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Fire Detection Methods for Coal Pulverizer Systems

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ABSTRACT

The Electric Power Research Institute (EPRI) performed an extensive investigation on fire detection for coal pulverizer or mill systems. The studies showed that there is an emergence of low rank, high reactive coals as a base fuel for power plants which is resulting in an increase in pulverizer system fires. Also, the EPRI study concluded that reducing the frequency of fires would reduce the risk of coal dust explosions. Unfortunately, less than 15 percent of the power plants have adequate fire detection systems for coal mills. The small group that has implemented different detection techniques has created a controversy over the reliability and effectiveness of detection methods. The EPRI project studied four fire detection methods: carbon monoxide monitoring, oxygen monitoring, temperature monitoring and infrared detection. Their performances are compared using the three basic mill systems. In addition, the effects of variations in operating conditions and coal reactivity are included. A major finding of the investigation is that each detection device is only effective under a limited set of conditions. Some methods may prove to be useless if they are applied to the wrong situation. In many instances a combination of methods is required to effectively detect fires in coal pulverizer systems.

DETECTOR TYPES

Currently, there is no standard method of detecting fires and there is no standard to determine what constitutes a fire. Some plants report a fire when the temperature control for coal drying cannot maintain temperatures below the alarm set point. However, at the time the alarm is sounded, the fire is generating more heat than is required by the primary airheater at full coal flow. Other plants report a fire after the paint starts peeling or when the equipment glows red. Because of the importance of quickly detecting fires, the paper discusses the advantages and disadvantages of different detection methods.

The methods discussed are carbon monoxide (CO) monitoring, differential temperature ($\triangle T$) monitoring, oxygen (O_2) monitoring, and infrared (IR) detection. There is no attempt to evaluate various manufacturers of similar systems. The investigation looks at the generic types of systems and how they function under different situations.

Carbon Monoxide Monitoring

CO monitoring samples the fuel/air mixture generally near the classifier exit. After a baseline of normal level of CO is determined, a rise in the CO level is interpreted as a pocket of smoldering coal. Without complete combustion, a smoldering pocket of fuel will produce CO. This type of monitoring has proven effective on pulverizer systems grinding bituminous coals that have high autoignition temperatures. When the autoignition temperature of the coal is higher then the operating temperatures of the drying air, pockets of coal will generally smolder prior to developing an open flame. The limitations encountered by CO monitoring include difficulties with detecting open fires. If sufficient air is present, the CO is converted to carbon dioxide (CO_2), and CO is no longer present for detection. This problem becomes more pronounced as the coal rank decreases. The lower the coal rank the lower the autoignition temperature of the coal. Another problem occurs when the CO enters the system from external sources. Entrainment from a leaking air heater, or smoldering fuel in the coal feed system will confuse detection. The problem of outside entrainment can be eliminated by measuring the CO differential across the mill. Comparing the inlet and outlet CO allows the system to alarm only when CO is generated in the mill.

Differential Temperature Monitoring

Monitoring of the change in fuel/air temperature as it passes through mill system equipment is used to determine if there is a heat source present in that equipment. Because the change in temperature is all that is being considered, the equipment operating temperatures do not affect detection. This type of detection is most effective with mills that mix the primary air and fuel prior to entering the mill system. The premixing allows interpretation of temperature differentials independent of mass flows. The mass entering any piece of equipment is equal to the mass exiting. If fire enters the mill from storage and exits the mill, there is little or no change in the differential. If the fire remains in the system, the ΔT will change. The ΔT detection functions effectively over a wide range of coals but not with all mill systems. Systems where the primary air and the fuel are combined in the mill do not allow for effective ΔT monitoring.

Because the temperatures in mill systems are affected by many external events which are not fires, the use of absolute temperatures for fire detection creates confusion. For example, high temperature alarms can be caused by changes in fuel feed rate, fuel type, fuel moisture, and equipment malfunction. Operators are required to determine the cause of the alarm by elimination. Only after all possible causes are investigated will the operator conclude that the high temperature is caused by a fire. However, considerable time may pass while a potentially dangerous situation exists. The high temperature alarms only inform operators of control problems, the ΔT alarm alerts to a fire.

Oxygen Monitoring

Monitoring oxygen gives an indication of the available O_2 exiting the mill system. When a fire is present a percentage of O_2 is converted to CO_2 and the exit O_2 content is reduced. However, with O_2 monitoring, smoldering pockets of fuel are not easily identified. This detection system has more success with high reactive coals. As the fuel autoignition temperature approaches the primary air temperature, open fires are more common. This condition would be detected more readily by monitoring O_2 exiting the system. If the primary drying system contains gases other than air, differential O_2 monitoring may be needed to eliminate the outside influence.

Infrared Detection

Infrared sensors detect infrared emissions from a heat source in predetermined ranges of infrared wavelength. The detectors are very accurate when discriminating between various temperatures. However, the detector must have a direct line of sight to the emitting body. Smoldering deep seated fires will not be detected until the surface temperature of the fuel has increased to the range of the instrument. The infrared detector has been very successful for fire detection in the section of vertical spindle mills below the grinding area. Independent detection in this area would give the operator additional knowledge of changes in mill conditions. Another area for infrared detector application is the coal feed inlet connection to a mill. Operators would be informed of fires entering the mill from storage. Plants utilizing this knowledge would be able to eliminate the risk of reducing fuel feed while fire is entering the mill.

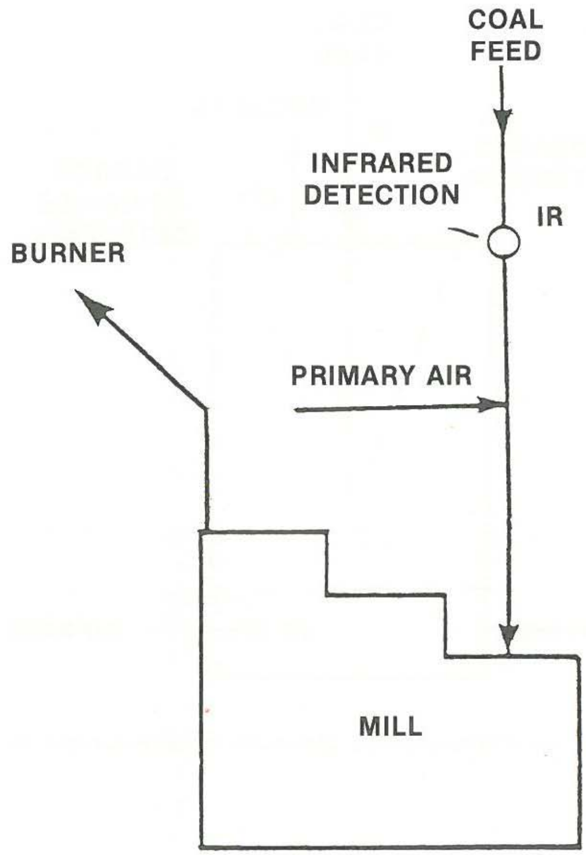

Figure 1 Suggestions for Enhanced Fire Detection on Attrition Mills

MILL TYPES

Three different generic types of mills were investigated: vertical spindle, ball, and attrition mills. Because of operational and physical differences between the mill types, different detection devices are required for each.

There is no detector system that is compatible to all situations. The added consideration of variations in coal types creates situations where a combination of detection devices may be necessary to produce an effective system.

Attrition Mills

The attrition mill is a high speed mill with little capability for retaining coal. Therefore, fuel pockets cannot form and create a smoldering fire. If fire enters the mill from storage, detection could be made only by infrared detectors at the inlet. Because the product moves through the pulverizer in approximately 30 seconds, the reaction time is limited. There does not appear to be a problem with bituminous coals. However, attrition mills grinding subbi tuminous coals should be considered for installation of infrared detectors in the mill feed line to monitor burning product exiting storage. An example of this is shown in Figure 1. High temperature or fire passing through the fuel system may cause extensive damage to the transporting equipment, even though the risk of an explosion is low.

Vertical Spindle Mills

The vertical spindle mill is a medium speed pulverizer and maintains a considerable amount of fuel in the mill system when operating. Coal collects on the grinding table, in the classifier, in the pyrite collection section below the grinding table, and at the fan exit for exhauster systems. These are the prime locations of fires. Fire detection of the complete system by one device is not accomplished easily.

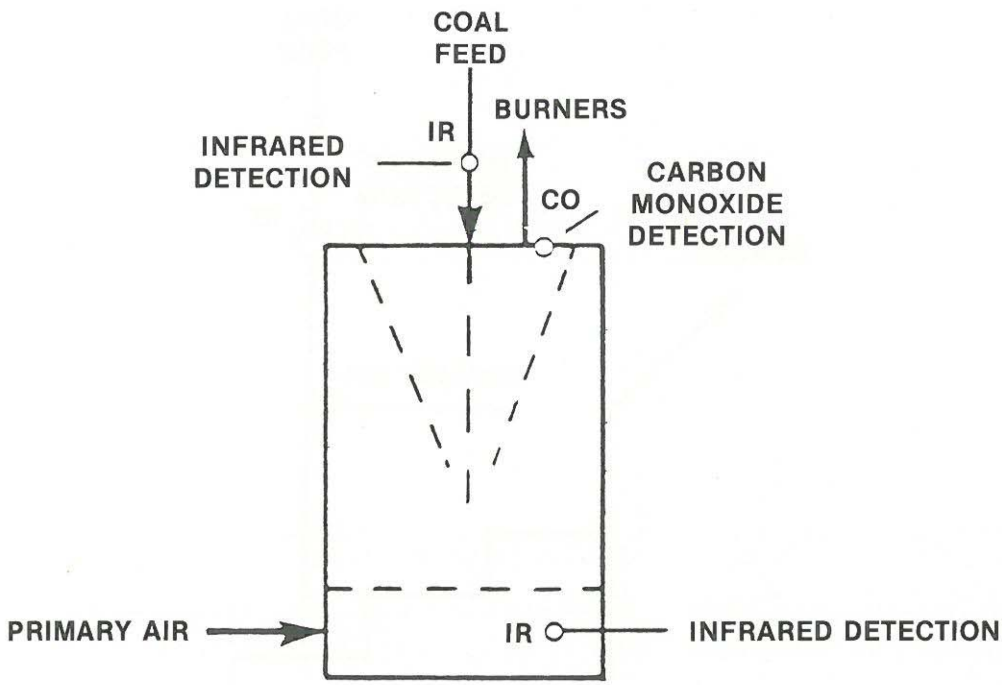

Figure 2 Suggestions for Enhanced Fire Detection on Pressurized Vertical Spindle Mills

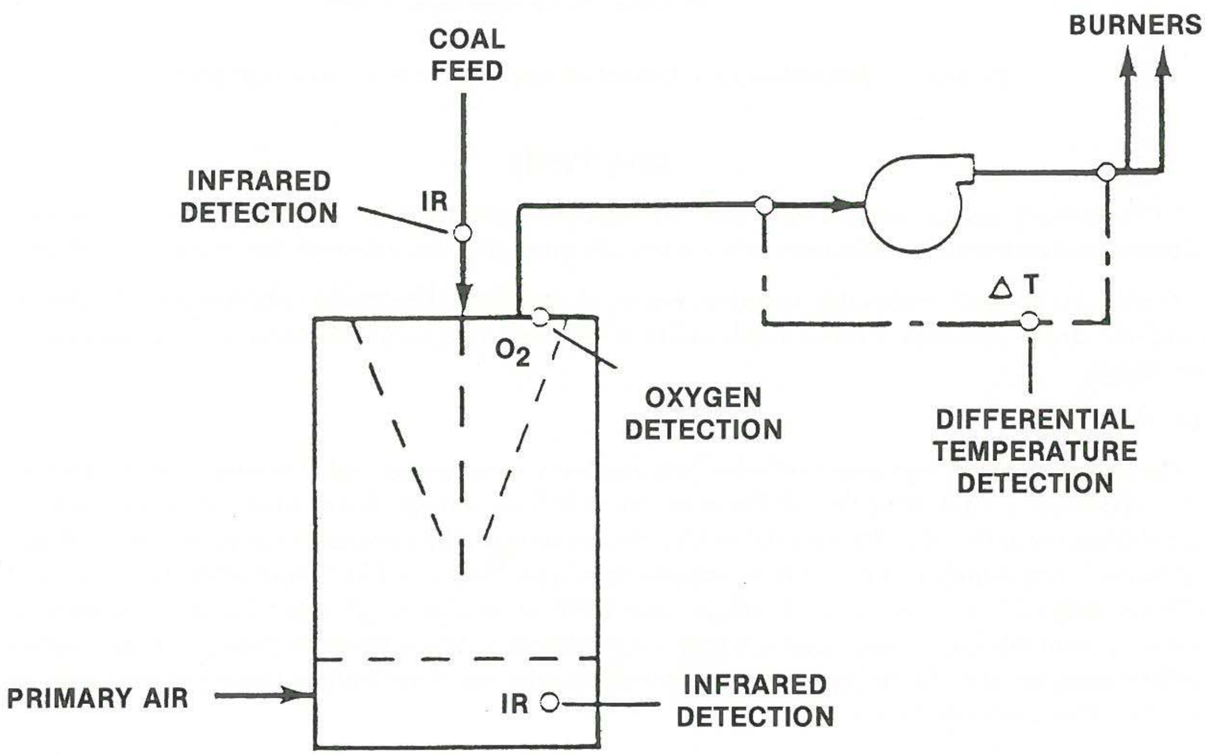

Figure 3 Suggestions for Enhanced Fire Detection on Vertical Spindle Mills with Exhauster

Bituminous coals with relatively high autoignition temperatures will smolder for considerable lengths of time prior to flaming. CO monitoring will detect the smoldering but will not determine the location. Because smoldering may continue for a considerable length of time, plants with extremely low frequencies of fires may only need to know that there is a fire developing. Then time would allow for consideration of corrective action. Vertical spindle mills grinding subbituminous coals usually experience a much higher frequency of fires. Fires may occur in a variety of locations and may or may not be smoldering depending on its position. Fires in the pyrite collection section or near the primary air inlet are usually open flames. Fires on the grinding table and in the classifier can be either smoldering or open flames. Areas upstream of the classifier more often produce smoldering fires. A major problem of grinding subbituminous coals is a high probability of burning coal being fed into the mill from storage. This event will upset detection devices and can be misinterpreted by operators.

System configurations determine the devices that are necessary for proper fire monitoring of the pulverizer system. An extreme example would utilize IR, CO, O_2, and ΔT. IR detectors could be placed in the coal feed and at the lower mill near the primary air inlet area. CO and O_2 monitoring could be used at the exit of the classifier and ΔT measured across the exhauster section. The reactivities of the fuel require the consideration of different fire detection devices. For example, mills grinding a very reactive fuel may utilize O_2 monitoring at the classifier exit, while mills with a low reactivity coal that tends to smolder at operating conditions would utilize CO monitoring. A medium range coal may require both devices for complete detection. Figures 2 and 3 illustrate a detection system for vertical spindle mills operating pressurized and with exhausters respectively.

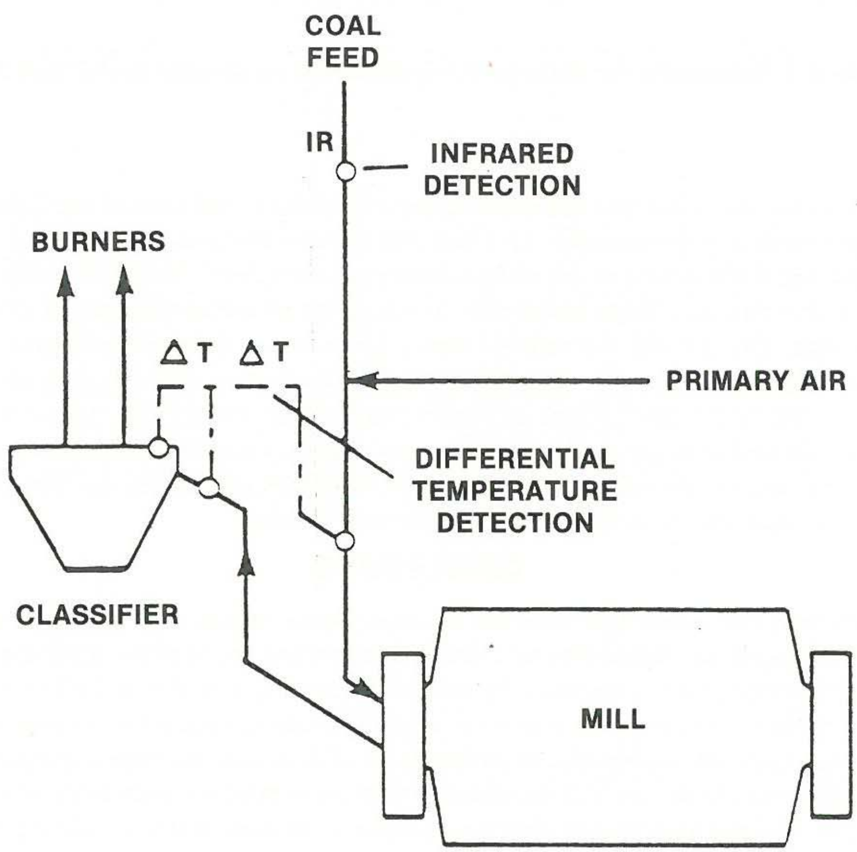

Figure 4 Suggestions for Enhanced Fire Detection on Single Ended Ball Mills

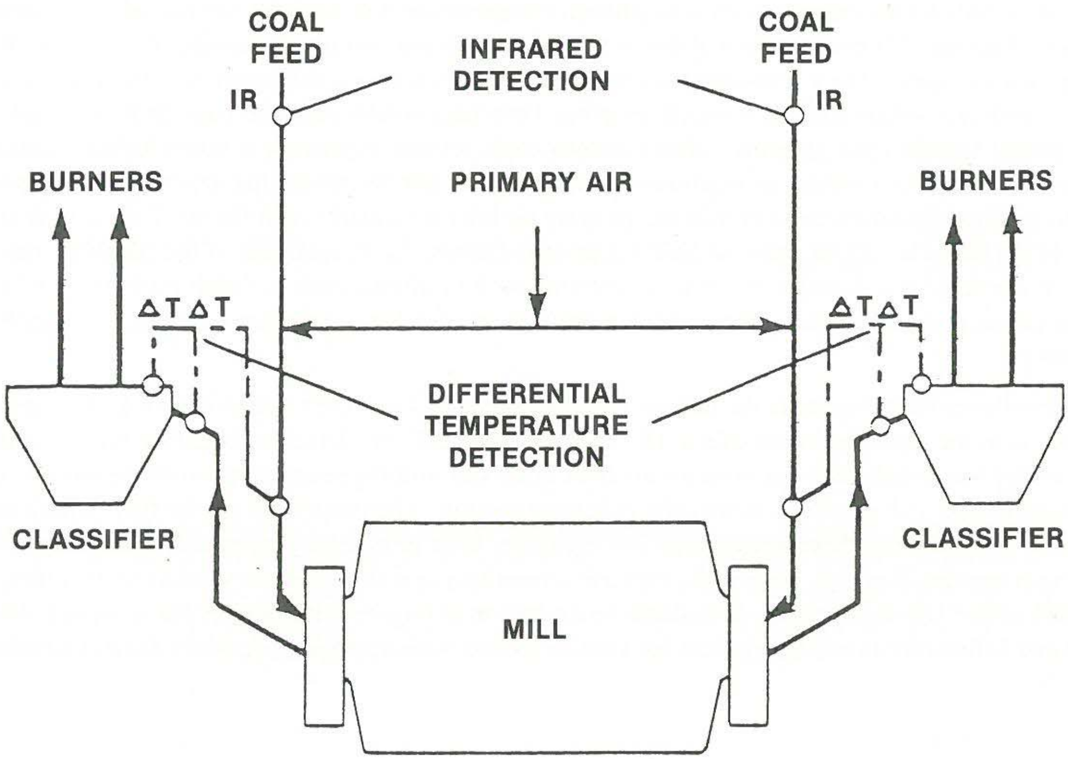

Figure 5 Suggestions for Enhanced Fire Detection on Double Ended Ball Mills

Ball Mills

The ball mill is a slow speed mill and has two primary areas where coal pockets can exist and create fires: the inlet/outlet ductwork and the classifier. In a ball mill the raw fuel and the primary air are mixed prior to entering the mill and initial drying of the surface moisture is completed. With this condition ΔT monitoring is known to be effective. In a single ended mill the temperatures are taken upstream of the mill inlet and at the classifier outlet. The ΔT will determine if heat is generated in the monitored area. In double ended mills an alternate approach is to employ ΔT monitoring across the two classifier exits to determine if heat is generated in one side or the other. Users of reactive coal should consider IR detectors on the coal feed to keep operators informed of developments in the supply. Figures 4 and 5 schematically represent the detection system for single and double ball mills. Differential CO and O_2 monitoring can also be effective on ball mills and would function similar to the vertical spindle mill system.

CONCLUSIONS

There is no detection devise that will work for all applications of coal type and mill systems. The more reactive the coal, the higher the probability of a fire and the greater the need for detection. The rank of the coal will effect the selection and placement of the devices. The mill system also will effect the type and placement of detection devices. Attrition mills may require an IR detection system for operator information. The vertical spindle mills could conceivably require all four types of devices to develope a comprehensive detection system. The ball may require IR and ΔT monitoring to provide effective knowledge to the operator. Fire detection devices on coal mill systems will alert the operator to burning material entering or within the mill.

Normal mill shutdown sequence should not be started or continued if a fire is detected. A fire entering or present in the mill system when the system is being removed from service will greatly increase the risk of an explosive event. When a fire is detected during this or other transient condition, the mill should be tripped and fire extinguishing activated. Correspondingly, a mill in a start up mode or while changing load that has a fire or the injection of a fire, will greatly increase the risk of an explosive event.

It is suggested that the system should not require constant operator monitoring. Alarms should be used to signal a system deviation with trend charts and digital readouts for investigation of a deviation. Extreme care should be taken to present the operators with clear information. Conflicting information or large amounts of raw data may lead to confusion and result in actions different from those expected. With adequate information the operator can take corrective action early and avoid panic decisions. Because of individual equipment configurations, the manufacturers of detection devices and mill equipment should be consulted on the selection of probe placement.

The systems presented here are only representative. There are many variations that will function for different equipment and fuels. Each user must determine the specific requirements of their detection systems, as well as the extent of operator action for the operation and monitoring of the systems.

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