THE DESERADO MINE MONITORING AND CONTROL SYSTEM

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ABSTRACT

The Bureau of Mines has studied the Deserado Mine computerized monitoring and control system, located in Rangely, Colorado, to acquire knowledge about the overall costs and benefits of mine monitoring systems.

The Deserado system is a complex system monitoring environmental parameters, electrical power, and operation of all mine equipment, and controlling the entire conveyor haulage system.

This paper discusses the evaluation of the Deserado monitoring system from initial design through system installation and operation. It also examines the costs, benefits, and performance of the monitoring system.

INTRODUCTION

The Bureau of Mines (Bureau) has a mandate to support the Federal Coal Mine Health and Safety Act of 1969 (PL 91-173), and the subsequent Federal Mine Safety and Health Amendments Act of 1977 (PL 95-164). These Federal laws require that the air quality in underground coal mines be maintained and controlled at specific levels.

In pursuit of this mandate, the Bureau has sponsored projects investigating computerized mine monitoring. The objective of these projects is to provide the miners with a more efficient, reliable means to comply with the regulations and to increase mine safety.

The Bureau received a request from the Western Fuels Association (WFA) for information on remote monitoring and control systems for underground coal mines. An initial meeting between WFA and the Bureau was held on March 12, 1982, at the Pittsburgh Research Center (PRC). WFA was in the process of developing the Deserado Mine, a large and complicated underground coal mine, and was interested in incorporating a computerized monitoring and control system into the mine plan. WFA saw this as essential to operating with the highest level of safety while producing coal in the most cost efficient manner.

In June 1982, the Bureau and WFA established a memorandum of agreement for the Bureau to lend expert assistance to WFA in planning the design and specifications for a computerized mine monitoring and control system. In return, the Bureau could document and evaluate the operational experience and benefits of the system.

The Bureau's objective was to validate much of its mine monitoring research in a large-scale mine complex. The documentation and evaluation of cost versus benefits and technical performance would provide assistance to other mines interested in this type of project. Important information would become available on all phases involved in the design, installation, and operation of a computerized mine monitoring and control system. The Bureau contracted the Colorado School of Mines to perform the evaluation by collecting information through regular mine visits.

DESERADO MINE DESCRIPTION

WFA's Deserado Mine is located near the western border of Colorado, approximately 8 miles northeast of Rangely. It supplies coal to the Bonanza Power Plant located near Bonanza, Utah. The power plant is operated by Deseret Generation and Transmission and uses a 400-MW power generator. The plant has been designed for the addition of a second 400-MW unit in the future.

Ground was broken at the Deserado mine site on August 28, 1981. The Deserado Mine extracts coal from a seam called the D seam, which averages 7 ft. Access to the seam is by a 400-ft-long, two-compartment slope entry whose depth at the bottom is 100 ft. The deepest point of the mine lies 1,300 ft beneath the surface.

The slope was completed and the first continuous miner was taken underground in October 1982. At completion of initial development Deserado will produce coal using one longwall and two continuous miners at a production rate of 1.35 million tons per year (TPY). Presently, the mine is using four continuous miners, including two for longwall panel development, at a production rate of approximately 0.96 million TPY. They currently work two production shifts and one maintenance shift per day, 5 days a week. Longwall operation is scheduled to begin by December 31, 1986.

A belt conveyor haulage system is used to transport coal from the working section out of the mine. Electric-powered, rubber-tired shuttle cars are used for face haulage. Rubber-tired diesel vehicles are used to transport miners and supplies. There are no tracks in the mine, except along the slope for the hoist. The upper compartment of the two-compartment slope entry contains the conveyor belts. The lower compartment is used to transport men and material in and out of the mine and also serves as a ventilation intake.

Coal moves from the mine portal to one of two 10,000-ton raw coal silos and then to a 750-ton-per-hour (TPH) preparation plant. Clean coal is transported via a 3-1/2-mile overland conveyor to a 25,000-ton slot storage facility and rail loadout. The final 35 miles to the power plant is by an electrically powered train.

DESIGN CONSIDERATIONS

Design considerations and requirements specified during the planning stages helped dictate the following architecture for the Deserado Mine monitoring and control system.

1. <u>Compatibility</u> - The mine monitoring system had to be compatible with an existing preparation plant system. This system monitored and controlled the preparation plant activities, an overland conveyor, the main mine ventilation fan, the mine hoist, and the raw coal system from the slope to the top of the silos. The prep plant system consists of two Allen-Bradley* PLC-3 programmable controllers, one of which acts as a hot backup, and a Process Control Industries D-1200 interface. The D-1200 supports a line printer and hard disks for data storage. This monitoring system uses three "intelligent" color video display terminals (VDTs) and one alarm printer for operator interface. Since WFA wanted monitoring of the raw coal system, the main fan, and the mine hoist to be integrated into the mine monitoring system, it had to interface to these existing sensor points with a minimum of reengineering.

2. <u>Reliability</u> - WFA wanted a reliable system that would operate continuously, so dual processors were recommended with automatic switchover upon failure of the primary. An uninterruptible power supply (UPS) was specified to protect the main processor from power fluctuations or power failure. It was recommended that the trunk cable be looped through two separate, parallel entries to prevent communication failure in the event of a break in the line.

3. <u>Information Management</u> - A supervisory computer was recommended to provide data storage, analysis, and reporting, and to tie together the complete mine complex by accepting data from both the mine monitoring system and the prep plant system.

4. <u>State-of-the Art</u> - The mine monitoring system was to be a proven, state-of-the-art system and was to provide good, interactive color graphics.

5. <u>Flexibility</u> - The mine monitoring system was to be flexible enough to monitor a wide variety of sensor inputs from the mine, involving many controllable points. It also had to be user friendly to allow mine personnel to update the system. The monitoring system had to be designed so that the belt conveyors and other critical production equipment could still be operated in a manual mode.

On April 27, 1984, WFA awarded Conspec Controls the contract as the successful bidder. Initial installation was scheduled to begin August 1, 1984, and the monitoring and control system was to be completely installed, tested, and handed over to WFA by October 1, 1984. The initial system would include the mine monitoring controller, hot backup, supervisory computer, software, telemetry system, and sensors to monitor the mine at its current state of development. Additional sensors and hardware would be purchased and installed as the mine developed. The vendor was responsible for installation, calibration, and startup procedures for the new system. The monitoring system was sold as an inclusive package with a total price of $387,420.

MINE MONITORING AND CONTROL SYSTEM DESCRIPTION

The system performs six monitoring and control functions. Two of these were transferred from the prep plant system, as discussed before. The four new underground functions include belt fire monitoring, power center monitoring, environmental monitoring, and underground belt monitoring. Figure 1 shows the system architecture. Each new function is discussed next.

1. Carbon monoxide (CO) sensors were specified for placement at 1,500-ft intervals along the beltways for fire detection. The status of the fire suppression system, located at each underground

*Reference to specific brands, equipment, or trade names is this report is made to facilitate understanding and does not imply endorsement by the Bureau of Mines.

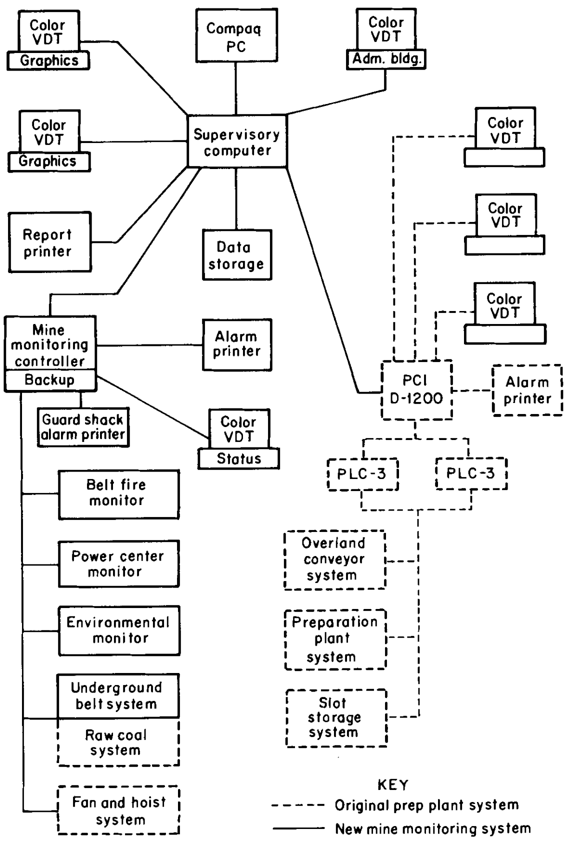

Fig. 1. Monitoring System Architecture.

belt drive, is also monitored. Eight CO sensors were initially installed. In the future WFA plans to petition MSHA for a variance so that the beltways can be used to provide fresh air to the working face.

2. Power center monitoring is accomplished through the use of electrical power (wattage) sensors at each underground power center. These wattage sensors give an indication of the equipment status and can be used to determine equipment run time. Equipment monitored includes continuous miners, shuttle cars, and roof bolters. The longwall will also be equipped with power sensors. Ground fault and phase fault sensors at the outside substation are monitored, as is circuit breaker status at each underground power center. Each power center has seven sensors. Two power centers were initially monitored and three more will be monitored in the future.

3. Environmental monitoring packages are in place at two return air locations and one intake air location to check the status of the air quality and quantity. Each environmental package consists of an air velocity sensor, a CO sensor, and a methane (CH_4) sensor. Some environmental sensors were set up individually throughout the mine also. The air velocity sensors measure 50 to 3,000 feet per minute (FPM) airflow, the methane sensors 0 to 5% CH_4, and the carbon monoxide sensors 0 to 50 parts per million (PPM) of CO.

4. Among other things, underground conveyor belts are monitored for belt speed, motor and bearing temperature, coal flow rate over the main belt scale, pull cord, plugged chute, belt slip, belt stoppage, misalignment, tension, and local lock-out. The mine monitoring system has the ability to remotely control the starting and stopping of the conveyors, with the option for local, manual control for offshift work or should the computer fail. The monitoring system monitors 300 points at 10 underground belts. Sensor locations are shown on the mine map in figure 2.

The mine monitoring and control system gives the current mine status on a color VDT and on a printer. Analog points are read in standard engineering units. The system allows alarm setpoints to be established on the surface. Alarms are indicated on the operator's terminal and alarm printer. An alarm horn and light responding to CO alarms are at each underground outstation. The mine monitor processor has 64K RAM memory in which the programs are stored and a 256K floppy disk drive. The system can accept a maximum of 800 data inputs.

Although the prep plant and mine monitoring systems operate independently, a supervisory computer communicates with and receives input from both systems. The supervisory computer handles data archiving, extensive data analysis, color graphics generation, and system control. It consists of a 16-bit processor with two 20-Mbyte hard disks. Reports document run time, production and environmental status, alarm summaries, historical logs, trend analyses, and equipment availability. The supervisory computer displays information on two color VDT's and a report printer. Graphic displays from both the mine monitoring system and the prep plant system are possible on either color VDT. The color graphics system permits the cursor on these displays to control the underground mine belts, but not the prep plant equipment.

There is also a color VDT in the administration building for status monitoring of the two systems. An alarm printer, horn and light in the guard shack allows for the detection and acknowledgment of alarms when the mine is idle.

INSTALLATION

According to the original time schedule, installation was to be complete by October 1, 1984. This date was not met and has continually been delayed by Conspec. The delays and other installation experiences are discussed below.

One cause for the delay in the installation of the system was lack of communication and understanding between the vendor and the installation subcontractor. The subcontractor was not aware of the underground work requirements. Their personnel had not had the 40-h MSHA underground mine training for electrical certification. Mine

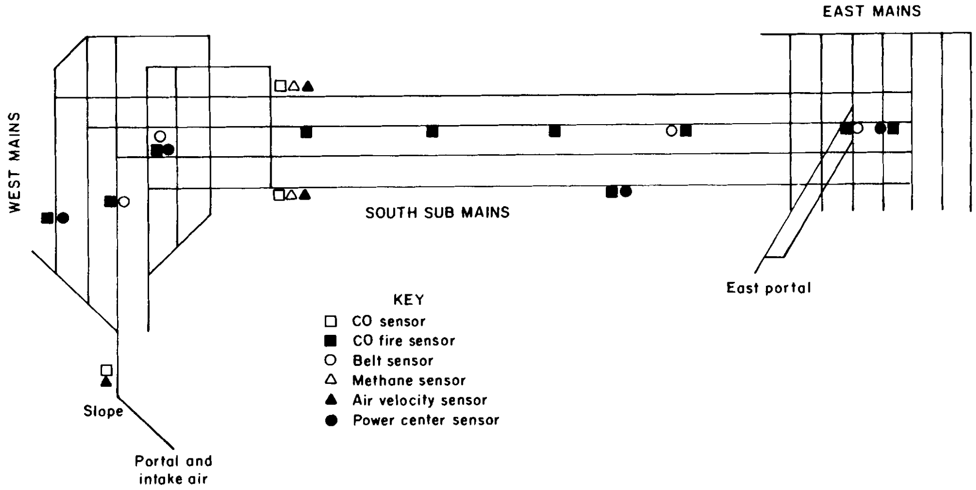

Fig. 2. Mine Map with Sensor Locations.

hazard training required an additional 8 h, and two 4-h sessions were needed to familiarize the subcontractor with the mine's layout and procedures. Many delays were experienced because of conflicts between normal mine operations and the subcontractor's work. Further delays occurred when it was necessary to borrow equipment from the mine because of inaccessibility to the subcontractor's main office in New Mexico.

Installation of the CO monitors presented some problems and occasional other, though less serious, delays. Following vendor's drawings the CO monitors were placed 2,000 ft apart along the beltways. The initial specifications called for 1,500 ft spacings. When the error was discovered, 2 h were lost in correcting it. Mounting instructions did not specify that the sensor cell was to be located at the bottom of the sensor housing and the transducers were mounted on their side. A full shift's work was required in fabricating new brackets and remounting.

Many problems and delays during installation might have been avoided if a vendor representative had been present during the entire installation period, instead of only at the very beginning and on a call basis. Conspec made several site trips during the installation at WFA's request.

WFA had planned acceptance tests immediately after installation, but because the problems and delays prevented completion the system started in phases rather than all at once. As of June 1, 1986, Conspec still had not completed installation: The supervisory computer, due for completion November 30, 1984, remains incomplete. The problem lies in the report generation software and the color graphics software. The vendor has now supplied WFA with a Compaq PC to interface to the supervisory computer for report generation. Color graphics are available from the mine, but only static conditions, not current sensor values, are being shown from the prep plant system. WFA completed the development of color graphics pages and sensor calibration.

OPERATIONAL EXPERIENCE

When monitoring system installation began, WFA hired a mine operations engineer to be responsible for its installation, operation, and expansion. As the mine and the monitoring system began to expand, WFA hired three additional full-time, entry-level engineers. The mine operations engineer has overall responsibility for the entire project. In addition to their primary responsibility as system operators, the three control room engineers have more specific functions. One is responsible for the mine monitoring computer, entering new monitoring points, developing control programs, calibrating sensors, and modifying programs as the mine expands. The second is in charge of the supervisory computer, developing the graphic display and control programs. His goal is to place as much of the mine as possible under graphic control. The third will develop software for the Compaq PC for manipulating data, and designing and generating reports for the mine manager, mine superintendent, and maintenance superintendent.

There have been no additional costs for equipment failure to date because the system remains under the original warranty until WFA acceptance. WFA engineers have done most of the troubleshooting work on the system, thereby reducing outside labor costs. Any wiring changes or additions have been made by mine electricians.

Originally, the trunk cable was installed in a loop, with each side in a separate entry, to provide a safeguard against a possible break in the line. The theory was that if one side was damaged, the other would still be usable for communications. A trunk break detector in the loop would alert the operator of the break. A problem arose when the break was not clean and the line conductors shorted. This interrupted communications and the parallel line became useless. Therefore, WFA removed the extra line in the loop and used it in other parts of the mine.

Repair times have been difficult for the operations engineer to estimate because WFA engineers have spent time working with and learning the system when problems arise. They agree, however, that the more experience gained with the system, the less time it takes to make repairs. Table 1 (1) is a summary of production delays and repair times experienced, during a 6-month period in 1985.

Table 1

Problem Type	Lost Production Time (min)	Repair Time (min)
Sensors	20	160
Software	30	105
Cables	0	885
Human error	320	1,395
Accessor fail	0	240
General equip.	0	450
Terminals	0	270
Unknown	0	140
TOTAL	405	3,645

The vendor's engineers have been available for advice over the telephone on problems and failures. If an immediate diagnosis could not be offered, they provided a method of isolating the problem. Vendor support has been good, but very slow. Delivery time for spare parts has usually been around 16 weeks, with some parts taking as long as 20 weeks. These delays have resulted in components being removed but not replaced. WFA has, therefore, decided to stock the common parts on site.

Calibration is required for all analog sensors. This includes environmental, power consumption (wattage), temperature, and amperage sensors. The CO and CH_4 transducers must be calibrated at least once a month. Airflow sensors need be calibrated only once every 3 months. The power sensors were calibrated prior to installation and again after the initial system startup. The temperature and amperage sensors in the conveyor belt drives were calibrated after installation.

A problem was encountered when calibrating the methane sensors because of their location in return airways. The calibration equipment is not intrinsically safe; therefore the CH_4 sensors must be disconnected, brought into fresh air, reconnected to the trunk line, calibrated, and finally returned to their original location.

SYSTEM BENEFITS

The main benefit of the monitoring and control system is in maximizing underground belt availability. The belts have been operating on an average of 95% of the time. Although historical data are not available, workers agree belt availability is higher now than before installation. If a belt stops, the control room engineer knows where and why. Using the mine phone, he can notify underground personnel of the location and cause of the failure. They can get the belt started again quickly. There has been a noticeable difference in the restart time of new belts still on local control and those already interfaced to the monitoring and control system.

Excess coal spillage has been reduced and miner safety has increased because of the rapid response of the computer in shutting off belt power. Tests that were run on shutdown times prove the capabilities of computer control. Under local control, relying on mechanical roller sequenceswitches, 1 min 47 s were needed to stop the first belt. Still under local control, shutdown using electronic switches took 20 s. With complete computer control, shutdown time was a mere 2 s.

Many potential production benefits have not yet been realized since the supervisory computer has not been completely operational. Comparison reports, such as electrical power consumption versus coal production, may lead to reductions in operating costs. Trend logs of bearing temperatures, power consumption, reducer box temperatures, etc., will help in preventive maintenance.

The biggest anticipated benefit of the monitoring and control system will be in providing a safe environment. CO-sensing devices help in the detection of fires along the belts, near switch gear and transformers, and in returns. There are currently 26 CO sensors in place, and 7 more will be added. The system can identify the fire location and provide extra warning time for safe evacuation of mine personnel.

Five airflow sensors are currently monitoring for proper ventilation in intake portals and return areas near the exhaust fans. Plans include an additional five to be placed in the sub mains and the longwall panel. Information received from these sensors will detect areas not properly ventilated and may help find an unknown roof fall or badly positioned regulators.

Methane monitors determine if methane is accumulating in an area. There are presently two in the returns near the exhaust fan, and two more will be installed near the longwall bleeders and at main ventilation intersections.

MINER AND MANAGEMENT OPINIONS AND ACCEPTANCE

Management has had high expectations for the monitoring and control system. They assumed two general benefits would result from the project: One was to generate historical data and trend analyses to help improve mine efficiency, lower electrical costs, and improve maintenance troubleshooting. The other benefit would be the provision of real time operating data, which would help improve efficiency and safety aspects.

Management had these and other specific goals in mind and have been very supportive of the project. Their attitude filtered to lower management levels and eventually to the hourly wage employees. Hourly employees learned much about the system by asking questions of the subcontractors as they were installing the hardware underground. Through their questions, the miners presented an open-minded view of the monitoring system.

Presently, the hourly mine employees find the troubleshooting capabilities very helpful. The computer system has been in service for over a year and there has been no tampering. Management, union officers, and individual employees feel the monitoring and control system improves safety. The miners look at the computer as just another productive mining tool. They value the added safety and continue to ask many questions and show an interest in the system's capabilities. Currently, management continues to support the project but has some mixed feelings. Generally, they have been pleased with the quality and benefits of the system but concerned over the delays. Every phase of the work has been behind schedule and improvement seems unlikely. The result has been that WFA has performed much of the work contracted to the vendor.

FUTURE EXPANSIONS AND GOALS

Presently, 600 points are being monitored on the mine monitoring computer, which has a capacity of 800 points. With present expansion plans, this capacity will be exceeded by the end of 1986. The installation of a second mine monitor will cover the expansions. Presently the computer polls all accessors in less than 3 seconds and should continue at this rate when the remaining points are added. The graphics system is monitoring over 1,000 points from the prep plant and collecting 21,000 pieces of information per minute on hard disk. This amount of data is expected to increase to 25,000 pieces/minute by yearend.

The biggest expansion to the monitoring system will come with the addition of the longwall panel, scheduled to begin producing by December 31, 1986. The areas of main monitoring interest will be the face conveyor, the head and tail gates, the crusher, and the stage loader. Temperatures in the motor, gearbox, and drive roller bearings will be monitored. The motor phase windings, the power center, and the pressure in 14 evenly spaced shields will also be monitored.

Environmental parameters will be monitored at the intake and bleeder points to the longwall. Air velocity and CO sensors will be placed to monitor intake and return air, and CH_4 sensors will be necessary to monitor return air at the bleeders.

The pump station that will serve the first four planned longwall panels will be monitored and computer-controlled for ease of operation. The pump station is located 6,000 ft from a longwall panel, making it difficult for longwall personnel to access the pump station. The option to control the pumps manually will also be available. Water levels, bearing temperatures, power consumption, and water pressure will be monitored.

The Deserado Mine uses an Mine Safety Appliances (MSA) rock dust system. Bulk storage on the surface is provided by a 140-ton tank. There are also four 10-ton tanks located underground. Presently, the sequential transfer of rock dust between tanks is accomplished manually. This task will be automatically controlled and operated by the monitoring system.

The mine has three major, long-range goals for the monitoring and control system. The first is to reach complete installation of the system and continue proper advancement as the mine expands. The second is to have control room engineers give the graphics system complete control over all equipment monitored by the system. The final goal is the completion of the supervisory system. WFA is excited about the possibilities for lowering production costs through improved equipment availability and improved maintenance. Also, the increase in safety will keep mine operations running smoothly and give miners a safe working environment.

SUMMARY

The Bureau of Mines and Western Fuels Association entered upon a memorandum of agreement to study the design, installation, and operation of WFA's Deserado Mine monitoring and control system, which is one of the most advanced systems in a U.S. mine. WFA is pleased with the quality of the mine monitoring system and the benefits that have resulted from the use of it.

The major benefit has been the increased availability of the conveyor belts. The monitoring abilities have greatly helped in troubleshooting problems, and the addition of report generation is expected to enhance preventive maintenance methods. Computer control of the belts has increased miner safety.

Many delays in delivery and completion of the monitoring and control system have occurred. However, WFA has been quite satisfied with the performance of the system. Both management and mine personnel acknowledge the benefits of the system and are willing to work at keeping it operating smoothly and continue to expand it as the mine develops.

REFERENCES

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