.93 (0.194).

Both of the above exercises are intended to show modeling methods may be used to predict the effects of airflow changes, at least over a limited range. Moreover, the possibility of being able to calculate the actual resistances involved is demonstrated. Aside from controlling the distribution of air flow, this could be one of the greatest assets of using remote control ventilation regulators.

Comparing the two sets of data obtained for position 10 shows a significant difference. This raises concern about the repeatability of the system. This is obviously a necessary property if meaningful ventilation control is to be accomplished. Table VI shows the range of angles for each position number used in the RC regulators. The remote control system was designed such that the vanes may stop anywhere in the angular range indicated for each position. If one assumes that the shock loss imposed by the regulator is proportional to a factor falling between the effective open area and area squared of the regulator, Table VII indicates the relative change of shock loss for each regulator position and corresponding range of vane angles. When fully open the regulator would yield a relative number 1.00 and 0 when fully closed. In either case, the range of values is too broad to yield repeatable results. Thus, it is concluded that for repeatable results to be obtained the regulator must be designed so that the vanes will stop within closer bounds than used here. This could be accomplished by causing the vanes to stop only at very exact angular positions or by permitting a continuous range of adjustment within certain bounds to achieve desired results.

Although only one brief test was possible with the remote control airflow regulators, significant results were obtained. Two design deficiencies were identified and the possibility of measuring airway resistances by flow modulation was demonstrated.

TABLE VI
POSITION ANGLES OF REMOTELY CONTROLLED VENTILATION REGULATORS

Position	Angle Range (Degrees)
0	0 - 1.41 (fully closed)
1	1.41 - 4.22
2	4.22 - 7.03
3	7.03 - 9.84
4	9.84 -12.66
5	12.66 -15.47
6	15.47 -18.28
7	18.28 -22.50
8	22.50 -26.72
9	26.72 -32.34
10	32.34 -39.38
11	39.38 -47.81
12	47.81 -59.06
13	59.06 -71.72
14	71.72 -85.78
15	85.78 -90.00 (fully open)

TABLE VII
RANGE OF LOSS FACTORS

	$(1 - \cos\theta)$		$(1 - \cos\theta)^2$	
Position	Low	High	Low	High
8	0.076	0.107	0.0058	0.0114
9	0.107	0.155	0.0114	0.0241
10	0.155	0.227	0.0241	0.0515

DISTRIBUTED MICROPROCESSOR SYSTEM

The research group at WVU is constructing a new microprocessor based system and incorporating some of the changes deemed necessary from the past experiences. This system will monitor and operate via remote control a set of ventilation control doors. This demonstration system has been assembled and is presently undergoing testing at WVU.

Overall System Structure

The system is a loosely coupled microprocessor network that has been designed utilizing the experience obtained during operation of the above described system. The new mine-wide system has been designed as a modular, low-cost, building-block type of system that can be expanded from a simple beginning level version to a very sophisticated mine-wide system.

The system is designed to be block structured so that it may be installed modularly as necessary. This is easily accomplished by creating independent subsystems that may operate alone or in groups communicating with a central system. The major modules described here are the environmental monitor, the remote control, and the communications system.

The entire system hardware is based upon a standard product-line of processor boards and peripheral controllers. This standardization was undertaken to allow a manufacturer to easily assemble duplicates of the system as well as allowing off-the-shelf parts stocking for the end user. With few exceptions, all computer system components are standard distributor stocked items.

All software for this distributed system is written in high level languages. The software is written in either FORTRAN-80 or PL/M, depending upon the applications of the particular processor. The environmental processor requires that mathematical calculations be done by the processor and hence uses FORTRAN for all of its software. The remote controller for ventilation requires only rudimentary addition and subtraction and hence uses PL/M for all of its software. PL/M is an industrial de facto standard software package used primarily for control systems.

Communication System

The microprocessors are designed to communicate using a digital mine-wide communication system that utilizes DDCMP (Digital Data Communications Message Protocol) (see Fig. 7). This system is FSK (Frequency Shift Keyed) as in the past, but is also full duplex. In addition, it is designed to maintain the same mine-wide, single twisted pair of telephone lines. One should recognize that the system is not, however, limited to telephone lines as the only means of communications even though that is the only intention here.

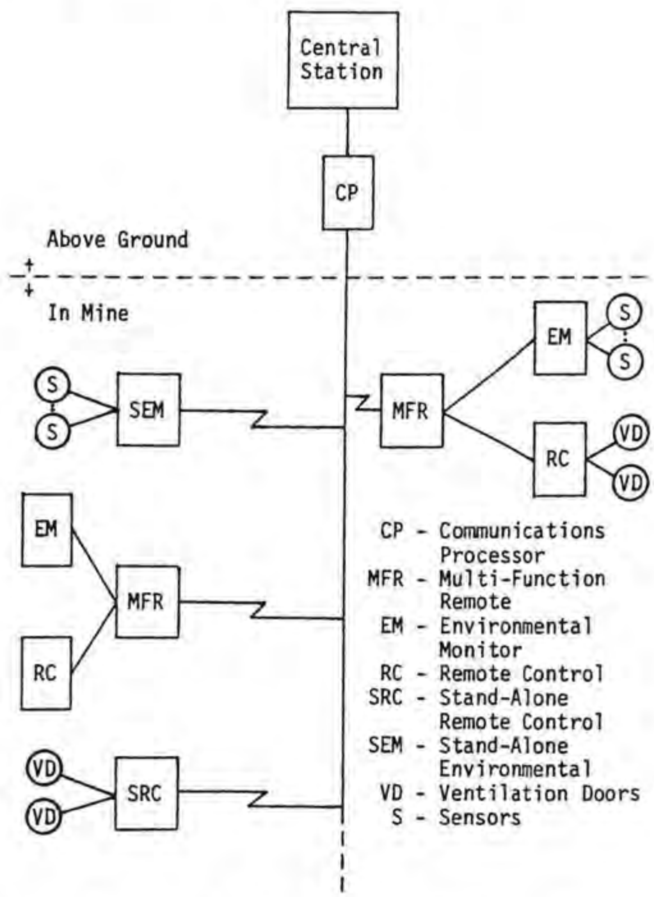

Figure 7. Block Diagram of a Possible System Employing a Central 'Control' Station

At the mine section level, another communications system handles communications among microprocessors on the section independent of the above ground system (see Figure 8). This communications among microprocessors allows the remote control ventilation processor to access the environmental monitor system to obtain local airflow data directly when necessary. This should one day allow one to "close-the-loop" of the ventilation control system if such a system should become desirable. In general, however, it allows any system located on the section to communicate data to any other system located within the section without disturbing mine-wide communications.

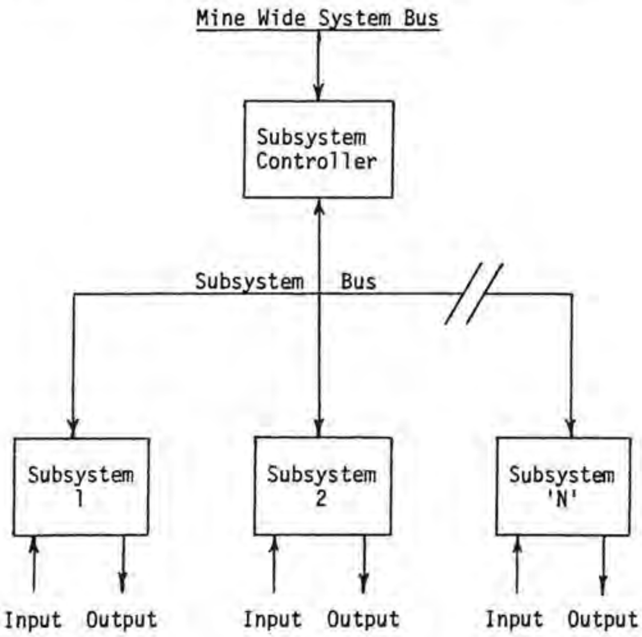

Figure 8. Simplified Block Diagram of Multifunction Remote Station

Environmental Monitor

As described above, the entire concept of mine ventilation control cannot be undertaken without monitoring the entire ventilation system for at least airflow. This would give an immediate indication of any changes in the mine ventilation system that are becoming troublesome.

The environmental monitor is a microprocessor based system that can monitor up to 64 analog inputs, convert these inputs to engineering units, display a selected value(s) on a local display for the section foreman, alarm locally (on the section) for any value going out of range, and transmit all values to the mine-wide system upon request (see Figure 9).

Remote Control

The remote control is a microprocessor based system that can operate eight (or optionally more) on/off conditions, as well as maintain control of the ventilation control doors that were described above in the previous design. The remote controller essentially maintains control using solid state relays for moving the regulator more open or more closed. These movements may be controlled by either a local command from the front panel switches (see Figure 10) or from a command from the central station of the mine-wide system via the mine-wide communication system.

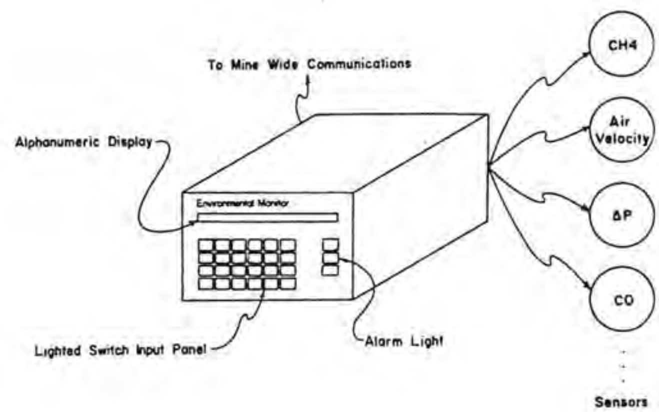

Figure 9. Environmental Monitor

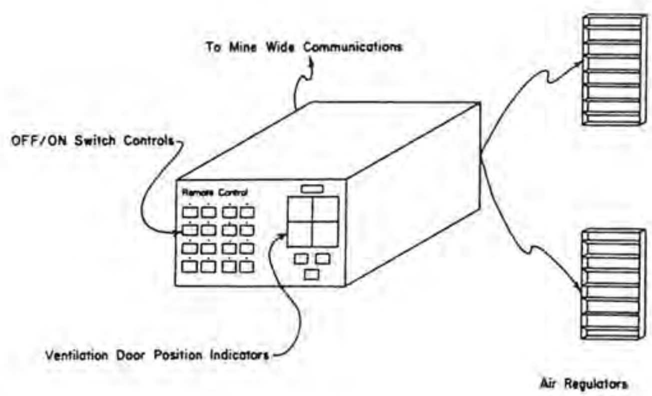

Figure 10. Remote Control

CONCLUSION

At this point, one can conclude that remote control of mine ventilation parameters is indeed possible as has been proven herein. The experiments already conducted inside an underground mine indicate that additional work should be carried on to develop faster converging algorithms for analyzing ventilation systems. These algorithms could then be used in microprocessor based controllers like the ones being developed by WVU and the U.S. Bureau of Mines to assist mining personnel in maintaining adequate airflow and during emergency situations assisting in the protection and safety of these underground mining personnel.

ACKNOWLEDGMENT

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Professor of Mining Engineering
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