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MITIGATION OF FIRES IN COAL-HANDLING FACILITIES: CONTINUOUS MONITORING OF CARBON MONOXIDE

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Abstract

While many power companies across the country rely on coal-burning facilities, fires and explosions in coal-handling facilities are of increasing concern. While facility housekeeping by means of controlling dust and preventing spills is very important, a good risk management plan must also include continuous monitoring of toxic and combustible gases. The use of carbon monoxide gas detectors has proved for years to be a very effective early fire detection system.

This paper describes a risk-management system that can greatly mitigate the possibility of fire by means of alarming at low levels of CO concentration. The authors present a pro-active approach, focusing not on detecting smoke, which indicates fire, but rather on detecting CO, which indicates the potential for fire. Covered are the benefits of CO monitoring over thermal monitoring and IR scanning, the importance of monitoring for any continual trend upward from background levels, and discussion of how proper alarm setpoints are determined, using case studies.

Introduction

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 is capable of ignition by coming into contact with hot surfaces, but can also be 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

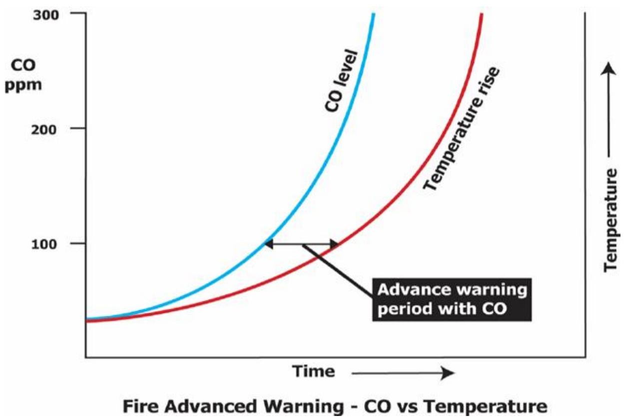
CO Monitoring Industrial-quality carbon monoxide monitors can be used as complete, stand-alone equipment or can be integrated into preexisting PLC or SCADA networks.

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. A CO detection system can provide warning of a potential fire up to two days before a flame is present.

FIGURE 1: GRAPH SHOWING TEMPERATURE INDICATORS OF POTENTIAL FIRE vs. CO DETECTION INDICATORS.



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**.**

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 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 involve 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.

Due to its friability, PRB coal 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 Study: PRB Coal-Burning Power Plant Gets Upgrade of Existing System

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

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.

Savage Harrington Case Study

Facility The coal-handling facility at Harrington (see Figure 1) 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 storage takes place. (See Figure 2.)

FIGURE 2. A VIEW OF THE COMPUTER STATION LOCATED IN THE OFFICE.

FIGURE 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.)

FIGURE 4: A CO MONITOR UNDERGOING CALIBRATION DURING INITIAL INSTALLATION AT THE TOP OF THE CONVEYOR STRUCTURE.

FIGURE 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.

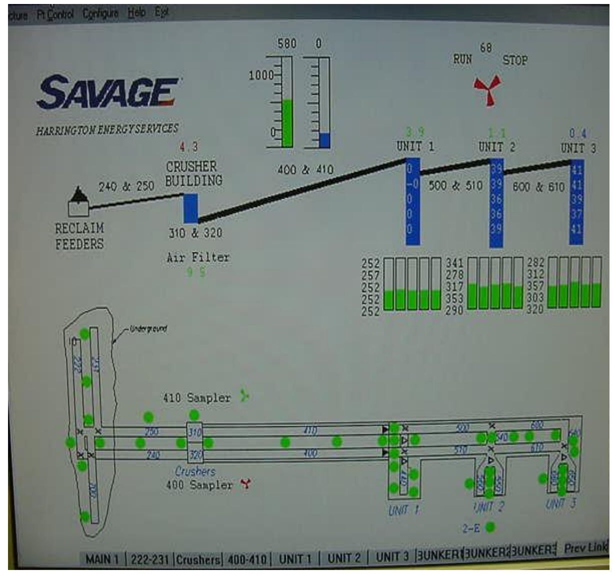
FIGURE 6: LOOKING DOWN THE MAIN CONVEYOR STRUCTURE. A CO MONITOR LOCATED ABOVE AND LEFT OF CENTER. TWO CONVEYOR BELTS ON EITHER SIDE, REDUNDANT TO MINIMIZE THE POTENTIAL OF SHUTTING DOWN THE PLANT IF A SINGLE CONVEYOR SHUTS DOWN.

FIGURE 7: A VIEW OF THE MAIN CONVEYOR AS IT HEADS INTO THE POWER PLANT BUILDING. THE TOP OF THE BUILDING 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 all displayed.

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 member's 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 8 shows the concentration of CO in the reclaim tunnel at Harrington.

FIGURE 8: HARRINGTON STATION SYSTEM STATUS 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.

FIGURE 9: HARRINGTON RECLAIM TUNNEL CO CONCENTRATION SCREEN.

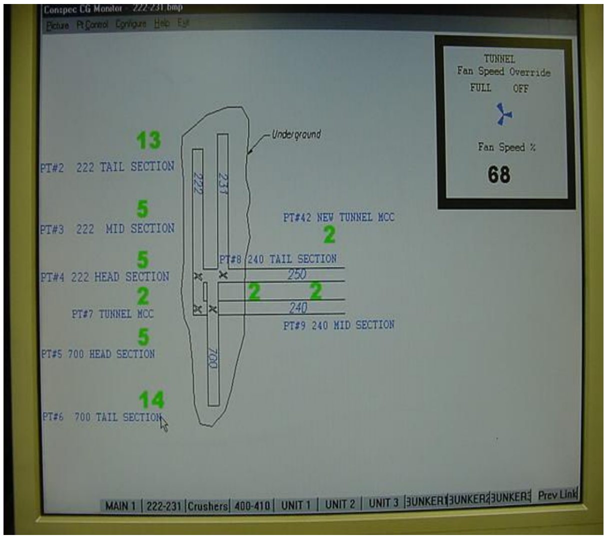
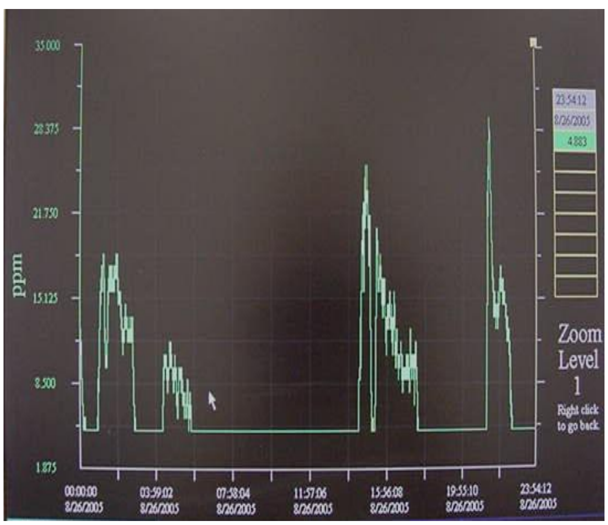


FIGURE 10: RECLAIM TUNNEL CO CONCENTRATION GRAPH.



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 increase 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 proven 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 Harrington, carbon monoxide monitors were installed within the reclaim tunnel, crusher building, belt galleries, tripper deck, and bag houses.

As an added precaution, five methane monitors were installed. Three methane monitors were placed within the reclaim tunnel, while two were mounted inside a building near the tunnel through which the coal enters the main conveyor line.

The monitors were tied to a central computer in the main office building, where alarming, trending, and historical 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 detection system status. The screen in Figure 12 shows real-time display of CO concentration levels at each sensor in the system.

Findings

Due to similarities with the Harrington facility, coal supply, and common owner/management structures, 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.

Very little methane has been detected or even registered by the five monitors. The methane sensor has a lower detection threshold of approximately 0.05% by volume, or 500 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.

FIGURE 11: FLIP DISPLAY OF CO DETECTION SYSTEM STATUS AT TOLK.

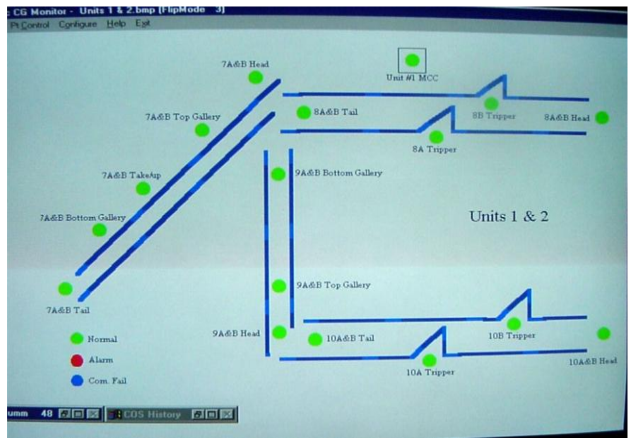
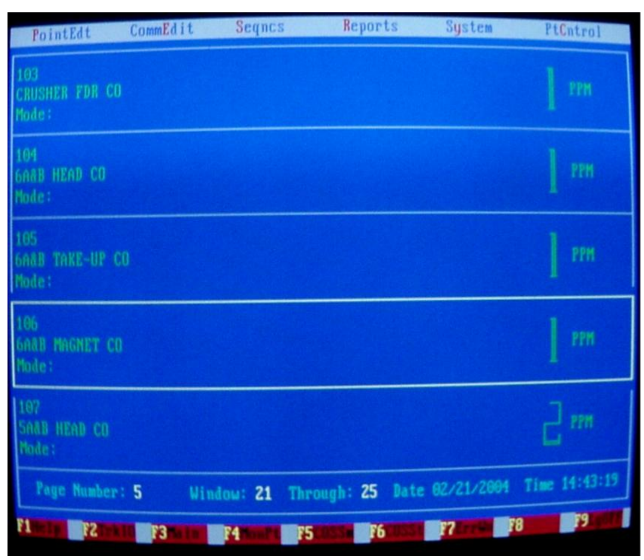


FIGURE 12: REAL-TIME CO CONCENTRATION DISPLAY AT TOLK.



Case Study: ARPA Lamar Case Study

Facility

The coal-handling facility at the Lamar Power Plant in southern Colorado is an interesting and somewhat unique design. The Lamar plant is a rather small generation station that serves several communities in southern Colorado and northern New Mexico.

Located in the middle of a light industrial and residential neighborhood, the plant originally was gas fired, and therefore did not have to deal with coal. In recent years, the plant has been converted to coal.

In order to meet permitting requirements by the State of Colorado, the coal-handling portion of this plant has been constructed essentially as a dust-tight facility.

Car Dump

The car dump consists of a ground level, bottom dump building. Doors on each side of the rail path are lowered while a car is being emptied to minimize dust exiting the immediate dump chamber. The coal is immediately transferred to one of two live pile storage locations.

Live Pile Domes

Two large dome structures have been erected to provide live pile storage. The domes contain the coal completely and are intended to be dust tight. Ventilation fans, part of the dust collection system, control air movement within the domes.

Coal Transfer Structure

Coal is transported from the live piles to day-storage bins in a relatively standard system of reclaim area, conveyor belts, belt transfers, etc. However, the entire structure has been designed to be as dust tight as practical. Beltways are maintained within sealed tube structures, and very little air from outside the containment zone is allowed to enter or exit uncontrolled.

Dust Collection System

A high-quality, extensive dust collection system is essential to the coal handling method. From the car dump, live piles, beltways, and crushing areas, coal dust is removed and recovered in bag house structures. The recovered dust is then fed to the furnace as fuel. For all essential purposes, air movement within the facility between the car dump and day silos is dependent on the dust collection system.

The dust collection system is effective in reducing the amount of dust that settles in the various areas in question. However, there is always a small amount of loose product that collects on surfaces exposed to the coal transport.

In order to meet strict fire prevention guidelines, those charged with the design and installation of the fire prevention detection suppression system drew on several different types of technology: CO detection, infrared (IR) scanning, and thermal detection. In the preconstruction phase, other facilities that use PRB Coal as the fuel source were studied.

Firetrol Protection Systems, Inc. (Denver, CO) oversaw the design and installation of the plant fire detection and suppression systems at Lamar Light and Power. Much of the design focused on proper use of NFPA 850 guidelines. Hazard Control Technologies (Fayetteville, GA), which provides PRB coal consulting services and specializes in fire prevention, detection, and suppression, provided consulting to Firetrol for the placement of inspection hatches and access ports necessary for the use of the HCT piercing rod with F-500.

CO sensors, IR black-body scanning, and thermal imaging are all used as parts of the fire detection system. CO tends to be the first line of defense due to the sensitivity electrochemical sensors provide.

FIGURE 13: THE INSIDE OF A DOME SHOWING THE VARIOUS COMPONENTS AND THEIR PURPOSES.

Figure 13 shows the inside of a dome. PRB coal is delivered through the large hole in the center of the dome. The smaller hole to the left is an inspection/ firefighting hatch, where personnel can observe and also insert a device (developed by Hazard Control Technology) called a piercing rod. Each dome contains four of these hatches. Two CO detectors are located at the top of each of the dome at about 180° apart.

Once such a system is in place, it may take several weeks to gather sufficient historical data to determine and set a baseline of normal CO concentration; this varies from one location to another. After a baseline is set, audible and visual alarms will alert personnel to take action when there is an upward trend in CO concentration level. Further, if the coal supply source changes, this will cause further variation of CO levels and require further evaluation.

If the rate of rise of CO concentration is noted in a silo, one of two actions can be taken immediately: the use of a piercing rod to displace CO, or a deluge wash-down using S500 solution. The fire suppression system is set up so that both actions can be taken quickly.

In the reclaim tunnel, three technologies are used: CO detection for early warning of the potential for fire, linear heat sensors to detect any stationary fire, and IR scanners (manufactured by Patol Ltd.) to detect any moving hot spots. CO detection is the first line of defense since the presence of CO exists up to two days before an actual fire occurs.

Installation

Carbon monoxide and methane monitors were installed throughout the coal transfer structure and dust collection system at key locations such as the domes, beltways, belt transfers, etc. In some instances, the sensors were incorporated directly into the dust collection hoods surrounding the belts at the transfer points.

The CO and methane monitors send their measured readings to several control panels, where individual alarming takes place. The alarm outputs consist of two relays for each monitor. A relay will energize when its associated monitor exceeds the level set for that device. The relay contacts are fed to a fire alarm system as part of a larger plant wide fire alarm and suppression system.

Findings

From the first day coal was loaded into the storage facility, it became apparent that the nature of the dust protection design was unique. When the air movement within the structure was stopped, relatively small amounts of coal dust produced fairly high-volume CO concentrations.

The initial run of coal into the plant was conducted between midnight and 4:00 a.m. Roughly five cars were unloaded into the car dump and sent to one of the domes. Following the completion of car unloading, all fans within the dust collection system were turned off. By 8:30 a.m., all the CO monitors located in the coal-handling areas were registering over 400 ppm, and several were above 500 ppm.

Operators at the plant reported the monitor and fire alarm systems were not working properly due to the levels seen on the controllers and fire alarm panels. The operators were advised to turn on the fans that had been shut off earlier. Within 5 minutes, all CO readings dropped to less than 50 ppm. The readings on top of the active dome remained in the 30 to 50 ppm range.

Thus began the process of trying to determine what constitutes a safe, normal level of carbon monoxide within the various coal transfer locations and what constitutes a level attributable to an impending or growing combustion danger.

The choice of hardware for the control panels and fire alarm system did not provide adequate information to conveniently allow a thorough analysis of the buildup of CO during and after cars are dumped and fans are run. It is worth noting that the rate of buildup is important to determining whether or not a safe or unsafe condition is present.

Plant personnel, at first, were quite hesitant to accept the presence of high levels of CO within the dump and transfer belt areas once active car dumping activities were complete. The truth is, that these levels exist, and are there primarily due to the lack of air movement built in to the mechanical design of the facility.

Discussion

Open versus Closed Systems The physical nature of the area being monitored has a significant effect on how a well a CO sensor can perform the task of early warning. Of greatest importance is whether the area is open to the atmosphere or enclosed in some way as to limit gas migration. For the purposes herein, the first condition will be called *open*. It may also be called non-confined or unbounded. The second condition will be referred to as *closed*. The degree to which an area is sealed off or closed will vary across a wide range, and must be taken into account on a case-by-case basis.

The most obvious open area would consist of a live pile placed on the earth surface with no physical structure impeding the flow of gas from the coal pile into the atmosphere. Although it may not be impossible to use CO sensors in this location, the economics most likely dictates this is not a reasonable place to monitor. Any wind present will very quickly disperse any gas produced inside the pile. Setting sensors around a perimeter places the sensors far from the point of origin. If heating is taking place during the CO generation process, convection movement likely removes the gases upward and away from the pile. Earth-moving equipment is almost constantly changing the coal pile. Any CO sensor located close enough to the pile to be effective would also be prone to damage from this machinery.

At the other extreme, closed areas exist when an environment does not allow air movement to readily purge gas buildup within a contained structure. Examples include dust collector tubing, covered coal piles, and certain storage bin types. The less air movement allowed or forced through the area, the further toward a sealed or closed area this becomes. Reclaim tunnels can create a very good closed area if ventilation fans are turned off.

Most coal-handling facilities and their desired CO sensor locations will fall solidly between the two ends of the open-closed spectrum. Each facility contains unique construction design and operational characteristics that must be taken into account and dealt with in order to create an effective early warning system.

CO sensors generally trade off minimum detection limit, or resolution, with maximum detectable range. If a sensor is selected to have great resolution, it will not be able to measure high concentration without going into saturation. On the other hand, a sensor built to measure high concentration will tend to deal poorly with resolving very low concentrations.

The more open an area is, the greater the need for low range and high resolution. As areas progress toward closed, the greater the need for high range and low resolution becomes. At no point in time should an electrochemical carbon monoxide sensor be exposed to CO concentrations above the maximum permitted range. To do so will invalidate readings, shorten the life expectancy of the sensor, and potentially render the sensor permanently damaged.

In short, locations for the detection of CO must be thought out, proper equipment must be specified, and methods of operation defined.

Volume versus Volume Production A natural and unfortunate carryover from fire alarm warning systems in non-coal-handling industries (such as high-rise buildings, apartment complexes, etc.) has been the belief that carbon monoxide volume itself is an acceptable performance measure when dealing with potential combustions. This is due to the fact that little, if any, carbon monoxide is present during normal daily activities. The mere presence of CO in those structures is cause for alarm.

Coal handling facilities, like coal mines, must be treated in a different and more sophisticated manner when establishing levels for alarm.

Under normal operating conditions, there will be some amount of carbon monoxide produced at every location and area in which coal is transported, stored, or contained. The amount may be as low as zero in some circumstances. In that case, the normal reading of CO will also be zero, regardless of whether the area is Open or Closed. Any appreciable increase in concentration above zero can, and should, be cause for alarm notification.

In many locations, especially highly Closed areas, the true measure should be volume production rather than volume. Concentration is a volume measure only. Operators need to be more concerned about the amount of CO being produced within a location rather than the fact that some is present.

If a reclaim tunnel, storage bin, or dust collection system is running large volumes of air as part of its normal operation, dilution of carbon monoxide will take place and the concentration readings will tend to be low. If the ventilation fans are shut off, the carbon monoxide levels will increase greatly, even if the amount, or volume, of CO production remains constant.

In practice, then, operators must be able to determine whether concentration level is enough to set off alarms or if a combination of concentration and total air volume movement needs to be applied.

In order to achieve the above measure, CO sensors must be equipped with, and central computer stations must be capable of accepting, proportional concentration measurements. The use of relays, energized at fixed levels, does not provide enough information to effectively determine volume production.

When CO concentration is plotted over time, an effective and accurate performance measure of normal versus abnormal volume of production can be used to initiate alarms. Therefore, rate-of-rise is used as the performance measure rather than level.

In all areas of a coal-handling facility, whether level alarming or rate-of-rise alarming is used, a certain amount of time is generally needed to build up a knowledge base of what constitutes a normal condition and what does not. Changes in air volume, working conditions, or coal supplier may also force some amount of re-evaluation from time to time.