PULVERIZED COAL-FIRED BOILERS

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1.0 SCOPE

This data sheet addresses the hazards associated with the firing of pulverized coal (anthracite, bituminous, sub-bituminous or lignite) in multiple-burner boilers. The guidelines may also be applied to the firing of other pulverized or granular carbonaceous fuels. However, each installation must be carefully evaluated, with consideration given to the characteristics of the fuel, the hazards involved, suitability of the equipment, and need for special protection. Refer to Data Sheet 6-13, *Waste Fuel-Fired Facilities,* for information on alternative fuel-firing. Related data sheets are Data Sheet 6-6, *Boiler-Furnaces Implosions*.

1.1 Changes

July 2023. Interim revision. Minor editorial changes were made.

2.0 LOSS PREVENTION RECOMMENDATIONS

2.1 Equipment and Processes

2.1.1 Firing Equipment and Flame Supervision

2.1.1.1 Igniters, SSOVs, and Flame Supervision

The following equipment recommendations for igniters, safety shutoff valves (SSOVs) and flame monitoring pertain to safe ignition and continued safe firing of igniter fuel and coal (Table 1).

Table 1. Igniters, Safety Shutoff Valves and Flame Supervision

Type of Equipment	*Requirements*
Igniters	Class 1 or Class 2
SSOVs for individual igniters and auxiliary fuel burners	2 SSOVs, 1 with proof-of-closure; both SSOVs with proof-of-closure if igniter > 12.5 MM Btu/hr
SSOVs for igniter and auxiliary fuel main and header lines	1 SSOV with proof-of-closure for the fuel main and for each header line
SSOVs for coal burners	1 swing gate with proof-of-closure for each coal feed pipe
Flame supervision for igniters and warm-up burners	Interlock flame scanner with individual SSOVs, and with either coal burner SSOV or pulverizer if no flame supervision is provided for coal burners
Flame supervision for coal burners	Required if coal burners are not provided with Class 1 continuous igniters

2.1.1.1.1 Install permanent Class 1 or Class 2 igniters for ignition of pulverized coal. The decision to use Class 1 or Class 2 igniters will depend on whether there is separate flame monitoring for the main burner and the igniter, and the conditions under which the burners and igniters will be fired.

Class 1 igniters are sized to provide sufficient energy to reliably ignite any combustible fuel-air mixture through the burner. These igniters may be left in operation continuously and if provided with flame supervision, are adequate proof of main burner flame.

2.1.1.1.2 Install two individual safety shutoff valves for each fuel-fired igniter and/or warmup burner; ensure at least one valve has positive proof-of-closure (such as valve seal over travel). For igniters and warm-up burners rated greater than 12,500,000 Btu/hr, ensure both safety shutoff valves have proof-of-closure.

In addition, gas safety shutoff valves with proof-of-closure need to be proved closed after shutdown. Ensure an audio-visual alarm will annunciate in the control room if a valve does not fully close.

Where energize-to-trip safety shutoff valves are used, provide redundancy as needed and design control power to be reliable so that a single event (e.g., loss of control power, relay failure, or fire) will not prevent these valves from being closed during a master fuel trip.

2.1.1.1.3 Install safety shutoff valves with positive proof-of-closure in the igniter and auxiliary fuel main line and header lines.

For gas-fired warm-up burners that use energize-to-close safety shutoff valves, install a motorized main shutoff valve (energize to open and close). Install end switches on the valve arranged to indicate the closed and wide open positions in the control room. Verify the main gas valve is closed immediately after shutdown and before startup for all boilers.

2.1.1.1.4 Install a safety shutoff valve (swing gate damper) with positive proof-of-closure in the coal feed pipe to each burner.

2.1.1.1.5 Provide flame supervision for each fuel-fired igniter and warm-up burner; interlock with individual SSOVs. Also interlock with coal burner SSOV or pulverizer if the coal burners are not provided with separate flame supervision. Ensure igniter(s) and flame sensing element(s) are securely installed so the position of each with respect to the others and the main burner will not change. Provide observation ports so these positions can easily be observed while the igniter and/or burner are firing. Equip flame scanners with a self-checking feature to protect against scanner malfunction, and provide them with cooling air. Ensure these units are readily accessible for inspection and cleaning.

2.1.1.1.6 Provide flame supervisory equipment for the main coal burners that are not equipped with continuously operated Class 1 igniters; interlock with individual coal pipe swing gate. See Section 2.1.2.4, Main Flame Failure Interlocks. Provide flame intensity meters or other means to enable the operator to detect deteriorating signal strength due to poor combustion or dirty lenses on the scanner or sight tube. Equip these scanners with a self-checking feature to protect against a scanner malfunction. Also provide them with cooling air, minimize soot accumulation around the lenses and inside the sight tubes in order to prevent nuisance tripping.

2.1.1.2 Low NO_X Firing

2.1.1.2.1 Take proper precautions when methods for reducing oxides of nitrogen (NOX) emissions are used as the potential for combustion upset and/or furnace explosion may increase. Precautions include the following:

A. Some NO_X reduction methods tend to increase the possibility of unburned combustibles and may reduce the tolerance for safely overcoming a combustion upset. Some of the more recent developments overcome this problem when properly tuned and optimized. CO analyzers are generally recommended for early warning of deteriorating combustion conditions.

B. Low excess air operation, particularly when excess oxygen is used for final trim of fuel air ratio control, demands accurate and reliable O_2 analyzers. Significant variation may be found in the O_2 distribution within the flue ducts. It is recommended that multiple instruments and sampling points be utilized. Localized combustion instability can occur even with other burners firing normally. Thus, for control purposes, use worst case conditions rather than average conditions, as the controlling variable.

Limit oxygen trim of the combustion control system, to avoid a runaway condition and possible air deficiency in the event of an instrument malfunction. Ensure “out-of-limits” O_2 readings are alarmed. Exercise caution to ensure that multiple instruments are properly wired to the control system to protect against false indication of high oxygen when maintenance is performed or an instrument is removed from service.

C. Perform flame stability tests to verify transients generated by burner fuel and air subsystems do not adversely affect burner operation.

D. Changes in flame characteristics may require relocation of flame scanners on existing units.

E. Perform instrument calibration in accordance with the manufacturers’ recommendations at various loads.

F. Burner optimization is critical to safe operation of new low NO_X burners, and must be done by highly trained personnel. Many problems can arise during the break-in period, resulting in adjustment to equipment or even a redesign of components. The state-of-the-art technology used in these burners, together with a more sensitive control system, help offset the risk associated with the inherent instability of these burners.

G. Flue gas recirculation is used to control the heat absorption rates in various parts of the furnace, superheaters, reheaters, and economizers, and can also be used as a method of NO_X reduction. Flue gas from the outlets of the furnace, economizer, or air heater may be reintroduced low in the furnace, at the burners, or as tempering gas near the furnace exit. When mixed with the secondary air or admitted at the burners (methods typically used for the purpose of minimizing the formation of NO_X), combustion can be adversely affected. Ensure the system is designed for adequate flue gas-air mixing. The ratio of flue gas to air, or the oxygen content of the mixture, needs to be monitored and properly controlled. Excessive flue gas recirculation to the burners can result in off-ratio firing or flameout. Whether the flue gas is induced by the forced draft fan or the burner itself, or delivered by a separate fan, the correct amount of flue gas recirculation needs to be delivered at all loads and during load changes.

2.1.1.3 Natural Gas Reburn

2.1.1.3.1 If reburn is used as a means of NO_X control, only use natural gas as the reburn fuel. See Figure 1 for an illustration of a furnace with gas reburn.

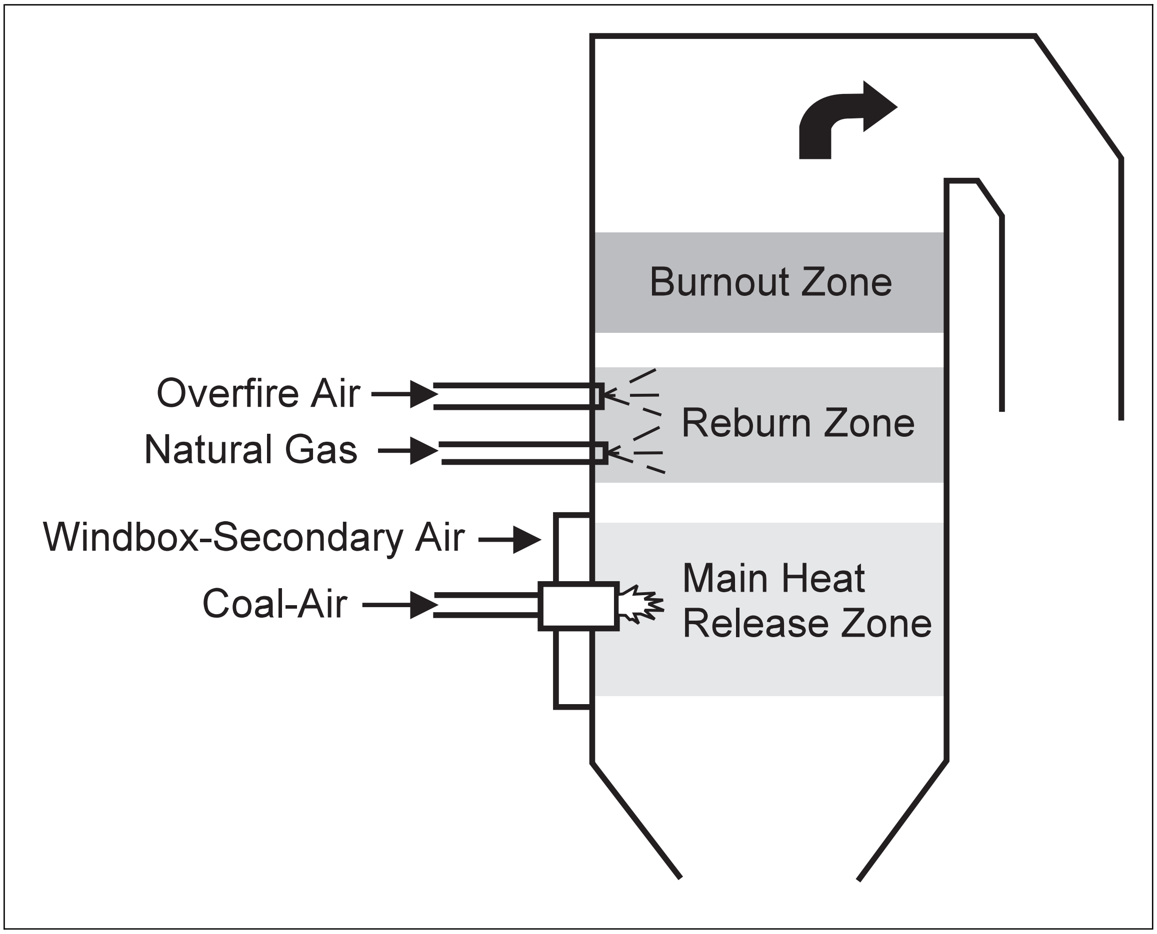

Fig. 1. Illustration of basic reburn system

2.1.1.3.2 Do not operate a reburn system at a rate higher than 20% of the total heat input. Excessive reburn can result in unburned gas exiting the furnace and causing an explosion in downstream equipment, such as an electrostatic precipitator. Unburned fuel might result from a fuel-rich mixture, not enough residence time, or quenching of furnace temperature.

2.1.1.3.3 Do not start the reburn system until the boiler is up to at least 50% of full load or within its normal operating control range, whichever is higher. This ensures that combustion is stable and furnace temperature is high enough to auto ignite reburn gas. Provide an interlock for this purpose. This interlock will serve as a reburn system start permissive and trip. It can be based on steam flow, furnace temperature or some means to prove that the boiler is operating at or above a specified load. Ensure the load is high enough so the furnace temperature in the area of reburn is at least above 1400°F (760°C) for the entire area of the furnace where the reburn fuel reactions are expected to occur. Also, there may need to be a minimum number and location of burners in service to achieve a temperature profile that optimizes the reburn reactions. Temperature profile also may be affected by the location of burners in service.

2.1.1.3.4 Provide an interlock to ensure the boiler is in the automatic mode before reburn system startup, and trip the reburn system when the boiler is switched to manual operation.

2.1.1.3.5 For reburn systems that use substoichiometrically fired burners, install an igniter, a flame scanner and all safety controls required for a conventional burner gas train. Ensure enough excess air is available to fully oxidize reburn gas (i.e., reburn gas that did not react with NO_X), whether the air is supplied from overfire air ports or through the burners themselves. Provide a low airflow interlock in the overfire air supply and reburn burner air supply systems.

2.1.1.3.6 Ensure there is enough excess air to fully oxidize injection reburn gas (i.e., reburn gas that did not react with NO_X) by means of a flow device in the air supply whether it is overfire air or secondary air. Set the device to prove there is at least enough air for minimum reburn firing. Interlock with reburn gas safety shutoff valves. The interlock will serve as a reburn system startup permissive and trip.

2.1.1.3.7 Install two safety shutoff valves with proof-of-closure for each reburn injector/burner or each group of burners/injectors that are operated together as a system.

2.1.1.3.8 Install high and low gas pressure switches interlocked with the reburn safety shutoff valves.

2.1.1.3.9 Design and locate injectors to ensure thorough mixing of the reburn gas, air and flue gases.

2.1.1.3.10 Provide either a CO or combustibles analyzer, and provide O_2 monitoring of the flue gas. Locate sensors downstream of the reburn area.

2.1.1.3.11 Operate reburn injectors as one system with fuel/air being controlled equally and simultaneously to all operating injectors. Ensure airflow leads reburn gas flow when increasing load, and lags when decreasing load.

2.1.1.3.12 Design the reburn system so the rate of increase of gas injection cannot exceed the response capability of the main combustion control system. Control of airflow must be more responsive than reburn system control.

2.1.1.3.13 Place the overfire air system (if applicable) in operation before reburn startup. Ensure air is ramped up before reburn fuel startup.

2.1.1.3.14 Ensure a master fuel trip (MFT) trips reburn fuel, but ensure overfire air remains at the same setting until the main combustion control system demands a change for unit purge or cool down.

2.1.1.3.15 If the reburn system trips, decrease overfire air and increase secondary air as necessary to maintain proper fuel-air ratio and furnace pressure.

2.1.1.3.16 Ensure the following conditions cause a reburn system trip:

- MFT
- Manual trip
- High or low reburn gas pressure
- Low airflow (secondary or overfire air)
- Low boiler load
- Switching to manual operation

2.1.1.3.17 Ensure the following conditions cause an audio-visual alarm in the control room in advance of a reburn system trip:

- Reburn high/low gas pressure
- Low airflow
- Reburn gas safety shutoff valves fail to close after a shutdown

2.1.1.3.18 Perform annual nondestructive examination (NDE) of waterwall tubes in the areas of the furnace where there may be a reducing atmosphere caused by reburn methods. Use ultrasonic testing (UT) to determine tube thickness. More corrosion-resistant materials or better protection of tubes, such as tube cladding or weld overlay, may be needed.

2.1.1.4 Fuel Switching

Fuel switching to a low sulfur western coal or to a coal blend will require modifications in order to store, handle, and burn this coal in a safe and stable manner, as well as to preserve boiler performance and minimize emissions. The following recommendations, based on the experiences of a number of utility stations, point out areas to be evaluated and issues that may need to be addressed when switching to a different type of coal.

2.1.1.4.1 Review storage area fire protection and dust collection. (Refer to Data Sheet 7-76, *Prevention and Mitigation of Combustible Dust Explosions and Fires,* and Data Sheet 7-73, *Dust Collectors and Collection Systems.*) Outdoor storage will result in more frozen coal due to retention of moisture, as increased fines have more surface area. Conveyor dust collection or suppression systems will be needed, as well as a washing system. Conveyors may need to be upgraded to handle more capacity.

2.1.1.4.2 Primary airflow may need to be increased. This may cause a swirling of the coal, resulting in plugging problems in the burner pipes, and requiring modifications to the burners. Coal-air mixture flow imbalance between the burners also may result.

2.1.1.4.3 Pulverizers may need modifications to better control fineness and handle higher primary airflows: consult the pulverizer manufacturer. If the grindability of the coal changes, the pulverizer capacity may be affected. (If one motor is used to drive the pulverizer and primary air fan, installing a separate fan motor will help to maintain the capacity of the pulverizer.) A system of coal cleaning may also be needed. The inerting and fire protection system may need to be upgraded to better control pyrite fires, and a remote means of isolating the pulverizer may need to be installed to control fires. Ensure the differential pressure across the pulverizer is alarmed.

2.1.1.4.4 Install thermocouples for each burner in a number of different locations (as many as five or six along the length of the burner) to detect overheating due to plugging, which can cause burner and windbox fires.

2.1.1.4.5 Secondary and tertiary air systems may need design changes.

2.1.1.4.6 Light off gas igniters daily to prevent plugging of the igniters where it can be a problem. (Sometimes the igniters are removed after the boiler is in normal operation if they are not continuous igniters.)

2.1.1.4.7 Coal flow and primary airflow may need to be better balanced; installing coal pipe orifices is one solution.

2.1.1.4.8 Increased primary air and less finely ground coal may increase coal conduit wear and burner coking, requiring more maintenance.

2.1.1.4.9 Coal pipe flows and fineness differences may be encountered. A means to measure coal flow and fineness differences between pipes (such as Rotorprobe™ testing) may be necessary. Solid-flow sensors may be used to monitor flow.

2.1.1.4.10 Alarm primary air-coal pressure drop across the burners for high/low differential pressure.

2.1.1.4.11 Increased frequency of sootblowing probably will be necessary to minimize accumulation of slag in various areas of the furnace, such as pendent superheaters and reheaters. Clinkers falling into the ash pit have caused large explosions due to pressure excursions and flameouts. The impact of clinkers falling onto the furnace bottom slope also can cause tube ruptures and a subsequent pressure excursion. It is important to keep all sootblowers in service, and additional sootblower coverage may be needed. Refer to Data Sheet 6-23, *Watertube Boilers,* for recommendations on sootblowers. Record steam flow to each sootblower to ensure each blower is operating satisfactorily.

2.1.1.4.12 Operation at low loads may cause inefficient, unstable combustion, resulting in excessive ash accumulation and slag buildup. Also, increased ash resistivity will affect electrostatic precipitator collection efficiency.

Flue gas conditioning may be needed as well as upgraded, more sensitive digital-type precipitator controls. Installation of a baghouse is another option, and filter bag selection can be optimized for the fuel being fired.

2.1.1.4.13 Boilers may need to be de-rated to prevent some of these problems from occurring.

2.1.1.4.14 Use only coal within specified design ranges. Have coal samples analyzed each time coal is delivered. There are advisory software programs that predict slagging in various areas of the furnace based on an analysis of the coal and ash, and also assist with modifying operational parameters. Furnace temperatures in the area of the superheater may need to be reduced to stay below the ash melting temperature so that ash does not adhere to tubes easily. Redesigned pendent superheaters and reheaters may be required. Ash handling requirements will also need to be analyzed.

2.1.2 Safety Control Interlocks

2.1.2.1 Purge Interlocks

2.1.2.1.1 Provide a timed pre-ventilation period to purge the boiler furnace, passes, and breeching. Ensure the purge consists of at least five volume changes of fresh air for a continuous period of not less than 5 minutes (allows time for controls to stabilize). Ensure the purge airflow rate is at least equal to 25% of that required for firing at maximum boiler output, but not more than 40% to minimize the potential of disturbing coal deposits (25% is the lowest rate that has been found to be adequate).

2.1.2.1.2 Provide interlocks to prove that the following purge conditions are satisfied. If any permissive interlock is lost during the purge timing, a re-initiation of the purge is needed.

1. No boiler trip present.

2. All pulverizers tripped and all igniter valves proved closed.

3. All burner registers and dampers required to maintain an open path, open to purge position. (Note that all dampers are normally opened at first. After startup of the first fan, idle fan dampers can be closed to prevent backflow.)

4. At least one forced draft (FD) fan and induced draft (ID) fan, if provided, proved running by means of flow, pressure differential, or shaft speed of the fan, and proper furnace draft established.

5. At least 25% but not more than 40% of full load airflow established.

2.1.2.1.3 Provide a complete purge after an emergency shutdown, or master fuel trip. Ensure fans that are operating remain running and fans that are tripped remain tripped. If airflow is less than the purge rate, ensure it remains at the same rate for at least 5 minutes and then gradually increases to the purge rate. Fans can be restarted after the 5 minute hold period as needed to achieve purge rate airflow. If the airflow is higher than the purge rate, gradually reduce airflow to the purge rate.

2.1.2.2 Ignition Interlocks

2.1.2.2.1 Provide basic interlocks as follows for startup and firing protection to ensure properly sequenced operation. Shut off pulverized coal and other fuels and ignition systems if interlock functions are not satisfied or hazardous conditions develop.

2.1.2.2.2 Place ID and FD fans in operation in that order.

Where two ID or FD fans (or both) are provided, it is acceptable to continue firing the boiler if only one fan or one set of fans is lost, provided an automatic fuel cutback system is installed. For example, when only one of two ID fans is lost, its associated FD fan must be tripped to avoid furnace overpressure. The fuel to the unit is automatically reduced to provide the proper fuel-air ratio for the reduced airflow that is still available.

2.1.2.2.3 When design purge airflow is in excess of 25% of full load volumetric airflow, an additional minimum airflow interlock may be provided to allow reduction of airflow to a minimum level of 25% of full load volumetric airflow for light-off.

2.1.2.2.4 Provide a high/low furnace-pressure interlock to shut off all fuel and ignition systems if excessive furnace pressure develops. This interlock can minimize the development of hazardous fuel conditions upon boiler tube rupture, outlet damper failure, or ash hopper steam surge.

2.1.2.2.5 Provide high and low fuel-gas pressure interlocks and low fuel-oil pressure interlocks to shut off the affected igniter/warm-up burner fuel supplies.

2.1.2.2.6 Provide atomizing-medium interlocks for steam or air-atomized fuel oil igniters/warm-up burners to prevent the introduction of fuel oil to the burners upon loss or impairment of the atomizing medium. Differential pressure of the oil and atomizing medium is often used for this purpose, and is sometimes controlled using a single control valve.

2.1.2.2.7 Limit the igniter flame establishing period to 10 seconds for gas and light oil, and 15 seconds for heated oils. Ensure loss of flame on an individual igniter is interlocked to close the igniter fuel shutoff valve and de-energize the spark.

2.1.2.3 Pulverizer Interlocks

2.1.2.3.1 Provide interlocks to ensure each individual pulverizer can be started only in the following sequence:

1. Igniters for all of the burners served by the pulverizer are put into service and proven.
2. Start primary air fan or exhauster fan.
3. Start pulverizer.
4. Start raw coal feeder.

2.1.2.3.2 Interlock each pulverizer system so the feeder, pulverizer and primary air fan/exhauster fan trip together. Ensure the pulverizer system trip also trips the individual coal burner valves or equivalent. Ensure loss of feeder is alarmed, and restarting blocked until feeder startup conditions are re-established. Ensure individual pulverizer system trips in the event of the following:

1. A pulverizer trip
2. Loss of primary air fan or exhauster
3. Low primary airflow
4. Loss of igniters or adequate ignition energy during pulverizer startup (Ensure this is an automatic interlock action in the event that an igniter is required to stabilize the main burner and tripping of main fuel from loss of flame is not provided.)
5. Loss of individual burner flame, unless arranged as described under Section 2.1.2.4
6. Master fuel trip signal

2.1.2.3.3 Ensure individual feeders will trip upon loss of coal feed to the burners associated with a pulverizer, unless Class 1 igniters are in service.

2.1.2.4 Main Flame Failure Interlocks

Provide automatic shutdown upon flame failure of a burner, a pulverizer-burner group, a zone, or the entire furnace-burner system according to the design and operating criteria developed with consideration for the burner and furnace configurations. Furnace configurations include wall-fired, angular down-fired or tangential-fired. Apply one or more of the following criteria designs.

2.1.2.4.1 Individual Burners

When individual burner's flames are monitored with automatic shutdown of each burner, arrange the pulverizer system to shut down when a specified number of burners supplied by that pulverizer system have been tripped and the remaining burners do not provide for stable operation. Ensure all components shut down simultaneously under trip conditions.

Note: Field testing is necessary to determine the number and arrangement of burners, burner groups, and zones that are required for stable furnace operation, and for adequate support for ignition. Test results conducted on other units of similar size and arrangement with burners of essentially the same capacity and using the same fuel may be applied. Analyze the requirements for each boiler based on factors such as furnace configuration, total number of burners, number of burners affected, load level, etc.

2.1.2.4.2 Burner Groups

When flame from burner groups are monitored, ensure the related pulverizer system will automatically shut down when the predetermined number of burners in a group or the number of burner groups are insufficient for stable operation. When Class 1 igniters are used, proven igniter flames provide adequate sustaining ignition energy for the burner group.

2.1.2.4.3 Zones

When adequate sustaining ignition energy in a furnace zone is not provided, ensure that loss of flame in that zone, or loss of flame in the entire furnace automatically initiates a master fuel trip. Adequate sustaining ignition energy in one zone may be provided by the combustion of the main fuel in an adjacent zone. Burners must be lighted by their own igniters (see Note following 2.1.2.4.1).

2.1.2.4.4 Provide an alarm to indicate loss of flame at individual burners, burner groups, or zones.

2.1.2.4.5 Consistent with the previous criteria, ensure a master fuel trip is automatically initiated upon partial loss of flame sufficient to cause hazardous accumulation of unburned fuel in the furnace. This situation is potentially more hazardous at lower load levels or when NO_x reduction methods are employed.

2.1.2.4.6 Ensure a master fuel trip is automatically initiated upon loss of all flame in the furnace.

2.1.2.5 Master Fuel Trip Interlocks

2.1.2.5.1 Ensure a master fuel trip (see Figure 2) is automatically initiated in the event of any of the following:

1. Loss of all flame, loss of zone flame if not provided with adequate sustaining ignition energy, or partial loss of flame sufficient to cause a hazardous accumulation of unburned fuel in the furnace (refer to Section 2.1.2.4).

2. Loss of all fuel input

3. High furnace pressure (see Data Sheet 6-6, *Boiler Furnace Implosions*)

4. Low combustion airflow. Total airflow measurement can be used for this purpose. Using an airflow switch is not sufficient to determine if there is a problem with the total combustion airflow to the furnace.

5. Loss of all induced draft or all forced draft fans

6. Low water condition

   a. Low water level in steam drum and/or loss of forced circulation flow (for boilers with a steam drum)

   b. Low water flow (for once through boilers with no steam drum)

2.1.2.5.2 Ensure a master fuel trip is initiated either automatically or manually in the event of any of the following:

1. Failure of the first pulverizer system to operate successfully due to automatic interlock action outlined in Section 2.1.2.3, *Pulverizer Interlocks,* or failure of main fuel to light upon admission to the furnace.

2. Loss of power to combustion control, burner management, or safety control interlock system.

3. Low furnace pressure (see Data Sheet 6-6, *Boiler Furnace Implosions*).

2.1.2.5.3 Provide a means for manual initiation of a master fuel trip.

2.1.3 Alarms, Indicators, Recorders, and Communication

2.1.3.1 Provide a means of communication between the control room and operators working on important boiler control equipment such as burners, fan damper controls, pulverizer systems, and air heaters. Explosions have occurred because the activities of operating personnel were not coordinated with those of the control room operator, particularly during critical situations such as equipment malfunction or other upset operating conditions.

2.1.3.2 Install instrumentation to provide the operator with adequate information concerning the status of operating equipment, position of valves, burner registers, damper position and other conditions that will permit ready evaluation of the operating situation.

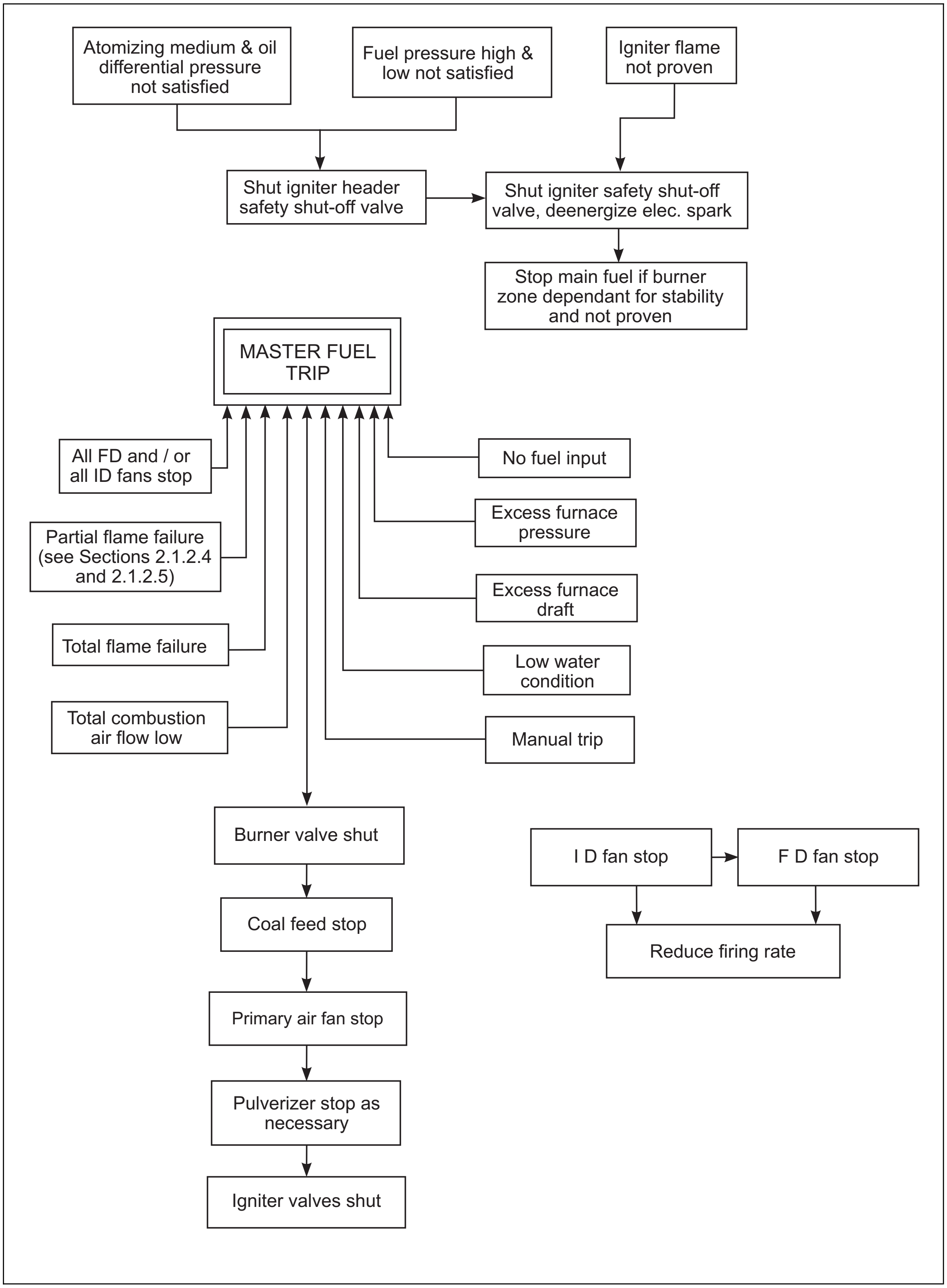

Fig. 2. Master fuel trip interlocks

2.1.3.3 Provide alarm systems that give both audible and visual indication of abnormal conditions. Annunciators and alarms are highly desirable to aid normal operation and warn operators of the development of abnormal conditions. Means may be provided to silence the audible alarm, but ensure the visual indication remains until the condition has been returned to normal.

2.1.3.4 Provide “First Out” indication for all safety interlocks that will initiate a master fuel trip.

2.1.3.5 Provide additional interlocks to initiate an alarm when abnormal conditions are detected that would result in a boiler trip or a hazardous situation, if left uncorrected. Typical alarms are listed below.

2.1.3.6 Ensure sensing taps and switches/transmitters for alarms are separate from those used for tripping interlocks.

Alarms

- Pulverizer trip
- Feeder trip or loss of coal flow to pulverizer
- Fan trip (FD, ID, primary air, exhauster)
- Furnace pressure high/low
- Low furnace airflow
- Loss of flame (igniter, burner, burner group, zone)
- Coal-air temperature high/low
- Igniter fuel header pressure low igniter atomizing medium to oil differential pressure high/low
- Loss of control power
- O_2 trim out-of-limits
- Water level high/low
- CO high
- Burner register closed
- Pulverizer differential pressure
- Fuel-air ratio high/low
- Failure of flue gas analyzer

2.1.3.7 Provide oxygen analyzer-recorders and combustibles or carbon monoxide analyzer-recorders as an operating guide to safe and efficient operation. Provide alarms to warn the operator of a possible hazardous condition in the event of high or low oxygen (oxygen trim out-of-limits) and measurable combustible or carbon monoxide indications. Also see Section 2.1.1.2.1, items 1 and 2. Provide monitoring for pulverizers.

2.1.3.8 Provide low water protection in accordance with Data Sheet 6-12, *Low Water Protection for Boilers.*

2.1.3.9 Many modern installations use computer systems as an operating aid, or as an integral part of boiler control systems. Typical functions include rapid data acquisition and periodic logging, limit checking and calculating, sequence of events recording, and acquisition of pre-trip and post-trip data. The effectiveness of these systems depends to a great extent on the reliability of the equipment, the adequacy of the computer programs, storage capacity and timing of data acquisition, and safeguards against data erasure and program changes.

Provide specific operating instructions and/or built-in safeguards that will protect against loss of data during critical operating periods. Security is also important (see Section 2.3.11). Refer to Data Sheet 7-45, *Instrumentation and Control in Safety Applications.*

2.1.4 Selective Catalytic Reduction

2.1.4.1 Design Considerations

2.1.4.1.1 Use the proper catalyst for the temperature range. Use a catalyst design appropriate for the fuel and ash content.

2.1.4.1.2 Maintain the temperature at the selective catalytic reduction (SCR) reactor in the range specified for the catalyst to prevent downstream fouling due to ammonia slip (low temperature) and to prevent overheating of the catalyst. Monitor flue gas temperature at the inlet to the SCR reactor and provide an alarm. Economizer bypass dampers may need limits for boilers with a split flow design in order to maintain proper superheat and reheat temperature.

2.1.4.1.3 Provide sootblowers or other suitable means of cleaning the catalyst surface. Maintain a pressure that is suitable for cleaning, but does not cause erosion of the catalyst surface.

2.1.4.1.4 Modify air preheater surfaces to resist corrosion if necessary. Using cold-end heater baskets with enameled surfaces may be needed.

2.1.4.1.5 Evaluate the potential for a furnace implosion if a booster fan has been added downstream of the furnace or if an ID fan capacity has been increased. Also evaluate all downstream equipment and ductwork for the increased draft and check to see if the boiler draft is affected. Some ductwork and equipment such as an electrostatic precipitator may need to be reinforced due to increased negative pressure.

2.1.4.1.6 Do not use copper or copper alloys with ammonia.

2.1.4.1.7 Provide an alarm to notify operators if the ammonia injection increases more than what the ammonia flow control unit (AFCU) is calling for.

2.1.4.1.8 Where a duct heater is used to maintain SCR reactor temperature during low load operation, provide a combustion safeguard, flame scanner, two safety shutoff valves (at least one having proof-of-closure), fuel pressure switches and a low airflow switch for the combustion air fan. (Refer to DS 6-4, *Oil or Gas Fired Single Burner Boilers* or DS 6-5, *Oil or Gas Fired Multiple Burner Boilers,* as applicable.

2.1.4.2 Ammonia Storage

2.1.4.2.1 Build anhydrous ammonia storage tanks to meet ASME Section VIII or equivalent applicable standard, and applicable state and local codes if they are the non-refrigerated type. The minimum allowable design pressure is 250 psig in the United States, and 265 psig in California, for example. Never fill the tanks with liquid more than 87.5% full to allow for expansion (above-ground uninsulated tanks). See OSHA 29CFR 1910.111, *Process Management of Highly Hazardous Chemicals,* for filling requirements of different types of tanks and under different filling conditions. Design the relieving system to prevent the pressure from exceeding the tank design pressure.

2.1.4.2.2 Install a storage tank high-pressure switch interlocked with the vaporizer. Set the switch lower than the relief valve setting and no higher than 20% above normal pressure.

2.1.4.2.3 Protect ammonia storage tanks against vacuum with a vacuum breaker or a low-pressure switch interlocked with the pump.

2.1.4.2.4 When emptying ammonia storage tanks, maintain the minimum level required to prevent damage to the vaporizer. Provide a low-level switch interlocked with the pump and vaporizer.

2.1.4.2.5 Check the storage area for ammonia leaks by walking through the area several times per shift, or install an ammonia leak detection system.

2.1.4.2.6 Install hose stations with spray nozzles at the storage area. Water spray can be used to scrub leaked ammonia from the air. See Data Sheet 7-13, *Mechanical Refrigeration,* for recommendations on emergency planning for responding to ammonia leaks. Alternatively, where adequately trained emergency response personnel are not always available, consider installing a sprinkler/deluge system at the storage area (covering the entire dike area) to provide water for scrubbing leaked ammonia from the air. Activate the system manually, or interlock it with a reliable ammonia leak detector. Size the dike area based on the flow rate from the deluge system and the anticipated system operation time. The time must be equal to the time for the ammonia tank to empty when a major leak occurs.

2.1.4.3 Operation of SCR Systems with Bypass Capability

2.1.4.3.1 Include the SCR isolation and bypass dampers in the open flow path verification associated with the boiler draft system.

2.1.4.3.2 Provide the following for installations where operational tie-in of the SCR system is to be done while the boiler is operating:

A. Removable spool piece(s), or other acceptable means of preventing ammonia or other combustible materials, including duct burner fuel where used, from accumulating in the SCR enclosure during isolation. A double block valve and vent valve arrangement does not satisfy the requirement for positive means of isolation for this application.

Exception: This requirement does not preclude the use of a double block and vent for isolation as required in the normal startup of the boiler.

B. A means to pressurize the isolated SCR enclosure and seal the SCR against flue gas entry while the boiler is in operation.

2.1.4.3.3 Where operational tie-in of the SCR is desired while firing the boiler, ensure the following actions were/are taken:

A. A post operational purge of the SCR enclosure to remove any combustible materials was performed after proving the acceptable means for isolation identified in 2.1.4.3.2 and prior to isolation of the SCR enclosure from the flue gas stream. The post operational purge of the SCR enclosure is for five minutes or five volume changes, whichever is greater, with a boiler airflow of at least 25% of the full load mass airflow or with an equivalent flow of functionally inert flue gas.

B. The acceptable means of isolation identified in 2.1.4.3.2 is continuously maintained while the SCR system is isolated.

C. The means to seal the isolated SCR unit from flue gas is continuously maintained while the boiler is in operation and the SCR system is isolated.

D. No purge of the SCR unit is required when putting the SCR unit back into the flue gas flow. However, ensure the flue gas is functionally inert during the tie-in process so purge credit is not lost in the event the tie-in has to be aborted and the SCR re-isolated.

E. Replace the spool piece(s) or other acceptable means of isolation identified in 2.1.4.3.2 once operational tie-in of the SCR into the flue gas path has been completed.

F. Do not operate the catalyst cleaning system until tie-in of the SCR into the flue gas path has been completed.

2.1.4.3.4 An SCR system not meeting all the items in 2.1.4.3.3 a) through d) requires the boiler to be shut down and a unit purge performed with the SCR system in the airflow path prior to restarting the boiler and putting the SCR system into operation.

2.1.5 Flue Gas Scrubber Systems

2.1.5.1 Design the boiler enclosure and all flue gas ducts and equipment from the boiler flue gas exit to the outlet of the ID fan(s) for a negative transient design pressure equal to the test block of the ID fan(s) or -35” H_2O (-8.7 kPa), whichever is less negative. Where the flue gas train has ID fan(s) and a booster fan(s) in series, the test block intended by this recommendation is the combined test block of the ID and booster fans. Refer to DS 6-6, *Boiler Furnace Implosions,* for additional guidance on enclosure design pressure and control of transient pressure excursions.

2.1.5.2 Retrofit Installation of a Flue Gas Scrubber Common to Two or More Boilers

2.1.5.2.1 When designing a retrofit installation where the flue gas streams from two or more boilers will be combined to exhaust through a common scrubber, install an ID booster fan, or multiple ID booster fans in parallel, in the common flue gas duct to the scrubber to ensure the point at which the flue gas streams combine operates at or slightly below atmospheric pressure.

2.1.5.2.2 Provide isolation gates in each of the boiler flue gas ducts upstream of the common point.

2.1.5.2.3 Interlock operation of the ID and/or FD fans of each boiler so that individual boiler fans can only be in service when at least one ID booster fan in the common duct to the scrubber is operating.

2.1.5.2.4 When the operating ID booster fan(s) in the common duct to the scrubber are not able to maintain a negative pressure at the common point of the flue gas stream, instruct operators to reduce load on operating boilers as needed to be within the control capacity of the operating ID booster fan(s). Load can be restored when additional booster fan(s) are returned to service.

2.1.5.2.5 Prior to starting the first ID booster fan, ensure an open flow path exists from the FD fan inlet of at least one boiler to the stack. For the purposes of this recommendation, the obstruction to natural draft induced flow created by the slurry pool in a jet bubbling reactor (JBR) scrubber or the operation of the slurry spray system in a tower scrubber are not considered impairments to the open flow path.

2.1.5.2.6 Start the fans of the first boiler to be placed into operation in accordance with the manufacturer's instructions and complete a unit purge prior to beginning light-off.

2.1.5.2.7 Prior to starting a subsequent boiler, ensure an open flow path exists from the FD fan inlet to the common point of the flue gas streams.

2.1.5.2.8 Start subsequent boilers in accordance with the manufacturer's instructions.

2.1.5.3 Actions Following a Boiler MFT

2.1.5.3.1 Following a boiler MFT with all fans in service, complete a unit post purge in accordance with the manufacturer's instructions. After unit post purge is completed, the boiler FD and ID fans, as applicable, may be shut down and air and gas dampers adjusted as desired to either maintain airflow through the unit or to bottle up the unit to preserve heat for the next start-up.

2.1.5.3.2 Loss of all ID booster fans in the common duct to the scrubber will cause an MFT on all units and all boiler fans will automatically trip. Complete a 15 minute hold time prior to attempting to restart any fans. During the hold time only adjust dampers as needed to keep boiler furnace pressure within transient design limits during fan coast down. After the hold time, dampers can be repositioned as needed to permit a normal restart of the (first) ID booster fan.

2.1.5.3.3 If the boiler ID fans are not operating following a boiler MFT, the FD fans will automatically trip. Complete a 15 minute hold time prior to attempting to restart any of the boiler fans. During the hold time only adjust dampers as needed to keep boiler furnace pressure within transient design limits during fan coast down. After the hold time, dampers can be repositioned as needed to permit a normal restart of the boiler fans, provided the cause of the MFT has been corrected. Complete a unit purge before restarting the boiler.

2.1.5.3.4 If the boiler FD fans are not operating following a boiler MFT, keep the boiler ID fans in service with adjustments as needed to maintain normal boiler furnace draft. Complete a 15 minute hold time prior to attempting to restart any fans. After the hold time, dampers can be repositioned as needed to permit a normal restart of the boiler FD fans, provided the cause of the MFT has been corrected. Complete a unit purge before restarting the boiler.

2.1.6 Carbon Injection

Activated carbon, in a variety of commercially available forms and compounds, can be injected into the flue gas stream of pulverized coal fired boilers to control mercury emissions. Its use in North America and other areas of the world is expected to increase as limits on mercury emissions are enforced by governmental regulation bodies such as the Environmental Protection Agency (EPA) in the United States.

Carbon injection is typically done upstream of the precipitator or baghouse using an injection grid that is designed to provide a uniform distribution in the flue gas. The following recommendations apply when such a system is installed. There are many design requirements that go beyond these recommendations and include, but are not necessarily limited to, delivery, storage, and pneumatic conveying of the activated carbon material as well as transport line erosion, flow distribution, and feed-rate control.

2.1.6.1 Provide fire and explosion/deflagration protection for the entire delivery, storage, and transport system in accordance with Data Sheet 7-76, *Prevention and Mitigation of Combustible Dust Explosions and Fires.*

2.2 Protection

2.2.1 Arrange fuel supplies safely as outlined in Data Sheet 8-10, *Coal and Charcoal Storage;* Data Sheet 7-32, *Ignitable Liquid Operations;* Data Sheet 7-88, *Ignitable Liquid Storage Tanks;* Data Sheet 7-54, *Natural Gas and Gas Piping;* and Data Sheet 7-55/12-28, *Liquefied Petroleum Gas.*

2.2.2 Provide a manual means of shutting off fuel gas supply to the boilers outside of the boiler building, as control of safety shutoff valves can be lost in a fire (outside of the turbine building also at an electrical utility plant, as a fire can occur in this area). If oil is used as the igniter fuel, provide an auxiliary means to secure power to the fuel oil pump outside of the boiler building, as control power may be lost in a fire. Post procedures for accessing the shutoffs in the control room.

2.2.3 Give recognition to the fire hazard imposed by leakage or rupture of fuel piping near the burner. Pay particular attention to flexible connections, hoses, swivel joints, etc. Pulverized coal escaping from the system will collect on any horizontal surface. When this dust falls or is blown into a cloud or when a major pipe failure occurs, ignition of the pulverized coal can result in a severe explosion. See Data Sheet 7-76, *Prevention and Mitigation of Combustible Dust Explosions and Fires.* Good housekeeping is a must.

Replace braided igniter fuel hoses periodically according to manufacturer's recommendations, and commit to a replacement frequency based on usage and consultation with the hose or boiler manufacturer. Older hoses may not flex properly and may cause leaks to develop at threaded connections in the fuel piping, especially if there are 90° bends. Hoses that are bulged, stiff, or corroded may be an indication of this condition. Hoses are subject to both tensile and compressive stresses, internal pressure, physical impact, reactive forces, ambient temperature extremes, vibration, and corrosive atmospheres.

Use double braided, noncombustible hoses. Ensure hoses are designed for the fuel being fired and are capable of withstanding four times the normal maximum operating pressure. Ensure hose couplings and fittings and minimum bending radius are in accordance with the manufacturer's instructions. If 90° bends are necessary, accomplish this with 90° elbows. Install valves upstream of hoses. Flexible hoses are a likely place for a fuel leak to develop, and need to be examined frequently and carefully for hardening and cracking. Inspect fuel piping for corrosion, especially outdoor piping where moisture can collect under insulation (such as near a vent pipe).

2.2.4 Provide fire extinguishers and small hose stations for manually fighting burner front fires.

2.2.5 In areas with concentrated arrangements of instruments, controls, auxiliary equipment, and fuel supplies in the vicinity of the burners, and where igniters and warm-up burners are fired with oil, a severe fire exposure may exist. In these situations provide fixed automatic protection systems such as water spray or automatic sprinklers. Manual systems may not be accessible during a fire; provide a means of remote activation for manually activated systems. Refer to Data Sheet 3-26, *Fire Protection Water Demand for Nonstorage Sprinklered Properties,* for fire protection density specifications.

2.2.6 Re-evaluate fire protection systems in all areas of the plant associated with coal whenever pollution reduction modifications (fuel switching in particular) are planned. Fire pump capacity may need to be increased.

2.3 Operation and Maintenance

2.3.1 Establish a program for the continued training of operating personnel. Give particular attention to the specific functions and limitations of the various safety controls. When modifications are implemented (such as those needed to comply with pollution control regulations), additional training will be necessary, as operating procedures may change, new types of controls may be installed, and new problems may arise when the boiler is put back into operation.

2.3.2 Ensure operating instructions and operating curves (for manual operations) are readily available to operators.

2.3.3 Make routine inspections each shift for slagging or coking of coal within the burner or burner throat, coal leaks, and slagging or clinker buildup in the furnace. The latter is particularly important if problems exist with the soot-blowing equipment.

2.3.4 Clean flyash hoppers frequently to minimize the possibility of accumulating unburned or incompletely burned coal. Generally this is done each shift, but may vary depending on coal ash content, size and number of hoppers, and capacity and operation of the ash removal system. A continuous ash removal system, when installed, must always be maintained in proper working condition.

Overloading of flyash hoppers can result in structural failure and collapse of the hoppers. If ash density is increased by more than 10% over design specifications, consult the manufacturer for a structural evaluation. Overflowing flyash hoppers may result in compacting, which will increase ash density. Water tube leaks above the hopper also will cause density to increase and may cause ash to solidify. If flue gas temperature is increased above original design specifications, hopper support members may be weakened. Inspect weld plates on major support members as well as truss end supports for corrosion, erosion, and cracking.

2.3.5 Pressure excursions and flameouts can result if ash bridges across the furnace bottom slope, breaks loose, and falls into the wet ash hopper. Ensure the furnace pressure trip is properly set, congruent with furnace operating parameters. When setting the pressure trip, consider not only the strength of the furnace walls, but also combustion fan operating curves. It is possible that a pressure excursion can cause an airflow reduction and off-ratio firing, resulting in a fuel explosion and an even higher secondary pressure excursion. Operate the boiler to minimize ash loading in the furnace bottom slope through efficient firing, operation within the boiler's design parameters, and proper load management of the burners.

Determine that ash does not bridge the furnace bottom slope each shift by visual inspection, and if bridging occurs, remove the boiler from service. If ash accumulation becomes a problem, sequence the sootblowers to minimize the amount of ash being dislodged into the hopper at any one time, and increase the sootblowing frequency. Ensure ash is not permitted to accumulate in a wet ash hopper, as this could cause ash buildup in the furnace bottom slope area.

Consider draining furnace bottom wet ash hoppers after a shutdown. Evaluate individual boilers to determine if this practice is feasible. Hot slag falling into a wet ash hopper can cause a violent steam explosion.

2.3.6 Inspect equipment enclosures and keep them closed to minimize tampering and the introduction of dust and dirt. Do not operate portable radio equipment in the vicinity of electronic control cabinets when the access doors are open. The break in electrical shielding may allow spurious signals to be generated within the control system.

2.3.7 Inspect furnace pressure sensing taps weekly for slag or flyash buildup that could cause plugging.

2.3.8 Clean the flame detector lenses and sight tubes to avoid loss of scanning sensitivity, false indication of flame failure, and loss of operator confidence in this equipment. The required cleaning frequency will depend upon local conditions. However, the need is usually indicated by a downward trend in flame signal strength. Provide self-diagnostic capability on new systems.

2.3.9 Establish periodic maintenance schedules based on equipment manufacturers' recommendations and the operating experience of the unit. Controls and safety devices may need to function under severe operating conditions. It is essential that equipment be maintained in good condition.

Prepare a carefully planned maintenance test procedure for each boiler. Include tests performed at prescribed intervals for tightness of fuel safety shutoff valves, response of supervisory equipment to flame failure, and proper action of interlocks and associated combustion control instrumentation. Check the calibration of safety controls as well as combustion controls. Check sensing lines for plugging and leaks. Perform tests following written test procedures using well-trained personnel who are familiar with the equipment and the specific functions of the various safety controls. List controls to be tested, condition, proper sequence, and method of performing the test in the inspection and test report. Have the employee conducting the inspection prepare the report and have it reviewed by a supervising official.

2.3.10 Make periodic functional checks of the safety interlock system in addition to scheduled maintenance. These checks are to ensure proper functioning when emergencies arise. Such checks are particularly important following an overhaul or extensive equipment maintenance, when improper installation or wiring of protective devices may have occurred.

2.3.11 If setpoints for safety and operating controls can be reprogrammed from an operator's console, incorporate security measures into the software program so these parameters can only be changed by authorized personnel. Approve all changes through supervisory or facility engineering management personnel prior to implementation, and document all changes and the reasons for these changes. Require that shift operating personnel communicate with contractors or instrumentation personnel working on boiler controls.

2.3.12 For boilers with low NO_X burners, areas in the furnace below the burners may be subjected to a reducing atmosphere. Conduct detailed inspections of the tubes in these areas. Also, inspect walls opposite the burners for evidence of flame impingement.

2.3.13 Establish a program documenting the evaluation and response to manufacturers' bulletins.

2.4 Electrical

Ensure electrical installations conform to the National Electrical Code (in the United States) or applicable local code.

3.0 SUPPORT FOR RECOMMENDATIONS

3.1 Loss History

Boiler fuel explosions are caused by the ignition of an accumulation of a combustible mixture within the furnace or flue gas passages. Explosions may occur during light off, normal firing, or after shutdown because of unburned fuel or flammable products of incomplete combustion. These explosions may be due to insufficient purging, improper fuel-air ratio, inadequate ignition, inadequate fuel-air mixing, and flameouts. Fires may occur in the windbox, burner assemblies, and flue gas passages, and also outside of the boiler due to igniter oil leaks.

Figure 3 shows the types and costs of incidents for the losses included in the study. Figure 4 shows the causes and contributing factors, alone or in combination, that resulted in conditions culminating in the 31 incidents studied. Many of these losses have more than one contributing factor. Since contributing factors are also listed, the total of the percentages shown in Figure 4 is greater than 100%; this graph illustrates that there is an average of 2.5 causes per incident for the losses studied.

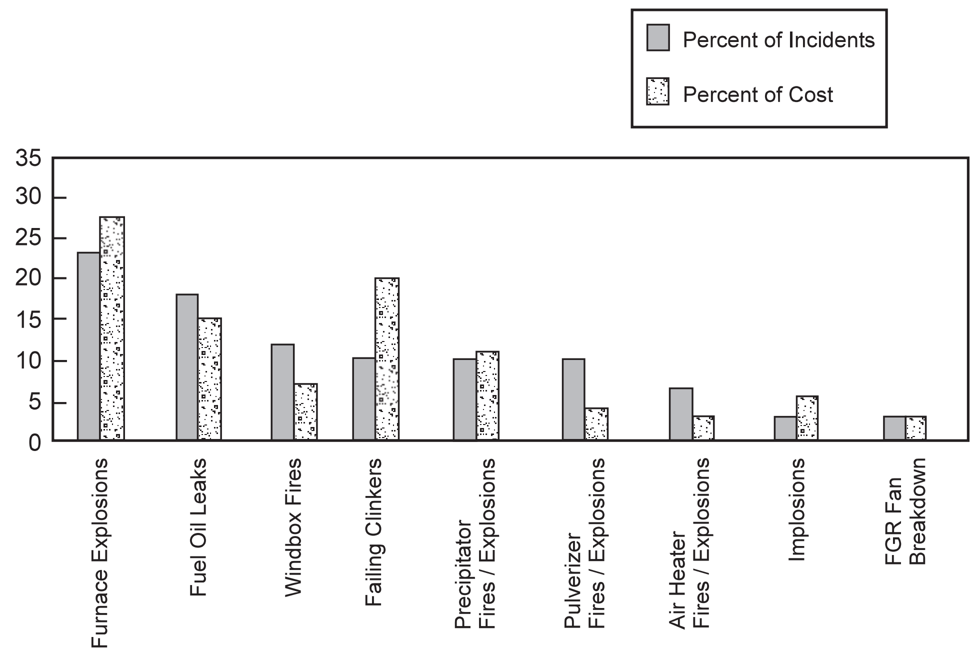

Fig. 3. Type of incident and cost for the surveyed losses

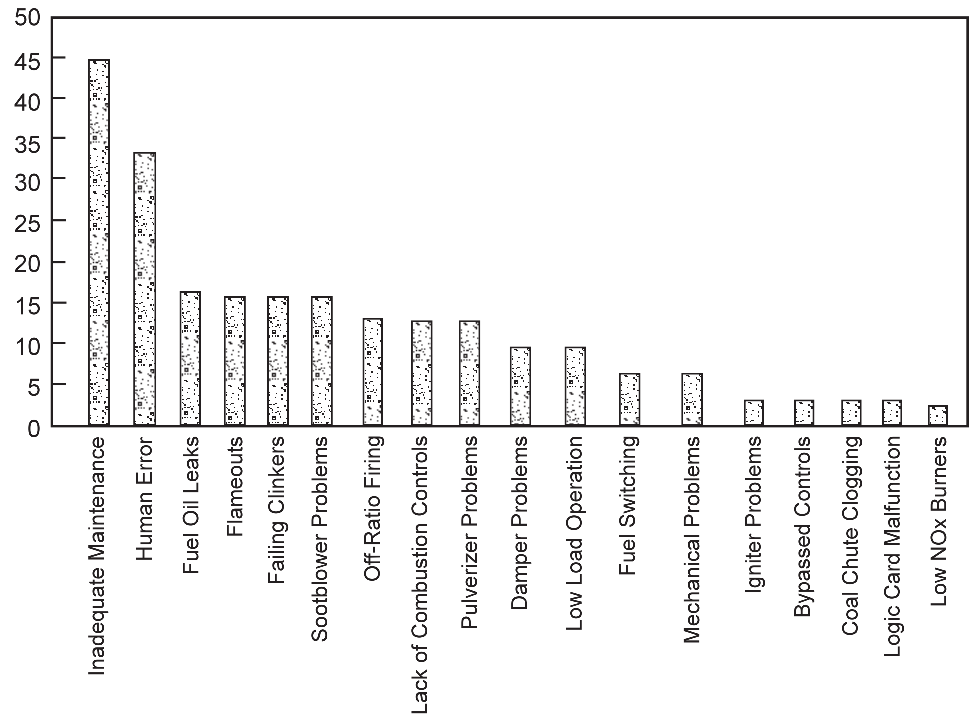

Fig. 4. Causes and contributing factors for the losses studied

4.0 REFERENCES

4.1 FM

Data Sheet 3-26, *Fire Protection Water Demand for Nonstorage Sprinklered Properties*
Data Sheet 6-4, *Oil- and Gas-Fired Single-Burner Boilers*
Data Sheet 6-5, *Oil- and Gas-Fired Multiple Burner Boilers*
Data Sheet 6-6, *Boiler-Furnaces Implosions*
Data Sheet 6-12, *Low-Water Protection*
Data Sheet 6-13, *Waste Fuel-Fired Facilities*
Data Sheet 6-23, *Watertube Boilers*
Data Sheet 7-32, *Flammable Liquid Operations*
Data Sheet 7-45, *Instrumentation and Control in Safety Applications*
Data Sheet 7-54, *Natural Gas and Gas Piping*
Data Sheet 7-55, *Liquefied Petroleum Gas*
Data Sheet 7-73, *Dust Collectors and Collection Systems*
Data Sheet 7-76, *Prevention and Mitigation of Combustible Dust Explosions and Fires*
Data Sheet 7-88, *Ignitable Liquid Storage Tanks*
Data Sheet 8-10, *Coal and Charcoal Storage*

4.2 Other

American Society of Mechanical Engineers (ASME). *Power Piping.* ASME B31.1.

National Fire Protection Association (NFPA). *Boiler and Combustion Systems Hazards Code.* NFPA 85.

National Fire Protection Association (NFPA). *Standard for Fire Prevention and Control in Coal Mines.* NFPA 120.

National Fire Protection Association (NFPA). *National Fuel Gas Code.* NFPA 54.

National Fire Protection Association (NFPA). *Flammable and Combustible Liquids Code.* NFPA 30.

National Fire Protection Association (NFPA). *National Electric Code.* NFPA 70.

APPENDIX A GLOSSARY OF TERMS

AFCU: Ammonia flow control unit.

BMS: Burner management systems.

FD: Forced draft fan.

FM Approved: Product and services that have satisfied the criteria for FM Approval. Refer to the *Approval Guide,* an online resource of FM Approvals, for a complete listing of products and services that are FM Approved.

ID: Induced draft fan.

MFT: Master fuel trip.

NDE: Nondestructive examination.

SCR: Selective catalytic reduction.

SSOVs: Safety shutoff valves.

APPENDIX B DOCUMENT REVISION HISTORY

The purpose of this appendix is to capture the changes that were made to this document each time it was published. Please note that section numbers refer specifically to those in the version published on the date shown (i.e., the section numbers are not always the same from version to version).

July 2023. Interim revision. Minor editorial changes were made.

October 2020. Interim revision. Minor editorial changes were made.

July 2015. The following changes were made:

- Added recommendations for flue gas scrubber systems.
- Reorganized the document to be consistent with other data sheets.

May 2010. Minor editorial changes were made for this revision.

January 2008. Editorial change was made in Appendix B, Document Revision History.

May 2006. Minor editorial changes were done for this revision.

September 2004. Cross-reference to recommendation numbers in Figure 2 were corrected.

May 2003. In section 2.1.1.1.2, which covers energize-to-trip safety shutoff valves, the recommendation has been changed to be less specific. Instead, it covers the intent and allows for design flexibility. Section 2.1.4.3, which covers purging of selective catalytic reduction (SCR) units, has been changed because of recent changes to NFPA 85, *Boiler and Combustion Systems Hazards Code*.

May 2002. New section 2.1.4, that addresses selective catalytic reduction (SCR), a method of NO_X reduction for large boilers was added. A paragraph was added to recommendation 2.1.1.1.2, recommending supplying two sources of power, one ac and one dc, where energize-to-trip safety shutoff valves are used. This is to assure that either main gas valves or individual burner valves can be closed if one source of power is lost. A paragraph was added to section 2.1.1.1.3, recommending a motorized main gas shutoff valve with position indication where energize-to-trip safety shutoff valves are used. This is to help assure that gas is not admitted to a boiler after shutdown.

January 2002. In section 2.1.2.1.2 (3), a clarification was made indicating that idle fan dampers can be closed after startup of the first fan to prevent backflow.

September 2001. Minor editorial changes were done for this revision.

May 2000. This revision of the document has been reorganized to provide a consistent format.

The following changes were made:

1. A new section covering gas reburn has been added. Gas reburn is used to reduce nitrogen oxide emissions. Natural gas is injected into the upper part of the furnace and reacts with oxygen in NO_X molecules leaving harmless N_2.

2. Low primary airflow has been added to the recommended pulverizer interlocks in Section 2.1.2.3 in agreement with Data Sheet 6-24/13-21, *Coal Pulverizers and Pulverizing Systems*.

3. Recommendations for purging after an MFT have been added to Section 2.1.2.1 in agreement with NFPA 8502.

4. A recommendation has been added Section 2.3.5 for considering draining a furnace bottom wet ash hopper after shutdown because a hot slag fall can cause a violent explosion. This procedure was implemented at one electric utility plant after an explosion occurred. Another similar incident occurred there after the procedure was not followed.

5. A recommendation has been added to Section 2.1.1.1.2 to prove gas safety shutoff valves closed after a shutdown. There have been a number of losses where fuel has leaked into a furnace after a shutdown.

6. In Appendix C, Section C.1.3, changes to the recommended sootblowing practices have been made. Soot in a coal-fired boiler is usually noncombustible flyash, and an explosion during sootblowing is very unlikely. Oxygen is usually already very low when firing at a high rate.

APPENDIX C SUPPLEMENTAL INFORMATION

C.1 Safe Operating Procedures

C.1.1 General

Well-trained operating personnel following proper procedures are essential to the safe operation of multiple burner power boilers. A fundamental operating procedure is the ″open-register″ or ″fuel-lean″ startup.

This procedure provides for a continuous airflow rate through the unit during the purge, startup, and initial load-carrying period of operation. The same number of burner registers or burner dampers required for purging the boiler are kept open at the normal firing position throughout the starting sequence. However, as a specific single burner is being started, its register or damper is usually readjusted to provide the proper reduced burner airflow just prior to lighting off. After the burner flame is established, the register is returned to the normal operating position. For some units, modifications to specific burner dampers or registers opened during the startup may be necessary to control temperatures in the boiler passes. However, such modifications should be made only if they are determined necessary after operating the installed unit.

This open-register procedure has the advantage of a highly air-rich furnace atmosphere that reduces the probability of explosion if a malfunction occurs, such as burner flameout. It minimizes fuel-rich flameout during the startup. Also, after the flow of purge air is established, only minor adjustments are required as additional burners are placed in service. The number of manual operations is reduced, decreasing the possibility of operating errors. The hazard of dead pockets of fuel in the boiler gas passes is also minimized. The specific, detailed operating instructions of the boiler manufacturer must be followed.

The following sections on startup, normal operations, and shutdown outline the principal objectives and procedures for safe operations. Certain functions may be actuated manually or automatically by means of interlocks and automatic control systems. The completion of each segment of the sequence must be verified before continuing to the next segment. This text specifies the verifying interlocks in the subsection on interlocks. Most units are started with the controls in the manual mode. During normal operations, the controls are in automatic mode unless some extreme low-load demand occurs.

C.1.2 Startup

1. Determine that the furnace is in good repair, free of foreign material and fuel accumulation, and that access doors and inspection ports are closed. Prepare pulverizers, feeders, and associated equipment for service. Set fan and burner dampers or registers at the recommended positions for purging and light-off and verify there is an open path from the FD fan inlet through the stack. Establish proper water level or circulation. Put combustibles and oxygen analyzers, if provided, into operation, and verify they are indicating zero combustibles and normal atmospheric oxygen concentrations. Special provisions may be needed to prevent

an accumulation of combustible vapors that may be heavier than air, or to detect and purge accumulations in the ash pit. Verify power is available to safety control circuits.

2. Prove the gas or oil fuel header and individual burner valves in the closed position. The pulverizing system must be conditioned to prevent leakage of coal into the furnace.

3. Start ID fans, FD fans, regenerative air heaters, and flue gas recirculation fans, if furnished.

4. Provide a timed pre-ventilation period to purge the boiler furnace, passes, and breeching. The purge is to consist of at least five volume changes of the boiler enclosure with fresh air for a continuous period of not less than five minutes. The boiler enclosure consists of the area containing the pressure parts and the combustion process. Large post-combustion components having sources of ignition such as precipitators and fired reheaters need to be purged also, and may govern the purge time if larger than the boiler enclosure. The purge airflow rate should be at least equal to 25% (but not more than 40%) of that required for firing at maximum boiler output. If a heavier-than-air gas, such as propane, is used for startup, the boiler should be designed to purge the ash hopper at startup.

5. Following purge, recirculation fans and regenerative air heaters may be shut down or continued in operation, as recommended by the boiler manufacturer, to establish proper light-off conditions.

6. Energize the ignition source and open the igniter shutoff valve on the igniter to be lit. If flame on the first igniter is not proven within 10 seconds (15 seconds for heated oils), close the igniter shutoff valve, then identify and correct the problem. If airflow has been maintained at purge-airflow rate, a repurge is not required, but allow at least one minute to elapse before attempting to relight this or any other igniter. Some units have igniters for pulverized coal burners that are controlled in groups. These igniters are simultaneously inserted and ignited by electrical spark. The ignition of these igniters should be automatically proven by the flame scanners. Refer to Data Sheet 6-5, Oil- and Gas-Fired Multiple Burner Boilers, for igniter fuel train arrangements and recommendations.

7. With the coal feeder and pulverizer off, check that coal is available to the feeder.

8. With the igniters in service for the burners and pulverizer to be operated, warm up and start the pulverizer system as recommended by the manufacturer. With the pulverizer coal feeder in service, a time interval will occur as the pulverizer is charged and the coal is finally transported to the burner.

9. Prove the main burner flame within 10 seconds after fuel is admitted to the furnace. If it is not proven, initiate a burner fuel trip. Determine and correct the cause of failure to ignite. A repurge of the furnace is required if no other main burners are firing. If other main burners are proven, wait at least one minute before attempting to relight this or any other burner.

10. With ignition established and the initial pulverizer burners fully lighted and stable, slowly open the burner air registers or dampers to their normal operating position. (Ensure ignition is not lost in the process.)

11. Class 1 and Class 2 igniters may be left in service. If all burners for an operating pulverizer are not in service, and increased firing rate is desired, a second pulverizer is usually started (and the first one shut down) rather than putting these burners into service. This avoids the problems of accumulation of coal in idle burner lines, coking and fires in hot burner nozzles and diffusers, and upsets to the fuel-air ratio of the operating burners for that pulverizer. In some instances these problems can be avoided, and the idle burners may be started on that pulverizer without shutdown and cleaning. It is preferable, however, to have all burners in a pulverizer system in operation. This is possible if the pulverizer system has a high turndown ratio. When a large change in load is needed, a complete pulverizer system is started or shut down.

12. Follow the same procedures to place additional pulverizer systems and burners with open registers in service as required to raise steam pressure, or to carry additional load. Maintain the fuel flow to each burner at a rate that is compatible with the airflow. Ensure operating instructions define a specific sequence in which burners are to be lighted or removed from service. Loss of ignition or failure to ignite any burner must result in stopping fuel flow to that burner. Never start igniters when fuel is being admitted to the furnace unless there is proof of normal fire in the furnace at the operating burners.

13. After the operating burners provide a sustaining ignition energy level, the Class 1 or Class 2 igniters may be shut off. For systems so designed, Class 1 or Class 2 igniters may continue in operation if all requirements and proper interlocks have been provided and verified by test.

C.1.3 Normal Operation

1. When changing the firing rate, maintain a safe air-fuel ratio using a lead-lag system. Only one control device should be manipulated to achieve the change in firing, while the other control follows automatically. Modern control systems will adjust both air and fuel simultaneously. On load changes, however, combustion should always be oxygen rich.

2. Keep individual burner shutoff valves (swing gates) in the full-open or full-closed position. Regulate the firing rate via the primary airflow rate and the feeder speed, not by throttling individual burner shutoff valves. Throttling individual burner shutoff valves will lead to layout of coal in the coal conduit to that burner. When throttling is removed, the coal is re-entrained, producing a fuel-rich mixture at the burner, and possibly an explosive mixture in the furnace.

3. When boilers are fired below approximately 40% of their rating, reduce the number of pulverizers in service to avoid having to turn down all pulverizer burners below the minimum stable firing rate. The actual minimum stable firing rate may vary with different fuel characteristics and fuel firing equipment. Burner turndown ratio will not be as large when firing coal with low volatiles and high fines. Do not increase the number of pulverizers and burners in service until the load has been increased enough to permit stable combustion, especially if the burners are not adjacent to the burners already in service.

4. Change the combustion control systems from automatic to manual operation when firing rates are too low for the equipment to automatically maintain a safe fuel-air ratio. This is usually necessary during the initial lighting-off cycles and extremely low load demand. Consult the equipment manufacturer and conduct tests to determine the specific conditions under which changeover to manual operation is necessary for a specific boiler.

5. Do not reduce the total furnace airflow below the minimum necessary for safe firing, as determined by the boiler manufacturer. The minimum normally will be set at 25% of full load mass airflow.

6. Ensure loss of flame at individual burners, pulverizer-burner groups, or the entire furnace burner system automatically shuts down the appropriate burner system, as described in Section 2.1.2.4.

7. Periodic soot blowing is necessary to maintain high thermal efficiency in pulverized coal-fired boilers. Also, although coal flyash is noncombustible, soot from auxiliary oil firing is combustible and can cause fires in air heaters and other downstream equipment.

a. Operate soot blowers only while burners are firing at high rates to avoid extinguishing the burner flames. The fuel-air ratio and combustion air may need to be adjusted. Consult the boiler manufacturer's instruction manual to obtain specific recommended operating procedures when blowing soot.

b. If soot blowing must be done when the boiler is out of service, ascertain that the boiler is cold and there is no other source of ignition. When blowing soot in cold boilers, use compressed air rather than steam. Condensing steam may dissolve sulfur in the soot and corrode boiler tubes.

8. Before operators attempt to loosen a clog in an operating burner, the igniter for that burner must be in service.

C.1.4 Shutdown

1. For a normal shutdown, reverse the procedure used during startup. Remove burners and pulverizers from service sequentially as the load is reduced. Leave burner registers in the firing position when approaching 25% load and when all burners are going to be taken out of service. Shift fuel-air ratio control from the total on-line input to individual burner-pulverizer input basis.

2. To avoid the admission of unburned fuel, place burner igniters into service prior to purging of coal from the pulverizer and burners into the furnace. Do not place igniters into service, however, without proof of main burner flame. Explosions have been caused by putting igniters into service after a flameout of an operating burner occurred.

3. With the igniters in service for the operating burners, reduce primary air temperature to allow a gradual cool down of the pulverizers, and reduce primary airflow and feeder speed to minimum. When temperature has dropped a set amount (typically about 25°F), shut down the coal feeder. After it has been determined that the coal has been sufficiently swept from the pulverizer and burners (using pulverizer pressure differential

or amperage), the pulverizer, primary air fan, and the burner valves (swing gates) may be closed and the igniters removed from service. For high storage pulverizers it may be desirable to retain coal in the pulverizer with an inert gas atmosphere.

4. After all firing is extinguished, maintain an airflow (secondary air) of not less than 25% of full load airflow for a period of not less than five minutes to accomplish a post-purge of the boiler enclosure and flue gas passages.

C.2 Other Standards

Additional information concerning explosion prevention in multiple-burner boiler-furnaces may be found in the National Fire Protection Association (NFPA) 85, *Boiler and Combustion Systems Hazards Code.* It is recommended that this standard be consulted for a more detailed explanation of system design considerations and operating philosophy. (Also see Section 2.1.)

Other related standards include:

- NFPA 120, *Standard for Fire Prevention and Control in Coal Mines*, which includes general information regarding conveyors and coal storage that is applicable to this OS
- NFPA 54 *National Fuel Gas Code*
- NFPA 30, *Flammable and Combustible Liquids Code*
- NFPA 70, *National Electric Code*
- American National Standards Institute (ANSI) B31.1, *Power Piping*