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DESERADO MINE COMPUTERIZED MONITORING AND CONTROL SYSTEM EVALUATION

Contract No. J0348003
Mining Department, Colorado School of Mines

BUREAU OF MINES
UNITED STATES DEPARTMENT OF THE INTERIOR

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CERTIFICATION OF THE ABSENCE OF PATENTS AND INVENTIONS

This statement certifies that at the grant report date, no inventions have been developed from Contract J0348003. Consequently, no patents are pending.

Robert H. King
Project Director

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The U.S. Bureau of Mines and Western Fuels Utah, Inc. entered into an agreement to plan, install, and evaluate a micro-computer based monitoring and control system at Deserado Mine, an underground coal mine. The U.S. Bureau of Mines contracted the Colorado School of Mines (CSM) to independently evaluate the project. CSM evaluated and documented costs, benefits, problems, and management and labor perceptions in this report. Recommendations are provided for mine operators and monitoring system vendors considering future installations.

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FOREWORD

This report was prepared by Colorado School of Mines, Golden, Colorado under USBM Contract Number J0348003. The contract was initiated under the Health and Safety Technology Program. It was administered under the technical direction of the Pittsburgh Research Center with Julie Mitchell acting as Technical Project Officer. Patrick Neary was the contract administrator for the Bureau of Mines. This report is a summary of the work recently completed as a part of this contract during the period September 1983 to April 1986. This report was submitted by the authors in June 1986.

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EXECUTIVE SUMMARY

The Deserado mine, located in Northwestern Colorado, is an underground coal mine with a design capacity of 2.7 million tons of clean coal per year. The mine is owned and operated by Western Fuels - Utah, Inc. The mine supplies coal to the Bonanza power plant, owned and operated by the Deseret Generation and Transmission Cooperative.

The mine construction was started in August, 1982, and by November, 1985 the mine was in production. The mine is expected to reach full production by January, 1987. Currently there are five Joy[1] 12CM continous miners in use, and a longwall will be installed and put on line in the last quarter of 1986.

Access to the coal seam is through an inclined two compartment slope approximately 600 feet long. The average coal seam thickness is eight feet. Coal is mined two shifts per day, five days a week, with the third shift used for maintenance.

The coal is cleaned on site by a water only preparation plant with a 750 ton per hour capacity. The plant is run by an Allen-Bradley[1] PLC-3 programmable controller which interfaces with a Process Control Industries[1] D-1200 color graphics system. The clean coal is transported 3.5 miles, by an overland conveyor belt, to a 25,000 ton slot storage facility. From here the coal is loaded onto an electric train which carries the coal to the Bonanza power plant on a 35 mile closed loop rail line.

[1] Reference to specific trade names and manufacturers is made for identification purposes only and does not imply endorsement by the Bureau of Mines.

In the early design stages of the mine, the management of Western Fuels decided to install a mine wide monitoring and control system. In order to realize the full potential from such a system, Western Fuels entered into a cooperative agreement with the U.S. Bureau of Mines to design, install, and operate a state-of-the-art system.

The primary function of this system is to provide mine personnel with continuously updated data on the status of a number of production, health and safety, underground belt, raw coal system, and fan and hoist parameters.

In addition to these functions, a supervisory system was provided which communicates with the mine monitoring system and also with the Allen-Bradley PLC-3 system. The supervisory system provides data archiving, data analysis and trending, and generates periodic reports.

The Bureau contracted the Colorado School of Mines to document and evaluate the project. This report is a result of that contract.

A system was purchased from Conspec Controls Ltd. and installation was begun in October, 1984. The system contains a primary monitoring and control processor and a supervisory processor.

The primary system monitors and controls approximately 700 points underground and on the surface. The supervisory processor is interfaced with the primary mine monitoring system and the preparation plant control system. It provides color graphic displays and generates periodic reports.

The project is considered successful by mine management since it has lowered production cost and increased safety. The system has met or exceeded all design parameters and performs reliably even though some problems were encountered with the vendor not meeting time schedules, and component repairs have been slower than expected.

Several recommendations for mine operators and monitoring system vendors resulted from this project. A mine considering a similar system should have an on-site project manager involved from the start of the project. This will provide continuity throughout installation, start-up and operation.

The system will be required to change as the mine expands and grows, and new uses will be found for the system as mine personnel gain experience with it. The system that is selected should be flexible enough to accommodate frequent changes in software and hardware.

Mine management must be willing to dedicate adequate resources to effectively utilize a system once it is installed. Western Fuels dedicated four engineers to this project.

It should be realized that many unforeseen problems will develop during the implementation of this type of system, and allowances must be made for this. The professional spirit of cooperation between Western Fuels and Conspec helped overcome numerous unforeseen problems. However, consideration should be given to providing penalties for time schedules that are not met.

INTRODUCTION

Background

The U.S. Bureau of Mines (USBM) has funded several research and development projects, both in-house and with contractors, in computerized mine monitoring. The hardware and software components have been sufficiently developed so that mine operators have been provided with efficient means to comply with federal regulations and increase mine safety. Several cost benefits have been documented by USBM projects as well, particularly in conveyor belt haulage availability improvements.

Because of these developments, Western Fuels - Utah Inc. (Western Fuels) approached the USBM to assist in planning, installing and evaluating a computerized mine monitoring and control system. The installation was planned for Western Fuels Deserado Mine located in Rangely, Colorado. Since the mine was originally planned to produce 2.7 million tons of clean coal per year from a large complex underground mine, Western Fuels projected significant benefits in safety and efficiency through a computerized monitoring and control system.

The USBM agreed to work with Western Fuels and on June 3, 1982, a memorandum of agreement was established between the two parties. A major part of the cooperative program was to document and evaluate the system design, installation, and operation. The purpose of the evaluation was to have an independent objective observer assemble information that would document the successes and problems of the Deserado Mine project to assist other mines to adequately design, specify, install, and operate future systems.

Subsequently, the USBM issued a request for proposals on February 4, 1983 to document and evaluate the project. The Mining Engineering Department of the Colorado School of Mines was the successful bidder and was awarded the evaluation contract on September 1, 1983. This report is the result of that contract.

Evaluation Contract Scope of Work

The USBM request for proposals (RFP) divided the project in three phases: Design and Procurement, Installation and Start Up, and Operation. The initial schedule was for design and procurement during April and May, 1983, installation from June, to August, 1983, and operation beginning September 1983.

The RFP anticipated a manufacturer of the monitoring and control system would be selected by March 1983 and the installation would begin in June or July of 1983. During the phase of design and procurement, CSM was required to document the system layout, component specifications, component compatability, acceptance tests and system capabilities. In addition, costs of hardware, software, and training were to be estimated. Furthermore, miner and management perceptions were to be determined through interviews.

The RFP expected the system to be installed during the period June-August, 1983. CSM was required to have someone resident at the mine to document quality of equipment, performance versus specifications, manufacturer assistance during installation, time and cost to install, installation problems, calibration time and procedure, miner acceptance, site acceptance tests, training program and costs, and start up problems.

After installation, CSM was required to collect data on the performance, operation costs, and operation benefits. The RFP expected this period to last from September 1983 to October 1984. Performance data includes calibration and failure information. Maintenance and operation costs were listed in the RFP as well as a set of data on production, safety, miner acceptance, and utilization benefits.

The RFP required that the analyzed data be submitted in this final report which addresses cost effectiveness, safety and production benefits, recommendations for improvements in future systems, utilization, and management and labor factors.

Mine Description

The Deserado mine plan and layout have important impacts on the monitoring system requirements. The mine planned to produce 2.7 million annual clean tons from two longwall sections and four continuous sections. The mine is presently being developed by two continuous miner sections operating under 700 ft of overburden in the 7.5 - 8.5 ft thick D Seam. Main, submain, and panel entries have been developed for the longwall, and equipment is on order for a late 1986 installation. Belt conveyors haul the coal from the mining sections to a 54-inch belt located in the upper compartment of the slope. The lower compartment contains a hoist for men and materials transport. From the slope, the coal moves to two 10,000 ton raw coal storage silos, then to a 750 tph preparation plant. After cleaning, a 3.5 mile overland conveyor carries the coal to a 25,000 ton clean coal slot storage and rail load-out facility.

The preparation plant, which was installed prior to the mine monitoring system, included Allen-Bradley monitoring and control hardware and software. It contained two PLC-3 programmable controllers and a Process Control Industries D-1200 which monitored and controlled the conveyors from the bottom of the slope to the top of the raw coal silos, the preparation plant, the overland conveyors, the main mine ventilation fan and the hoist. The system operator uses three "smart" color video display units to monitor and control this network, and an alarm printer is included for hard copy records.

Monitoring System Specifications

In December 1983, Western Fuels presented a complete specification document to prospective supplier/manufacturers. The major points from the specification will be presented here, however, the entire document is included in Appendix A. The specifications were followed by a prebid meeting. Changes resulting from supplier recommendations during and after the prebid meeting are also presented in Appendix A.

The successful proposal from Conspec Controls Inc. provides additional details about the system. It is included as Appendix B. After proposal submission, Western Fuels met with the vendor to clarify several points in the proposal. The vendors written response to the clarification questions are also in Appendix B.

The specifications required that the new mine monitoring system be integrated into the existing preparation plant and coal handling system. The new system was required to perform six monitoring and control functions which were divided into the following subsystems: belt fire monitoring, power monitoring, environmental monitoring, underground belt monitoring and control, raw coal system monitoring and control, and fan and hoist monitoring.

The raw coal and the fan and hoist subsystem were part of the existing preparation plant and coal handling system. Therefore, specifications required the vender to transfer these subsystems to the new mine monitoring system. This required that the vendor insure that the two systems be able to communicate and coordinate their activities in a logical manner.

Periodic reports, data analysis, and data archiving were specified by Western Fuels through the use of an additional "supervisory" computer. The system layout that resulted is shown in figure 1. The sensor types are listed in table 1, and their locations are shown in figure 2.

The belt fire monitoring operation required a series of carbon monoxide (CO) sensors to be placed at 1500 foot intervals along each belt line. Western Fuels anticipated requesting a 101C variance from the Mine Safety and Health Administration (MSHA) to allow the use of beltway air for face ventilation.

The power monitoring component was primarily for management information. Main production equipment such as longwalls, continuous miners, shuttle cars, and roof bolters were to be included. Power (wattage) sensors were to be located in each power center. Power versus time data was to be analyzed and reported by the supervisory computer for management information about equipment status and run time. Ground fault and phase fault sensors located at the substation were also to be included.

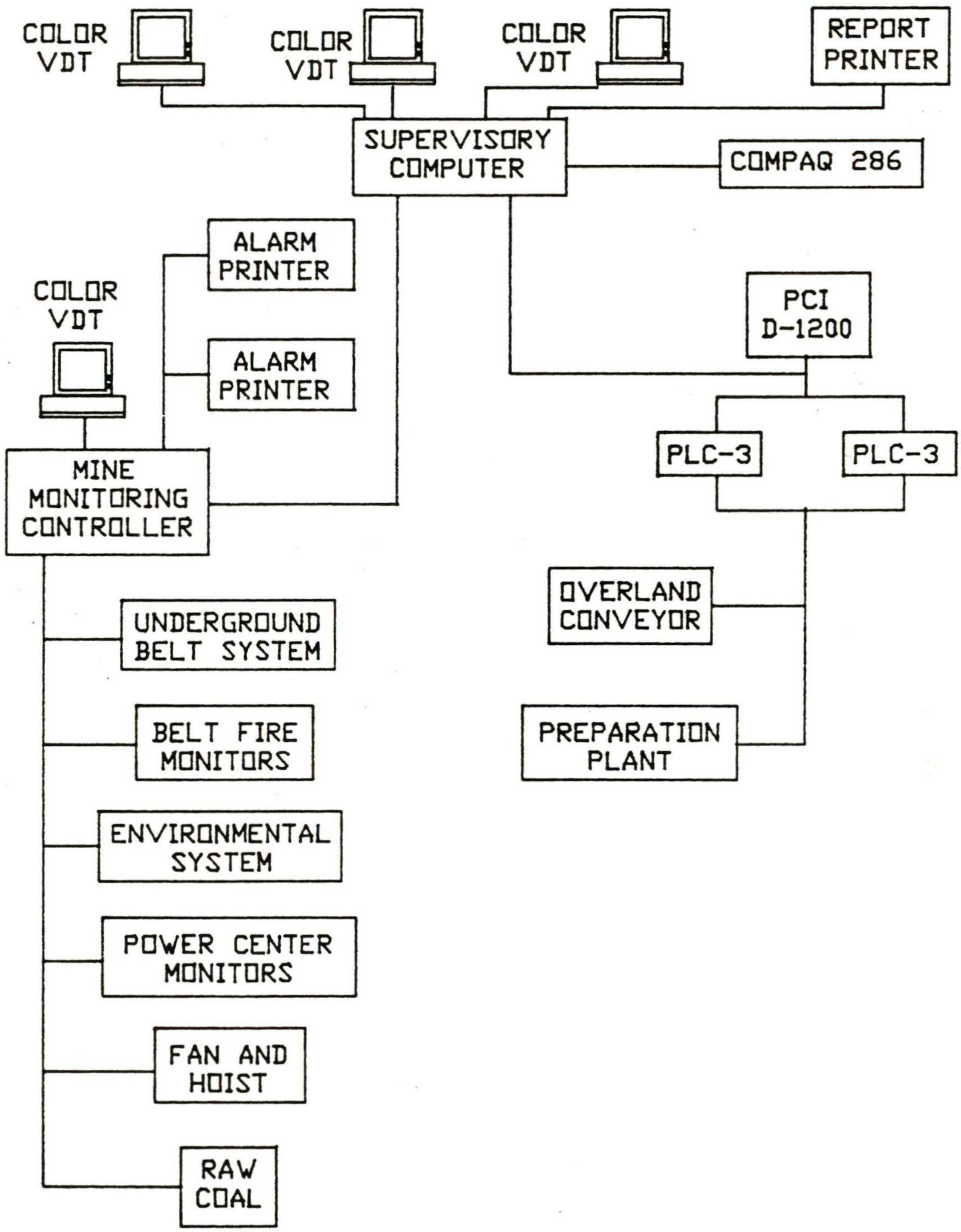

FIGURE 1. - System layout

TABLE 1. - Mine components monitored by the system

Underground belts:

- SCR temperature
- plugged chute
- fire suppression (at drive rollers)
- belt tension
- emergency pull cords
- remote on/off (switches located at head and tail rollers)
- belt slip
- phase faults
- 750 KVA transformer circuit breakers
- motor winding temperature
- belt misalignment
- sequence sitches
- local on/off switches
- motor amps
- gear reducerbox oil temperature
- inboard motor bearing temperature
- outboard motor bearing temperature
- point heat sensors full length of belt
- carbon monoxide sensors:
  - above each drive
  - above each belt transformer
  - every 1500 feet along belts
- total kilowatts from belt transformer

Belt computer controlled points

- start/stop command
- auto/local command
- reset (used for restoring computer control)
- emergency strobe light control
- emergency horn control

Environmental

- 27 carbon monoxide sensors
- 2 methane sensors
- 5 air velocity sensors

Section power centers

- total kilowatts on the 995 volt circuit
- total kilowatts on each 480 and 995 volt breaker

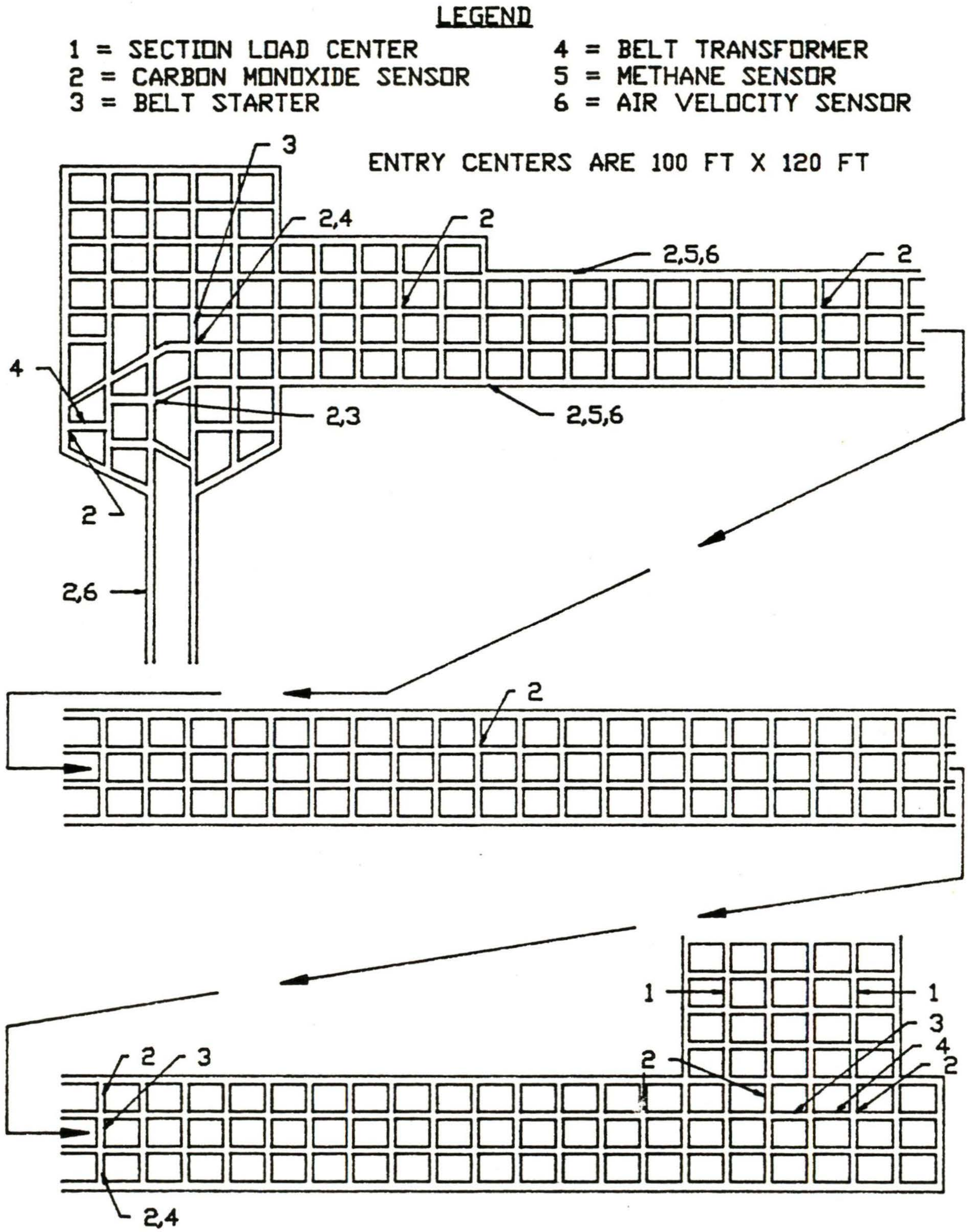

FIGURE 2. - Deserado mine sensor locations

Environmental sensors were intended to provide real time data on the quality and quantity of the air in the primary returns. The data to be collected included CO, air velocity, and methane. Real time display and alarms, data archiving, and trend analysis was required for the environmental parameters.

Maximum conveyor utilization through reduced trouble shooting time was expected with the belt sensors and microcomputer components. The sensors were to monitor belt speed, motor and bearing temperatures, coal flow rate, plugged chutes, belt stoppage, belt slip, belt misalignment, and local lockout.

The fifth subsystem was the raw coal handling operation which was to be transferred from the Allen-Bradley system. It included all the belt conveyors from the bottom of the slope to the top of the raw coal silos and the surge bin, vibratory feeders, and the rotary breaker.

The sixth, the fan and hoist, subsystem was to be transferred to the mine monitoring system from the existing preparation plant/conveyor system.

The outstations or accessor boxes were required to process digital and analog signals. Both the outstations and the sensors were required to be mine worthy and approved, so they had to have battery backup power with remote or automatic disconnect features in event of ventilation interruption.

Detailed specifications were written for each sensor type. They are presented in Appendix A.

A dual redundant communication system required vendors to address the issue of cable safeguarding and breakage in their proposals.

The mine monitoring controller was required to be capable of showing the status of all sensors, providing alarm signals, converting sensor output to engineering units, and performing any data processing required to control the system and display system status. Two 19-inch color video display terminals were to be provided that could also be used for programming, and the software was to be stored in solid state random access memory. In addition, a printer to provide a chronological record of all alarms and acknowledgements was requested. The video displays and printer were mounted in the console shown in Figure 3.

A 19-inch color video display and a black and white display for programming were requested for the supervisory computer. It was required to produce graphic pages of mimic diagrams and annunciator displays of raw (input) and processed data from both the mine and the preparation plant monitoring systems. The mimic displays indicate status of the environmental, power, and belt fire sensor data. The annunciator displays should use the surface preparation plant display format and symbols and permit the operator to monitor sensor outputs and diagnose alarms and system malfunctions. A 16 bit processor was requested with a hard disc and a backup cassette tape.

A printer with a keyboard was requested for installation in the guard shack to monitor any alarms on holidays, weekends, and idle shifts. The printer was to be equipped with an alarm horn and light which would be activated until the alarm was acknowledged by the guard. A color VDT was also specified for location in the administration building to monitor the mine and preparation plant status.

FIGURE 3. - Video display and printer console

Reports generated by the system were to provide extensive management information. Three periodic report types were requested in addition to the capability to produce on-demand or real-time reports. These reports were to present summarized information for shift, day, and month period. Detailed reporting requirements are given in Appendix A.

Several very important general stipulations were required of vendor proposals. For example, prospective vendors were required to conduct a complete set of factory-floor acceptance tests, and since the vendor was to be completely responsible for installation, another set of tests was required at the mine site upon completion of installation. A one week training program was to be provided on operation and maintenance of hardware and software, and four complete documentation sets were to be delivered. Furthermore, a list of necessary spare parts and costs were to be supplied. Appendix B presents the vendor's response to these requirements.

Planned Events and Roles from Design to Operation

Table 2 lists events and milestone dates that were originally planned for the Deserado project. These dates were extracted from the USBM RFP and the USBM memorandum of agreement with Western Fuels. Several expectations of elapsed time to complete specific tasks can be extracted from this table. For example, monitoring system design was expected to take four to five months. After design, three months were planned for writing the contract specifications and request to bid document. One month was allocated to the vendors for proposal preparation and another for Western Fuels' evaluation of proposals. The installation period, expected to last three months, was to be followed by one month of

TABLE 2. - Deserado mine monitoring project proposed milestones

EVENT	DATE	TIME (Months)
Memorandum of Agreement	June 1982	NAp
System Design Completed	Nov. 1982	4
Specification Document Completed	Feb. 1983	3
Pre-bid Meeting	Mar. 1983	NAp
Vendor Proposal Deadline	Mar. 1983	1
Vendor Selected	Apr. 1983	1
Begin Installation	June 1983	2
Installation Completed	Aug. 1983	3
Start-Up and Calibration Completed	Aug. 1983	1
Begin Operation	Sept. 1983	1
TOTAL		16

NAp = Not Applicable

calibration and start-up activities. After that the system was expected to be fully operational. The next section of this report compares the actual events and dates with these planned milestones.

EVALUATION OF INSTALLATION, START-UP, AND OPERATION ACTIVITIES AND COSTS

Proposed Versus Actual Milestones

Table 3 compares the initial plan, given in Table 2, with actual key dates by presenting the amount of time each was delayed. In several instances, the planned elapsed times were correct; however, the entire project began later than expected and the installation, which started in October 1984, is still incomplete as of June 1986.

Slow economic growth in the Bonanza Power Plant initially delayed mine development and the project. However, system design, specifications document preparation, and proposal evaluation tasks were completed within the scheduled elapsed times. However, project installation was delayed considerably, for the following reasons.

Conspec subcontracted installation tasks to the Gardner-Zemke Company subcontractors who arrived at the mine site unaware that there was any underground work involved and did not have their MSHA 40-hour underground training or their MSHA electrical certification. They attended a 32-hour off-site training course to satisfy this requirement; however, about 6 hours were lost trying to locate someone who could provide the training. An eight-hour, on-site mine hazard training session was also required. After the training, the contractors had to take the MSHA electrical test which required leaving work early on

TABLE 3. - Deserado mine project actual milestones

Event	Delay[a]	Date
Memo of Agreement	NAp	June 1982
System Design	NAp	NAp
Ten Month Scheduled Delay		
Specification Document Completed	10 mo.	Dec 1983
Prebid Meeting	10 mo.	Jan 1984
Proposals Received by WF	11 mo.	Feb 1984
USBM Documentation Contract Start	4 mo.	Aug 1983
Installation Begins	15 mo.	Oct 1984
Installation Completed-Surface Portion	17 mo.	Feb 1985
Installation Completed-Underground Portion	20 mo.	June 1985
Installation Completed-Management Information System	30 + mo.	NAp

[a]Comparison with planned dates from Table 2.
NAp - Not applicable

several shifts to study for the exam, and one shift was missed for travel to the exam site. These delays could have been avoided if the vendor and subcontractor had established better communications.

Because the installation was subcontracted to non mine personnel, the employees were not familiar with the mine site layout and had to spend two four-hour sessions getting oriented to the property. In cases where mine personnel install a system, this delay will be avoided. In addition, the underground work was delayed several times because the contractors were unfamiliar with certain underground work procedures. For examples, until they gained more experience they were not allowed to lock out the high-voltage feeder line, which resulted in several delays waiting for the mine electricians to lock out the equipment.

A few delays were caused by conflicts between the contractor's work schedule and normal mine operations. For example, when an area was being rock dusted, or had power locked out for repairs, it was unavailable to the contractors. To solve this problem a mutual understanding was reached that resulted in the mine work being rescheduled or the installation work being done in another area. This friendly atmosphere eliminated many other potential problems such as disagreements on interpretation of the contract. At all times Conspec's subcontractors were friendly and pleasant to work with. This type of attitude did much to ease tension and allow work to progress while the management of the two companies worked out their differences.

Several existing telephone lines were used to connect the terminal in the mine manager's office to the central terminal. These phone lines were labeled incorrectly by the telephone company when the lines were installed and had to be traced for four hours to establish the correct terminations. After the central console was installed, two vendor field representatives traveled to the mine to check the system and the project progress. However, they were unable to test the computers by entering any of the programs that would be used upon startup, because the programs had not yet arrived. The programs arrived five days later.

When the existing programmable controllers, which run the surface equipment, were tested, the controllers failed numerous times causing delays of up to six hours. These delays were not caused by the Senturion system but they slowed the project. If Conspec had not found these problems, they might have caused costly operating down time at a later date.

The original plans called for the management information and color graphics system (MIS) installation by the end of November 1984. However the system is still not completely on line, because this was the first 16 bit computer ever used by the vendor. They proposed an 8 bit computer which they used extensively; however, Western Fuels believed that an 8 bit system would limit future development.

In the vendor's proposal, they stated five additional weeks would be required for delivery of the 16 bit system. They ran into unexpected development problems and were unable to deliver until July 1985. When the system was delivered it was not accepted since it lacked the specified report documentation capabilities.

The final plan agreed on by both parties was to have the vendor purchase a personal computer and provide software to transfer the management information data. To date this plan has not been fully implemented.

Installation and Start-up Problems

The time to install system components varied considerably, depending on local conditions. The installation times improved as the electricians gained experience with the system components. Because of this variation it is difficult to predict installation times for other mines that are planning monitoring systems; however, the list in Table 4 reflects typical experience at Deserado.

TABLE 4. - Typical installation times

Component	Installation Time
Central console	32 hours
Conduit and wiring for console	64 hours
Belt starter control	16 hours
Belt transformer interface	16 hours
Section power center	40 hours
Environmental sensor	2 hours
Trunk line, (u/g, no conduit)	4000 feet/shift
(surface, in conduit)	200-2000 feet/shift

The vendor did not have one of their own employees on the project at all times, so there were several times when it was difficult for them to understand some of the problems that arose. For example, the original plans did not call for trunk-line conduit along the slope, but later it was apparent that this would be necessary. The vendor believed that the original plan should be followed unless Western Fuels wanted to pay the extra cost. Western Fuels felt that the original plan was inadequate and the vendor should have been aware of this condition all along. The vendor sent one of their field representatives to examine the situation, and then agreed that the conduit was needed and supplied it.

As previously discussed, the installation subcontractors had never worked in a mine. Most of the problems were solved with cooperation from Western Fuels. In return, the subcontractors put in extra effort that would not normally be expected or received in other contracting situations. For example, Gardner-Zemke people did not have any form of transportation underground. This would have been a major problem as the plans called for approximately 15,000 feet of cable to be hung throughout the mine, so Western Fuels lent them an underground jeep. There were numerous times when Western Fuels loaned tools or supplies, but in all cases the subcontractors reciprocated by doing work beyond the scope of their responsibilities. This cooperative agreement benefited both parties greatly.

The subcontractors were based in New Mexico and therefore all their supplies were located several hundred miles from the mine. This presented problems when unanticipated needs for materials arose. For example, when their portable hand held drill broke, they had no local source of replacement. They were not able to borrow the mine's drill until the next shift, so several hours were lost while they worked without the proper tools. When unanticipated materials were needed, the subcontractors had to make special trips into town. These delays accounted for at least 16 hours of lost time.

Installation was delayed when the externally mounted accessor boxes, made from stainless steel, arrived at the job site without trunk-line entrance holes. The holes were very difficult to punch underground. Several drill bits were broken, and one hole punch set was also damaged. Had these holes been knocked out prior to delivery at least six hours would have been saved.

All of the surface conduit already contained wires. In many cases the line box spacings were excessive which increased the time and difficulty of installing the feeder line. This problem will exist in other mines where preexistent conduit is used.

The CO monitors were scheduled to be installed every 1500 feet along the belt entry. The vendors drawings contained the wrong scale which led to 2000 foot spacings instead. This error was discovered and corrected by the contractors, but a two-hour delay resulted. In addition, the CO monitor mounting instructions did not explain that the sensor cell must be placed on the bottom of the housing, and the cells were placed on the side of all 12 monitors. Remounting required a full shift and fabrication of new brackets.

The initial discussions between Western Fuels and the vendor were conducted with the Denver office project engineers and the mine site engineers. However, an on-site engineer was not assigned as project engineer. This made it difficult to answer many small questions that arose during the planning stages. For example, the vendor was told that various items (sections of conduit, belt misalignment switches and plugged chute indicators on the underground belts and thermal sensing units for the underground gear reducer boxes) were in place as shown on the design prints. However, it was discovered that these units were not in place when the subcontractors attempted to connect them to the system. An on-site project engineer would have improved this and similar tasks.

The intent of the contract between the vendor and Western Fuels was for a fully operational system. Western Fuels anticipated conducting the acceptance test very soon after completion of installation. However, many delays occured and unexpected problems developed which prevented timely completion. As a result, the system was started in phases rather than at one time.

When the system was first operated, it monitored and controlled the surface but only monitored the underground. None of the environmental monitors, temperature sensors, or electrical power sensors were calibrated. Conspec made several mine site visits to complete the installation, but never reached a point where all sensors were on line and calibrated. Western Fuels employees finished the installation and calibrated the equipment.

The graphics system was supposed to display all the pictures available from the prep plant control system. However, the pictures only showed static conditions and would not show the current sensor values. This part of the graphics development was left for Western Fuels to complete.

Prior to applying power to the trunk lines, tests were conducted to identify shorts and any stray currents on the line. No incorrect terminations were found on the surface; however, one problem occurred in the underground 1000 KVA power center. A confusing electrical drawing resulted in several incorrect terminations which were corrected within two hours.

The system was started with only the underground trunk line connected. The computer ran perfectly and the system responded correctly to several induced alarms. When the surface trunk line was added several days later, one surface accessor went into communication failure and was repaired on site.

Although all accessors were on line at the start, the underground analog transducers had not been calibrated. Considerable calibration and travel time was required by Western Fuels personnel during the start-up period. The methane and air flow monitor's calibration were not included with the other manuals the vendor provided with the system, but were supplied immediately after the omission was evident.

The software loading procedures were somewhat cumbersome during the first two weeks, because the vendor had made several software changes in the operating system and had not yet put all the changes together on one diskette. Approximately one month later, the changes were organized onto one diskette.

The underground system was left on local control and monitored only for the first month, to allow the mine operations engineer time to learn the system and to more throughly test the signals. There is no way to operate the surface equipment in a local mode so automatic control occurred as soon as the surface trunk line was added to the system. The Conspec surface control software worked well, with only a few minor problems. Most of the errors were copied from the Allen-Bradley software.

Contract and Component Specifications Assessment

The system specifications were defined by Western Fuels in their Specifications for Mine Monitoring System in Appendix A. Several clarification meetings with three bidders followed the original specification release, and after the contract was awarded there were numerous meetings with the successful bidder. All meetings were well documented for later reference and communication procedures were established between the two companies.

One of the specifications document goals was to allow flexibility in the system parameters. This was considered important as Western Fuels did not want to exclude possible improvements to the system design. Consequently, as the project progressed there was very little need to modify the original specifications. However, one significant change was the method used in communicating with the Allen-Bradley PLC-3 preparation plant controllers. Since it was possible to directly poll the PLC-3's memory, Conspec[1] eliminated the proposed interface equipment.

If every one of the details in this or similar projects had been included, the contract document would have been too voluminous and restrictive. Therefore, it was important that the two parties develop a good working relationship, to allow maximum progress even when areas of disagreement arose. Any companies involved with the installation of a monitoring system should find a vendor or contractor that cooperates professionally.

During the contract discussions, Conspec planned to have a field representative at the mine site during the installation period. Western Fuels understood this to mean the entire installation period. However Conspec intended field representative visits at the installation start and also when the installation neared completion. Conspec successfully started the system without having people on site for the entire installation period because the subcontractors were very capable electricians, and because the monitoring system installation steps were well documented. When the software was installed, Conspec sent two technicians to the mine to make sure that the system was operating correctly.

The contract between Western Fuels and Conspec was unclear in certain areas, consequently several misunderstandings resulted. For example, Western Fuels believed that they would be able to control all mine systems by using the color graphics computer. However, this feature did not exist, and the contract did not specifically address this topic, but it had been discussed in several meetings between the two companies. Ultimately, the question was solved and color graphics control was developed, but only after several more meetings took place.

The contract stipulated that the vendor would develop the report generation and color graphics software implementation. However, since the software has not been delivered to date, Western Fuels engineers will have to develop it. The vendor agreed to purchase a personal computer, provide a data link to the color graphic system and assist the mine engineers with software development.

The component layout of the system worked very well. The equipment is easily accessible yet well protected. The underground equipment has withstood the hostile environment very well. In most cases it is housed in sturdy stainless steel boxes, and in the remaining cases housed within existing equipment such as belt starter boxes or transformer boxes. Environmental monitor accessors are located inside the monitor housing. All accessors are resin coated and are not affected by dust. The mine is dry and no problems have been experienced with condensation on the boards.

The trunk line cable has two neoprene jackets with a steel braid between them. All four internal cables are insulated and wrapped in a foil shield. The data transmission cable is additionally enclosed in a second foil shield. The shields protect the cables from electrical fields which would induce stray voltage onto them. No problems have been caused by induced currents.

The central console is well designed for the operator and provides good maintenance access. However, the console operator's table could be improved, since it is not deep enough to hold a standard computer printout next to the keyboards. Another problem was the operation room overhead fluoresent lamps, which made the graphics screens extremely difficult to read. Installation of recessed incandescent lights solved the problem. The fluoresent lamps were left on a separate circuit to be used for floor cleaning, maintenance and other activities that require bright lights.

The vendor's warranty covered all equipment designed by them for one year following customer acceptance. Any equipment built by other companies but part of the monitoring system carried the same warranty provided to Conspec by the manufacturer.

Since the report generation package and several underground sensor calibrations have not been completed, Western Fuels has not conducted an acceptance test. Therefore, the warranty period has not yet started. The vendor believes the equipment was accepted because Western Fuels has been using it for over one year. A meeting is scheduled to resolve this question. This problem could have been avoided if the calibrations had been completed when the system was installed. Necessary additional training could also have been provided.

Two acceptance tests were scheduled prior to the system being accepted by Western Fuels. The first test was held at Conspec's factory in Toronto before the system was shipped to the mine site. This test was attended by the management of Western Fuels and the Conspec engineers. The second test was to be held at the mine once the system was installed and ready to run.

The factory acceptance test was not as useful as expected, because it was really more of a demonstration than a test. The time that was spent on setting up the equipment in the factory could have been better spent on the job site, because the Senturion computer has been used in many applications and is well tested. Problems are more likely to occur when the system is installed at the mine site, because there is a possibility of field wiring being incorrect, equipment being damaged in shipment, or installation directions being misunderstood. Once the system is set up at the mine, the actual instrument calibration could also be checked as part of the acceptance test.

A mine site test should always be conducted even if the system was factory tested. The mine site test should be scheduled for a period of several days, allowing enough time to check each point in the system individually, and for a total system test.

The Deserado system is currently very near its capacity; however, it is only monitoring five underground belts rather than the fourteen originally specified. The system is monitoring or controlling 150 points on the belts, which is very close to the 154 points specified. Each belt was originally expected to have 11 points monitored, but Western Fuels added 19 points to each belt.

The polling time, or scan time as it is called on this system, is another critical feature. The scan time on the system supplied by the vendor is two seconds, which allows a rapid system response to changing conditions. The "Specifications for Mine Monitoring System" specified a maximum 20-second polling time at full capacity. The 20 second design parameter is now seen as unacceptable. A system running that slow would not be able to react to changing mine conditions quickly enough, and the usefulness of the system would be greatly reduced.

A problem would be encountered with a system running at that speed when a plugged chute is detected. The belts are immediately shut down, but some spillage still occurs because the belt continues to coast to a stop. The Deserado mine conveys coal from underground at 750 TPH. If the belt was allowed to run for another 20 seconds a spillage of over four tons could result whenever the belts shut down under load. As the mine grows, this problem will increase.

The event printer has worked well even though the printing speed is less than specified. However, the 150-cps speed is adequate.

Although the graphics system has not yet met its goals, it is anticipated that it will do so in the near future. At the present time, the system is able to reproduce the graphics from the preparation plant system, and display the graphic status from the mine.

The vendor suggested that the contract be changed so a personal computer could be added to permit use of off-the-shelf software for the MIS. Western Fuels agreed as report format and data manipulation flexibility would be increased. Western Fuels has considered many potential uses of the data, and this approach will allow a variety of data applications and also allow new software use. Another advantage is that Western Fuels will not be dependent on the vendor for any software changes.

A significant system design change was made during installation in the belt starter boxes. The computer system was designed to be wired in parallel with the starter boxes, thereby allowing the operator to choose either the computer system or the hard wiring system to control the belts. If one system failed, the other system would be available. This design provides high reliability, however it presents safety problems.

If the computer can start the belt system without going through the hard wiring controls, the possibility of a serious accident is introduced. The mine engineers were concerned that an underground employee might trip a pull cord to prevent a belt from starting while he worked on it. If the pull cord safety was removed from the computer permissive list, or overridden, the computer would be able to start the belt.

The problem was solved by wiring the two in series, so that the computer signal goes first to the belt starter. If the starter box is clear to run, it will energize the belt motors. But if the computer tries to start the belt when a permissive contact is in the wrong condition, the control box will still prevent a start. This wiring arrangement will also provide protection against software logic errors.

Another hardware change was made when it was found that trunk line lengths of over 12,000 feet resulted in accessor card communication failure problems. Conspec engineers conducting on site testing concluded that the Accessor Trunk Extender (ATE) power supply was not large enough. The power supplies were exchanged for larger models, and the trunk line has now been extended to approximately 18,000 feet with no communication problems.

In addition, the two trunk extender stations used slightly different components which made interchange difficult. The vendor modified the older model to conform to the newer design.

The Conspec system could be classified as hardware simple and software intensive. It is believed that this accounts for the high system availability. The software is housed in a controlled environment where it is not likely to be damaged, and the software is not subject to wear or failure as is the hardware. By making the system more dependent on the software than the hardware, system reliability improves.

Training and Operating Procedures

The maintenance superintendent and the mine operations engineer attended a three day training and factory acceptance test in Toronto, Canada. The training introduced the Senturion system and explained how to use the basic functions. Vendor personnel explained the graphics system capabilities and gave a brief explanation about the programming method. They also provided two complete manuals.

The training provided a background for more thorough training when the vendor technicians visited the mine site for the system startup. In addition, the operations engineer worked with vendor representatives over the telephone whenever a new problem was encountered.

Currently, Western Fuels employs four engineers working full time on the system. The operations engineer has overall responsibility, while each of the control room engineers operates the system during production shifts. Each is also assigned a specific area of system development.

During a production shift the control room engineer ensures that the system is functioning properly, and communicates with the underground personnel. If any of the belts stop, or problems develop, the engineer pages or calls the appropriate personnel on the mine phone. And conversely, if a belt man needs to stop a belt for maintenance, he calls the engineer on the mine phone, and the belts are stopped in sequence.

With the control room engineer coordinating the belt line activities in this manner, the Deserado mine has been able to average a belt availability of 95% for a period of four months. The ability of the engineers to very quickly direct underground mechanics and belt men to the source of the problem is the biggest factor contributing to this high availability.

The control room engineers man the system and mine phone continually during production shifts and are able to act as mine dispatchers. Consequently, the maintenance and shift foreman call the engineer periodically and inform him of their present and future locations.

Each of the engineers are assigned a specific area to develop on the system. Normally they are able to spend the majority of their time on development work, however on shifts where a lot of problems occur, very little system work gets done.

One of the control engineers modifies the Senturion software. He enters new points and integrates them into the control programs, and as new equipment is added, he modifies the programs. He tries to reduce operator keyboard input by programming the computer to control as much as possible. In addition he calibrates the analog sensors.

The second control room engineer programs the graphics displays. He tries to control as much of the mine as possible with graphic displays to reduce the amount of operator input and the operator error rate.

The third control room engineer develops the personal computer software which will generate reports and manipulate data. He is designing reports for the mine manager, the mine superintendent and the maintenance superintendent.

The operations engineer is responsible for the design and implementation of all expansion projects. He supervises the control room engineers and the underground electrician that maintains and installs hardware.

Production and Safety Benefits

The Deserado Mine is currently going from development into production, and is expanding at a rapid rate. At the present time the system is directly monitoring about 700 points. Plans for the remainder of the year call for equipment installation that will exceed the monitoring capacity of 800 points. Therefore, a second system is being planned that will be monitoring approximately 300 points by year end, in addition to the approximately 800 points in the first system. The graphics system is also monitoring over one thousand points in the preparation plant.

At the present time the system is collecting 21,000 pieces of information a minute, and by the end of the year it is expected that there will be about 40,000 a minute. The data are saved on hard disk and available for analysis and report generation.

Many of the potential benefits have not been realized since the MIS is not completely operational. Western Fuels plans on using the data to generate daily reports for the production superintendent, the maintenance superintendent, and the mine manager. The reports will be tailored to individual needs, and will be generated automatically. A plan to give the foreman a weekly report is also being considered. The report would allow the individual foreman to compare his performance and provide feedback that would aid in self improvement.

Studies are planned on electrical usage versus coal production with the goal of reducing the power consumption and lowering operating costs. It is also hoped that some programs will be developed to recognize the signatures of various electrical equipment. These programs could then notify the operators of changes in trends as they are detected.

The MIS will log and examine conveyor belt down-time causes with the expected result being an increase in belt availability. The control room engineers have already been keeping records on belt stoppages and have documented that there is more time lost caused by small recurring problems than by larger nonrecurring problems.

For example, a plugged chute detector alarm caused the belt line to stop many times over a three-day period. The mechanics had not considered this serious because it was always possible to restart the belts quickly, but the lost time amounted to several hours in the three days. Without recording the actual amount of time lost, it would have been difficult to realize the significance of this problem.

Recurring events may cause serious secondary problems. For instance, an inspection of the belt after solving the plugged chute detector problem revealed that several mechanical splices were pulling apart from the repeated start up of the loaded belt. Had the frequent restarts continued, it is possible that one of the splices would have failed.

The main impact on production has been increased underground conveyor belt availability. Since the belt line has been on computer control, the belt availability has averaged about 95%. The surface belt availability has not significantly changed as the surface belts were previously controlled by the Allen-Bradley system.

A belt availability study was not conducted prior to the installation of the system; however, all personnel that worked with the belts have agreed that the availability is higher than it was before installation. When a new belt is added there is often a delay before the system interface panels can be installed, and the new belt runs under local control. When the belts stop, while they are not being monitored, the time needed to find the problem greatly increases.

The availability is higher because when the belt line stops the control room engineer immediately knows the reason. The engineer notifies the belt person or mechanic, and the belts start again quickly. This feature has convinced skeptical underground miners that the system is valuable.

The mechanic's time to troubleshoot is reduced with the system. In fact, some intermittent problems clear themselves before a mechanic arrives. The monitoring system records all alarms on a printer, so even if they have cleared, the problem was documented.

It is advantageous to compare current and historical sensor data. This will be enhanced with the MIS, and it will be available to the maintenance department on very short notice. Reports for the mechanics are anticipated to consist of graphs more often than text, to allow a fast comparison. Even without the MIS this valuable feature has proved useful.

For example, one surface belt draws 39 to 40 amps when running empty. One morning this belt was pulling 44 amps when empty. A close visual inspection revealed that a piece of timber had jammed against one of the snubber rollers. Friction between the belt and the jammed roller caused the increased motor current. Early detection prevented any belt equipment damage and avoided the obvious potential safety hazard.

Belt-line spillage and personal injury hazards have been greatly reduced, because the computer can stop the belts very quickly. The shut-down speed was tested by running the belts under local control and stopping the first belt in the belt line and relying on the mechanical roller sequence switches to stop the other belts. One minute 47 seconds elapsed until the last belt stopped. Another test was conducted by replacing the mechanical roller switches with electronic switches while the belts were still under local control. The elapsed shut-down time reduced to 20 seconds. Finally, the test was conducted under computer control and the time was further reduced to 2 seconds.

The mine was only running four underground belts during the testing. A larger belt system would give even more dramatic results since the computer-controlled belt shut-down time does not depend on the number of belts.

At present, the sensors that monitor section equipment are on line, but the data is not being utilized. Plans are to record equipment availability and run times to help maximize production. For example, equipment availability records will assist maintenance management to focus resources. Equipment utilization records will likewise assist production managers.

Additional production improvements are expected from preventive maintenance. In the future, the management information system should produce trend logs of data such as bearing temperatures, power consumption, and reducer box temperatures, that will allow maintenance managers to predict component failures and schedule preventive actions on nonproductive shifts.

It is anticipated that the biggest benefit to mine environment and safety will be carbon monoxide sensing. All belt drive locations are monitored and there is a CO monitor every 1500 feet along the belt line. All switch gear, transformers, and return entries are monitored. Currently there are fifteen CO monitors underground and fifteen more will be installed soon.

If CO sensors have been located correctly, they will detect combustion before smoke or flames are visible. There have been cases reported at other mines where CO sensors detected smoldering coal on belt idlers which presented a fire hazard. Even if the CO sensors do not detect combustion soon enough to prevent a fire they should provide enough warning time to allow a safe evacuation. It should also be possible to identify the fire location which could provide valuable information in dealing with the problem.

Underground fire protection is provided not only by the CO monitors, but also by sensors that monitor the belt drive motor bearing and the gear reducer box oil temperatures.

Air velocity sensors are located in both intake portals and in the return entries near the exhaust fan. There are five air velocity sensors in service now, with five more waiting to be installed. These will measure submain and longwall panel air flows. A ventilation simulator will be run on the proposed micro computer using the real-time air flow values from the monitoring system to provide a continuous check on the ventilation system.

Continuously monitoring air flows in various areas of the mine will also increase underground safety by detecting areas that are not being properly ventilated. If a major change in the ventilation pattern was detected it could lead to the discovery of problems such as an unknown roof fall or incorrectly positioned regulators.

There are two methane sensors located in the return entries near the main exhaust fan, and plans call for the installation of two more. Since the Deserado Mine has encountered very little gas underground, methane sensors will be located only in the longwall bleeders and at the main ventilation intersections.

Costs

The mine monitoring system installation was designed as a turn key project in which the vendor would be responsible for all installation, calibration, and start up procedures. The bid submitted by the vendor included all hardware, software, and installation costs.

Several different software options are available; therefore, the vendor proposed the system which they felt best suited Western Fuels' needs. The monitoring system was sold as a package which included the software and hardware and installation. The total system price was $387,420. Component costs are listed in Table 5.

There have been two significant changes to the system layout that affected costs since the vendor proposal was accepted. The first change was the report generation system discussed previously. The other was reconfiguring the underground trunk line.

The trunk was to be installed in a loop with each side in a separate entry so if one line was damaged, data could still travel through the other line. Furthermore, by mounting a trunk break detector in the loop, the system could alert the operator when the trunk was damaged.

However, Western Fuels concluded that the loop arrangement was not likely to work in actual mine conditions. The only time the trunk was damaged, the break was not clean and the line conductors shorted. This damaged the Accessor Trunk Extender (ATE) circuits which further interrupted communications and the parallel line was useless. Since a short circuit is expected to be the most common fault condition the loop network is an unnecessary expense unless improvements are made in the ATE.

Consequently, the trunk line was converted to a single line and mounted over the main conveyor, a protected location. The change

TABLE 5. - Component costs

Component	Cost in Dollars
Central Processing Station	72,000
U/G Environmental Sensors	17,400
U/G Power and Belt Monitors	50,000
Surface Monitoring Accessors	21,000
Trunk Line Cable	12,000

shortened the length of trunk line by approximately 6,000 feet and saved about $5,000. The reclaimed trunk line was used in other parts of the mine.

Troubleshooting and repair costs are difficult to estimate. The majority of equipment failures experienced at the Deserado mine have been with accessor cards which the vendor has fixed by replacing faulty components. The system is still under warranty, so there have been no equipment repair costs charged to Western Fuels. Repair charges in the future will range from the cost of a new card to the shipping costs on equipment still under warranty.

The labor cost has been low as most of the troubleshooting has been very simple. When an accessor card fails to respond to the central processor, a communication failure message is displayed. If changing the card solves the problem, the faulty card is sent out for repair. When an accessor does not respond correctly to an input signal, it is also changed. Actual wiring changes and repairs have been done by certified electricians, but this amount of time has been small.

During the first six months after startup, records were kept documenting system reliability and maintenance. A total of 405 minutes of production time was lost during the six months due to system problems. This is equal to 0.77% of the total production time during those six months. Therefore, an increase of only 1.0% in belt availability would offset this lost time. Although belt availability records were not kept prior to system installation, the mine supervisors believe that the increase in belt availability was much greater than 1.0%.

Western Fuels encountered some unexpected costs during installation when they found it necessary to travel to Toronto to discuss the color graphics control system. Their understanding was that the system operator would be able to fully control the belts and related equipment with color graphics. The vendor indicated that this feature would not be operational until some time in the future.

It also became evident at the start up of the system that the existing lighting would not work with the color graphics displays and supplemental lighting was purchased.

All levels of management have expressed the opinion that the system has considerable value as evidenced by their decision to hire additional engineers to support it. For example, the system has greatly increased conveyor belt availability. In addition, equipment performance and management information will soon begin to increase mine efficiency. Furthermore, the system is capable of preventing accidents or major disasters. This value cannot be overestimated.

Monitoring and Control System Failures

Monitoring and control system failures are listed in Table 6, and summarized in Table 7. The tables explain which component failed and, if known, why it failed. The time to repair and production time lost are presented for each failure.

Several levels of problems can affect the system. The most serious affects the central processor, because if the processor fails the whole system fails. This problem can result from a power loss to the central processor, or a computer failure.

To guard against power failures, the system uses an uninterruptible power supply (UPS) at all times. The incoming AC line power feeds a 10KVA battery bank charging system. The battery supply is converted to AC power for the computers.

This system has several advantages over direct AC power. First, if the incoming power fails, the computer is already running on the batteries so there is no switch over process. Second, the batteries deliver very clean power without spikes and surges.

TABLE 6. - Monitoring system failures production delays and repair times

Date	T[1]	LP[2]	T[3]	Reason
3/25	1	0	60	A plugged chute alarm had gone unrepaired on A/B[4] system. The mercury tilt switch was replaced.
3/26	1	20	60	Emergency high level detector went into alarm in silo #1. Possibly a bad tilt switch that was unrepaired on A/B system, and still unrepaired, caused surge bin feeder to shut down and the surge bin to overflow. The high surge bin level went undetected, because the level detector was not wired into system.
3/26	7	0	30	Several points went into communication failure for an unknown reason. Rebooting solved the problem.
3/27	1	0	40	System was unable to monitor the surge bin level. The instrument technician examined the input signal and found a defective sensor.
3/27	8	0	60	System was unable to control the dust gate. An electrician examined the motor controls and found a burned out motor.
3/27	2	0	45	No input signal was present for the BC-101 plugged chute indicator. The sensor was mislabeled in the software.
3/27	4	15	25	An electrician disconnected the power to a limit switch while repairing the burned out motor, which put switch into alarm and stopped the surface belts. The limit switch was removed as permissive and the surface belts were restarted.

TABLE 6. - Monitoring system failures production delays and repair times - Continued

Date	T[1]	LP[2]	T[3]	Reason
3/28	4	15	480	An emergency stop button was moved from the wall to the central console. Power was lost to the switch during the move which caused a shut-down. Power was restored to the switch after the move.
3/28	4	45	15	Trouble shooting A/B circuits in the preparation plant caused four surface shut downs during the day by removing power from the emergency shut-down switch.
4/1	7	20	20	The system crashed for unknown reasons. Reboot was successful.
4/2	7	0	30	Several underground points cycled in and out of communication failure for unknown reasons.
4/2	4	45	120	An operator programming error caused a surface shut-down when restart was attempted, the system started several field units out of sequence. The operator detected the problem and rebooted an old program.
4/3	4	15	20	The reversible belt on top of the silos started in the wrong direction. The error was detected by the operator before any damage occurred. The error occurred because the operator overrode the field limit switches as permissive.
4/9	2	15	30	An air compressor failed on the surface and caused all of surface to stop, because it was programmed incorrectly on the A/B system.

TABLE 6. - Monitoring system failures production delays and repair times - Continued

Date	T[1]	LP[2]	T[3]	Reason
4/16	4	20	20	The system crashed when the printer and CRT were unplugged. It was rebooted with no problem.
5/6	4	0	25	Three emergency high level tilt switches for silo #1 were found to be omitted from Conspec software. They were put back on the system.
5/9	3	0	90	CRT #3 failed because the data line cable was damaged.
5/10	8	0	180	Conspec repaired a faulty verifier unit in the central console.
5/14		0	240	Underground maintenance people tested belt control points on system, by triggering every input to make sure each could be detected.
5/15	4	0	60	An incorrectly wired pull cord signal was repaired on an underground belt. The remote on/off was wired in series with the pull cord, so either generated the same signal.
5/17		0	480	Underground trouble shooting was completed, so all underground and surface points are now on line with three in communication failure. The underground analog points still need to be calibrated.
5/20	4	30	30	Power was interrupted over the weekend so the underground accessor truck extender batteries discharged. The underground belts were not monitored until batteries recharged. Diagnosis was difficult since the operator did not understand the alarm that the computer generated when the recharger failed.

TABLE 6. - Monitoring system failures
production delays and repair times - Continued

Date	T[1]	LP[2]	T[3]	Reason
5/20	4,6	0	300	The instrument technician installed belt scale and belt totalizer accessor cards, but the wire numbers provided by Conspec were incorrect so wires had to be traced. The belt scale accessor was defective and replaced.
5/30		0	240	An underground electrician checked the points on each belt.
5/31	4	0	120	PDP factory wiring was modified to allow amps transducers on belt drive starter boxes to send amp signals to system boards. Conspec instructions had not been followed by the installer.
6/3	9	0	60	A faulty CRT was replaced.
6/6	4	0	120	CO monitor hoods were modified to allow calibration gas access to heads. Conspec originally supplied the wrong hoods.
6/11	4	120	180	New operators experienced software problems which prevented morning start up. Lack of adequate operator training caused the problem.
7/3	8	0	184	The problem which has caused several underground points to stay in communication failure was traced to a weak power supply in the ATE box. The power supply replaced by a larger model, and it was discovered that the two ATE boxes were not interchangeable.
8/14	3	0	15	The batteries discharged in the ATE box due to a power interruption. The belts ran in local control, but by end of shift the system still would not come up.

TABLE 6. - Monitoring system failures
production delays and repair times - Continued

Date	T[1]	LP[2]	T[3]		Reason
8/15	3		0	300	An investigation revealed that the underground trunk line was cut and shorted. Removing the damaged section allowed the system to come back on line.
8/16	3		0	480	When trunk line was cut an ATE board was damaged so we switched to a back up board. Trouble shooting took all day.
8/26	9		0	60	The mine managers CRT failed and was removed from service for repair.
8/26	4		15	30	The system was switched back to the main ATE board by mistake, and switching to standby board cured the problem, verifying that the main board is bad.
8/27	2		15	30	All back up disks were tested by running them on line. One set had some old programs which caused delays. We will update all back up programs on a regular schedule.
8/30	7		15	60	The operator attempted to start underground and surface simultaneously with the auto-start program. An unknown software problem caused both to shut-down. A separate start-up caused no problem.
9/3	9		0	60	The instrument technician worked on the mine manager's terminal, but could not repair it. We will return it for warranty work.
9/9	6		0	90	We swapped a bad analog accessor card in an underground belt starter box.
9/11	8		0	30	One of the graphics system ports is not functioning, and we switched to spare port.

TABLE 6. - Monitoring system failures production delays and repair times - Continued

Date	T[1]	LP[2]	T[3]	Reason
9/18	9	0	90	The mine managers CRT was returned and still does not work correctly.

[1]T = Failure type for Table 6 summary
[2]LP = Production time lost
[3]RT = Total man minutes for repair
[4]A/B = Allen-Bradley

TABLE 7. - Summary of production delays and repair times by failure type[1]

	Type of Problem	Lost Production (minutes)	Repair Time (minutes)
1.	Sensor problems	20	160
2.	Software	30	105
3.	Cables	0	885
4.	Human error	320	1395
5.	Accessor failure	0	240
6.	General equipment	0	450
7.	Terminals	0	270
8.	Unknown	35	140
	Totals	405	3645

[1]Compiled from Table ~~5~~ 6

The preparation plant also runs on the UPS and while exact battery life is not known, the system has been run for several hours with the charging circuit off. The UPS system is monitored by the prep plant control system and by the color graphics system, so problems are quickly detected.

The repair time is difficult to estimate because in most cases the problem could have been repaired more quickly since when a hardware problem arose it presented an opportunity to learn more about the system. Therefore, the engineers spent some extra time working with the equipment to better understand it. The repairs took less time as experience was gained.

The system has a second computer which is running and ready to take over if the main processor fails. A verifier unit watches the trunk line signals to insure that the main processor functions correctly. If any trunk line loses communication with the computer, the verifier automatically switches to the backup. Each processor has its own trunk driver card, and the verifier also switches to the backup driver card. By operating in this manner, the backup system will correct the problem if the processor or the trunk driver card has failed.

A less serious problem can develop if a trunk line fails, due to one of several problems, including a trunk line short circuit or a short on an accessor card. If this problem occurs on the underground trunk line, the belts can run in local control. If the surface trunk line experiences this problem, however, the surface belts will stop.

Individual accessor cards can fail also. If the failed card monitors a belt the computer will stop that belt and any other belts that load onto it. It is possible to put any individual underground belt under local control while keeping the rest on the computer.

Operator mistakes can also cause the belts to stop. Someone may activate the wrong controllable point, or enter an incorrect command. There are many safety checks in the hardware and software, so it is very difficult to actually damage any equipment with a mistake.

If it becomes necessary to run the underground belts under local control, there can be a drop in production due to the increased time needed to find problems when the belts stop. It is also likely that there will be increased spillage when the belts are stopped as they will not stop as quickly under local control.

Vendor maintenance support has generally been very good. The engineers are always available for advice on any system problems, and in those cases where they were unable to immediately diagnose the problem, they were always able to provide a method to isolate it. In situations where the mine production was involved, such as the mine being down due to a system malfunction, their support was superb. In one case a critical component of the main processor failed, which resulted in running on the standby processor with no back up. The vendor flew a replacement board to the mine in two days and advised the mine engineers in the proper replacement procedure.

With less critical problems, the support has been good, but very slow, especially when trying to order spare parts for replacement or as inventory stock. In most cases the standard item delivery time has been around 16 weeks. This has caused many components to be removed from service without replacment due to the lack of available replacements; therefore, Western Fuels has decided to stock all common parts on site. All accessor card types in use have at least one spare, and the more common types are backed up with two spares. Communication boards are also stocked. The two central processors, each with its own trunk driver cards, are backed up by design. The underground accessor trunk extenders (ATE) booster stations are also dual models with automatic switch-over gear.

Repairs have also been very slow, and the vendor recently opened a Pittsburgh repair facility to eliminate the time delay caused by sending equipment across the U.S./Canadian boarder. However, turn-around-time has not improved yet. Some accessors have taken as long as 20 weeks to be repaired.

The monitoring system is fairly easy to repair in most cases as the hardware is relatively simple. Built-in diagnostics at many different levels are very helpful in trouble shooting. Most problems experienced at the Deserado Mine have been with input signals from the field sensor or the accessor card. The software will detect some accessor failures and alert the operator. In other cases, the operator will detect the problem and determine the cause. For example, if the accessor input signal is correct, the accessor card is usually at fault, which can be checked by replacing the card. If the accessor input signal is incorrect or not present, the problem is in the sensor or cable.

There have been several cases where the entire trunk line failed, making trouble shooting very difficult; however, the vendors supplied training in this area which has been very helpful to the mine operations engineer. In one case, a defective trunk extender card failed when the trunk line was damaged. An improper test procedure caused a delay in diagnosing the problem, but the repair was quite simple once the problem was found. In a second incident, a portal protector card was damaged when 120 volts was inadvertently put on the data line, which normally handles 11 volts. Again, an incorrect test procedure failed to spot the problem, but when the test procedure was explained by the vendor, the problem was quickly solved. Both problems occured in the early project stages and were the result of inexperience.

In all cases where equipment failed, the vendor repaired or replaced the equipment at no charge. When the equipment was damaged by mine personnel, Western Fuels paid for the repairs.

The trunk line was crushed against the roof when a belt head pulley was being moved. As the belt was a temporary installation, less care than usual had been taken in choosing the trunk line location.

Two CO alarms have occurred. The first was when the sensor had been in service for less than one day, and it is believed that the CO cell had not stabilized. The second incident involved alarms from two adjacent sensors. The underground foreman investigated the area and found no reason for the alarm since no CO gas was detected.

The computers are located in the change house office area which is kept dust free and climate controlled year round. The central air conditioning failed in the building last summer and the operations room reached a steady temperature of 95 degrees. The computers operated at this temperature for several days with no apparent problems before a portable air conditioning unit could be installed.

During the winter season, relative humidity drops below 5%, which caused severe problems from operators touching the printer or keyboard and discharging static electricity into the system. Radio transmission from distances as great as 50 feet have also caused the computers to fail. However, in the summer months, radio transmissions from less than 3 feet have not effected the system.

Carbon impregnated carpets have been installed around the central console, and static control touch pads have been placed under the keyboards. These measures seem to have made no difference at all. But when a room humidifier was installed in the operations room and allowed to run on a continuous basis the computer failures stopped. For a period of two months during last winter the humidifer broke down, and many computer and printer failures again occurred but stopped when the humidifier was repaired. A relative humidity gauge is on order to more closely monitor room conditions.

Sensor Calibration

Calibration is required for all analog sensors, for environmental, electrical power consumption, and conveyor belt monitoring. The environmental group consists of five air flow monitors, fifteen carbon monoxide monitors and two methane monitors. The CO and methane sensors are calibrated once a month, and the air flow sensors should be calibrated once every three months. At this time the air flow sensors have not been calibrated, but they have been on line for about one year and appear to be functioning well.

The methane sensors have been calibrated only once, so there is no calibration history available. A problem was encountered with calibration because both sensors are located in return entries and are intrinsically safe. However, the calibration instrument is not, so the monitors must be calibrated in fresh air.

The monitors are mounted on J hooks and the junction box contains a quick disconnect plug to allow quick removal. They are taken through a man door to the other side of the stopping and reconnected to the trunk line using the quick disconnect plug. The calibration then takes place in fresh air, and the monitors are returned to their working location. As there are only two methane monitors, the problem is not severe.

The carbon monoxide monitors have been calibrated every month for four months, and overall have performed well. The calibration procedure is still being evaluated and changed to improve the efficiency of the procedure. Currently a kit containing 25 PPM CO gas and 99% pure air and a flow meter is used. First, a calibration card that displays the raw data is plugged into the accessor card in the CO monitor. Then a plastic hose is fitted over a nozzle on the bottom of the CO sensing cell and attached to the flow meter. The flow meter is connected to the CO gas and the gas flows to the cell at the specified rate.

Since the cell is calibrated to operate in the range of 0 to 50 PPM CO, it should generate a signal proportional to 25 PPM CO. If the monitor reads within plus or minus two PPM, it is considered to be within allowable limits and not adjusted. If adjustment is required, the monitor is flushed with pure air and the zero setting is checked and corrected if needed. Then the CO gas is reapplied and the span setting is corrected. This procedure is repeated to verify the settings.

The CO monitors use a replacable cell with a one year expected life. If it cannot be adjusted to read full span it should be replaced.

The electrical power monitors are located in the section and belt drive power centers. Total kilowatts and major circuit breaker contact positions are monitored. In the 1000 KVA section power centers, the total power being used in the 995-volt circuit is monitored as well as the power going through each of the individual circuit breakers. The 480 volt circuit total power is also measured as well as the power to the three main circuit breakers.

The power monitors were calibrated prior to installation, checked after start-up, and found to be very accurate. The readings sent by these sensors are real power since the monitoring gear contains transducers which measure the power factor.

The only analog point monitored on 750 KVA belt starter transformers is the total power. These values were checked after installation and found to be correct.

The analog sensors in the belt drives include the motor amps, reducer gear box temperatures, and motor bearing temperatures. The amperage readings, gearbox oil temperatures, and the motor bearing temperatures were calibrated by Western Fuels employees. The computer was set up to display the raw data from the accessor and print the values every minute. The engineer used a temperature probe to measure the actual temperature of the bearings and oil, and compared it with the sensor output data. This method requires that two sets of readings be taken, one while the equipment is hot, one when it is cold. The sensor was found to correspond linearly with the temperature readings.

The surface analog points include conveyor belts, electrical power, coal surge bin and silo levels, the main ventilation fan motor, and the hoist conveyance position and motor amperage. The surface belt sensors differ slightly from the underground because the internal winding temperatures are monitored rather than bearing temperatures, and the gear reducer box temperatures are not monitored. The only electrical power monitor on the surface belts is for motor amperage on large motors.

There are two, ten-thousand ton silo coal level monitors, and methane sensors are located at the top of the silos. The methane sensors are on the preparation plant system and the mine system only monitors the high level contacts. The silo coal levels are monitored by sonar devices located in the top floor. The sonar sensors have been quite reliable, but the sensor in silo two is located such that when the silo is less than 30% full, the coal trajectory falls below the sonar beam and generates a false reading. The sensor is scheduled to be moved.

The hoist is not currently in use at the Deserado mine and therefore, the hoist motor amps sensor and the trolly position indicator have not been tested.

The main ventilation fan does not have an amps transducer installed as specified; therefore, one is on order. The main fan is pulling a minimal load as the mine is still quite small; however, it is anticipated that this will change quite soon. The motor winding temperatures have been checked against the local meters and the readings are very close.

Software Analysis

All the Senturion 200 software has been written by Conspec in machine language and is not accessible by the user. However, there are provisions for the user to completely tailor the programs to their specific application. This programming is done through the use of interactive programs that Conspec has provided. These interactive programs allow the user to input his own logic controls on any equipment being controlled by the system. They also allow the user to specify what action the system should take on any event that the system detects. For example, the user can specify that for any event A the system will respond with action B. These programs use everyday English in a question and answer format. Almost all of this type of program application can be done while the system is on line.

The basic structure of the software controls are as follows. The system monitors a series of points and stores the status of these points in memory. Many other programs are running simultaneously which watch for changes that occur in the memory. When a change occurs, the program checking for that change is activated.

Any new points being added to the monitoring system can be added while on line. There is a simple command which, when evoked, will ask the user a series of questions. The answers to these questions will define the parameters of the new point and allow the point to be added to the system.

Analog points can have their parameters changed at any time through the use of another command. This command allows the user to change the parameters for alarm levels, change the delay timers on the alarms, or change the definition of the equation which describes the sensors response to its inputs.

A set of programs called devices are set up by the user which define the parameters of the field units being controlled by the computer. These parameters consist of previously defined points that the system is monitoring. The devices can also contain interlocks with other devices so that when one unit is stopped, other units will also be stopped. When all of the permissives are in the correct state, the device is enabled. If any of the permissives are found to be in an unallowable condition, the device is disabled. If the device is disabled the device program immediately stops that field unit.

An editor program is used to create or modify the device files, and the files are then compiled and copied onto the system program disk. These device programs are written by the user, but cannot be written while on line. There are commands which will allow the device program to be modified while on line, but these modifications cannot be saved permanently.

Any piece of equipment can be controlled by the user activating the appropriate device, assuming the device is enabled. However, this would involve entering many device commands when the mine starts up at the beginning of shift or stopping many devices at the close of the production day. Therefore another level of programming is available which can control the devices. This is called a sequence programmed unit or SPU.

The SPU is a simple program which consists of three types of commands. These are tests, commands, or special commands. The SPU is written while on line, using an interactive program which will ask the user a series of questions in order to define the SPU. The SPU will test any defined point for certain conditions, or command a specific commandable point, or execute a large number of predefined special commands. This format of programming is somewhat constrictive for the accomplished programmer, but makes it very easy for someone without previous programming experience to use the system.

There are three ways that an SPU can be activated. One method is for the system user to activate the SPU through a keyboard command. The second method is for an SPU to be called by another SPU. The third method is to use a trigger point.

A trigger point is a defined point in the system, which will activate an SPU when the point passes a test which the user defines. For example, the user could specify that if a certain point goes into alarm, a specific SPU should be activated. Trigger points are a very useful feature of the system as they allow the system to react to changing mine conditions in a predefined manner. This reduces the need for operator input, which reduces operator error.

The Senturion software has been completely reliable. In no case has the software been responsible for any system errors. The only problems encountered have been faulty logic entered into the system by the engineers.

With four engineers entering programs into the system, the structured manner of program writing has been very useful as all programs are written in the same manner. This allows the engineers to quickly understand each other's programs.

There have been several times when the Western Fuels engineers have had suggestions for new software commands that would make using the system easier. These suggestions have been given to the Conspec engineers who have made the changes.

The color graphics system operates by reading the Senturion's memory and then displaying the conditions graphically on a CRT screen. The user first programs a static picture, and then tells the program which points to display on the screen, and how to display them. Once the display is programmed it can be called up at any time and will automatically update the picture as conditions change. The operator can also control field units through the graphics by moving the cursor next to the equipment he wants to control and entering the appropriate command. The graphics system does not monitor or control anything itself, but communicates to the Senturion system the information that the operator is entering or requesting. If the graphics system should fail, the Senturion system will still operate independent of the graphics system.

The color graphics system requires user programming to generate the graphic displays. This system also uses machine language to allow a fast system response to changes, but the programming that the operator does is very similar to basic. The programming is quite straight forward and can be learned by an inexperienced user quickly. The displays can be modified at any time by the users and new displays can be generated as mine conditions change.

The system will soon be saving all the Senturion data on a hard disk. The binary points will be saved every time they change status, and the analog points will be saved once a minute. There will also be a method of saving analog points on a significant change basis. The operator will define a significant change for a specific point, and then whenever that change occurs it will be saved on disk. The number of analog points that can be saved on the significant change basis will be limited so that the data bus between the two computers will not be overloaded. It will be possible to save changes as often as every two seconds using this method.

One major problem has been present with the graphics system since it was installed. There are currently two color graphic screens in the operations room and one in the mine managers office. The system was designed as a multi-user system; however, if more than one person is using it at a time the system will often crash. This was traced to a problem with the operating system that Intel had provided with the basic computer. A new version of the operating system is now available. It is anticipated that this will cure the problem. At this time Conspec is still testing the new version on their computer.

A report generation project using a Compaq 286 computer with off the shelf software is beginning to generate reports for various members of management. The graphics system will dump the data that it stores on its hard disk over to the Compaq which will then manipulate the data into usable forms and generate the reports based on that data.

It will also be possible to use the data for other purposes. Time studies should be possible using this system that will be far more comprehensive than the traditional methods normally used. There are also plans to generate line graphs displaying data on various components that are monitored such as motor bearing temperatures. These graphs could be set up to display hourly averages over long periods of time to be used by maintenance for diagnostics.

Changes in Mine Personnel Perceptions

Several interviews were conducted with managers and hourly employees at different stages of the project. Initially, the hourly employees were not informed about the project. As the system was being installed, several miners asked the subcontractors questions about the system. Most questions were presented in an open minded manner, and the subcontractors answered them.

Upper management had well defined ideas about the system and were supportive of the project. This attitude filtered down to lower management levels.

Two general benefits were expected by management. The first was generating historical data and trend analyses. It was believed that efficiency could be improved and electrical costs lowered with long term historical data. The data would also be useful for maintenance department trouble shooting by examining equipment operating trends.

The other general expectation was on line application. If the mine manager or production superintendent was able to have important real-time operating section data available, it would aid decision making and further improve efficiency.

The safety aspect is an extremely important management expectation. The system has numerous obvious safety advantages.

Management's current perception is one of mixed feelings. In general they are pleased with the quality of the system and the benefits that it has presented so far. However, they are frustrated because several project phases were behind schedule.

Informal discussions with many hourly employees have shown that in general they value the added safety the system provides. They have asked many questions about the system's monitoring abilities, and after a recent safety meeting many underground employees inspected the system operations room. Maintenance personnel and beltmen have found the trouble shooting capabilities to be very helpful.

The employees accepted the system readily since it was operational before most of them started working at the mine. Increased resistance to installation may have been present at an older mine.

The monitoring system has been in service over one year, and so far no one has tampered with it. All the underground equipment boxes can be locked, but this has not been necessary. The mine management, the union officers, and the individual employees that have been interviewed all feel that the system improves mine safety, and it is unlikely that anyone underground would want to jeopardize that.

All levels of management have expressed the opinion that the system has lowered the coal production costs and greatly increased mine safety. Cost impacts have resulted from the greatly reduced conveyor belt downtime. Maintenance personnel are impressed with the data concerning equipment performance, and management will soon have similar operating information to use for increasing mine efficiency.

RECOMMENDATIONS TO IMPROVE MINE MONITORING AND CONTROL SYSTEM PROJECTS

An on-site project engineer should be involved from the beginning with any extensive mine monitoring project. At Western Fuels the monitoring and control project was designed as a turn key installation, and it was believed that a project engineer was not required. Within three months, the need for someone to represent Western Fuel's interests was realized.

The benefits of an on-site engineer are numerous. For example, thorough training will be gained, since the engineer will be involved in setting goals, in selecting a supplier, in installing, and in operating the system. Futhermore, mine specific modifications to hardware and software can be efficiently supervised by an on-site engineer. Since many applications were not considered in the design stages, a project engineer is necessary to implement expansion projects. As the mine monitoring system grows so does dependence on the system. Therefore, having someone at the mine site capable of trouble shooting and repairing problems is very important.

To fully utilize a modern monitoring and control system, the system must be flexible enough to accomodate the dynamic mine conditions. As the mine expands and adds new equipment, the control system must be able to accomodate the changes. There will be areas of the mine that close or become inactive, and the system will have to be adjusted for these changes. As information is gathered about equipment and environmental parameters, the alarm levels on the analog sensors may also change. This requires that the mine personnel be trained and capable of modifying the software. The equipment supplier could provide all programming, but this will leave the mine dependent on the supplier for future changes.

The software used in real time monitoring is written in machine language to facilitate fast response. This requires a high level of programming skill. Therefore the manufacturer should supply interactive, flexible software.

The hardware must be able to withstand a mine environment, and it should be designed so that it is a simple process to add or subtract components. Trained mine personnel are essential for these changes.

Critical components should be stocked on site since it is often necessary to change several components when a problem occurs before finding the malfunctioning unit. Maintaining a supply of system components also facilitates faster replacement.

Adequate inventory is also necessary for system expansion. Western Fuels often orders new equipment, such as power centers, with enough lead time to allow the monitoring gear installation prior to putting the equipment in service. This allows the monitoring equipment to be installed in the surface shop. When the monitoring gear arrives late or is not available in inventory, the equipment must be placed in service without it. Furthermore, installing the monitoring gear underground takes more time, and often disrupts other work in the mine when power is locked out.

Western Fuels experienced many late equipment deliveries while installing the system. Other purchasers may want to consider a penalty for missed delivery dates as a means of holding suppliers to agreed upon dates.

Careful consideration should be given to the amount of field experience a system has accumulated before purchase. Western Fuels selected a well tested and proven system for monitoring and control, but chose to use a new and untested graphics and MIS report generation system. As a result, excellent performance was obtained from the monitoring and control components, but the report MIS still is not on line.

The mine operator should be prepared for some start up problems with both hardware and software, even though a proven system may have been purchased. The proven system is modified for each mine, since conditions and management objectives differ. Therefore schedule and expense projections should include a start-up period.

When a mine monitoring system is installed in a mine, the mine operators should insist on manufacturer's training prior to beginning operation of the system, and further instruction after the system in running. In addition, to reduce the impact of mistakes made by new operators, software provided by the vendor should contain certain safety interlocks.

A three day training session was provided by the vendor prior to installation to demonstrate the basic operating procedures and explain the various system functions. The initial training was very important as it helped the operators understand the basic structure and interactions. However, the most productive training took place after the system was installed. When the operators started using the system daily, their knowledge increased very quickly. Other critical training occured whenever a vendor representative visited the mine to work with Western Fuels engineers.

The vendor was responsible for installation in the Deserado mine. They subcontracted the work to a company whose employees were not experienced or certified in mining. Improvements in timing, familiarity, and customizing the layout could have been achieved by mine operator installation.

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WESTERN FUELS-UTAH INC.

1. DESERADO MINE PROJECT

1.1 Project Description

Western Fuels-Utah, Inc. (Western Fuels) is soliciting bids for a mine monitoring system for use in an underground coal mine currently being developed. The new mine is called the "Deserado Mine" and is located approximately eight miles northeast of Rangely, Colorado. This mine will supply coal to a power plant, the "Bonanza Power Plant," being built by Deseret Generation and Transmission Cooperative. The power plant is located near Bonanza, Utah. Coal from the mine will be transported to the power plant on a transportation system consisting of a 3-1/2-mile overland conveyor and a 37-mile electrified railroad. The transportation system, which is currently under construction, is also being built by Western Fuels.

When fully developed, the Deserado Mine will produce 2.7 million tons of clean coal per year using two longwalls and four continuous mining machines. The coal will be transported out of the mine on a belt located in an upper compartment of the slope entry. The surface facilities near the mine portal consist of the mine buildings, a 750 TPH coal preparation plant, two 10,000 ton raw coal silos, and a 3-1/2-mile overland conveyor to the clean coal slot storage and rail load-out facility.

Mine development work is proceeding with one continuous miner unit. The coal is being transported to the surface on a slope belt conveyor. This conveyor is remotely controlled by the existing preparation plant control system. Installation of the mine monitoring system is scheduled to start on August 1, 1984.

1.2 Monitoring and Control Systems

1.2.1 Overall Description

The mine monitoring system to be purchased under this bid specification will be integrated into the existing monitoring system. The existing system primarily consists of two Allen-Bradley PLC-3 programmable controllers; one Process Control Industries D-1200 interface dedicated to the slope belt conveyor and surface conveyors up to the top of the silos, the preparation plant, and overland conveyors; three smart Video color Display Terminals (VDT's); and an alarm printer. The existing system, henceforth referred to as the "preparation plant/conveyor system," is designed to monitor and control the operation of the slope conveyor, the preparation plant, the surface conveyors at the mine site, and the overland conveyors.

Figure 1 is a block diagram which shows the existing system as well as the final architecture of the complete monitoring system for the Deserado Mine.

The new system, henceforth referred to as the mine monitoring system, will perform six monitoring and control functions underground at the Deserado Mine: 1) belt fire monitoring, 2) power center monitoring, 3) environmental monitoring, 4) underground belt monitoring, 5) coal system monitoring (which includes conveyors from the bottom of the slope to the top of the silos, surge hopper, rotary breaker and the silos) and 6) fan and hoist system. Currently, the raw coal system, and the fan and hoist system are part of the existing "preparation plant/conveyor" system. The vendor will be responsible to transfer them to the mine monitoring system. The six functions will be under the control of an independent "mine monitoring controller". This two branch approach is expected to provide some overall reliability advantages by allowing each system to operate independently of the other. However, the underground belt monitoring system must be compatible with the raw coal system to be transferred from the existing system; the two systems should be able to communicate and coordinate their activities in a logical fashion.

In addition to the six basic functions described above, the new system (the supervisory computer, in particular) will also provide mine personnel with periodic reports, data analyses (trends), and data archiving.

1.2.2 Mine Monitoring System

The primary function of this system is to provide mine personnel with continuously updated data on the status of a number of production, health, safety, underground belt, raw coal system, fan and hoist parameters. This data is obtained from four monitoring subsystems located underground and two subsystems located principally on the surface. The first subsystem consists of a series of carbon monoxide fire detectors located along each of the underground conveyor belts. This system is intended to be used as a replacement for the standard thermal sensors in anticipation of a petition for a variance so that the beltways can be used to provide fresh air to the working faces. That is, it is intended to be the basis for an application to MSHA for a 101C variance for modification of the 30CFR75.326. This system will also monitor the status of the dry powder fire suppression system on each belt drive.

The second subsystem will incorporate electrical power sensors at the underground power centers and switchgear to permit real-time monitoring of equipment running time. This monitoring will be concentrated on the main production equipment, i.e., longwalls, continuous miners, shuttle cars, roof bolters, etc. The data from this system will be used to analyze equipment downtime to assist in maintaining the high productivity anticipated from this mine.

The third subsystem is an environmental subsystem which is intended to provide real-time data on the quantity and quality of the air in the primary air returns in the mine. This will be accomplished using "environmental sensor packages" placed in each of the air returns. Initially, these environmental packages will contain three sensors: an air velocity sensor, a carbon monoxide sensor, and a methane sensor.

The fourth subsystem is an underground belt monitoring system which will enable the system operator to remotely start or stop all conveyors without spillage or stopping loaded conveyors. In addition, this system will provide the operator with information on belt speed, motor and bearing temperatures, coal flow rate over the main belt scale and plugged chutes. The system shall also provide indication of belt stoppage, belt slip, belt misalignment, and local lock-out by underground personnel.

The fifth subsystem is the existing raw coal system which is to be transferred to the main monitoring system from the existing preparation plan/conveyor system. This system monitors and controls the status of all the belt conveyors from the bottom of the slope to the top of the silos including the silos, rotary breaker and surge hopper. The raw coal system must be integrated with the underground belt system for a sequential start-stop of all the belt conveyors within the two systems.

The sixth subsystem is the existing fan and hoist system which is to be transferred to the mine monitoring system from the existing preparation plant/conveyor system.

The underground mine monitoring system will be capable of providing current status reports on all parameters on a color video display terminal (VDT) and on an alarm printer. The system will display all measured parameters in standard engineering units. Alarm set points will be established on the surface, and all alarms will be indicated both on the operator's VDT and on an alarm printer which will maintain a hard copy of all alarms and operator acknowledgements. In addition, alarms will be installed in each underground outstation.

1.2.3 Supervisory Computer

The reporting, archiving, and any extensive data analysis will be the responsibility of a supervisory computer to be supplied with the underground mine monitoring equipment. This computer will be mini- or microcomputer based, and must be able to communicate with all branches of the complete system.

The supervisory computer will receive input from both the underground mine monitoring system and preparation plant/conveyor system to generate end-of-shift, daily, and monthly reports. For the preparation plant/conveyor system, the supervisory computer will interface with the existing Process Control Industries D-1200 systems to receive the necessary data. Process Control Industries Interface Port has presently an RS232C set up to interface with a DEC system but can be configured to almost any computer. The bidder will be responsible for correct implementation of this interface and the necessary interchange of data so that the supervisory computer can generate its reports.

These reports will document equipment running time, production, environmental status, alarm summaries, etc. See Section 2.3.2.4 for detailed reporting requirements. The computer shall also enable the system operator to perform trend analysis on raw input and processed data.

1.3 Description of Procurement

1.3.1 Proposal Due Date

Vendors' proposals are due at the Western Fuels office in Rangely, Colorado, by the end of business on February 13, 1984.

1.3.2 Anticipated Award Date

It is anticipated that the contract award date will be, April 2, 1984.

1.3.3 Procurement Format

Because this system is for a new mine, the procurement will be a phased procurement. The initial installation will start on August 1, 1984 and will be completed, tested and handed over to Western Fuels by October 1, 1984. The equipment to be installed at the time will include the supervisory computer with its peripherals and the mine monitoring controller with a hot back-up and its peripherals. (i.e., cable, outstations, and sensors). The remainder of the underground equipment will be purchased and installed as the mine develops. The development schedule and equipment requisition schedule is discussed in Section 2 of this bid specification.

1.3.4 Hardware Requirements

The underground hardware shall consist of telemetry devices (outstations), cabling, sensors, and control relays. See Section 2.2.1 for detailed information regarding equipment specification. The construction of all underground equipment shall be suitable for underground service and shall meet all applicable MSHA regulations. The underground equipment shall use mine power for normal operation and be provided with battery back-up in case of power outage.

The aboveground equipment shall consist of the supervisory computer (to be supplied with a Black & White VDT with keyboard, a color VDT with keyboard, and a report printer), and a mine monitoring controller with a hot back-up (to be supplied with two color VDT's and a black & white VDT with keyboard and an alarm printer). A color VDT with keyboard shall be located in the administration building for status monitoring. A printer with keyboard shall be installed in the guard shack to monitor any alarms. This printer shall sound an alarm horn and an alarm light to attract attention until acknowledged by the guard. This gives the mine protection on idle days, holidays and weekends. The guard will notify on-call mine personnel. Also to be supplied are data storage peripherals (hard disks) and an operator's console built to house above mentioned equipment. This console will be located in the changehouse control room and be supplied with power from an uninterruptible power supply (provided by Western Fuels). See Section 2.2.2 for aboveground equipment requirements.

1.3.5 Software Requirements

The supervisory computer to be purchased shall be supplied with all of the software required to operate the system, monitor and display the status of the mine monitoring system and preparation plant/conveyor control system, establish alarm set points, initiate audible/visual alarms, analyze trends and produce reports.

The mine monitoring system to be purchased shall be supplied with all of the software required to operate the system, monitor and display the status of all of the underground sensors, establish alarm set points, initiate audible/visual alarms, analyze trends, and produce reports.

The software must be user friendly so that mine personnel can readily alter report and graphic formats as the mine develops, or as requirements change.

1.3.6 Acceptance and Installation

Two sets of acceptance tests will be required for the monitoring system: factory and in-mine acceptance tests. Prior to the factory test, the vendor shall submit to Western Fuels a test plan for approval. The vendor, upon approval from Western Fuels, shall set up and perform a complete set of factory-floor acceptance tests, to be supervised by Western Fuels (or their representatives). These tests will exercise all sensors, inputs, outputs, and control functions, as well as give representative output on all peripheral devices. Upon successful completion of the factory tests, the vendor shall submit an installation plan and schedule to Western Fuels prior to shipping the system. The vendor will be fully responsible for the installation of the system.

The in-mine acceptance test will be conducted after installation of the initial system is completed, and will exercise all system functions. The tests will be supervised by Western Fuels personnel. A sample test plan, both factory and in-mine acceptance tests, shall be included in the proposal.

The vendor shall also provide on-site training for mine personnel in system operation and basic maintenance as well as full documentation for both system hardware and software (See Section 4.1.2).

1.3.7 Warranties

All bids shall be based on providing a twelve-month warranty on hardware and software. If a vendor's standard warranty is different from the above, the vendor shall provide terms for both.

Vendors shall also state whether a service agreement is available and the terms of the agreement.

1.3.8 Applicable Documents

The following documents are appended to this bid specification to assist potential vendors in preparing their proposals.

Exhibit:

1. "D" Portal Area Site Grading and Paving Plan (FB&DU DWG. No. D-346-C-100).

2. Belt Conveyor Drive Locations (WF DWG. No D1P1011-C0.

3. Deserado Mine Five Year Mining Plan.

4. Underground Sensor Location BBN DWG. No. D32890).

5. Underground Power Distribution Plan (WF DWG. No. DIP3-012C).

6. "D" Portal Area Change House Floor Plan and Finishing Schedule (FB&DUDWG. No. D-346-A-215).

2. TECHNICAL SPECIFICATIONS

2.1. Overall System Description

2.1.1 Introduction

The mine monitoring system considered in this bid specification has six primary underground functions: (1) Belt Fire Monitoring; (2) Power Center Monitoring; (3) Environmental Monitoring, i.e., air quality and quantity; (4) underground belt monitoring, (5) raw coal system monitoring (which includes conveyors from the bottom of the slope to the top of the silos, surge hopper, rotary breaker and the silos); and (6) fan and hoist systems. This system will consist of underground and surface sensors and controls necessary to perform these functions, telemetry devices and cabling necessary to transmit the data to the surface located equipment (such as computers, peripherals, video display terminals (VDTs), printers, etc.).

Furthermore, this monitoring system shall be capable of being fully integrated into an existing preparation plant/conveyor monitoring and control system. Figure 1 is a block diagram of the overall system architecture. The currently existing system is not part of the bid specification except for the raw coal system, and the fan and hoist system which need to be transferred to the mine monitoring system. While it is intended that both the underground monitoring system and the preparation plant/conveyor system communicate with the supervisory computer, which will archive data and generate status reports, either shall be able to operate independently.

2.1.2 Mine Description

The mine monitoring system is being specified for Western Fuels' Deserado Mine near Rangely, Colorado. The Deserado Mine, which is a slope entry underground coal mine, has been producing development coal since the third quarter of 1982.

The surface facilities for the underground mine includes a surge hopper, rotary breaker, two 10,000-ton raw coal silos, a preparation plant, a shop, a hoist building, a warehouse, a changehouse, an administration building, and a series of conveyors to transport the coal from the mine to the preparation plant. In addition, there is an "overland conveyor' that will transport the clean coal 3-1/2 miles to a rail head where the clean coal is stored in a 25,000-ton slot storage before being loaded onto trains for transport to the power plant.

When fully developed, the Deserado Mine is expected to produce 2.7 million tons of clean coal per year using longwalls and continuous mining machines. Underground haulage will be via conveyor belts.

Access to the coal is via a two compartment rock slope. Coal from the mine is transported to the surface on a 54-inch belt conveyor (slope conveyor) located in the upper compartment of the slope. The lower compartment of the slope is used for transporting men and material in and out of the mine by using a slope hoist.

2.1.3 Existing Monitoring System

The mine monitoring and control system shall be capable of communicating with the existing preparation plant/conveyor monitoring and control system. As shown in the block diagram of Figure 1, the existing system controls the slope and surface conveyors to the top of the silos, the preparation plant and the overland conveyors to the slot storage.

The existing system is controlled by two Allen-Bradley PLC-3s (one is used as a hot back up). Access to the system for monitoring of slope and surface conveyors, plant functions or control of overland conveyors is provided by three "smart" VDTs located in the preparation plant. The Process Control Industries' (PCI) D-1200 also supports a line printer and data storage devices, (hard disks). Additional items such as main fan, hoist and fire control system are also monitored from this location.

2.1.4 Functions of New Monitoring System

As described in Section 2.1.1, the mine monitoring system has six basic functions.

The first function, belt fire monitoring will primarily consist of carbon monoxide detectors located along each beltway. It is intended to be the basis of a 101C petition to be filed with MSHA for variance to Section 326 of 30 CFR Part 75 thereby allowing the use of the beltway as an intake air course. In addition to the analog signal from the carbon monoxide sensors, the mine monitoring system shall also monitor the status of the fire suppression system required for fire prevention at each underground belt drive. This will be a digital signal, i.e., a switch closure, that indicates whether the system has been tripped.

The second function, power center monitoring shall utilize an analog power (wattage) sensor for each piece of underground face equipment. Sensors are to be installed at the power center. This data will also be sent to the mine monitoring controller which will be able to log the data and analyze trends, as well as provide the system operator with a real time display of the status of the operating equipment. The mine monitoring controller will also receive status information from the ground fault and phase fault sensors located at the substation.

The third function, environmental monitoring, will be restricted, at least at the outset, to monitoring the air quality and quantity in each of the primary air returns. The parameters to be monitored are air velocity, carbon monoxide, and methane. The analog signals from these sensors will be transmitted to the mine monitoring controller for real-time display, archiving, and trend analysis.

The fourth function, underground belt monitoring, will enable the system operator to remotely start or stop all conveyors without spillage or stopping loaded conveyors. The belt parameters to be monitored are belt speed, motor and bearing temperatures, coal flow rate, plugged chutes, belt stoppage, belt slip, belt misalignment and local lock-out by underground personnel.

The fifth function is the monitoring and control of the raw coal system to be transferred from the existing preparation plant/conveyor system.

The sixth function is transferring the fan and hoist subsystem to the mine system from the preparation plant system.

2.2 Hardware Requirements

2.2.1 Underground Equipment

The following sections describe the underground equipment requirements. The construction of all underground equipment shall be suitable for operation in typical underground coal mine environment, which may cover a range of 0-40 degrees C, 0-95% relative humidity, and be relatively dusty.

2.2.1.1 Mine Monitoring System

Belt Fire Sensors

The belt fire monitor will consist of carbon monoxide sensors placed along each belt line. It is presently anticipated that sensors will be placed at approximately 1500 ft intervals as shown on Exhibit 4. While all systems shall be bid on this basis, the systems shall be flexible enough to handle a range of sensor spacings from 1000 ft. to 3000 ft.

All carbon monoxide monitors along the belt lines shall have a measurement range of 0-50 ppm +/-2 ppm CO at 0 ppm CO and +/-4 ppm CO at 50 ppm CO and a response time of less than 2 minutes to 90% of final values. All sensors shall be equipped with a minimum four hour battery back-up in case of local power failure. This can be done either individually at each sensor, or at the outstation for all the sensors. In either case, the system shall be capable of notifying the operator of the time and location of the power failure. A local alarm that consists of flashing light and a horn shall be provided at each outstation. The alarm can be triggered automatically by the outstation or by a command from the surface.

Eight (8) carbon monoxide fire sensors are scheduled to be installed by October 1, 1984 based on 1500 foot spacing. However, the hardware and software should be capable of controlling and monitoring at least a total of twenty seven (27) such sensors.

Environmental Sensors

Initially, underground air quantity and quality will be monitored by measuring air velocity, methane, and carbon monoxide content in the primary air returns. Therefore, an "Environmental Package" containing one sensor of each type shall be supplied for each air return. The sensors must be approved by MSHA for operation in return air. Seven (7) environmental packages, each package including one air velocity, one methane and one CO sensor, are scheduled to be installed by 1984. However, the hardware and software should be capable of controlling and monitoring at least a total of thirteen (13) environmental packages.

The air velocity sensors shall use the vortex shedding principle and have the capability of measuring air velocity in the range 100 to 1500 ft per minute +/-5% of full scale, except the air velocity sensors used near the mine fan shall have a range of 100-2000 ft per minute +/-5% of full scale. The output shall be an analog signal proportional to the air velocity.

The methane sensors shall be of the catalytic bead type and be capable of measuring methane content in the range of 0 to 5% with accuracy as specified in CFR 30, Part 22, Section 7 (d,2). The sensor output shall be an analog signal proportional to the methane concentration.

The carbon monoxide sensors shall be capable of indicating carbon monoxide content in the return in the range of 0 to 300 ppm+/-8% of full scale. The output of the carbon monoxide sensors shall also be an analog signal proportional to the carbon monoxide concentration.

Underground Belt Sensors

All underground conveyor belts have the following sensors to monitor:

1. Belt Operation and Sequence Interlock
2. Belt Slip
3. Belt Underspeed
4. Belt Misalignment
5. Emergency Stop with Pull Cords
6. Gear Box Temperature
7. Remote Start-Stop/Local Lockout
8. Motor Temperature
9. Motor Amps
10. Local Run
11. Plugged Chute

All of the sensors are of the switch closure type, i.e., digital, with the exception of the two analog temperature sensors and one motor amp sensor. The belt slip sensor trips when belt slip reaches 2% of belt design speed, and the underspeed sensor closes when belt speed reaches 90% of belt design speed. There are two misalignment switches at each terminal pulley (both head and tail) of each belt, which can be adjusted to signal belt misalignments. The emergency stop sensors are activated by the belt pullcord.

In addition to the sensors described above, a plugged chute switch is supplied for each transfer point and an analog belt scale sensor is furnished for the slope belt.

The hardware and software should be capable of controlling and monitoring fourteen underground belts or 154 sensors.

Outstations

All outstations shall conform to applicable MSHA regulations. In particular, while it is anticipated that all outstations will be placed in fresh air, some will control sensors located in return air. Any such outstations shall be of the "BLUE" type, i.e., equipped with MSHA electrical barriers.

In the event that ventilation is lost in the mine, the outstations shall be able to be disconnected from battery power either remotely by the system operator or automatically.

Cables

The underground mine monitoring system shall have a Dual Redundant Communication system. The cable system shall conform to appropriate MSHA and NEC regulations. The cable system shall have sufficient capacity to extend continuously into the mine as it expands plus spare capacity of 20% over total design capacity. The vendor shall also indicate how the underground cable will be safeguarded against breakage and how the integrity of the system will be maintained should a cable break.

2.2.2 Surface Equipment

2.2.2.1 Mine Monitoring Controller

The "mine monitoring controller" will receive input data from all of the underground monitoring equipment, raw coal system, and fan and hoist system. It will also receive ground fault and phase fault status information from the ground monitor located at the substation. The mine monitoring controller shall be fully capable of monitoring and storing the status of all sensors under its control, establishing and initiating warning and alarm signals, remote conversion of sensor output to engineering units, and performing any data processing required to control the system and provide the operator with system status.

The mine monitoring controller shall be supplied with an alarm printer to provide a chronological record of all alarms and acknowledgements and color video display terminal (VDT's) and keyboard for programming. The controller must also be able to communicate with the supervisor computer (see Section 2.2.2.3) for trend analysis, graphical display, reporting, and archiving. The mine monitoring controller will be supplied with a hot back-up.

All programming software for the controller will be stored in solid state random access memory.

It is presently anticipated that the controller will be required to support a total of approximately 650 data inputs including 154 inputs for the underground belt monitoring function and 400 sensors for the raw coal, and fan and hoist system. In order to provide for as yet unanticipated functions, the data input capacity of the mine monitoring controller shall be at least 100 more than that required for the total design capacity. The polling cycle time, for the total design capacity, should not exceed twenty seconds.

2.2.2.2 Supervisory Computer

The primary function of the supervisory computer is to store, analyze, display, and report status information from both the mine monitoring and preparation plant/conveyor (PCI D-1200) systems. It must be able to display graphic pages from both the systems. Additionally, it should also have the capability to store hard disk data in a cassette tape for back up purposes.

The computer shall be a 16 bit mini- or microprocessor and have sufficient capacity to store the operating programs within a random access memory. Archiving of data and secondary programming can be stored on hard disks. The computer shall use a standard operating system, and shall be able to interface with both the mine monitoring controller and the Process Control Industries D-1200 system. The computer shall be supplied with one black and white VDT with keyboard for programming changes, one color VDT with keyboard for graphical/data displays, one high speed report printer, and any required storage devices. The supervisory computer must also be supplied with the intelligent alarm printer with keyboard in the guard shack and the color VDT with keyboard in the administration building.

2.2.2.3 Display

Three 19" high resolution color video display terminals (one with the supervisory computer and two with the mine monitoring controllers) shall be supplied to provide tabular and graphical displays of the system status. The terminal shall be supplied with a separate full function keyboard through which the operator can communicate with the system (see Section 2.3.2 about operator interface flexibility).

2.2.2.4 Printers

One high speed, report quality printer shall be supplied for use with the supervisory computer. This printer must be capable of producing high quality copies of data listings, graphs and reports for general distribution and/or record-keeping. The report printer shall be cable of printing at leat 600 characters per second on "8 1/2 x 11" fan folded, continuous-feed paper. It shall also be capable of producing as many as three carbon copies with the original.

In addition to the report printer, another printer shall be supplied for use with the underground mine monitoring controller. Since this printer will only be used to provide a hard copy for all alarms and acknowledgements, it need not be as fast as the report printer.

One intelligent printer with keyboard shall be supplied for remote use (3000 ft.) in the guard shack. This printer will provide hard copy of all alarms and shall sound a horn and light until the alarm is acknowledged by the guard.

2.2.2.5 Disconnects

The system shall be supplied with suitable disconnects for the underground equipment in the event of loss of ventilation. All disconnects shall meet MSHA requirements.

2.2.2.6 Uninterruptible Power Supply

The monitoring equipment located on the surface, i.e., the supervisory computer, mine monitoring controller, PLC-3s, VDTs, etc., will be powered by an uninterruptible power supply (UPS) which will keep the system running in the event of a power outage. The UPS and its associated line conditioner will be obtained prior to the purchase of the mine monitoring system.

2.2.2.7 Hardware Location

The Allen-Bradley PLC-3s, PCI D-1200, and the peripherals, that are supported by this equipment are located in the preparation plant. The mine monitoring controller, the supervisory computer, and the associated peripherals, that are the basis of this bid specification, are to be located on the second floor of the changehouse (see Exhibit 6) except for a color VDT in the administration building and an alarm printer in the guard shack.

2.2.2.8 Console Requirements

Part of the equipment to be supplied under this bid specification is an opertor's console for the monitoring equipment located in the change house. This console will be a custom unit with space for each of the VDTs and peripherals to be acquired under this package. This console shall be compatible with the existing preparation plant/conveyor monitoring console. Detailed design specifications are to be determined.

2.3 Software Requirements

2.3.1 Mine Monitoring Software

The mine monitoring software must be user friendly. The functional software must be flexible enough to allow mine personnel to modify graphic packages, report formats, warning and alarm set points and to add new data inputs or features as the mine develops.

2.3.1.1 Color Graphic Displays

The basic color graphic displays shall include mimic diagrams and annunciator displays. Software shall also be provided to permit the system operator to display graphically, i.e., bar graphs, pie charts, etc., either raw input data or processed data.

The mine monitoring system operator shall be able to monitor operation through mimic diagrams and annunciator displays. The mimic displays shall indicate status of the environmental, power center, and belt fire sensor data.

The annunciator displays are intended to permit the system operator to monitor sensor outputs and diagnose alarm and system malfunctions. The colors, symbols, and other format parameters shall match the existing graphic display format for the surface conveyors.

The detailed format specifications are to be determined.

2.3.1.2 Alarm Printer

Software is to be provided to generate a chronological hardcopy of all alarms and operator acknowledgements. Alarms will initiate an audible alarm (either bell or horn) until the alarm is acknowledged by the operator. Current alarm status will also be displayed on the VDT. Some alarms such as belt fire will also initiate local underground audible and/or visual indicators.

2.3.1.3 Trend Analysis

As discussed in Section 2.3.1.1, software for graphical display or trend analyses shall be supplied with the system. The software shall allow the trend plots of raw and processed data to be displayed on the color VDT and printed on the report printer. The trend software shall be user friendly to allow ready access, and be flexible in terms of changing trend parameters (e.g., time base).

2.3.1.4 Report Generation

Three periodic (shift, daily, and monthly) and one realtime, i.e., on demand, reports shall be available from the system on the VDT. Hard copies of any reports are to be available from the report printer.

The information consists of data from the underground sensors, data entered manually by the system operators during the shift, and any preprogrammed information such as maintenance or calibration reminders. A summary of data from the underground system is presented in Table 2.1 The majority of this data will be presented in raw form, with the exception that alarms and alarm algorithms require the generation of software.

Typical requirements are for reports at the end of each shift, a summary of the three shifts at the end of each day, and an additional summary at the end of each month. Alarm conditions shall be automatically printed out in addition to being summarized in the shift reports. The system shall be capable of providing an alarm on a sensor input. The operator of the mine monitoring system shall be required to acknowledge the alarm. For example:

Belt fire
Silo fire
Environmental exceptions
Additional alarms such as belt stop may also be considered.

The anticipated content of the shift, daily, and monthly reports is listed below.

TABLE 2.1. - Data available from mine monitoring systems

SYSTEM	DATA AVAILABLE	
Slope Belt	Tonnage Status Cause of outage Duration of outage	Fire suppression status Motor power draw Motor temperature Gear box temperature
Mine Belts	Status Cause of outage Duration of outage	Fire suppression status Motor power draw Motor temperature Gear box temperature
Belt Fire Monitor	CO level Fire alert - Fire alarm	
Main Fan	Status Water gauge Motor power draw Motor temperature	Bearing temperature Vibration Gas concentration
Environmental Monitors	Air flow CO concentration CH_4 concentration	
Power Center	Production machine status Production machine operating time	Production machine power consumption
Other data	Manually entered data Maintenance and calibration reminders	

Shift Report

- All alarms
- Tons of raw coal from mine
- Tons of raw coal feed to preparation plant
- Tons of clean coal
- Percent refuse
- Prep plant status
- Silo levels
- Mine fan water gauge - average, maximum, minimum
- CO, CH_4 concentrations

Belt outage - cause and duration
Equipment out at end of shift
Operator comments
Power center, hoist outage - cause and duration

Daily Report

Number of alarms
Tons of raw coal from mine
Tons of raw coal feed to prep plant
Tons of clean coal
Percent refuse
Silo levels
Belt outage - cause and duration
Power center, hoist outage - cause and duration
Equipment out at end of day
Maintenance and calibration reminders
Operator comments

Monthly Report

Tons of raw coal from mine
Tons of raw coal feed to prep plant
Tons of clean coal
Percent refuse
Belt outage summary
Power center hoist outage summary
Maintenance review

In addition to the shift, daily, and monthly reports described above, the system operator shall be able to obtain, upon request, reports on current status and on detailed information not given in the periodic reports. These reports shall be available on the VDT as well as the report printer.

2.4 Installation and Checkout

Prior to shipping the initial mine monitoring system, the vendor shall conduct a complete set of factory-floor acceptance tests. These tests will exercise (or simulate) all inputs, outputs, and all monitoring and control functions. A test procedure will be generated by the supplier and approved by Western Fuels (or their agent). The test shall be supervised by Western Fuels (or their agent) who will provide the vendor with shipping approval upon satisfactory completion of the test.

Upon completion of the installation, a complete set of on-site acceptance tests will be conducted by Western Fuels prior to actual acceptance. A sample test plan, both factory and in mine acceptance test, shall be included in the proposal.

The vendor shall also provide a short, e.g., one week, training program for the Western Fuels' systems users. This training program shall cover system operation, hardware maintenance, and software maintenance.

3. MAINTENANCE AND WARRANTIES

3.1 Maintenance

As part of the bid, vendor shall provide a description of the vendor's maintenance and repair philosophy, the location of the service center (or personnel) closest to the Deserado Mine, and the expected response time in the event that difficulties develop with the mine monitoring system.

Vendors shall also provide Western Fuels with a recommended maintenance and calibration schedule which addresses the number and skill level of the people required to maintain and calibrate the system as well as any specialized equipment required.

3.2 Documentation

Vendors shall provide, with the system, complete documentation (4 sets) of both the system hardware and software. The documentation shall be to the best commercial practice and a sample shall be included in the vendor's proposal.

3.3 Spare Parts

The vendor's proposal shall also contain a list of the spare parts the vendor either feels is necessary to maintain the system or is necessary to comply with the condition of the warranties. The list shall also contain the estimated price of the required parts.

3.4 Warranties

The vendor's proposal shall be based on providing a twelve month warranty on hardware and software. The prospective vendor shall include in the proposal the cost and terms for a one year service agreement on hardware and software.

4. TERMS AND CONDITIONS

Western Fuels-Utah's terms and conditions for this bid specification are attached with this document. If vendor takes exception to any portion of the terms and conditions, he must signify paragraph number and state exception taken. Exceptions must be included in the Bid Response.

5. CERTIFICATE OF COMPLIANCE

Western Fuels-Utah's Certificate of Compliance is attached with this document. This form must be signed and included with Bid Response.

APPENDIX B

PROPOSAL FOR MINE MONITORING SYSTEM

By

CONSPEC

February 17, 1984

TABLE OF CONTENTS

CENTRAL STATION:

The system is complete with dual hot on line Data Handling primary Senturions and 16 bit Graphics and Management Processor with auxillary options to meet your specifications:

System Includes:

3	Local 19" Color Terminals
2	B & W Terminals
1	Local Alarm Printer
1	Local Report Printer, 600 character per second
2	Primary Processor 64K RAM 7K EPROM
2	Co-Processor 64K RAM 2K EPROM
2	512K Floppy Disk 8"
1	System Watch Dog and Auto Switching Network
1	16 Bit, Color Graphics and Management Processor
2	15 Megabite Hermetically sealed Hard Disk
1	Floppy Disk Back-up
1	Primary System Power Supply
1	Stand-by Power Supply
1	Primary Communications Modem
1	Stand-by Communications Modem
2	Primary and Secondary Modem Line Protectors
1	Primary Local Accessor Trunk Driver c/w Power Supply
1	Back-up Accessor Trunk Driver c/w Power Supply
1	Desk Assembly as per Specification.

Remote Stations - Executive Office

1	19" Color Terminal with Keyboard

Guard House

1	Tractor Drive Alarm Printer
1	Alarm Horn and Beacon Assembly

SYSTEM SOFTWARE INCLUDED IN PRICE

Basic Software

Includes all basic software scanning of binary points, descriptors, alarm generation, alarm display on CRT, alarm horn and print out on event and data printer.

Also includes:

- Alarm and Status Event Log
- System Status Report by Group
- Descriptor Log
- Accessor Scan List
- Screen Auto-Acknowledge or Roll
- Immediate Status Request
- Continue Display on Master Field
- Remote Pulse Accumulator Control

System Diagnostics

Provides on line and off line diagnostics for both remote equipment and central station processor, CRT and printer.

Provides video display and printout reporting of failed equipment.

Basic Analog Software

Includes scan of analog points keyboard entry of calibrations, scaling "o" offset, engineering units, descriptors and delay to alarm. CRT display of alarms and print out provides floating decimal point on all analogs. Provides analog correction factors from .0000001 to 10,000,000.

Includes: Analog Scaling Log
Analog Offset Log
Online Calibration &

Review.

Shift End Report I

Provides up to 5 daily shift end reports or hourly reports. Selected analogs are printed with their average value for shift.

Running Time

Totalization

Running time of motors monitored by the system.

Control

* 2 and 3 State Commandable

* Analog Output Control

and	* Log of Operator Command Request Action
	* Control Accessor On Line
Diagnostics Event Initiated Sequencing	* Provides 2286 Steps of Automated Sequencing
	* Provides 2286 Timers
priority	* Provides priority sequences and control
Sequence	* English Language Prompting for Programming
	* Printout of Sequences
	* Printout of Sequence Triggers
Devices Sequencing	* Provide software that proves predefined status, then after startup, checks all time delayed interlock status thus providing true interlocking, and high speed response to conveyor start up and shut down requirements.
Color Graphics	* Provides up to 1000 Active Color Graphic Displays
	* Each Active Display Picture may have up to 32 Alarms, 32 Status and 32 Analog Points
	* Supports up to four terminals. Each terminal accessing independent data
	* Message transfer from one terminal to another
Trending	* Color trending stores data on all trends for 1 3/4 years
	* Up to four trends may be displayed simultaneously
	* Trend: Analog versus Time Analog versus Analog

	* Zoom feature
Alarm Display Area	* Continuously display of all group numbers containing acknowledged and unacknowledge alarms on bottom of all CRTs.
Message	* Messages may be sent from one terminal to another or from same terminal . Messages are stored in the message buffer and annunciated with a flashing "M".
Time of Day/Day of Week Programming	* Allows stopping and starting of equipment on a schedule basis. Schedules may be different for work days, Saturday, Sunday and Holidays.
Preventative Maintenance Scheduling	* Provides Preventative Work Order
	* Provides Preventative Maintenance Report Trigger from present condition, e.g., alarm running time, vibration, etc.
	* Up dates Work Order Outstanding file.
Production Stoppage Analysis	* Provides shift, daily, weekly, and monthly equipment stoppage analysis
	* Provides statistical data on reasons for outages on each piece of equipment
	* Pin points all major causes of production losses.
Data Storage	* Provides means to archive collected data for future recall and system use.
Report Generator	* Allows customizing of both report forms and each report contents by user. Allows user lay out of forms on the screen. Completed forms may be revised easily.
	User can define the data-entry field anywhere in his reports. The report program is provided with a word processor program which allows

easy viewing and editing of reports before issuing.

A report menu is provided to organize the access to your forms and reports.

The word processor will allow you to easily create a customized issue list for each report generated.

Special Software Included	*	Software has been provided to allow information from the preparation plant to enter directly into the Management Processor. An interpreter will be provided to allow this data to be handled indentically as information being received by the Accessor System.

Surface System Interface - programmable Controller Communicator

To execute the task of transferring the control of raw coal and fan/hoist systems to the monitoring system, and a data link between the DI200 and the supervisory processor, our engineers purpose to interface using the same data port as the DI200 and the PLC-3 using our PLC Interface Processor. The processor will then split the addresses so that all I/O addresses relating to control will be translated into Accessor Transmission Protocol and connected to the monitoring system. The remaining data will be translated to Serial RS 232 Protocol and directed to a port directly connected to the supervisory processor. Any display desired can be generated and updated by this link and displayed on any terminal as needed. We recommend that we provide a program in the PLC to inhibit any control codes from the program relating to Raw Coal, Fan & Hoist. This inhibit should take the form of a time delayed permissive contact. As long as the Senturion 200 resets this permissive, no control of Raw Coal or Hoist and Fan will be allowed at the main control room. We would be pleased to provide this program change in the PLC at an extra charge once we have received the present program.

This benefit provides four benefits. First, all information and controls relating to Raw Coal, Hoist and Fan is easily transferred to the Senturion System. Second, all status information is still available with no change in the existing system, only control is inhibited. Third, should anything happen to the communications interlink, control will automatically be transferred back to the existing control room. Last, the present programmable controller system and its field wiring is left intact and unchanged.

Graphic Pictures From Central Room

Some graphic pictures which presently exist in the Central Room Graphic System will be required in the Mine Management System. We have not included the charge for this duplication because we are not sure of their content.

These pictures may easily be duplicated by your personnel once training has been completed. Alternately, with some description of what is required, we would be pleased to do this task either for a fixed cost or at an hourly rate of $40/hr.

FIELD HARDWARE

SURFACE

Preparation Plant

1 PLC Communication Module
1 PLC Interface Processor
1 Power Supply
1 Enclosure C/W All I/O Connectors and Cables

Mine Substation

1 Single Accessor Enclosure NEMA 4
1 B24 Accessor
1 Stub Cable

Slope Conveyor

1 Single Accessor Enclosure NEMA 4
1 D1 Accessor Pulse Input (Conv. Weigh)
1 Stub Cable

Field Hardware - Underground

2 Portal Protectors s/s Enclosure
1 Dual Red Outstation s/s Enclosure
1 Trunk Break Detector s/s Enclosure

3 Conveyor Drive Assemblies, Each Comprising:

1 NEMA 4 s/s Enclosure. 20% Spare Space
1 Reset Push Button
1 Beacon
1 Horn
2 B24 Accessors 4 Binary Input
1 B25 Accessors 5 Binary Output
1 B25 Slave Relay Pack
2 A63 Accessors Temp Monitoring
1 A56 Accessor 4-20MA Input (AMPS)
1 Dual Analog Isolator
1 Watch Dog Accessor

Power Centers Each Comprising:

- 6 3 Phase - 4 Wire Watts Transducer
- 18 Current Transformer
- 12 Potential Transformers
- 1 NEMA Enclosure S.S.
- 6 A56 Accessor 4-20MA (Watts)
- 2 B24 Accessor
  4 Binary Inputs (Breaker trip)
- 8 Stub Cables

Environmental - Fresh Air - 8 Locations Each Comprising

- 1 CO Sensor, S/S Enclosure 0-50 PPM c/w Integral Accessor and Local Calibrating LED'S.

Return Air - 3 Locations Each Comprising:

- 1 Blue Outstation Barrier s/s Enclosure
- 1 Methane Monitor 0-5% s/s Enclosure c/w Integral Accessor
- 1 Air Flow Monitor 100-1500 FPM s/s Enclosure c/w Integral Accessor
- 1 CO Monitor 0-300 P.P.M. s/s Enclosure c/w Integral Accessor

Testing

Inplant fully simulated test.

Installation

Installation will be complete with all interface connections to your existing equipment. The surface system will be installed in existing empty conduit. It is assumed that a pull cord is available in these conduits or that there is no obstructions to a mouse feeder. All the underground interface wiring is within 10 feet of the conveyor drives.

Installation will be done by Union Contractor licensed for underground work and meeting union requirements of Western Fuels Association Inc.

Senturion system and all remote equipment is manufactured by Union employees and will carry Union Labels.

PERSONNEL TRAINING AND START UP ON SITE

Includes the following:

Training	-	Covering Operations, Installation, Maintenance
Manuals	-	Four sets of:

Operating Manuals
Accessor and Trunk Manuals
Diagnostic Manual
Installation and Maintenance Manual
CO, CH 4, and Air Flow Monitor, Operation, Installation and Maintenance Manuals.

Start-Up - Includes:

Check out of Computer System

Start-up of Computer

Verification of correct operations

Acceptance testing by owner

TOTAL SYSTEM PRICE: $394,150.00

All taxes extra where applicable.

Terms: Net 30 Days
F.O.B.: Jobsite Installed
Warranty: See Warranties attached

Alternative Bid #1:

There is no deviation from the intent of your specification.

The standard Senturion Monitoring System provides a programming zone by using a split screen technique. Therefore, a separate black and white terminal is not required by providing a multiposition terminal selector switch the operator can use any available terminal to make changes. All changes can be executed on-line.

The Conspec System is not enhanced by use of a 600 CPS report printer. In view of the cost we propose a DEC LA120, 120 CPS Printer which will provide the same system response.

If acceptable deduct $9,800 from the base price.

Deviations from Specification Using Alternative Bid #2 Standard Senturion Model 10

1. The guard does not have Hard Copy of Alarms, only Visual Display. Acknowledge by the Guard can only be executed when keyboard control is assigned by the Control Station Operator.

   The system only acknowledges individual points on points assigned to the graphics. Page acknowledge or Auto Ack is standard on the monitoring system. The time of acknowledge is not printed.

   All system logs are printed but not all are displayed on the video terminal. The only logs displayed are trend logs on the graphic system. A Color Printer/Plotter is provided for Hard Copies.

   The supervisory processor is Multi User 8 Bit. The system will not produce bar graphs or pie charts. The system will not subtract clean tonnage from total tonnage to provide waste tonnage all alarm events are only printed on the event printer as they occur.

   The Management report format is fixed (see attached sample).

   All procedures for obtaining Reports, Report Formats, and System Operation is as the standard manuals.

If acceptable deduct: $87,000 from base price.

System Integrity and Availability

The Conspec Basic Senturion 200 Mine Monitoring System was originally designed with system availability and mean time to failure, as the prime object in the hardware and software design philosphy. All important operations to be executed in reliable RAM memory. The only use of the Floppy Disk is to down load the program on System Start Up or for long term record keeping. The disks switch themselves off as soon as the load is complete and verified by the permanently residing diagnostic program (EPROM) and is not used again by any operating programs. We consider the processor the least vulnerable part of our system.

To comply with our perceived intent of your specification, the proposed underground system has incorporated in the design 100% back up of all devices affecting system operation. We have included in our price a dual central monitoring processor assay. This is a true back up comprising of processor, multi-serial port (octal SIO) processor, device sequencing processor, disk drive, power supply, local trunk driver, local trunk power supply, local PSK Modem interface card, secondary line protector. Data verifies on all four trunks and is supplied with processor switching module, C/W processor selector and status indicators. From the central station to the portal we have incorporated alternatively routed communication cables, each terminating on its own portal protector. From the protectors, dual cables terminate in a dual remote long distance Red Out station. This station incorporates dual PSK Modems, dual Interface Cards, dual Trunk Drivers, Dual Power Supplies and a data verifier. The verifier compares data received from the central processor in PSK formats and the data output to the accessor in accessor format. If identical it then checks on data sent from the accessors and compares it to data transmitted in PSK to the Central Processor. Should any of this data not prove out, the verifier switches to the standby and output a "system on standby signal."

There is a 4hr battery installed in this station C/W charger, low battery cut off, low battery signal output, a battery not connected signal output and a system on battery (mine power fail) signal output, all these signals are connected to a B24 accessor to alarm at central, should any of the above conditions occur at the dual trunk driver. We have included a class "A" accessor trunk loop, with a trunk break detector at the mid point of the loop. These loop cables will be installed as far apart as possible to give maximum protection. The system will either identify trunk break or communications fail on specific accessors making break identification instant and easy to locate.

MAINTENANCE AND REPAIR PHILOSOPHY

Conspec Manufactured Products

The system is totally modular. Parts are removed either by disconnecting plug connectors to the printed circuit boards, or by complete change of draw assemblies. The defective PCB is replaced from spares (accessors). All other devices have dual back up designed into the system.

The defective parts are returned to Conspec's representative Triune Inc., Palisade Colorado. Either by their weekly pick up at the mine or by express courier.

A full set of spare PCBs are always stock in Buffalo for emergency use and are shipped by overnight courier. Other local service organizations are situated to handle fast turn-around service the following system peripherals.

Color Terminals and Plotters

Return or call: Instrument Repair Lab
Boulder, Colorado

303-449-2721
Attention: Mr. B. Hendrick

Event, Guard Printer, and
B & W Terminals:

Return or call: TRW
Colorado Springs, Colorado or
Denver, Colorado

Report Printer

Return or call: Centronics Representative
Denver, Colorado

RESPONSES TO QUESTIONS FOR CONSPEC
AS PER OUR MEETING OF
28TH MARCH 1984

Q1. Explain the overall configuration of the system being delivered. Give details of interfacing the supervisory computer with the PLC-3.

A1. The Conspec Basic Senturion 200 Mine Monitoring System was originally designed with maximum system availability and mean time to failure, as the prime objective. All important operations are executed in reliable RAM memory. The only use of the Floppy Disk is to down load the initial program from the disks which switch themselves off as soon as the load is complete, and verified. They are not used again by any operating programs. That is the system software does not use overlays that have to be down loaded while the system is in operation. We consider the processor the least vulnerable part of our system.

To comply with the intent of your specification the proposed underground system has incorporated in the design 100% back up of all devices that affect system operation. Refer to dwg. #T1 for a block diagram of the system being offered.

We have included in our price, a dual central monitoring processor assay. Each monitoring processor comprises of a Z-80 processor, multi-serial port (octal S10) processor, a device sequencing processor, (utilizing a second Z-80 processor), a disk drive, power supply, local trunk driver, local trunk power supply, local PSK Modem interface card, and secondary line protector.

From the central station to the portal we have incorporated dual routed communication cables, each terminating on its own portal protector. From the protectors, dual cables terminate in a dual remote long distance Red Out station. This station incorporates dual truck driver, dual power Supplies and data verifier. The verifier compares data received from the central processor in PSK formates and the dta output to the Accessor in Accessor format. If identical it then checks on data sent from the Accessors and compares it to data transmitted in PSK to the Central Processor. Should any of this data not prove out, the verifier switches to the standby and outputs a "system on standby signal."

There is a 4hr battery installed in this station C/W charger, low battery cut off, a low battery signal output, a battery not connected signal output and a system on battery (mine power fail) signal output, all these signals are connected to a B24 Accessor to alarm at central, should any of the above conditions occur at the dual trunk driver. We have included a class "A" Accessor trunk loop, with a trunk break detector at the mid point of the loop. These loop cables will be installed as far apart as possible to give maximum protection. The system will either identify trunk break or communications fail on specific Accessors making break identification instant and easy to locate.

Interfacing the PLC3 to the supervisory computer

In the system offered we will be interfacing to the PLC-3 via the presently spare 1775-S4B I/O Scanner-Message Handling Module. This will require a software program in the PLC-3 to establish communication with our PLC-3 communication processor. (This program is estimated to take up less than 2K of the existing spare 16K of memory). Our PLC-3 communication processor will then be able to poll the PLC-3 for all the necessary status for transfer to the supervisory computer. It also will be capable of altering the data tables within the PLC in order to effect control of the raw coal, fan and hoist circuits.

Our PLC-3 communication processor has the ability to map the PLC-I/O into our field I/O data format thereby allowing our monitoring system to both control and monitor the PLC-I/O as if it were another one of our outstations.

Q2. What is the recommended maintenance and calibration schedule?

A2. The recommended maintenance and calibration schedule is as per MSHA and manufacturer recommendations, and is as follows:

a) For Co instruments:
   i) Weekly inspections visual
   ii) Monthly calibration

b) For Methane instruments:
   i) Weekly inspections
   ii) Monthly calibration

c) For Air Flow instruments:
   i) Monthly inspection
   ii) Three monthly calibration

d System cabling, outstations and other instrumentation:
   i) Recommended visual inspection every three months

Q3. Provide a sample acceptance test plan.

A3. A. Perform a complete functional test on the mine monitoring system, utilizing switch contact inputs, and simulated analog inputs for all transducers at Conspec's plant. Verify system alarming, reporting and control capabilities. This hardware will then be field installed. (i.e. mine controller plus underground data gathering system)

B. Next phase is to perform functional tests on the mine management graphic system. This will be interfaced to a mine controller using sample inputs to verify its operation and report capabilities. (Note not all inputs will be present on this test, in particular the PLC-3 inputs).

C. Final acceptance testing will be done on site with all pieces connected together. This will allow for full checking out of all aspects of system (including the PLC-3 interface).

Q4. There is a change in the number of Power Centers. Currently, the mine has four power centers instead of three as mentioned in our letter of January 26, 1984. There are three 750 KVA power centers for three conveyor drives, and one 1000 KVA at the face for six face equipment. How will this affect your cost?

A4. Our original price included 3 power centers:

ONE ONLY LARGE POWER CENTER CONTAINED:

6	-	3 Phase - 4 Wire Tranducer
18	-	Current Transformers
12	-	Potential Transformer
6	-	A56 Accessors 4-20 MA (watts)
2	-	B21 Accessors Single Binary Inputs (breaker trip)
8	-	Accessor Cable Assemblies
1	-	NEMA 4X Stainless Steel Enclosure

TWO ONLY - SMALL POWER CENTERS

Each Containing:

1	-	3 Phase - 4 Wire Transducer
3	-	Current Transformer
2	-	Potential Transformers
1	-	A56 Accessor 4-20 MA (watts)
1	-	B21 Accessor Single Binary Inputs (breaker trip)
2	-	Cable Assemblies
1	-	NEMA 4X Stainless Steel Enclosure

All the above is installed underground. Curent transformers and potential transformers are to be installed in the power Centers. The other equipment is contained in the NEMA 4X enclosure. This enclosure is mounted and wired to the current and potential transformer and to the Accessor trunk.

<u>Addition</u>

Add one additional Power Centers

Containing

1 - 3 Phase - 4 Wire Transducer
3 - Current Transducer
2 - Potential Transformer
1 - A56 Accessor 4-20 MA (watts)
1 - B24 Accessor 4 Binary Inputs (breaker trip) 3 spare points
2 - Cable Assemblies
1 - NEMA 4X Stainless Steel Enclosure

The above to be installed similar to other Power Centers.

Extra Price: $3,486.00

Q5. Have you discussed with McNally the details to inhibit any control codes from the PLC program for raw coal, fan and hoist? Is PLC-3 memory enough to accommodate this program?

A5. Our Engineers have reviewed your requirements and from the information we have at present which is:

i. There is 16 K of available memory in the present PLC-3 system.

ii. One S4B I/O Scanner - Message Handling Module is available for us to interface to.

iii. That we will receive from Western Fuels Association, Inc. a copy of the existing PLC software (ladder diagram) and a memory map within two weeks of contract award.

We fully expect this to be sufficient to perform the necessary tasks that you require, which is:

i. Inhibit control codes from the D1200 for raw coal, fan and hoist.

ii. Extract all necessary statuses for report and graphic generation in the Senturion monitoring, and supervisory system.

Q6. What is the effect of the mine and the prep plant operation of installing the new system?

A6. The effect of the installation of the system on the prep-plant operation will be minimal and will be of the order of, at most, three two hourly intervals. This is in order to load the modified PLC software.

Q7. Will the supervisory computer display the graphics pages at random, or will it be limited to those being displayed by the controller?

A7. Yes, the supervisory computer display will display graphics pages at random.

Q8. Explain the Power Center field hardware to be supplied.

A8. Each field power center is equipped with a 3 phase transducer c/w 3 current transformers which are mounted on each leg of the 3 phase supply and two potential transformers which are wired across 2 phases.

By monitoring each of the 3 phases we obtain accurate power readings even during unbalanced loading conditions. As well, we can detect the lost of one phase of power.

Lower cost single phase monitoring, could be used. However, the superior accuracy and ability to detect phase loss is worth the extra monies.

Q9. Will there be alarms on each underground outstation?

A9. Each underground outstation will be equipped with both an 8000 candle power strobe light and alarm horn.

Q10. How will the mine cables be safeguarded against breakage?

A10. The mine cables are duplicated and form an Accessor Trunk loop. To protect the cables we can either, install on two different walls of the entry, or wire each leg of the loop down ajoining entries. A Break Detector is supplied to alert the operator at central to a break in the cable.

Q11. Does the basic color graphic displays match the existing graphic display format for the surface conveyors?

A11. On the Conspec 16 bit management processor the display format will be identical with that of the existing graphic display.

If however, the optional 8-bit management processor is used, then the system will display analogs dynamically as numerical quantities and not as bar graphics which alter their heights dynamically.

Q12. What do the periodic reports (shift, monthly, daily, on demand) contain?

A12. The periodic reports on the 8-bit system comprise of: (Standard Issue)

a) Run Time Report
b) Shift Report for analogs (producing average, high and low values).
c) Totalization Report
d) Alarm Counts Report (indicating number of alarm transitions)
e) Activity Report (indicating number of charges of state for a particular device)

f) Stoppage Analysis Report
g) Maintenance Work Order

On 16-bit processor they will be as per spec.

Q13. Is the 31-hour training enough?

A13. The 31-hour training will be sufficient in that additional installation and trouble shooting training will result from the man or men assigned to accompany our technician during installation and start-up. Additional training will also result from participation in the acceptance testing.

Q14. What is the procedure for disconnecting batteries for belt CO sensors?

A14. The procedure for disconnecting batteries for underground red out stations is clearly outlined in the attached manual #R1083 - Installation and Maintenance Manual for a Mine Wide Monitoring System. Refer to section 2.0.

Q15. How many I/O points have you provided for each belt drive?

A15. Inputs and Outputs provided for each belt drive are:

8 - Binary Inputs
5 - Binary Output Controls
  1 - Start
  1 - Stop
  1 - Auto Manual
  1 - "Start" Horn
  1 - Strobe and Horn remote control
1 - Communications "Watch Dog" to switch to manual control in event of communications failure.
2 - Temperature Monitors
1 - Current Monitor
1 - Current Transducer ground isolator to prevent ground loops

ALSO

1 - Beacon and Horn
1 - Reset Button

Space for 20% spare capacity is provided for any future needs.

Enclosure is NEMA 4X reated stainless steel

Q16. Why are three "Blue" type outstations provided for environmental sensors instead of two?

A16. Three "Blue" outstations have been included in error, where only two are required. Delete one station.

Credit: $ 700.00

Q17. Give dates for the beginning and completion of installation and for Western Fuels acceptance.

A17. Delivery:

The dual primary system complete with all programming and sequences as well as all field equipment will be ready for factory acceptance testing 15 weeks after receipt of an order. If the lower cost 910 Management Processor is ordered this as well will be ready for acceptance testing. The equipment will be shipped to the job site to arrive on the 17th week.

Site wiring will commence on the 14th week and will be completed by the 21st week, at which time system check out will commence.

Should the larger 16 bit Management Processor be ordered, it will arrive on the 22nd week.

Final acceptance testing will take place on the 24th week.

Final training will commence immediately thereafter.

Q18. Who are the manufacturers of the CO, CH4 and air velocity sensors?

A18. Instruments:
Methane Instruments are: J-Tec
Air Velocity Instruments are: J-Tec
CO Sensors are: Energetic Science*

* As an alternative a Conspec CO Monitor using a City Technology cell may be supplied (pending final MSHA acceptenace).

Q19. Explain advantages and disadvantages of alternative No. 1 and 2. Where is the management report format sample as mentioned?

A19. <u>Alternative No. 1</u>

As per our quote this is essentially two separate items.

<u>Item A</u>:

This option is to remove the black and white programmers VDT on the mine monitoring - controller system, and to instead utilize one of the exisiting color terminal with a switch (supplied by Conspec and integrated into the desk) which will allow for performing both functions within the terminal.
Save: $1800 using this option.

Item B:

This option is to replace the printer (600 cps) with a 120 cps printer, namely a DEC LA120.
Save: $8000

If a 350 cps printer is used, then the recommended printer is an OKI-Data Pacemark Model 2410.
Save: $7,000

Alternative No. 2

This alternative relates to the utilization of Conspec's 8-bit standard offering.

a) The 8-bit standard system allows for the use of two operator consoles (remote and local consoles). It is suggested that the remote console be located in the guard-house, thereby providing the guard with visual display of all pertinent alarm conditions, and a keyboard from which alarms can be acknowledged. This keyboard is only active when control is passed to it from the local console by the control station operator.

b) The standard system allows point acknowledging only on the graphic pictures. Page acknowledge and auto-acknowledge is standard on the monitoring system. The time of acknowledge is however not printed.

c) In the 8-bit standard system all reports are only available on the printer.

d) The standard supervisory processor in this case is a multi-user 8-bit Z-80 processor. This system has the following capabilities:

   i. Capable of maintaining up to 1000 active graphic pictures.

   ii. Allows for maintaining 999 Alarm Instruction phrases

   iii. Capable of trend programming and analysis for up to 100 analog points.

   The trend program collects 4-minute samples of each analog pt. assigned to it. These samples are retained for a period of 2 days on the Winchester disk, and may be copied onto a floppy disk. After the 2 day period the samples are condensed to hourly averages which are recorded onto the Winchester for a period of time between 8 and 18 months depending on the number of points for which data is collected.

   Both Analog vs. Time, and Analog vs. Analog plots are available.

iv. Stoppage analysis capability on up to 200 devices

v. Maintenance Work Order Generation on up to 200 devices

vii. Support for up to three color terminals. If acceptable deduct: $87,000 from base price.

If the 16-bit supervisory processor is used, then the following additional capabilities are provided:

i. Bar and pie-graph generation capabilities

ii. Support for up to 12 terminals and/or printers

iii. Report generation capability. Flexible reporting. Refer to Appendix A for details.

The following options are available if the 8-bit standard processor is used. (Note these are already included in the 16-bit system price).

If using standard system, (8-bit) above, then if hardcopy printer with keyboard is required at guard house as per specification. (See 2(a) above). Seven days: add an extra $2,240 to the 8-bit processor price.

If using standard system (8-bit) above, and if printout of acknowledge and point acknowledge is required as per specification. (See 2(b) above). Twenty-one days: add an extra $6,720 to the 8 bit processor price.

If it is desired to display reports on the CRT, per specification. (See 2(c) above). Add extra $3,200 to the 8-bit processor price.