MONITORING CARBON MONOXIDE AND METHANE FOR EARLY FIRE DETECTION IN COAL-HANDLING FACILITIES

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While most coal-handling facilities today have some type of plant-wide monitoring and control system in place for fire detection, many of these still employ outdated devices and methods for effective suppression of fires and prevention of explosions. With increasing liability insurance premiums in the coal-fired power industry, and a growing need to increase productivity in these plants, it is more important than ever to focus on early detection and to employ preventive rather than reactive measures.

More and more power plants and coal preparation plants today are utilizing carbon monoxide detection to pinpoint hot spots or smoldering fires, and methane detection to prevent explosion. This presentation will describe two such cases.

BACKGROUND

While many power plants across the country now utilize coal-burning facilities, fires and explosions in these facilities are of increasing concern. Rather than merely react to fires once they start, however, plant engineers should focus on proactively minimizing the potential for fire through early detection.

With increasing liability insurance premiums in the coal-fired power and cogeneration industries, and a growing need to increase productivity in these power plants, it is more important than ever to employ preventive rather than reactive measures.

THE CHEMISTRY OF COAL FIRES

Coal-handling facilities typically have two sources of ignition that need to be considered. The first is coal itself; the second is the belt material used in the transport of coal. Belt material is basically inert but when heated by an external means will produce CO. This can be caused by hot burning coal loaded onto the belt or contact with hot metal rollers heated by belt slip or damaged bearings. Coal can ignite when it comes into contact with hot surfaces and is also capable of self-ignition through the process of spontaneous combustion.

AN OUNCE OF PREVENTION: THE ADVANTAGES OF CO DETECTION

While most coal yards today have some type of plant-wide monitoring and control system in place for fire detection, many of these still employ outdated devices and methods for effective fire prevention. For instance, whereas a sprinkler system can respond to a fire, an integrated CO monitoring system can warn of a potential fire up to two days before a flame is present.

By minimizing the risk of fire in coal-handling facilities power generation companies can see an increase in personnel safety as well as a decrease in downtime and loss of resources. In short, they can save money.

Fewer Fires = Lower Insurance Premiums

Less Downtime = Increased Productivity

CO MONITORING

Industrial-quality carbon monoxide monitors can be used as complete stand-alone equipment or can be integrated into preexisting PLC or SCADA networks.

Real life experience has demonstrated that the use of CO detection is the most effective way of providing early warning of fire. In many cases the use of CO monitors could have prevented fires and explosions. A major one worth noting is the accident at Oak Creek Wisconsin, where six contractors were injured. The plant had relied on heat-source detection, which in this case came too late to prevent a fire.

THERMAL MONITORING AND IR SCANNING

All power plants must have some type of risk-management system to mitigate the possibility of fire. A proactive approach to fire prevention focuses not so much on detecting smoke, which indicates fire, but rather on monitoring CO, which indicates the potential for fire. Any delay in dealing with the *potential* for fire only increases the rate of burning.

Thermal scanning utilizes thermocouples to indicate a fire inside a bunker or silo. It will not, however, provide early warning of the potential for fire. A fire of considerable size can be present before any alert is given.

Infrared (IR) scanning can be effective in detecting hot spots. Periodic monitoring of a bunker or silo using an IR thermographic camera to scan the inside or outside such enclosures is a common practice. Such a scan can pinpoint hot spots precisely. This can be helpful, but should not preclude CO monitoring. (See Figure 1.)

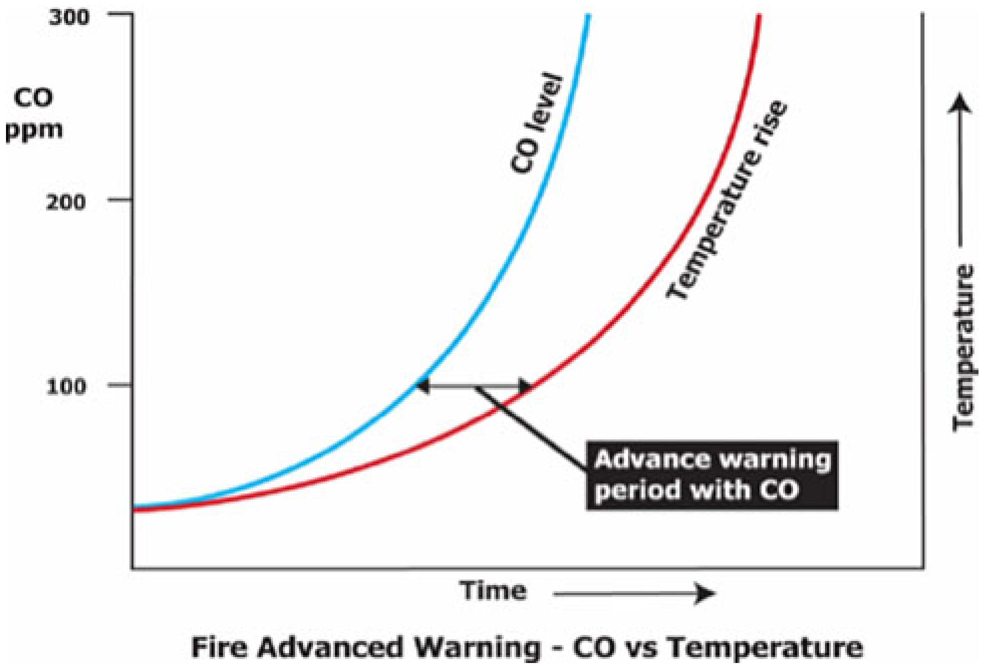

fig. 1 - Graph showing temperature indicators of potential fire vs. CO detection indicators

THE IMPORTANCE OF MONITORING FOR UPWARD TRENDS

Once normal, safe operating levels are established, any upward trend of CO from those background levels can indicate a problem. It is predictable that while coal is being loaded, CO levels will rise sharply. Once the coal has been loaded and ventilation fans are running, CO levels will begin to drop back to normal and level off.

In power plants, it is normal to see a 50 ppm background level, especially when coal is actively being moved, and this does not necessarily indicate an alarm condition. It is crucial to determine these normal background levels first in order to adjust the alarm levels.

DETERMINING THE BEST SENSOR LOCATIONS

In general, it is wise practice to locate an adequate number of sensors at strategic locations based on knowledge of the potentials for ignition.

When considering belt fires, sensors should be located in close proximity to drives, tail pieces, and main rollers.

When coal is the issue, any location where accumulation of coal dust or bulk quantities is likely or expected should be considered. These include belt transfers, crushers, dust collection systems, and storage bins (silos, bunkers, etc.).

ENVIRONMENTAL CONCERNS

In order to work effectively, carbon monoxide sensors must be installed in locations and in ways that do not impede the sensor’s capabilities.

The temperature needs to be maintained within upper and lower boundaries. Because the electrolyte within the sensor is water based, the sensor should never be allowed to operate below –20°C. Lower temperatures will render the sensor inactive, and may cause permanent damage. The upper temperature limit for most sensors is +50°C.

The ambient pressure in which the sensor operates must be held close to standard. The inlet side of dust collection or bag house fans should be avoided. Normally, the exhaust side is a better choice, since outside pressure is rather constant.

Moisture can be a problem, particularly if the CO sensor is housed within an explosion-proof housing. Flame arrester components built into the sensor housing can be clogged if water comes into direct contact. In areas of concern, splash guards and/or porous membrane filters should be placed in front of the sensor to prevent the flame arrester from ingesting water.

Dust accumulation in front of the sensor is also of concern. Care must be taken not to mount a sensor in a location where large amounts of dust can collect on the sensor housing. This is typically a concern when mounting the sensor above storage bins.

HOW THE CO MONITORING AND CONTROL SYSTEM WORKS

When CO levels rise to critical levels, the control system will automatically respond by warning personnel, who can then take appropriate action by shutting down a piece of equipment via the control system and/or increasing ventilation fan speed. In addition, audible and visual alarms will alert personnel immediately, so that they can take appropriate action.

THE SPECIAL CHALLENGES OF POWDER RIVER BASIN COAL

Many coal-fired power plants across the United States have switched from the traditional high-sulfur bituminous coal to Powder River Basin (PRB) coal. PRB coal offers several advantages: it has a low sulfur content, reserves are plentiful, and it can be acquired using surface mining methods.

However, the increased use of PRB coal has presented special challenges in fire prevention at power plants. PRB coal has a lower BTU and higher moisture content, and produces more dust than regular bituminous coal. Fires in PRB coal-burning facilities have ranged from minor fires in coal piles to major events that have cost millions of dollars. The PRB Users Group recommends CO detection for fire prevention in bag houses and silos.

Along with the increased moisture of PRB coal comes the increased potential for spontaneous combustion. As the moisture in the coal is liberated and the coal oxidizes, both heat and carbon monoxide are created. Heat can build up to the point at which spontaneous combustion can occur.

Because it is extremely friable, that is, easily crumbled or pulverized, PRB coal creates airborne coal dust and hence requires more stringent housekeeping methods, such as proper maintenance of stockpiles, guarding against accumulations of coal in the fuel-handling system, compaction of stockpiles, cleaning spills and washing float dust. An effective fire-prevention plan must also include a system-wide CO monitoring and control system.

CASE STUDIES: TWO PRB COAL-BURNING POWER PLANTS

When Savage Energy Services began fuel-handling operations in two power plants in Texas, engineers there began to investigate methods to enhance the safe handling of PRB coal. Liberation of CO can indicate the presence of oxidizing coal before a fire begins. Correcting the problem during this incipient phase greatly mitigates the possibility of having a fire.

The cooperative effort to incorporate a CO detection system into the power plants began at the fuel-handling systems owned and operated by Savage at Xcel Energy’s Harrington Station in Amarillo, Texas, and at Xcel’s Tolk station in Muleshoe, Texas. Part of this effort included engineering an overall system design plan.

The system at each facility consists of CO sensors, a cable to provide a communications highway, and a central computer station to interpret the data.

SAVAGE HARRINGTON CASE STUDY

FACILITY

The coal-handling facility at Harrington utilizes an elevated rail and bottom dump coal cars to create a live pile above the underground reclaim tunnel. Large earth-moving equipment is used to maintain and move the live pile for storage and retrieval.

When bunkers feeding the furnaces need replenishment, the live pile is dropped into the reclaim tunnel, moved through a series of conveyor belts, a crusher building, and transfers on its way to the top of the storage-level tripper deck. It is common to see burning coal being dropped out of rail cars as a train is being unloaded.

The monitors are tied to a central computer in the main office building, where alarming, trending, and historical data storage takes place. (See Figure 2.)

fig. 2 - A view of the computer station located in the office

fig. 3 - The main conveyor structure at Harrington rises from the crusher building behind the trees. The live pile, car dump, and reclaim tunnel are located on the far side of the crusher building. The walls and floors are corrugated metal and there are numerous openings in the structure.

INSTALLATION

Carbon monoxide monitors were initially installed within the reclaim tunnel, crusher building, belt galleries, and tripper deck. Additional units were added to bag houses and bunker locations. (See Figures 4 – 7.)

fig. 4 - A CO monitor undergoing calibration during initial installation at the top of the conveyor structure

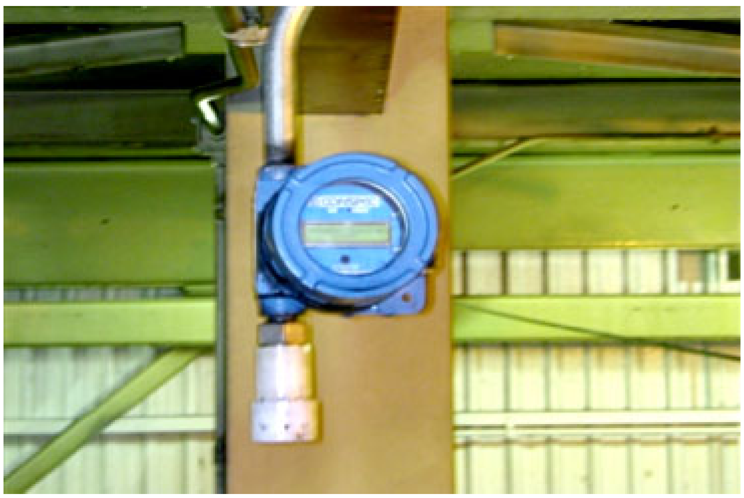

fig. 5 - Typical CO monitor installed along a belt head drive location. Note the white cap on the sensor head. This is the splash guard used to prevent wash-down work from loading the sensor with water.

fig. 6 - Looking down the main conveyor structure. A CO monitor located above and left of center. Two conveyor belts on either side, redundant to minimize the potential of shutting down the plant if a single conveyor shuts down.

fig. 7 - This is the view of the main conveyor as it heads into the power plant building, which is about 13 stories high

Figure 8 is a photo of the system status screen used at the fuel-handling facility at Harrington Station. On this screen, information essential to the operation of the coal-handling system was added. Shown are the amounts of coal currently in the bunkers. This information is entered into the computer system via 4 20-mA process loop sensors. Bunker levels, coal mill feed rates, conveyor flow rates, bag house differential pressure, as well as proper operation of the reclaim tunnel fan and sample system are also displayed.

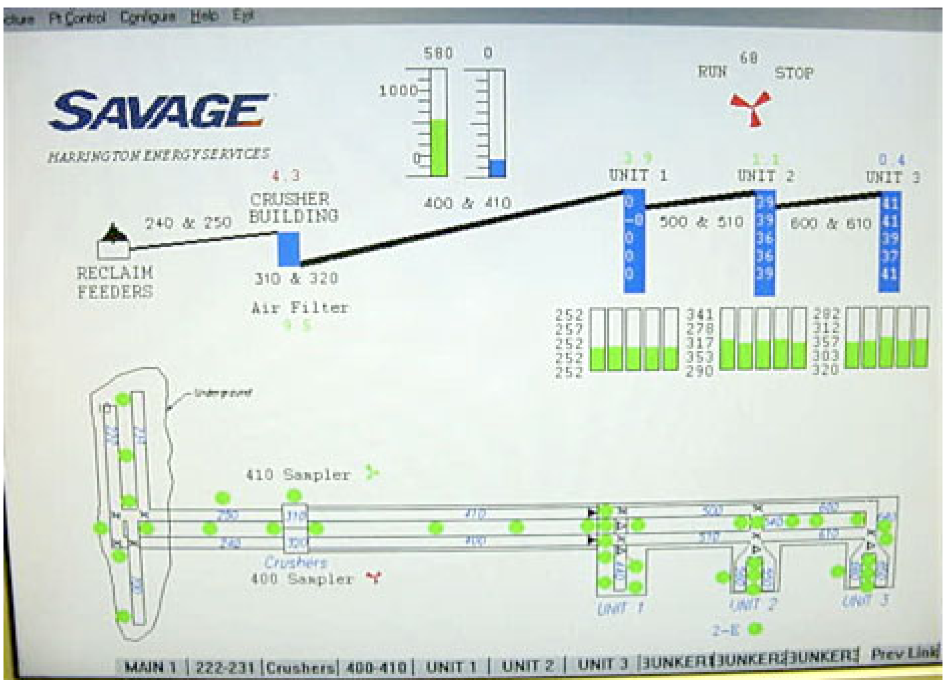

fig. 8 - Harrington Station system status screen

If the concentration of CO at a sensor rises above the adjustable alarm points, the detection system sends an alarm signal to the control stations. A voice module also sends alerts over the intercom system and coal-handling system team members' radios. Procedures have been established to respond to elevated levels of CO to ensure the safety of all team members. Protocol dictates that all CO alarms be investigated to determine the cause. One example would be elevated CO levels in the reclaim tunnel as coal is being transferred. The natural oxidation process liberates CO in amounts that can be detected easily in the confines of the reclaim tunnel. Figure 9 shows the concentration of CO in the reclaim tunnel at Harrington.

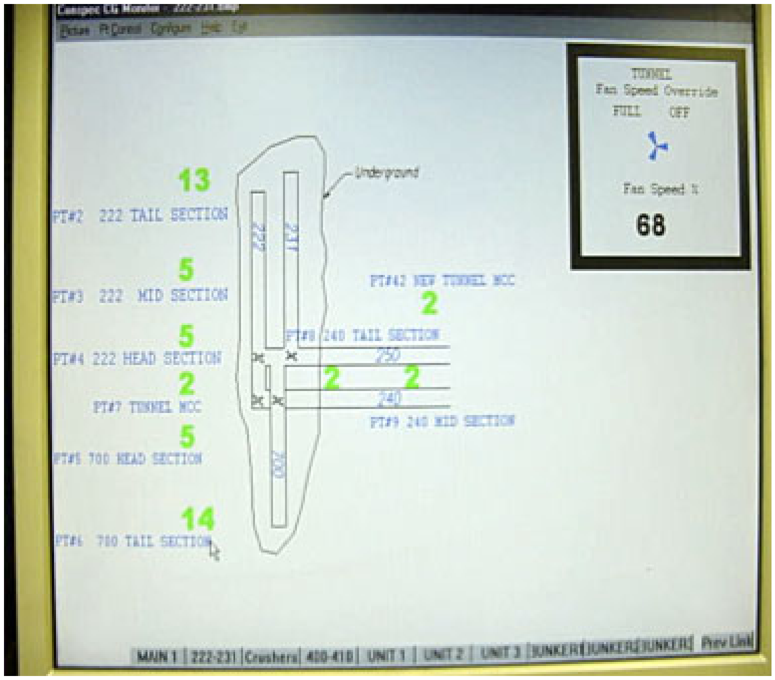

fig. 9 - Harrington reclaim tunnel CO concentration screen

Another feature of this system is its ability to control remote devices. The box in the upper right corner of Figure 9 indicates that the reclaim tunnel fan is operating at 68% speed. The monitoring and control system controls the speed of this fan to keep the concentrations of CO in the tunnel below the OSHA-permissible exposure limit of 35 ppm for an 8-hour period. It was interesting to find that the levels of CO in the tunnel can become elevated during the normal course of operations. These findings led to the installation of a higher-volume ventilation system for the tunnels at both operations to provide an additional level of safety. Figure 10 shows the normal variations in CO concentration in the reclaim tunnel during a typical 24-hour period. Note the abrupt increase in CO levels as coal is dumped. This variation is normal and expected.

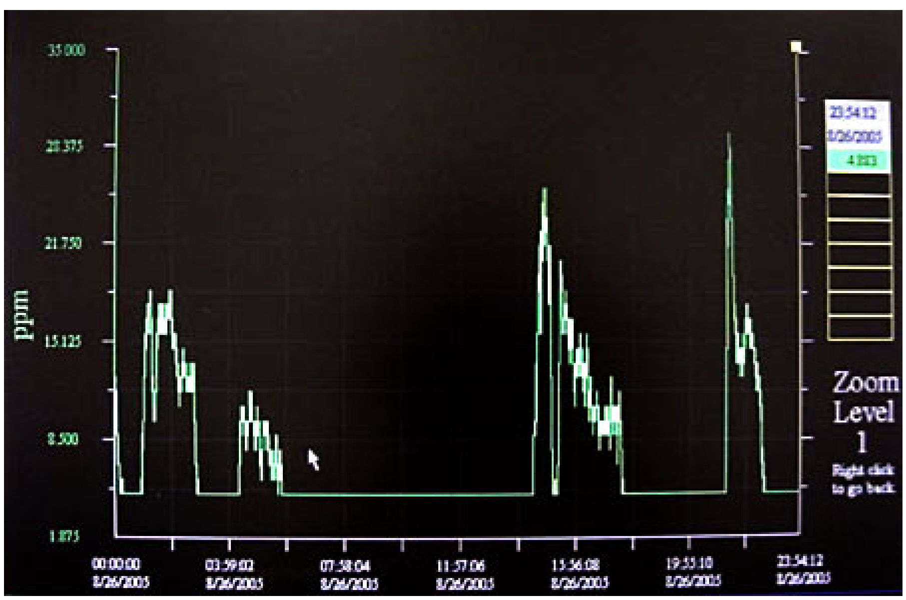

fig. 10 - Reclaim tunnel CO concentration graph

Savage also works in cooperation with Xcel's plant management to selectively monitor CO concentrations in bunkers. Normally, bunkers are continually refilled with coal. The new coal tends to smother any heating or burn process. It was found, however, that when a bunker goes inactive, the risk of spontaneous combustion and fire increases as coal and dust within the bunker sits. CO monitors are typically added temporarily to the bunker as an added safety measure until the bunker is put back into normal operation. This effort with plant operations has defused situations before they could become more serious.

FINDINGS

Immediately upon installation of the CO monitors, it became apparent that readings approaching 100 ppm or more would be seen in the reclaim tunnel whenever coal was being actively transferred. As soon as the coal passed to the next section of belt and left the reclaim tunnel, all readings along the remainder of the system remained below 4 ppm. Thus, it appeared that CO was being created or liberated within the depths of the live pile and followed the path of coal into the reclaim tunnel. Once the CO reached the tunnel, it was nearly all drawn off by a ventilation fan.

The reclaim tunnel is nearly a confined space. Without the ventilation fan, very little air movement would be possible. In contrast, the belt galleries, crusher building, and tripper decks above the bunkers are very open to air movement. The "open" nature of these areas makes it hard to determine whether CO is being created in any appreciable quantity.

Alarm levels for the reclaim tunnel CO monitors were made variable to take into account the high levels experienced during coal transfer versus normal idle conditions. Prior to beginning coal transport, operators select high alarm levels on the central computer and keep them until the bunkers have been filled. Once complete, lower alarm levels are re-established.

The ventilation fan in the reclaim tunnel was subsequently updated to have a variable speed controller. Operators determined they could save money by running the fan only when needed and increase the speed to a level intended to keep all CO monitor readings held in check during the coal transfer process. During times when coal was not being moved, the fan was turned off or kept to a very low speed. If the CO concentration rose above a predetermined level, the fan speed was increased.

By adjusting the ventilation fan speed and watching the resulting CO concentrations, operators at the plant realized that more than just the CO level was required to determine whether an active combustion process was occurring. If air movement was also taken into account, a relative measure of CO volume production could be used as the performance measure for alarming.

The Harrington plant incorporates dust collection systems to help keep buildup near belt transfer points to a minimum. Bag houses, connected to the transfer points by metal ducts, draw air from the transfer points like a large vacuum system. CO monitors were installed in the outlet side of the bag house airflow. In at least one instance, an impending fire was detected in one of the ducts leading to the bag house. Operators noticed an increase in CO concentration at one of the bag house locations. Inspection of the bag house showed no sign of hot zones. The monitor appeared to be intact and working correctly, so inspection of the incoming ductwork began. A hot zone was detected in one of the hoods above a transfer point, and the potential fire was prevented from going any further.

Following the system installation, a CO monitor located above a storage bunker began showing higher than normal readings. This particular bunker had not been in use for several days, and was thought to be safe due to being empty. Upon further inspection, a hot zone at the bottom of the bunker, near the pulverizer was found and contained. Monitoring of bunker CO levels subsequently was intensified.

In general, the use of CO monitors within this coal-handling facility has proved to be effective at providing an early warning of potential dangers. In particular, hot zones in locations where coal or coal dust accumulate have been detected, allowing operators to take corrective action before the danger becomes obvious. Managing the risk of fires at this site has been enhanced greatly by use of carbon monoxide detectors at key locations and also by appropriate alarming methods that include dynamic operating conditions.

SAVAGE TOLK CASE STUDY

FACILITY

The coal-handling facility at Tolk is very similar to Harrington with the exception of a rotary car dump rather than an elevated bottom dump. Coal drops out of rail cars into a temporary storage pocket prior to being moved onto the surface live pile.

INSTALLATION

In a fashion similar to that at Harrington, carbon monoxide monitors were installed within the reclaim tunnel, crusher building, belt galleries, tripper deck, and bag house at the Tolk facility.

The PRB Coal Users Group recommends the use of methane monitors in coal-fired power plants. Five IR methane monitors were installed at Tolk, three within the reclaim tunnel and two in the upper and lower portions of the dump houses.

These monitors, like the CO monitors, are tied to a central computer in the main office building, where alarming, trending, and historical data storage takes place.

Figures 11 and 12 show the screens at the monitoring station located in the control room of the fuel-handling system at Tolk Station. The screen in Figure 11 flips through three diagrams to give visual indications of the gas detection system status. The screen in Figure 12 shows real-time display of CO concentration levels at each sensor in the system.

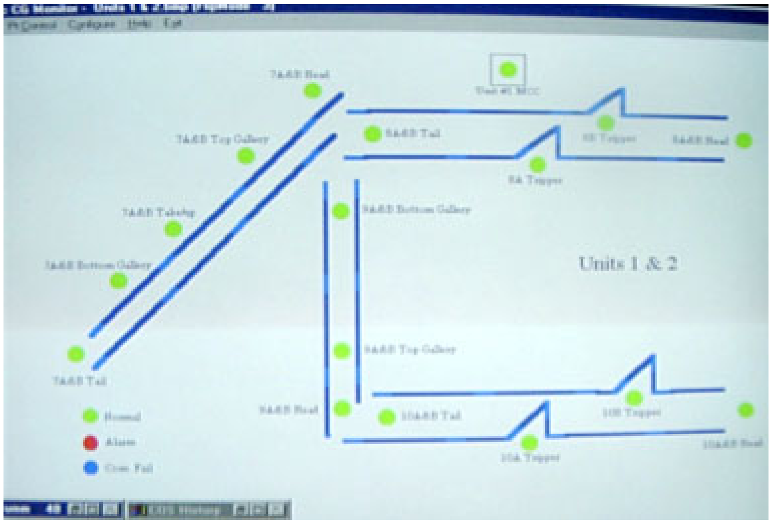

fig. 11 - Flip display of CO detection system status at Tolk

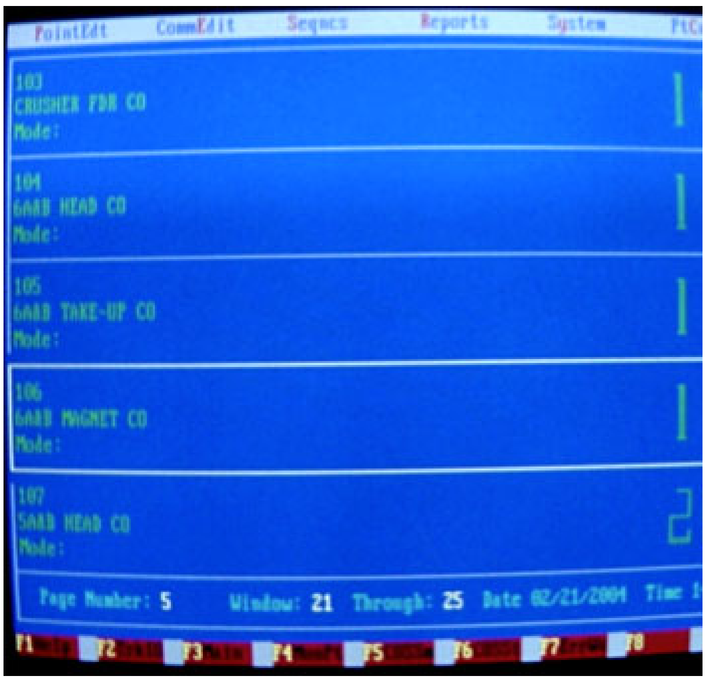

fig. 12 - Real-time CO concentration display at Tolk

FINDINGS

Due to similarities to the Harrington facility, coal supply, and common ownership and management safety philosophies, the results of the installation at Tolk and Harrington mirror one another in most respects.

Operators have mentioned several instances where increased carbon monoxide readings have led to detection of hot zones in bag houses and bunkers.

Over the last two years, we have only occasionally seen detectable levels of methane, whereas detectable CO levels are seen daily. The methane sensor has a lower detection threshold of approximately 0.05% by volume, or 500 ppm, whereas CO is detectable at levels as low as 1-2 ppm. When viewed as an early warning device for fire detection, it appears that carbon monoxide is a better and more reliable gas upon which to base measurements.

More information can be found at www.conspec-controls.com or by contacting the author, Kurt Smoker, at 1-303-650-1699.