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Vol. 147 • No. 8 • October 2003



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Fire-protection guidelines for handling and storing PRB coal

Most plants that burn PRB coal were not designed to deal with the fuel's propensity to ignite in bunkers, silos, and hoppers. Recognizing this, the PRB Coal Users' Group has come up with a set of recommended practices for safely preventing, detecting, and extinguishing coal fires at power plants.

By Edward B. Doublerly, Utility FPE Group Inc.

The PRB Coal Users' Group has developed recommended fire-prevention practices and guidelines for plants that burn PRB coal by itself or in blends. The guidelines are not equipment-specific because the physical layouts of coal-handling facilities vary significantly and because all fires are unique. The guidelines also are not comprehensive; their purpose is to recommend general practices that must be adapted for the specific needs of your plant.

The guidelines provide information about three areas: fire prevention and detection, firefighting equipment and training, and firefighting.

Fire prevention and detection

Operators familiar with the unique requirements of burning PRB coal will tell you that it's not a case of "if" you will have a PRB coal fire, it's "when." The prevention of fires and explosions is the foremost objective for any plant burning PRB coal. Although prevention is cheaper than repairing fire and explosion damage, its costs always seem difficult to justify.

Fire prevention must be addressed in the following areas.

Housekeeping. Housekeeping means controlling dust and preventing spills. For example, float dust must be contained within transfer points, and spillage from belts must be minimized. The accumulation of PRB coal below a conveyor or on conveyor parts can contribute to spontaneous combustion. Float dust either in the air or settled on beams, pipes, conduits, equipment, and fixtures provides fuel for explosions. A manual, daily washdown with a hose is beneficial but generally is not totally effective in removing PRB coal debris from under conveyors or from overheads (Figure 1).

Fixed washdown systems designed for 100% coverage are commercially avail-

able, greatly reduce labor costs, and significantly improve housekeeping over manual washdown. Plants that have installed these systems report being satisfied with their performance.

Preplanning. For planned outages, operators should take every precaution to ensure that all idle bunkers and silos are completely empty and verify that by visual checks. Bunkers and silos should be thoroughly cleaned by washing down their interior walls and any interior structural members—but not their horizontal surfaces.

Idle bunkers and silos that contain PRB coal should be monitored frequently for signs of spontaneous combustion by using CO monitors, infrared scanning, or temperature scanning. Don't rely just on your

senses—by the time you see or smell burning coal, a fire is already under way (Figure 2).

Some plants make bunkers or silos of PRB coal inert with carbon dioxide (CO₂) when they are expected to sit idle. For this practice to be effective, the enclosure must be completely sealed—especially the bottom cone, because CO₂ is about 1.5 times heavier than air. The amount of CO₂ needed to effectively render an enclosure inert is 3.3 lbs per ft³, so a silo measuring 22 feet in diameter and 55 feet high would require 3.2 tons of CO₂. A bulk supply of CO₂ and an extensive piping system for bunkers and silos may be necessary to implement this system.

Bunker and silo design. An active bunker or silo typically doesn't experience



1. Debris dump. An extreme case of PRB coal accumulation at the tail of a conveyor not designed for PRB coal. Courtesy: Utility FPE Group Inc.

The two systems work hand-in-glove. The calculated optimum air-fuel balance at each elevation and corner is transmitted as a bias signal to the windbox damper controllers. The resultant closed-loop control minimizes NO_x production while ensuring that enough air flows with the fuel to minimize the formation of CO.

The TLN3 system was engineered, fabricated, and delivered to the plant in 16 weeks by Foster Wheeler. Modifications included installation of the SOFA take-off duct on the east and west sides of the unit. The duct was routed through existing structural members without restricting access to any wall blowers. Four SOFA windboxes were placed about 30 feet above the primary windbox (Figure 5).

The work also included changes to the plant's original windbox damper actuation system. New bearings were installed, damper compartments were modified to maintain control even if secondary air is lost, and damper actuator controls were upgraded to provide independent actuation and feedback to the plant control system. Watkins Engineers and Constructors Inc. (Tallahassee, Fla.) installed the equipment and made it operational in four weeks. In conjunction with this work, Watkins also installed new stationary coal nozzles that had been resized by Foster Wheeler to replace the lignite nozzles, which were worn out. Four new Beck nozzle-tilt drives with independent control and feedback replaced the original pneumatic drives that were actuated by a single demand signal.

The ECT-CADM fuel injection system already has been commissioned. With the complete system in service, the plant now enjoys a significant reduction in NO_x as well as improved O₂ distribution and temperature balance.

The final phase

Following the successful completion of rough combustion tuning during the 2002 spring unit outage, Emerson Process Management (Houston, Texas) began work tuning Gibbons Creek's WDPF 2 plant control system from Westinghouse Electric Co. This work was performed prior to precommissioning work on the Foster Wheeler fuel injection system to take advantage of the availability of the project team to troubleshoot the firing systems as they were being tuned.

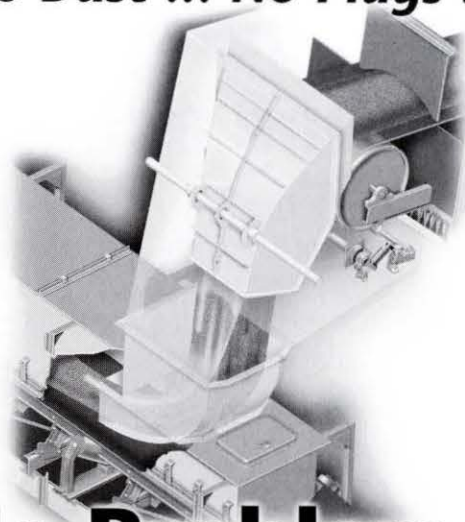
Because of new demands imposed by the Electric Reliability Council of Texas as part of its deregulation of the state's electricity market, the controls upgrade will allow Gibbons Creek to operate in true load-following mode rather than as a classic baseload plant. In this mode, the plant can respond more quickly to dispatchers' call for more supply to meet demand.

In addition to making the changes to Gibbons Creek's fuel-delivery and combustion systems, TMPA contracted with Pavilion Technologies Inc. (Austin, Texas) to install its Pegasus Power Perfecter artificial intelligence software to predict and manage NO_x-related parameters. The application has been effectively used at other utilities to lower heat rate, reduce emissions, and allow quicker, more efficient operation of boilers.

The bottom line

To date, the results of the NO_x-reduction project have been very encouraging. The emission rate for the pollutant has been documented at 0.11 lb/mmBtu, with CO emissions at 0.5 lb/hr. With some mill combinations, NO_x output at full load has averaged less than 0.11 lb/mmBtu. The unit's heat rate is less than 10,100 Btu/kWh, and temperature distribution is more even across the boiler. The saving in fuel costs resulting from the decrease in the plant's net heat rate is expected to be \$250,000 per year. TMPA personnel anticipate that, once system tuning is complete, Gibbons Creek's NO_x emissions will be less than 0.1211 lb/mmBtu with less than 10 ppm of CO. As a result, the plant may find itself in compliance with the 2005 TCEQ NO_x limit of 0.165 lb/mmBtu two years early. ■

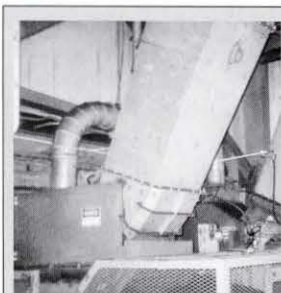
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2. Smoke means fire. Immediate response is required when an odor of coal roasting or burning is detected as coming from a silo, bunker, or hopper. Delays in taking action only allow the rate of burning to increase. *Courtesy: Utility FPE Group Inc.*

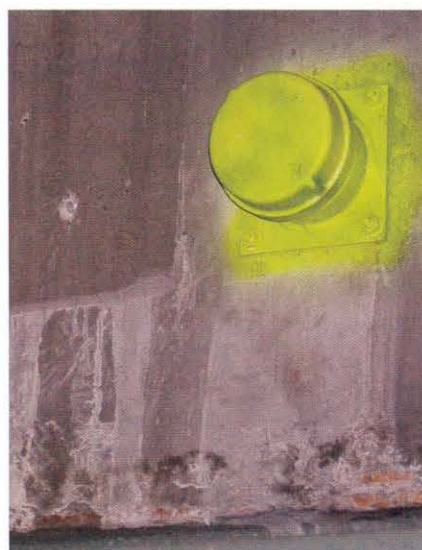
a fire under normal operating conditions. If a fire occurs while the bunker is actively moving coal, the bunker may have design irregularities that are contributing to coal bridging or some kind of stoppage. PRB coal is notorious for hiding within cracked weld joints and spontaneously combusting.

Although the construction of bunkers and silos differs from plant to plant, they

share one function that is independent of age and design: maintaining the mass flow of PRB coal. When raw coal is loaded into a bunker or silo, size segregation begins to take place. Large chunks of coal tend to roll out to the periphery of the bin, while smaller chunks and fines stay in the center. This size segregation facilitates air migration up along the sides of the bunker or silo. It also presents a practical fire-fighting challenge when applying water from above: Water tends to "rathole" through voids and can bypass the seat of the fire. Design changes in older plants may be required, such as eliminating flat bottoms in bunkers and obtaining free flow through bottom cones. If you don't have mass flow conditions, we recommend that you perform an evaluation of the cone's lining.

Access to the interior of bunkers and silos for firefighting is one of the most important aspects of successful fire suppression and one of the most difficult to obtain. Ease of access is often severely limited; the PRB Coal Users' Group recommends that you plan how to access hard-to-reach spaces. You may need to install access ports around the bunker or silo and at various levels (Figure 3).

Silos that are taller than 50 ft should be provided with access ports at various elevations to accommodate the injection of firefighting agents. The specific location of these ports must be determined by analysis



3. Thinking ahead. A firefighting access port retrofitted to a bunker not designed for PRB coal. *Courtesy: Utility FPE Group Inc.*

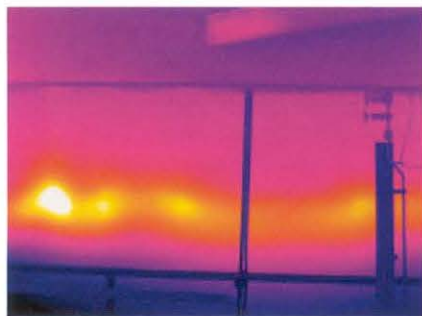
of the silo's design. Although directly attacking a fire using a piercing rod is most effective, using a rod on a fire in a silo taller than 55 ft is extremely difficult. You should consider installing a fixed hazard mitigation system zoned to apply an agent only at levels expected to be fire-prone. Use infrared thermography to locate fires and to determine the zone(s) that should be activated.

Fire and gas detection. A major consideration in minimizing the impact of fire is where to install gas- and/or temperature-monitoring devices in bunkers and silos. Each type of instrument has its own application criteria that also must be considered. Both types of monitoring devices have proven effective at early detection of fires at plants burning PRB coal.

CO monitoring. Monitoring for the presence of carbon monoxide is the way to find out soonest whether there is a fire in the making. CO is an odorless, toxic gas that is liberated at the very early stages of incomplete combustion. CO is flammable at 12% to 75% volume in air (OSHA's permissible exposure limit for CO is 35 ppm at an eight-hour time-weighted average). Though it may be normal to experience a rise and fall of background CO levels in bunkers and silos during normal operation, monitoring will provide notification if the gas begins to continually trend upward from background levels. Desired alarm setpoints can be determined after the normal background level of CO is determined for your particular plant. The best way to make use of CO monitoring is to watch for a continuing upward trend of CO rather than to wait for the level of CO to reach a specific setpoint.

Thermal monitoring. Thermal detection, using thermocouples, also can provide an indication of a fire inside a bunker or silo. However, thermal detection will not provide the early warning that CO monitoring does. Thermal detection relies on the presence of heat to activate, so a fire may already be of considerable size before the thermal detector senses the excess heat.

Infrared scanning. Coal is a very good insulator, so a deep-seated fire may not produce extremely high temperatures on the exterior surfaces of a silo or bunker. Periodic monitoring of the bunker or silo using an infrared thermographic camera to scan the outside and/or inside of the enclosure is a common practice. Such a scan (Figure 4) provides a visual picture of the coal's thermal condition and is especially helpful at pinpointing the exact location of a hot spot deep inside a silo or bunker.



4. A thermographic image of a PRB coal silo fire. The fire, shown by the lighter horizontal strip, follows a weld seam around the contour of the silo. The fire layer is approx. 5 ft in depth and is about 12 ft below the surface of the coal. *Courtesy: Utility FPE Group Inc.*

Firefighting equipment and training

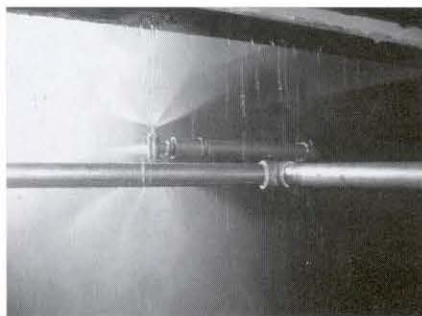
Dealing with a fire inside a bunker or silo is a dangerous business that must be addressed with the correct equipment and training. There are three recommended methods for fighting a silo or bunker fire: using a fixed system installed inside the enclosure, using a special tool called a piercing rod, or both. Experience indicates that the very best method of attack is to get the extinguishing agent directly to the seat of the fire. If you have an organized and thoughtful game plan, you will usually have plenty of time to deal with the fire.

Fixed hazard mitigation systems.

Fixed (permanent) systems installed inside bunkers or silos must be designed specifically for that enclosure. Such systems are not fire-suppression systems per se. They are hybrids that can be used for dust control and housekeeping or activated to deliver an extinguishing agent in the event of fire. The downside of fixed hazard mitigation systems is that they must flood their entire enclosure with the agent to have any chance of reaching the fire's hot spot (Figure 5).

Silos taller than 55 ft should be zoned so that the extinguishing agent can be directed to any section of the silo that's susceptible to fire. The zoning also may require activating a zone discharge at the level just above the fire. It is recommended that the mitigation system be prepared to deliver a mixture of water and a micelle-encapsulating agent.

Manual firefighting tools. Experience has shown that the best method of extinguishing a fire is to get the agent directly to its seat. To do this, you have to know the location of the fire within the enclosure, have access to the enclosure, and have the



5. A hazard mitigation system installed inside a silo. It sprays a combination of water and F-500. *Courtesy: Utility FPE Group Inc.*

proper tools to deliver the agent.

The primary tool used to deliver agent directly to a hot spot is a piercing rod (Figure 6). These rods are designed to pierce the surface of the coal and be manually maneuvered to the hot spot. The benefit of piercing rods is that they can be used to render inert the bunker or silo atmosphere by spraying the sides and surface of the coal with agent prior to storing it.

The rod is assembled in 5-ft sections. But the longer the rod, the harder it is to maneuver it inside the enclosure. Rods are generally made of stainless steel and come in several diameters (0.75 inches, 1.25 inches, and 1.5 inches). The tip of the rod is perforated and cone-shaped, which allows it to be easily inserted deep into the coal and used at any angle. The rod can be

inserted through the top or the sides of the enclosure if access ports have been preinstalled.

Using a fire hose to stream water through the top of a bunker or silo is definitely not recommended. Nor is using a stream to "drill" into the coal in an attempt to reach the fire. This technique most likely will stir up the coal and dust and result in a flash explosion inside the bunker or silo. A secondary explosion can also occur outside the enclosure as the heat ignites float dust in the air.

Fire-extinguishing agents. Many extinguishing agents are suitable for use on coal fires. The table (page 73) describes the extinguishing properties of several agents.

Plant fire training. When a fire does occur, an operator's first instinct will probably be to try to fight it. It is strongly recommended that no one without proper training, of at least the structural fire brigade level, attempt to put out a fire in a bunker, silo, or hopper. Personnel who have been trained at the incipient fire brigade level or lower are not properly trained to fight such fires. Municipal utilities that may be exempt from complying with OSHA training regulations should not exploit that status by avoiding proper training. OSHA's 1910.156 Fire Brigade Standard delineates the training levels.

Dialing 911. Some plants rely on the services of their local fire department. However, be cautioned that most municipal fire departments are not prepared to deal with a



6. Piercing rod. An emergency response team gets basic training on using a piercing rod on a coal pile fire. *Courtesy: Utility FPE Group Inc.*

Properties of typical firefighting agents

Agent	Properties
Water	Water can be effective at fighting PRB coal fires. However, water alone is not recommended. The surface tension of water does not allow it to penetrate deep below the coal's surface and reach the fire unless large quantities are injected. Large quantities of water inside a bunker or silo will ruin the coal inventory and may place additional loading on structural members.
Wetting agents	Wetting agents allow water to penetrate Class A material by reducing the surface tension of the water. They extinguish by cooling.
Foams	<p>Foams contain a wetting agent that acts as the carrier of the foam. The primary function of foams is to blanket the fuel's surface, thereby reducing the oxygen supply.</p> <p>Foams are not very effective on coal fires due to the length of time it takes to smother a coal fire and the need to keep the foam blanket in place. Mechanical foams also tend to break down and dissipate before the fire is completely out.</p> <p>Deep-seated Class A fires cannot be effectively extinguished with foams. Foams that pass UL Fire Performance Criteria are Class B.</p> <p>Foams that do not pass the test are classified as Class A and do not meet any usage criteria other than the manufacturer's own recommendations.</p>
Micelle-encapsulating agents	<p>These agents, when used with water, are the extinguishing media of choice for PRB coal fires and for flammable liquids fires (Class A and B fires).</p> <p>These agents have the following three suppression mechanics:</p> <ul style="list-style-type: none"> ■ Micelle formation. On Class B fires, the agents encapsulate both the liquid and vapor phase molecules of the fuel and immediately render them nonflammable. ■ Surface tension reduction. The agents reduce the surface tension of water from 72 dynes/cm² to less than 30 dynes/cm². This action provides up to a 1,000% increase in the wetted area, compared with using water alone. ■ Free radical interruption. The agents interrupt the free radical chain reaction of the fire tetrahedron. For this application, they are governed by NFPA 18 and are listed for both Class A and Class B usage. Agents can be used effectively on coal fires at concentrations of 0.5% to 1.0%.
Other agents	Gases such as CO ₂ and N ₂ have been tried as fire-suppression agents but have not proven effective. Reasons include their poor cooling capacity and their general inability to maintain proper concentration levels in bunkers and silos. Accordingly, these agents require extended use—for hours or even days—depending on the quantity of the coal burning and the complexity of the fire. Independent testing has shown that the effectiveness of gases is a function of fuel geometry, the stage of the fire, the tightness of the enclosure, and the duration of application.

Source: Utility FPE Group Inc.

PRB coal fire. It is strongly recommended that the plant sponsor specialized training for the local fire department on the specifics of PRB coal and other major fire hazards found within the plant.

Firefighting

The PRB Coal Users' Group recommends a three-step approach to firefighting. Those steps are summarized below; full details are available in the guidelines, which are posted on the group's Web site.

1. Develop an action plan. This step entails initial investigation of the suspected fire, performance of a thermographic survey, mapping the fire within the bunker or silo, and suspending coal-feeding operations to the affected area.

2. Prepare the area. After the action plan has been developed, the next step is to prepare the area for firefighting operations by neutralizing dusting in the immediate area, ventilating the area, and staging equipment and personnel to prepare to attack the fire.

3. Extinguish the fire. After all preparations have been made, firefighting can begin. Monitoring the fire at this stage is key to the effort's success.

A final note

The PRB Coal Users' Group's Coal Bunker, Hopper and Silo Fire Protection Guidelines are available in the member's section of www.prbcoals.com. They are intended for use by personnel with the experience and training required to safely deal with the hazards of coal fires. The guidelines were written by Ed Douberly—president of Utility FPE Group Inc. and a member of the PRB Coal User's Group board of directors. Expertise and peer review were provided by Eric Dorbeck, PE (Consumers Energy); John Ritter, PE (PacifiCorp); Jim Beller, PE and Bob Taylor (American Electric Power); Norm Rockwell (Tennessee Valley Authority); Jim Coco, PE (Marsh Inc.); and C.E. Wilson (Southern Company). ■



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