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WASTE FUEL-FIRED FACILITIES

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1.0 SCOPE

This data sheet covers processing waste streams as a fuel source and the firing of those and other waste fuels in boilers. The term “incinerator” is primarily used in Europe as equivalent to the term “boiler.” For consistency, the term “boiler” will be used throughout this document.

The equipment and process information in this data sheet is primarily for boiler installations, but may also be used for firing waste fuels in furnaces.

Fire protection guidance is provided for all areas of facilities in which waste fuels are processed, including tipping halls, fuel storage bunkers, and fuel processing equipment areas such as shredder buildings. Also covered is protection of combustible flue gas equipment, and other areas where fire protection is warranted. Equipment guidance is divided into three sections by type of fuel: gaseous, liquid, and solid.

This document does not cover every type of waste fuel (e.g., chemical process waste streams). Additional guidelines for waste fuel-fired boilers are contained in the following data sheets:

- Data Sheet 6-2, *Pulverized Coal-Fired Boilers*
- Data Sheet 6-4, *Oil- and Gas-Fired Single-Burner Boilers*
- Data Sheet 6-5, *Oil- or Gas-Fired Multiple Burner Boilers*
- Data Sheet 6-6, *Boiler-Furnaces Implosions*
- Data Sheet 6-7, *Fluidized Bed Boilers*
- Data Sheet 6-12, *Low-Water Protection for Boilers*
- Data Sheet 6-22, *Firetube Boilers*
- Data Sheet 6-23, *Watertube Boilers*

1.1 Changes

January 2021. Interim revision. Updated contingency planning and sparing guidance.

1.2 Hazards

1.2.1 Fire Hazards

Energy from waste facilities have numerous areas with fire hazards. In areas that store waste fuel in a pile, such as tipping halls (floors), fuel storage bunkers (mass burn facilities), refuse derived fuel (RDF) storage buildings, and RDF processing buildings, the fire hazard is typically a surface burning and burrowing fire. These types of fires spread slowly and are not as intense as other fires. Areas with pre-sorted storage or baled recycling storage with pile separation, flue spaces, and potentially higher storage heights will result in larger and more intense fires, requiring higher sprinkler densities.

It is also typical for facilities burning waste to have boiler flue gas equipment and ductwork made from stainless steel or FRP or other combustible materials. The flue gas ductwork typically has large diameters, and potentially long runs, directing the flue gas through emissions equipment and eventually to a stack or chimney. Since this ductwork and equipment is critical to the operation of the boiler, any fire involving this equipment can create a potential for long shutdowns. Effective equipment contingency planning and management of exposures can reduce this exposure.

1.2.2 Boiler and Machinery Hazards

Firing waste fuel in dedicated waste fuel-fired boilers or boilers in which waste fuel is burned along with conventional fuel presents the following hazards and concerns:

- A reliable ignition source must be provided for the waste fuel.
- Additional combustion air may need to be provided if waste fuel is added to existing fuel firing.
- Continuous ignition support may be necessary to maintain stable firing of the waste fuel.
- Additional fuel supply interlocks may be required to ensure conditions in the boiler are acceptable for the introduction and burning of waste fuels.
- Corrosive combustion byproducts may increase the potential for furnace tube failures.
- Upsets in the process that creates the waste fuel may result in excessive heat input.

- Fly ash generated by the combustion of waste fuel may accelerate tube thinning (erosion- corrosion).
- When waste streams are mixed with the combustion air supply, upsets in the process may cause a waste fuel-air stream that is normally below the lower flammability limit (LFL) to become flammable, be ignited by the burner, and burn back into the transfer duct work.

2.0 LOSS PREVENTION RECOMMENDATIONS

2.1 Introduction

Energy from waste (waste-to-energy) facilities receive municipal or commercial waste by road, rail, or ship; store and process it onsite; and burn the waste in a boiler, which generates steam to drive a steam turbine generator, or for heat distribution such as district heating. There are other types of fuel-fired equipment that may utilize municipal waste, refuse-derived fuel, and other solid, liquid, or gaseous “waste stream” fuels as their primary fuel.

2.2 Construction and Location

2.2.1 Waste Fuel Handling Areas

2.2.1.1 Use noncombustible or FM Approved Class 1 building materials for exterior and interior construction.

2.2.1.2 Provide minimum 1-hour fire-resistive construction for all fuel storage and handling areas. This could include tipping halls (waste off-loading areas), bunker buildings, and fuel transfer buildings, as well as separate buildings for fuel processing such as shredder, sorting, and separation buildings.

2.2.1.3 Between fuel storage and handling buildings and other areas in the facility, provide FM Approved fire doors having the same or greater fire rating as the walls in which they are installed.

2.2.1.4 Locate fuel shredders in a separate building away from fuel storage and other combustibles.

2.2.1.5 Provide dust collection systems on any dust-producing equipment such as hammer mills, flail mills, or shredders associated with RDF processing.

2.2.1.6 Construct the fuel bunker control and crane operator rooms and windows with minimum one-hour fire-rated construction.

2.2.2 Flue Gas Handling

2.2.2.1 Construct all flue gas handling equipment using metal or other noncombustible materials in accordance with Data Sheet 7-78, *Industrial Exhaust Systems*. This includes ductwork, baghouses, fan housings, scrubbers, desulphurizers, environmental equipment, and stack liners.

2.2.2.2 Design and construct baghouses in accordance with Data Sheet 7-76, *Combustible Dusts* .

2.2.2.3 Provide noncombustible filter bags within flue gas baghouses.

2.2.2.4 Use only FM Approved (class 1) or noncombustible material (e.g., mineral wool) for exterior insulation of equipment and ductwork.

2.2.2.5 Construct chimneys in accordance with local building codes.

2.2.3 Other Areas

2.2.3.1 Use noncombustible or FM Approved Class 1 building materials for construction of emissions-monitoring buildings or enclosures.

2.3 Protection

2.3.1 Protection of Tipping Halls

2.3.1.1 Install automatic sprinkler protection throughout the tipping hall in accordance with Data Sheet 3-26, *Fire Protection Water Demand for Nonstorage Sprinklered Properties*, and as follows:

A. Treat locations handling household and business solid waste as an HC-2 occupancy.

B. Treat locations handling shredded waste, and/or mixed pre-sorted recycling as an HC-3 occupancy.

2.3.1.2 Limit the storage of ignitable liquids in tipping halls. When ignitable liquids are stored in this area, protect them in accordance with Data Sheet 7-29, *Ignitable Liquid Storage in Portable Containers*.

2.3.2 Protection of Fuel Bunker (Refuse Pit Area)

Due to the potential for large ceiling clearances in fuel bunkers, ceiling-level sprinkler protection alone will not be effective at controlling a bunker fire. However, ceiling-level protection is critical in cooling the building structure during a fire to maintain the integrity of the building, the cranes, and other infrastructure. Monitors will have a greater effect on controlling a fuel bunker fire as they can direct large streams of water at the seat of the fire.

2.3.2.1 Ceiling and Exposure Protection

2.3.2.1.1 Provide automatic sprinkler protection for all areas of the bunker shown in Figure 1 in accordance with Sections 2.3.2.1.2 through 2.3.2.1.6. Install automatic sprinklers in accordance with Data sheet 2-0, *Installation Guidelines for Automatic Sprinklers*.

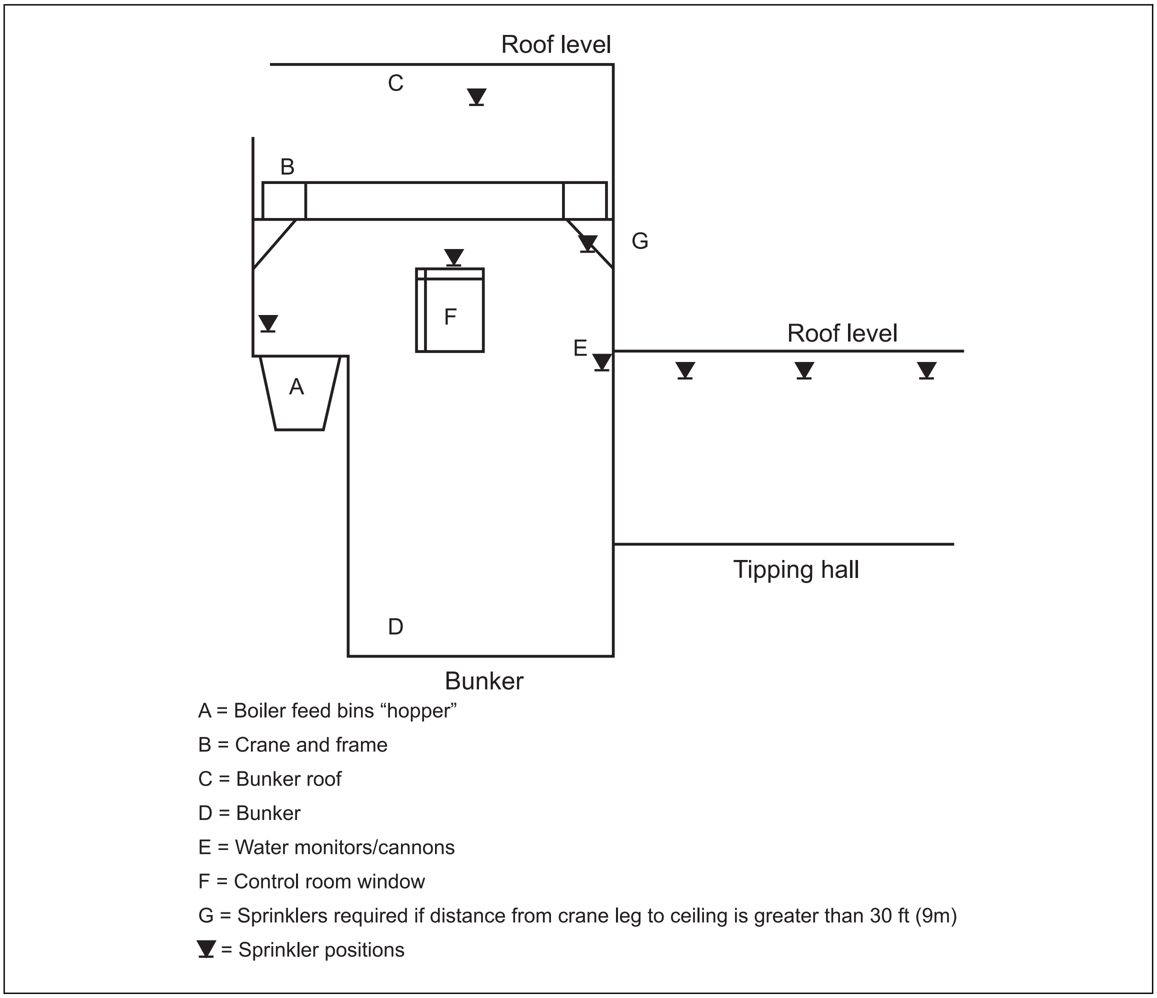

Fig. 1. Sprinkler locations for waste fuel bunker

2.3.2.1.2 Install ceiling-level automatic sprinkler protection throughout the fuel bunker area designed to provide a minimum 0.3 gpm/ft^2 (12 mm/min) over 2500 ft^2 (230 m^2). Use minimum K11.2 (K160), 256°F (120°C) temperature-rated sprinklers, with a maximum spacing of 100 ft^2 (9.3 m^2) on a wet system. If a dry system is to be used, increase the demand area to 3250 ft^2 (300 m^2).

2.3.2.1.3 Protect the bunker control room windows with an automatic water deluge or closed nozzle water spray system in accordance with Data Sheet 1-20, *Protection Against Exterior Fire Exposure*. Use minimum K5.6 (K80) nozzles designed to provide a minimum flow rate of 15 gpm (56 L/min).

2.3.2.1.4 Provide a wet automatic sprinkler system for the bunker control room support structure when it is cantilevered over the storage bunker and could be directly exposed to fire. Design the fire protection to provide a minimum of 0.3 gpm/ft2 (12 mm/min) over the exposed area beneath the control room or 2500 ft^2 (230 m^2), whichever is greater.

2.3.2.1.5 Protect boiler fuel feed bins (hoppers) with an automatic water deluge system delivering at least 0.3 gpm/ft^2 (12 mm/min) over the hopper area.

2.3.2.1.6 Provide heat detection, infrared (IR) detection, or pilot line detection to activate the deluge protection. In addition to automatic operation, provide a manual activation for deluge systems that is accessible from a safe location.

2.3.2.2 Monitors

2.3.2.3.1 Provide permanent automatic or manual monitors positioned to cover the entire bunker. Design the system to provide at least 300 gpm (950 L/min) at 100 psi (6.9 bar) per monitor.

2.3.2.3.2 Design the water demand for the bunker area to be the combined flow from the bunker ceiling system, the control room window protection system, any auxiliary sprinkler systems in the bunker area, and two monitors operating, for a minimum of 60 minutes.

2.3.2.3.3 Ensure the monitors are protected from a bunker fire by appropriate positioning or by providing local sprinklers or water spray or by adjacent monitors.

2.3.2.3.4 Provide fixed or oscillating local or remotely moveable monitors, depending on the situation and area requiring coverage.

2.3.2.3.5 Route the power and control wiring for the monitors to avoid exposure to a bunker fire. If unavoidable, provide FM Approved cable wraps rated for a minimum 60 minutes.

2.3.2.3.6 Activation of the monitors can be either by a reliable fire detection device suitable for the environment, or manually from a 24/7 monitored control room with direct sight to the bunker.

2.3.2.3.7 Thoroughly train operators in the details of the entire fire protection system.

2.3.2.3.8 Conduct flow testing, and full functional operation testing at least monthly.

2.3.3 Fuel Processing Equipment

2.3.3.1 Provide protection for all conveyors processing waste fuels in accordance with Data Sheet 7-11, *Conveyors*.

2.3.3.2 Use FM Approved hydraulic fluid or provide protection over the hydraulic skid and drives of the shredder or within the shredder enclosure in accordance with Data Sheet 7-98n, *Hydraulic Fluids*. Provide automatic hydraulic shutoffs for each unit, with a manual shutoff provided and accessible from a safe place.

2.3.3.3 Park all mobile equipment outside and a minimum of 100 ft (30 m) away from critical buildings and storage when not in use.

2.3.4 Boiler House or Building

2.3.4.1 Where the building construction does not warrant sprinkler protection, provide localized automatic sprinklers in buildings containing oil-fired, gas-fired, and waste fuel-fired boilers subject to the presence of combustible load.

2.3.4.2 Design the sprinkler system as follows:

A. Provide local fire protection over the boiler burners and immediate perimeter per Data Sheet 6-5, *Oil- and Gas-Fired Multiple Burner Boilers*.

B. Provide automatic sprinkler protection in accordance with Data Sheet 7-32, *Ignitable Liquid Operations*, if fuel oil system components (e.g., tanks, pumps) are located within the boiler room, or the oil piping system in the boiler room is not designed in accordance with Data Sheet 6-4, *Oil- and Gas-Fired Single Burner*

Boilers, and Data Sheet 6-5, *Oil- and Gas-Fired Multiple Burner Boilers*, and provide protection for tanks in accordance with Data Sheet 7-88, *Ignitable Liquid Storage Tanks*.

C. Provide local fire protection over hydraulic systems per Data Sheet 7-98, *Hydraulic Fluids*.

Hydraulic systems are typically used to drive the boiler grates and bottom ash conveyors.

2.3.5 Control Rooms

2.3.5.1 Protect control rooms in accordance with Data Sheet 5-32, *Data Centers*.

2.3.5.2 In addition to the minimum recommendations in Data Sheet 5-32, design and protect control rooms located in the steam turbine building in accordance with Data Sheet 7-101, *Steam Turbines and Electric Generators*.

2.3.6 Emissions Monitoring Building

2.3.6.1 Provide smoke detection for emission monitoring buildings. Hardwire the smoke detection to a constantly attended location, such as a control room, or external monitoring service.

2.3.6.2 Provide an FM Approved clean agent fire suppression system for emissions monitoring buildings or enclosures.

2.3.6.3 Provide sprinkler protection above emission-monitoring buildings or enclosures with combustible construction when located within another building. Design sprinklers to provide a minimum density of 0.2 gpm/ft^2 (8.1 mm/min) over 2000 ft^2 (190 m^2)with sprinklers located above and 20 ft (6 m) beyond in all directions.

2.3.7 Combustible Flue Gas Ductwork

2.3.7.1 Use noncombustible materials wherever possible for equipment and duct systems.

2.3.7.2 Separate individual flue gas treatment lines from each other and other critical plant areas.

2.3.7.3 Clearly label all equipment of combustible construction (such as GRP, FRP, or rubber lined) for ignition source control.

2.3.7.4 When the occupancy and building construction do not warrant sprinkler protection but combustible ductwork exists in the space, provide a single line of sprinklers directly over the ductwork. Base the water supply on 20 gpm (75 L/min) per head over a maximum of 100 lineal ft (30 m) of duct and use 165°F (74°C) rated sprinklers. See Data Sheet 2-0, *Installation Guidelines for Automatic Sprinklers*, for details. If the duct is covered with foam plastic insulation (polyurethane, polystyrene, etc.), follow the surface treatment and sprinkler protection recommendations in Data Sheet 1-57, *Plastics in Construction*.

2.3.7.5 Provide automatic sprinkler protection within ducts that have a cross-sectional area greater than or equal to 80 in^2 (520 cm^2), or that have diameters greater than or equal to 10 in. (254 mm) in accordance with Data Sheet 7-78, *Industrial Exhaust Systems*.

2.3.8 Combustible Flue Gas Vessels and Equipment

2.3.8.1 Provide automatic sprinkler protection for concentrations of plastic equipment, such as scrubbers, absorbers, fabric filter housings, etc., located inside buildings. Design the system to provide 0.3 gpm/ft^2 (12 mm/min) over 2,500 ft^2 (230 m^2) at the ceiling and under solid floors or intermediate mezzanines, Extend protection 20 ft (6 m) in all directions beyond the equipment.

2.3.8.2 Protect outdoor plastic equipment and ductwork with open sprinklers or water spray protection. Design the system in accordance with the following specifications:

A. Locate the sprinklers or water spray nozzles to provide coverage over exposed tank surfaces.

B. For pilot sprinklers, use FM Approved quick response sprinklers within 6 in. (150 mm) of the scrubber surfaces.

C. Use a discharge pressure of 20 psi (1.4 bar) for open sprinklers or nozzles greater than or equal to ½ in. (13 mm). Use 30 psi (2.1 bar) for smaller nozzles.

2.3.8.3 Do not store combustibles or construct combustible enclosures or buildings under outdoor combustible ductwork or flue gas processing systems. If possible, restrict fueled vehicles from being parked or from routinely being driven under these systems. Label duct clearance to avoid vehicle impact.

2.3.8.4 Provide a means of protecting combustible equipment during periods of process upsets, maintenance and/or construction. The following provides a list of potential options that can be implemented to minimize the potential for a loss:

- Connect flue gas desulfurization vessel slurry nozzles to a quench water tank that is located above the inlet into the scrubber unit.
- As a backup to the quench water system, have the fire water supply connected to this system.
- Provide mobile water spray extinguishing systems for the inside of combustible equipment. The use of the existing water/slurry spray nozzles may be considered for this purpose.
- Install mobile smoke detection inside the equipment to supplement internal monitoring by workers.
- Isolate the flue gas treatment equipment from other equipment and areas.
- Insert fire stop seals at expansion joint gaps or other flanges upstream and downstream from the isolated equipment. Ensure the seal is constructed of fire-resistant material with a fire resistance of no less than 90 minutes design, or a metal panel supplemented with water spray protection.

Under normal operating conditions flue gas desulfurization units are water/slurry filled and wet, which makes them much less likely to be involved in a fire. The addition of a quench tank and fire water backup can help protected against thermal damage to the vessel from process upset conditions that result in high flue gas temperatures. The fire hazard for this equipment is greatest during the construction of the units and during overhauls and longer stops when the units are dry.

2.3.8.5 Restrict hot work in areas where FRP or rubber-lined tanks are present and empty. Follow special precautions, including use of a permit system and a combustible gas detector, whenever hot work must take place near, on, or above such installations. Take special care during plant shutdown when plastic tanks may be dry and open.

2.4 Boiler Operation and Maintenance

2.4.1 Train operators to standard and emergency operating procedures. See Data Sheet 10-8, *Operators* for guidance on developing operator programs. Train operators in the proper operation of the waste fuel-fired boiler and its ancillary equipment and in the specific functions of the various safety controls. Provide documented standard and emergency operating instructions and have them readily available in the boiler control room.

2.4.2 Establish and implement a waste fuel fired boiler inspection, testing and maintenance program. See Data Sheet 9-0, *Asset Integrity* for guidance on developing an asset integrity program.

2.4.3 Inspect and test safety controls and perform other maintenance required by the manufacturer’s instructions to ensure proper functionality functioning when emergencies arise. Failure to make these periodic checks may not only result in fire or explosion damage or mechanical or electrical failure, but also may contribute to accidental shutdown and loss of production.

For pressure part inspections, follow the guidelines in Data Sheet 6-22, *Firetube Boilers*, and Data Sheet 6-23, *Watertube Boilers*.

2.4.4 Maintain all equipment in good condition. Maintenance details and schedules depend on the equipment and the operating conditions. Follow a specific routine recommended by the manufacturers of the various components.

Some aspects of the maintenance and testing programs for various components of waste fuel-fired boilers and ancillary equipment are discussed in other data sheets, listed below:

- Data Sheet 6-4, *Oil- and Gas-Fired Single-Burner Boilers*
- Data Sheet 6-12, *Low-Water Protection*
- Data Sheet 6-22, *Firetube Boilers*
- Data Sheet 6-23, *Watertube Boilers*

- Data Sheet 7-76, *Combustible Dusts*
- Data Sheet 12-43, *Pressure Relief Devices*

2.5 Boiler Equipment and Processes

2.5.1 Purge and Startup

2.5.1.1 Use FM Approved equipment and devices, such as fuel safety shutoff valves, supervisory switches, combustion safeguards, etc., when available and suitable for the application.

2.5.1.2 Provide a timed purge for the boiler furnace, passes, breeching, and stack. Ensure the purge consist of at least five volume changes of fresh air for a continuous period of not less than five minutes. Arrange for the purge airflow rate to be at least 25% (less than 40% for solid fuels) of that required for firing at maximum boiler output.

In cases where waste fuel is a secondary fuel, the boiler needs to be operating in stable condition prior to introducing the waste fuel. In this case a purge prior to firing the waste fuel is not practical or necessary. However, there should be an interlock, such as “steam flow greater than 30% of full load” or “the furnace temperature greater than a minimum value specified by the boiler manufacturer” that will ensure stable operation in the furnace prior to the entry of the waste fuel.

2.5.1.3 Provide interlocks to prove that the following purge conditions are satisfied. If any permissive interlock is lost during the purge timing, reinitiate the purge.

1. Main gas and igniter header safety shutoff valves and all main burner safety shutoff valves closed. When provided, interlock the operation of the FM Approved supervisory cocks with the purge timer to ensure all cocks are closed prior to and during the purge period. (For additional guidance on FM Approved supervisory cocks refer to Data Sheet 6-18, *FM Cock Safety-Control System*.)

2. All required burner registers or dampers open to the purge position.

3. At least one set of I.D. and F.D. fans running.

4. Not less than 25% of full-load volumetric air flow.

2.5.1.4 Provide basic interlocks as follows for startup and firing protection to ensure properly sequenced operation, and shut off all fuel and ignition systems if interlock functions are not satisfied or hazardous conditions develop.

1. Place induced and forced-draft fans in operation in that order. Arrange for failure of the fan or fans to shut down any fan following it in the order of actuation, and shut off and lock out all fuel and the ignition system.

Where two induced or forced draft 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 induced draft fans is lost, its associated forced draft fan is tripped and the fuel to the unit is automatically reduced to provide the proper fuel-air ratio for the reduced air flow that is still available.

2. When purge air flow rate is in excess of 25% of full load volumetric air flow, an additional minimum airflow interlock set at 25% of full load volumetric air flow is often provided. This will allow reduction of air flow to a minimum level for low load operation.

3. Provide a high and low furnace-pressure interlock to shut off all fuel and ignition systems if excessive furnace pressure develops. This can minimize the development of hazardous fuel conditions upon boiler tube rupture or outlet damper failure. (See Data Sheet 6-6, *Boiler-Furnace Implosions*.)

4. Limit the igniter flame establishing period to 10 seconds. Interlock the loss of flame on an individual igniter to close the igniter shutoff valve and de-energize the spark.

2.5.2 Gaseous Fuels

2.5.2.1 Provide safety shutoff valves on the main and igniter fuel supply headers and at each burner and igniter in accordance with the recommendations in DS 6-4, *Oil- and Gas-Fired Single-Burner Boilers*, or 6-5, *Oil- or Gas-Fired Multiple Burner Boilers*, as applicable.

2.5.2.2 Provide permanent and ready means for making periodic tightness checks of the header and main burner gas safety shutoff valves. (See Data Sheet 6-0, *Elements of Industrial Heating Equipment*.)

2.5.2.3 Provide high and low fuel-gas pressure interlocks.

2.5.2.4 Provide permanently installed igniters that have sufficient capacity to ensure prompt ignition of the main burner fuel. Provide flame supervision for each fuel-fired igniter.

2.5.2.5 Install igniter(s) and flame sensing element(s) securely so the position of each with respect to the others and the main flame will not change. Provide observation ports so these positions can easily be observed while the igniter and/or main burner are firing. Ensure these units are readily accessible for inspection and cleaning.

2.5.2.6 Provide a non-recycling, flame-supervisory combustion safeguard arranged to prove the existence of a reliable igniter flame before permitting the main burner safety shutoff valve to open.

Where a high-energy spark-igniter assembly is provided, the fuel burning igniter and proof of igniter flame may be omitted. Where the igniter is of the retractable type, ensure it is proved in the correct position for proper lighting-off of the main-burner fuel before the ignition cycle can proceed and the main burner safety shutoff valve is opened for a limited trial-for-ignition.

When an igniter is proved by a combustion safeguard, ensure supervision is at a location where the igniter flame will effectively ignite the main burner or burner unit. A main burner should be ignited immediately by its igniter, even when the igniter is reduced to the minimum flame capable of holding the flame-sensing relay of the combustion safeguard in the energized (flame-present) position.

2.5.2.7 Provide flame supervision for main burners.

2.5.2.8 Limit the igniter-flame-establishing period to the shortest practical interval, generally not exceeding 10 seconds. Upon completion of main burner trial-for-ignition period, arrange the non-recycling, flame-supervisory combustion safeguard for direct supervision of the main burner flame only. Limit the trial-for-ignition of the main burner to the shortest practical time, generally not exceeding 10 seconds. Because of the time required for large remote operated valves to open, or the distance from the valve to the burner, longer periods may be required to achieve burner light-off. In any case, ensure the fuel lights immediately upon entering the furnace.

2.5.2.9 Ensure loss of flame at an individual waste fuel burner flame envelope causes the safety shutoff valve for the individual burner to trip. Some firing methods admit fuel and air into the furnace in a manner such that the entire furnace acts as a single burner arrangement. With these systems, flame outage may occur at one or more burner nozzles without resulting in a hazardous condition in the boiler furnace. The exact conditions that will result in a hazardous situation are affected by furnace configuration, number of burner nozzles, number of burners affected, load level, etc., all of which will require a careful analysis of the entire safety control system for the particular boiler. Total loss of flame in any boiler furnace should trip all fuel to the unit and require a complete furnace purge.

2.5.2.10 For locations that have a boiler firing hydrogen gas supplied by a process also at the same location, treat hydrogen gas pipelines the same as natural gas pipelines. There is no need for flashback arrestors in the hydrogen pipeline. However, provide the system with two valves, one burner safety shutoff and a similar valve at the supply compressor. Arrange both to shut down upon system shutdown. Also, at the supply end of the pipeline, provide a chlorine detector set at 1% and an oxygen or other oxidizer detector set at 2% for shutdown of the system. In addition, purge the hydrogen lines with a noncombustible inert gas prior to startup and just after shutdown of the piping system.

2.5.2.11 For locations where dilute waste gas streams are blended with combustion air, monitor the waste stream for combustible concentration. Divert the waste stream to atmosphere or an alternate incineration point (flare) when a process upset causes the combined waste and air stream concentration to exceed 50% of the LEL.

2.5.3 Liquid Fuels

2.5.3.1 Provide safety shutoff valves on the main and igniter fuel supply headers and at each burner and igniter in accordance with the recommendations in Data Sheet 6-4, *Oil- and Gas-Fired Single-Burner Boilers*, or Data Sheet 6-5, *Oil- or Gas-Fired Multiple Burner Boilers*, as applicable.

2.5.3.2 Provide low fuel-pressure interlocks for both main and igniter fuel supplies. Where fuel must be preheated, provide high and low fuel-temperature interlocks.

2.5.3.3 Where applicable, provide atomizing-medium interlocks for steam or air-atomized fuel burners to prevent the introduction of fuel to the burners upon loss of, or impairment of the atomizing medium.

2.5.3.4 Provide permanently installed igniters that have sufficient capacity to ensure prompt ignition of the main burner. Provide flame supervision for each fuel-fired igniter.

2.5.3.5 Install igniter(s) and flame sensing element(s) securely so the position of each in respect to the others and the main flame will not change. Provide observation ports so these positions can easily be observed while the igniter and/or main burner are firing. Ensure these units are readily accessible for inspection and cleaning.

2.5.3.6 Provide a non-recycling, flame-supervisory combustion safeguard arranged to prove the existence of a reliable igniter flame before permitting the main burner safety shutoff valve to open.

Where a high-energy spark-igniter assembly is provided, the fuel-burning igniter and proof-of-igniter flame may be omitted. Where the igniter is of the retractable type, have it proved in the correct position for proper lighting-off of the main burner fuel before the ignition cycle can proceed and the main burner safety shutoff valve is opened for a limited trial-for-ignition.

When an igniter is proved by a combustion safeguard, locate supervision where the igniter flame will effectively ignite the main burner or burner unit. A main burner should be ignited immediately by its igniter, even when the igniter is reduced to the minimum flame capable of holding the flame-sensing relay of the combustion safeguard in the energized (flame-present) position.

2.5.3.7 Provide flame supervision for main burners.

2.5.3.8 Limit the igniter-flame-establishing period to the shortest practical interval, generally not exceeding 10 seconds. Upon completion of main burner trial-for-ignition period, have the non-recycling, flame-supervisory combustion safeguard arranged for direct supervision of the main burner flame only. Limit the trial-for-ignition of the main burner to the shortest practical time, generally not exceeding 15 seconds. Because of the time required for large remote-operated valves to open, or the distance from the valve to the burner, longer periods may be required to achieve burner light-off. In any case, ensure the fuel lights immediately upon entering the furnace.

2.5.3.9 Ensure loss of flame at an individual burner flame envelope causes the safety shutoff valve for the individual burner to trip. Some firing methods admit fuel and air into the furnace in a manner such that the entire furnace acts as a single burner arrangement. With these systems, flame outage may occur at one or more burner nozzles without resulting in a hazardous condition in the boiler furnace. The exact conditions that will result in a hazardous situation are affected by furnace configuration, number of burner nozzles, number of burners affected, load level, etc., all of which will require a careful analysis of the entire safety control system for the particular boiler. Total loss of flame in any boiler furnace should trip all fuel to the unit and require a complete furnace purge.

2.5.4 Solid Fuels

2.5.4.1 General

2.5.4.1.1 Clean ash hoppers continuously to minimize the possibility of accumulated unburned or incompletely burned fuel that may settle out in low velocity areas of the boiler.

2.5.4.1.2 Install thermocouples in ash hoppers, set to alarm in the control room. Thermocouples will alert operators to over-temperature conditions and may indicate a dumping system malfunction. In addition, install ash hopper level indicators and/or valve monitors (for installations provided with rotary airlock valves), set to alarm in the control room, to indicate problems with ash-removal systems.

2.5.4.1.3 Dryers may be used to lower fuel moisture prior to burning.

2.5.4.2 Fuel Handling

Arrange and protect conveyors in accordance with Data Sheet 7-11, *Conveyors*.

2.5.4.2 Solids Fired in Suspension

2.5.4.2.1 Provide permanently installed Class 1 or Class 2 igniters for ignition of solid waste fuels. The igniters may be intermittent or continuous. (For definitions of igniter classes, refer to Data Sheet 6-4, *Oil- and Gas-Fired Single-Burner Boilers*)

2.5.4.2.2 When a continuously operated Class 1 igniter is provided, ensure it is sized and located to reliably ignite incoming fuel from its associated burner during all operating modes of the burner. Supervise the igniter flame with a flame scanner or detector appropriate for the igniter fuel.

2.5.4.2.3 When an intermittently operated igniter that meets the size requirement of a Class 1 igniter is provided, ensure it is located to reliably ignite incoming fuel from its associated burner whenever it is in service. Provide flame supervision using one or more scanners or detectors that detect both igniter flame and main burner flame. The presence of either flame is sufficient to begin or continue feeding the solid fuel-fired in suspension.

2.5.4.2.4 When a Class 2 igniter is provided, ensure it is sized and located to reliably ignite fuel from its associated burner during prescribed light-off conditions. Provide supervision of the igniter flame and independent supervision of the main burner flame. Supervision of a Class 2 igniter does not by itself provide adequate flame supervision. Supervision of the fireball produced by the burning solid fuel burned in suspension using a scanner that can discriminate between igniter flame and main fuel flame or that is positioned so as to not see igniter flame is also needed. Although a Class 2 igniter may be used to support ignition of the solid fuel, it does not have sufficient energy to ensure light-off of the solid fuel during all operating conditions. Loss of main (solid fuel) flame needs to be detected and cause termination of solid fuel feed.

2.5.4.2.5 Securely install igniters and flame scanners or detectors so the position of each with respect to the other and the main burner will not change. Equip scanners in continuous service for more than 24 hours with a self-checking feature to protect against a scanner malfunction. Equip all scanners with a safe start check feature (to prove no flame is detected before igniter or burner light-off, as appropriate). Equip scanners used to monitor solid fuel flame with flame intensity meters or similar means to enable the operator to detect deteriorating signal strength due to dirty lenses on the scanners or sight tubes.

2.5.4.2.6 Install safety shutoff valves for each igniter. Also install safety shutoff valves in the igniter and auxiliary fuel headers.

2.5.4.2.7 Provide the supply of fuel to the igniters and the solid fuel burners with interlocks equivalent to those associated with conventional fuels.

2.5.4.2.8 Prove igniter flame is present before solid fuel is admitted.

2.5.4.2.9 Provide automatic shutdown of the waste fuel burner upon loss of flame in accordance with Recommendations 2.5.4.2.2, 2.5.4.2.3, and 2.5.4.2.4.

2.5.4.2.10 For multiple burner installations, when safe firing conditions can be maintained with loss of flame at individual burners, burner groups, or zones, alarm such loss of flame.

2.5.4.2.11 Ensure a master fuel trip is automatically initiated upon partial loss of flame sufficient to cause hazardous accumulation of unburned fuel in the furnace.

2.5.4.2.12 Ensure a master fuel trip is automatically initiated upon loss of all flame in the furnace or upon loss of all fuel input into the boiler.

2.5.4.2.13 Provide means for manual operator initiation of a master fuel trip.

2.5.4.2.14 Ensure solid fuel fines cannot be admitted to the furnace unless the waste fuel burner is specifically designed to handle fines.

2.5.4.2.15 Have the fuel flow to the burner proven. Have it set to alarm in the event that fuel flow is interrupted.

2.5.4.3 Wood Fired in Suspension

2.5.4.3.1 Ignition and flame supervision of suspension burning of wood fines can be obtained by following the recommendations in Section 2.5.4.2, Solids Fired in Suspension.

2.5.4.3.2 Alternatively, when a reliable and continuous flow of properly sized wood fines from kiln-dried lumber (typically less than 10% moisture) is available, manual ignition may be used as described in the following paragraphs.

Acceptable size distribution of wood fines is dependent on the boiler design and the type of burner or stoker used to deliver the fuel to the boiler. For pneumatic stoker feed, operating experience indicates the following size distribution is acceptable:

- 60% course sawdust
- 10% to 20% “match stem” material (approximately 1/8 in. [3 mm] diameter pieces) 20% to 30% “flour” consistency
- Occasional oversize (up to 1/4 in. [6 mm] diameter)

Floors of boilers using pneumatic stoker feed are typically brick lined. The occasional oversize pieces burn as embers on the floor and generally congregate around the edge of the floor at the walls. There is no accumulation or pile burning. For wood fines delivered through burners designed for this fuel, maximum size depends on the manufacturer. Top size is typically either 1/16 or 1/8 in. (1.5 or 3 mm)

Manual ignition of kiln-dried wood burned in suspension through pile burning at startup by an experienced, competent operator is an acceptable means of operation, provided the following recommendations are adhered to:

1. Provide two flame detectors. Use only flame detectors demonstrated to have the necessary sensitivity and discrimination to detect the fireball from burning wood without detecting heat reflected by hot refractory.Ensure at least one detector sees flame either from the burning pile at startup or from the wood burning in suspension to permit wood fuel to enter or continue entering the boiler.

2. Ensure the feed rate of the wood fuel does not exceed the minimum startup rate unless at least one detector is sensing flame and at least one of the following conditions is met:

   a. Boiler pressure is not less than 80% of normal operating pressure;

   b. Boiler steam flow is not less than 25% of full load or the minimum stable operating load, whichever is greater; or

   c. The boiler furnace/combustion area is proved to be sufficiently hot to support ignition of incoming wood fuel. This is generally accomplished by a stack temperature switch set at a value that ensures a bridgewall temperature not less than 800°F (425°C) permissive.

Stack temperature is an indirect indication of bridgewall temperature and the relationship between stack temperature and bridgewall temperature varies for different boiler operating modes. To establish the minimum safe stack temperature interlock setting, have stack temperature and bridgewall temperature monitored during different operating modes. Include startup and any alternative fuel(s). Conduct testing for a period of not less than one week to ensure a comprehensive sampling. Select the most conservative(highest) stack temperature as the interlock value. This will ensure a bridgewall temperature interlock for wood firing of at least 800°F (425°C) during all modes of operation.

3. Ensure that, upon loss of flame by both flame detectors, wood feed into the boiler is terminated. Operator action is required to restart the feeding of wood and only after a manual fire is present and sensed by at least one of the two flame detectors.

2.5.4.4 Semi-suspended Firing and Pile Burning (Burning on Grates)

2.5.4.4.1 Dryers may be provided to limit the amount of moisture in the fuel.

2.5.4.4.2 In addition to recommendations 2.4.1 to 2.4.3, 2.5.1.1 to 2.5.1.3, and 2.5.5.1 to 2.5.5.2, have under-grate air flow proven prior to purge.

2.5.4.4.3 Install an auxiliary fuel-fired start-up burner in accordance with Data Sheet 6-4, *Oil- and Gas-Fired Single-Burner Boilers*, or Data Sheet 6-5, *Oil- or Gas-Fired Multiple Burner Boilers*, as applicable.

2.5.4.4.4 Where it is impractical to use flame scanners to monitor fuel beds, use other methods, such as furnace temperature interlocks or steam flow interlocks, to prove the furnace is hot enough to support combustion in a semi-suspended firing condition.

2.5.4.4.5 Have the fuel feed drive motor controllers interlocked with limit switches to shut down and prevent fuel feed on inadequate induced draft, inadequate forced draft or under-grate air, inadequate distribution air for the burners, or excessive furnace pressure.

2.5.4.5 Municipal solid waste (MSW): Only burn MSW in boilers specifically designed for this waste fuel. (See Appendix C.)

2.5.5 Indicators and Alarms

2.5.5.1 Provide adequate means of communication between operators in the control room and operators at important boiler control equipment, such as burners, fan damper controls, air heaters, etc. This is particularly important during critical situations, such as lighting off, bringing the unit up to temperature, and during equipment malfunction or other upset operating conditions.

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

2.5.5.3 Provide alarm systems that give both audible and visual indication 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.

2.5.5.4 Provide “first out” indication for all safety interlocks that initiate a master fuel trip.

2.5.5.5 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 and measurable combustible or carbon monoxide indications.

2.5.6 Electrical

2.5.6.1 Ensure both ac and dc safety control circuits are two-wire, one side grounded. Ensure all safety control switching is in the hot ungrounded conductor, and provide overcurrent protection. In addition to circuit grounds, also ensure non-current carrying metal parts, such as equipment enclosures and conduit, are grounded.

In unusual cases where an ungrounded dc power supply cannot be avoided, locate all switching in one conductor and provide ground fault detection.

2.5.6.2 Set all controls and interlocks to fail in the fail-safe mode.

2.5.7 Additional Recommendations

2.5.7.1 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.

2.5.7.2 On a monthly basis, inspect furnace pressure-sensing taps for slag or flyash buildup, which could cause plugging.

2.5.7.3 Keep flame detector lenses and sight tubes clean to avoid loss of scanning sensitivity and false indication of flame failure. The required cleaning frequency will depend upon local conditions. However, the need is usually indicated to the operators by a downward trend in flame signal strength.

2.5.7.4 Depending on the type of fuel being fired, follow fire protection recommendations for fuel storage and handling as described in one of the following standards:

- Data Sheet 7-11, *Conveyors*
- Data Sheet 7-32, *Ignitable Liquid Operations*
- Data Sheet 7-54, *Natural Gas and Gas Piping*
- Data Sheet 7-76, *Combustible Dusts*
- Data Sheet 7-88, *Storage Tanks for Ignitable Liquids*
- Data Sheet 7-91, *Hydrogen*

- Data Sheet 8-10, *Coal and Charcoal Storage*
- Data Sheet 8-27, *Storage of Wood Chips*

2.6 Human Factor

2.6.1 Housekeeping

2.6.1.1 Develop a formal housekeeping program for all areas throughout the facility. At a minimum, have housekeeping conducted on a regular basis to minimize the accumulation of dust and other combustible particles that can create a fire or explosion hazard within the buildings. This is most applicable to the bunker building wood chip storage and handling areas. Also consider the following:

- Tipping hall/floor
- Bunker building
- Fuel transfer and processing areas
- Boiler building
- Boiler burner front
- Bulk oil storage and pumping areas

2.6.2 Control of Ignition Sources

2.6.2.1 Conduct regular and formalized inspections and temperature monitoring for municipal waste storage areas. Fires in piled waste storage are more prevalent in summer than in winter. Temperature monitoring may be done more frequently during these periods. Municipal waste is very diverse and can contain hazardous materials as well as wet organic material. When shredded, sparks or even small explosions can occur. When left alone, spontaneous combustion may occur.

Determining the frequency of inspections and temperature monitoring will depend on many factors, including the size of the facility, how often the waste is turned over, whether the area is constantly monitored or remote, and whether the area has adequate detection/protection.

2.7 Contingency Planning

2.7.1 Equipment Contingency Planning

When a waste fuel-fired boiler breakdown would result in an unplanned outage to site processes and systems considered key to the continuity of operations, develop and maintain a documented, viable waste fuel-fired boiler equipment contingency plan per Data Sheet 9-0, *Asset Integrity*. See Appendix C of that data sheet for guidance on the process of developing and maintaining a viable equipment contingency plan. Also refer to sparing, rental, and redundant equipment mitigation strategy guidance in that data sheet.

In addition, include the following elements in the contingency planning process specific to waste fuel-fired boilers:

A. Replacement or repair of long lead-time utility and support system equipment, unique components (including the flue gas handling equipment), and critical combustible ductwork.

B. Evaluate the potential use of temporary duct work constructed of different material, other workarounds, repair options, and de-rates that would occur until the equipment or process is fully restored.

C. Develop a replacement/repair options matrix to support the evaluation of replacement and repair options.

D. Potential equipment rental resources.

E. Identify and prequalify potential contractors, consultants, manufacturers, and vendors (including contact information) required for investigation, analysis, installation, testing, and startup.

F. Maintain equipment information, including the following:

- Equipment data sheets, nameplate data, drawings, commissioning and maintenance test records, field diagnostic and test reports, and original factory acceptance test (FAT) reports.

- System one-line diagrams

3.0 SUPPORT FOR RECOMMENDATIONS

3.1 Loss History

3.1.1 Fire Protection Loss History

Nearly three quarters of all losses in waste-to-energy and waste storage processing facilities are a result of fire, mechanical breakdown, and electrical breakdown with nearly half coming from fires alone as shown in Figure 2.

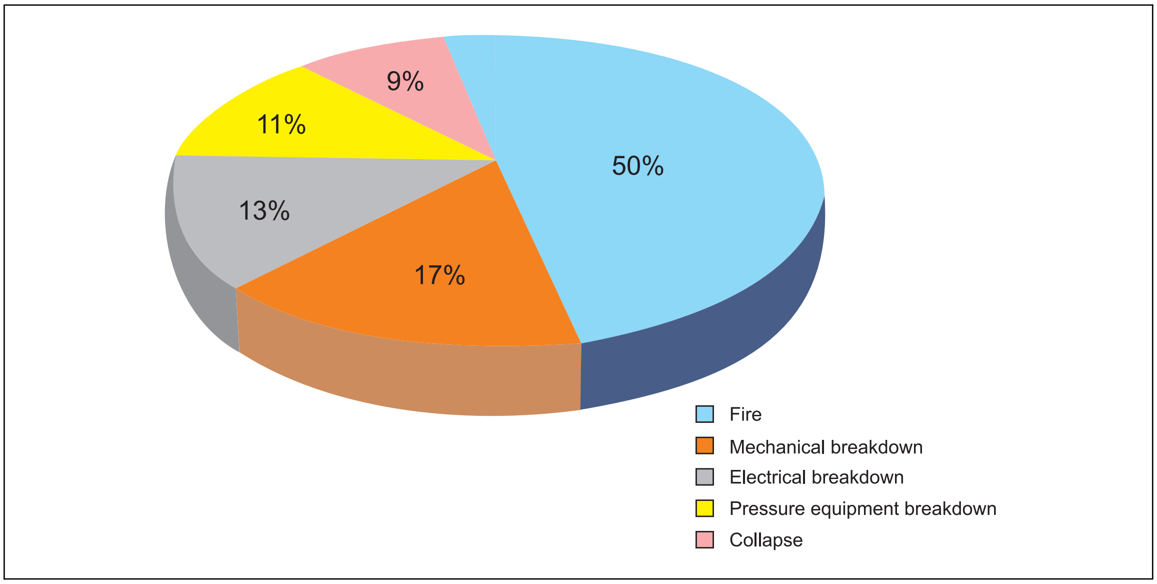

Fig. 2. Waste-to-energy losses (gross loss by peril, losses greater than US$1 million)

Fire losses in this industry are primarily due to the storage and processing of waste fuel. Another critical area that has a low potential frequency but high severity for fires is the flue gas processing equipment. This equipment is typically custom made for individual sites and is made from Stainless Steel or FRP components due to the corrosivity of the flue gas. As such these systems present a long lead time exposure.

3.1.2 Boiler and Machinery Losses

Boiler furnace explosions are caused by the ignition of an accumulated combustible mixture within the confines of the furnace or flue gas passages. Explosions may occur during lighting-off or firing because of unburned fuel or flammable products of incomplete combustion.

Several factors alone or in combination have contributed to conditions that led to an explosion. They include incomplete monitoring and interlocking of fuel-air supplies; lack of proper light-off and operating procedures; lack of, bypassed, or disconnected safety interlocks; insufficient purging; improper trials for ignition; poor atomization of liquid fuel; improper fuel-feeding systems; and insufficient ignition energy.

Except for higher erosion-corrosion rates associated with waste fuel firing and one loss that was the result of corrosive fuel, no pressure part or mechanical losses are unique to waste fuel-fired boilers.

Table 1 shows the losses occuring in a 14 year period with waste fuel-fired boilers. Pressure equipment was the leading cause of loss followed closely by fire.

Table 1. Loss Experience for Waste Fuel-Fired Boilers, 1999-2013

Peril	*Percentage by Gross Loss Cost*	*Percentage by Number of Losses*
Fire	32%	12%
Explosion	1%	9%
Escaped liquids damage	0%	2%
Collapse	1%	2%
Electrical	1%	2%
Mechanical breakdown	5%	9%
Pressure equipment	58%	60%
Miscellaneous	2%	5%
Grand Total	100%	100%

4.0 REFERENCES

4.1 FM

Data Sheet 1-20, *Protection Against Exterior Fire Exposure*
Data Sheet 1-44, *Damage Limiting Construction*
Data Sheet 1-57, *Plastics in Construction*
Data Sheet 2-0, *Installation Guidelines for Automatic Sprinklers*
Data Sheet 3-26, *Fire Protection Water Demand for Nonstorage Sprinklered Properties*
Data Sheet 5-4, *Transformers*
Data Sheet 6-0, *Elements of Industrial Heating Equipment*
Data Sheet 6-2, *Pulverized Coal-Fired Boilers*
Data Sheet 6-4, *Oil- and Gas-Fired Single-Burner Boilers*
Data Sheet 6-5, *Oil- or Gas-Fired Multiple Burner Boilers*
Data Sheet 6-6, *Boiler-Furnaces Implosions*
Data Sheet 6-7, *Fluidized Bed Boilers*
Data Sheet 6-12, *Low-Water Protection for Boilers*
Data Sheet 6-18, *FM Cock Safety-Control System*
Data Sheet 6-22, *Firetube Boilers*
Data Sheet 6-23, *Watertube Boilers*
Data Sheet 7-11, *Conveyors*
Data Sheet 7-29, *Ignitable Liquid Storage in Portable Containers*
Data Sheet 7-32, Ignitable Liquid Operations
Data Sheet 7-43, *Process Safety*
Data Sheet 7-54, *Natural Gas and Gas Piping*
Data Sheet 7-76, *Combustible Dusts*
Data Sheet 7-78, *Industrial Exhaust Systems*
Data Sheet 7-88, *Ignitable Liquid Storage Tanks*
Data Sheet 7-91, *Hydrogen*
Data Sheet 7-98, *Hydraulic Fluids*
Data Sheet 7-101, *Fire Protection for Steam Turbines and Electric Generators*
Data Sheet 7-109, *Fuel Fired Thermal Electric Power Generation Facilities*
Data Sheet 7-110, *Industrial Control Systems*
Data Sheet 8-10, *Coal and Charcoal Storage*
Data Sheet 8-27, *Storage of Wood Chips*
Data Sheet 9-0, *Asset Integrity*
Data Sheet 10-8, *Operators*
Data Sheet 12-2, *Vessels and Piping*
Data Sheet 12-43, *Pressure Relief Devices*

4.2 Other

NFPA 30, *Flammable and Combustible Liquids Code*
NFPA 54, *National Fuel Gas Code*
NFPA 70, *Natural Electric Code*
NFPA 85, *Boiler and Combustion Systems Hazards Code*
NFPA 120, *Coal Preparation Plants*
NFPA 850, Recommended Practice for Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations

VdS 2371, *Flue Gas Desulfurization Plants*

APPENDIX A GLOSSARY OF TERMS

Bagasse: The portion of sugar cane left over after sugar is extracted.

Blast Furnace Gas (BFG): A low BTU off-gas from a blast furnace.

Coke Oven Gas: A byproduct of the high-temperature carbonization of bituminous coal to form coke.

FM Approved: Products or 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.

Municipal solid waste (MSW): Waste from non-industrial sources such as residential homes, restaurants, retail centers, and office buildings. Typical MSW includes paper, discarded food items, and other trash, including green waste (yard clipping, leaves, trees, etc.) and non-combustible material.

Refinery Gas: A byproduct of the process used to turn crude oil into gasoline.

Refuse-derived fuel: Fuel produced from MSW that has undergone processing. Processing can include separation of recyclables and noncombustible materials, shredding, size reduction, and pelletizing.

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).

January 2021. Interim revision. Updated contingency planning and sparing guidance.

January 2019. Interim revision. Figure 2, Waste-to-energy losses was updated.

October 2018. Interim revision. The following changes were made to provide guidance on energy from waste facilities:

A. Changed the title from *Waste Fuel-Fired Boilers* to *Waste Fuel-Fired Facilities* to reflect that the document includes all facilities that handle waste fuels.

B. Updated the scope to include fire hazard information throughout the document.

C. Added construction guidance.

D. Added fire protection guidance for waste fuel storage and processing areas, boiler areas, control rooms, environmental monitoring rooms, and flue gas equipment.

E. Added housekeeping guidance.

F. Added contingency planning guidance.

July 2015. The following changes were made:

A. Updated operating and maintenance recommendations.

B. Updated guidance for the use of FM Approved equipment.

C. Updated recommendations for safety shutoff valves for gaseous and liquid fuels.

D. Added guidance for incineration of dilute gas streams blended with combustion air.

E. Added a definition of and guidance for the incineration of municipal solid waste (MSW)

F. Updated loss history.

G. Added definition added for refuse-derived fuel (RDF).

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

May 2007. Minor editorial changes were made for this revision .

January 2007. Made corrections to Table 3, Heating Values.

August 1999. This revision of the document has been reorganized to provide a consistent format.

APPENDIX C SUPPLEMENTAL INFORMATION

C.1 Background

Until recently, many waste fuels were considered to be of little value and only created disposal problems. Today, however, these waste fuels play an important role in energy planning by facility management.

Several factors have led to this new interest in waste fuels. The more important of these are cost and the problems of waste disposal. The cost of waste fuel is lower than conventional fuels. Also, incinerators and flue gas cleaning equipment costs are comparable to the cost of a boiler with flue gas cleaning equipment. The boiler also produces steam for commercial use. More and more restrictions are being placed on landfills, discharge of gases to atmosphere, and boiler emissions. Because of generally lower sulfur content, waste fuel firing usually falls within the environmental limitations for sulfur emissions.

Generally, solid waste fuels are burned on grates in fuel beds or in suspension much the same as coal. Liquid wastes are burned similarly to oil. Gaseous wastes may require treatment somewhat different from natural gas.

Waste gaseous fuels differ substantially from natural gas because of large amounts of inert gases or dust carryover. Most problems involved with these waste gases are typified in the handling of steel and copper reverberatory gases, blast furnace gas, and catalytic cracker regenerator gas.

There are several properties that must be known before a waste fuel can be properly handled and burned. They include ignition temperature, density, explosion potential, percent of volatile matter, and heating value. Heating value is probably the most significant.

Table 2 is a comparison of heating values of some waste and conventional fuels.

Table 2. Heating Values

Fuel	*Btu/ft^3*	*kJ/m^3*
Gases		
Blast furnace gas	92	3432
Coke oven gas	569	21224
Producer gas	150	5592
Natural gas	960	35791
Low Btu gas	100-200	3730-7460
Medium Btu gas	200-500	7460-18650
High Btu gas	1000	37300
Liquid	*Btu/lb*	*kJ/Kg*
Methanol	9700	22,500
#4 fuel oil	18844	43,795
Solid	*Btu/lb*	*kJ/kg*
Wood	6300	14648
Coal, bituminous	14030	32620
Coke	13500	31836

C.1.1 Gases

C.1.1.1 Blast Furnace Gas (BFG)

Blast furnace gas requires special treatment for use in boilers because of its low heat content (sometimes as low as in the 80 to 85 Btu [84 to 89 kJ] range) and because it is usually very dirty. Blast furnace gas varies with the individual facility but consists of approximately 30% CO, 10% CO_2, 1% hydrogen, and the rest nitrogen. The limits of flammability in air are from 35% to 74%. Approximately 0.7 ft^3 (0.02 m^3) of air per ft^3 of gas is needed for combustion.

Handling is very difficult and it is virtually impossible to maintain conventional valves in a gas-tight situation for very long. Butterfly valves that are closed by spring action and opened by air-operated pistons are usually used. In some older valves, weights are used to close the valves. Newer valves are rubber lined and both the lining and the rubber seats are eroded by the grit that is almost always present. Sliding gate valves (goggle valves) are normally used for complete shut-off. When a line is taken out of service, it is usually purged with steam.

BFG can be burned either by mixing it with some other gas, such as dirty coke oven gas (DCOG), or by introducing it into a boiler with a stabilizing flame from some other fuel present.

In most steel plants, BFG is considered completely interruptible. Therefore, boilers are usually arranged to fire several fuels. Variability of fuel-fired requires special operator attention to keep heat input levels at a constant rate. Figure 3 shows a boiler designed to burn BFG.

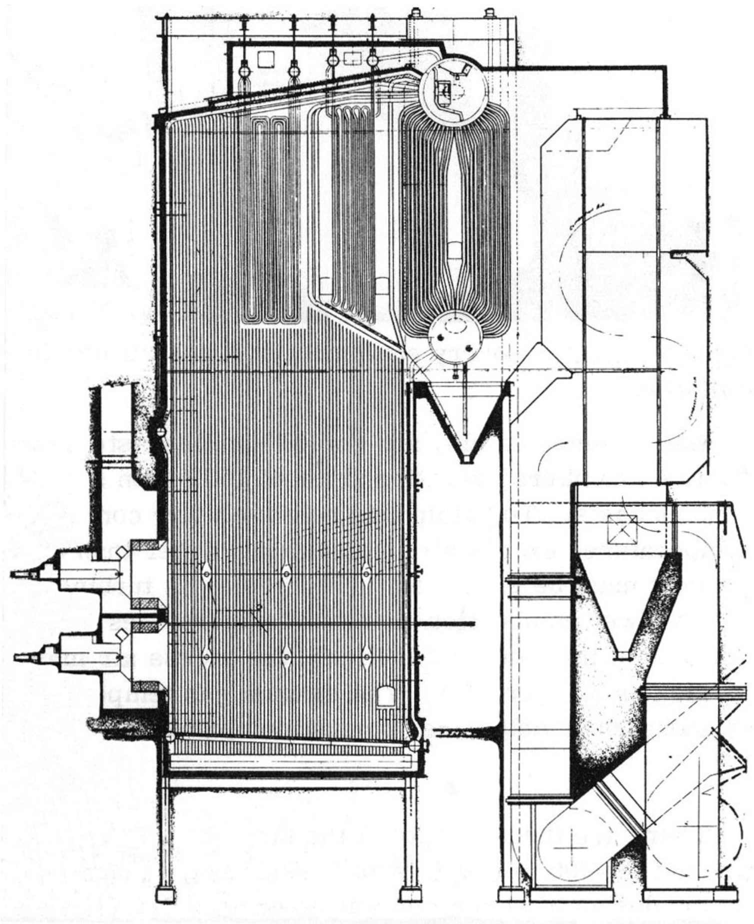

Fig. 3. Tangentially-fired industrial boiler designed to burn blast furnace gas and coal.

C.1.1.2 Coke Oven Gas (COG)

Coke oven gas is a byproduct of the high-temperature carbonization of bituminous coal to form coke. The quality of COG depends to a large degree on the type of coal used. Average flammability limits for coke oven gas in air are from 4.4% to 34%. COG has an average heat content of 569 Btu/ft^3 (21224 kJ/m^3).

COG is usually fired through nozzles with large openings. Even though it is cleaned prior to firing, it may still contain some particulate matter. It can be burned easily with few changes from a standard fuel gas system provided the burner is adjusted for possible entrained particles.

Figure 4 is a schematic of a BFG and COG fuel supply system for a boiler.

C.1.1.3 Refinery Gas

Refinery gas is a byproduct of the process used to turn crude oil into gasoline. Heating values vary depending on the type of crude oil. Generally, the heating value of refinery gas is greater than that of natural gas. Usually, refinery gas is mixed with other gases from the plant to lower the heating value to about 1500 Btu/ft^3 (55950 kJ/m^3). Refinery gas can be burned the same as natural gas.

C.1.1.4 Low-Medium-High Btu Gases

Low: 100 to 200 Btu/ft^3 (3730-7460 kJ/m^3), medium: 200 to 500 Btu/ft^3 (7460-18,650 kJ/m^3), and high: 1000 Btu/ft^3 (37,300 kJ/m^3) Btu gases are produced by gasification of solid or liquid hydrocarbon or other organic substance. Producing a gas from a solid or liquid is usually accomplished by partial oxidation of the material. In order for partial oxidation to take place, heat must be applied to the base material. This may be done by combustion or heating from some external source in an air atmosphere.

Gasifiers may be designed to operate at pressures ranging from atmospheric to 1000 psi (6894 kPa) or more. One or more oxidants may be used. Gas quality depends on the base material and type of oxidant used. Fuel gases produced from coal contain carbon monoxide, hydrogen, carbon dioxide, methane, nitrogen, and water. Byproducts include ash and slag and may also include tars and heavy hydrocarbons. High Btu gas is also known as or substitute natural gas (SNG).

C.1.1.5 Hydrogen

Hydrogen ignites easily in air and burns rapidly. The only byproducts produced in burning hydrogen are water vapor and nitrogen oxides. Although hydrogen has a relatively low heating value as compared to natural gas, a given pipeline would be able to transmit an equal amount of energy due to hydrogen's lower viscosity. Hydrogen's high diffusivity allows the gas to be mixed below flammable levels.

Hydrogen is usually fired along with a conventional fuel. It is fired similarly to natural gas except it is not burned in the burner throat area because hydrogen burns so rapidly. Burning in the burner throat area may create pulsations. For this reason, a premix burner is not used. Gas spuds similar to those used for natural gas should be used for hydrogen. The spuds should be lengthened, however, to introduce the hydrogen in the furnace rather than the burner throat area.

For locations that have boiler installations where hydrogen gas is being supplied by a process also at the same location, there is no need for flashback arresters in the hydrogen pipeline. These lines can be treated the same as natural gas lines provided the fuel is transported through the pipeline outside of the explosive ranges. Two valves are supplied at either end of the pipeline, one a burner safety shutoff valve and a similar valve at the supply compressor both of which should shut down upon system shutdown. Chlorine and oxygen detectors are also used on pipelines.

C.1.2 Liquids

C.1.2.1 General

Industrial liquid wastes can be burned by conventional burners in boilers with little to no modification. Like waste gas, liquid wastes have several variables that must be considered for proper handling and burning. They are viscosity, heating value, flash point, and fire point. With the value of these variables known, air flows can be adjusted for the waste fuel and proper heat input can be supplied. Some waste liquids currently burned are solvents, resins, oil sludges and slurries, waste oils, tars, combustible chemicals, greases and fats. These

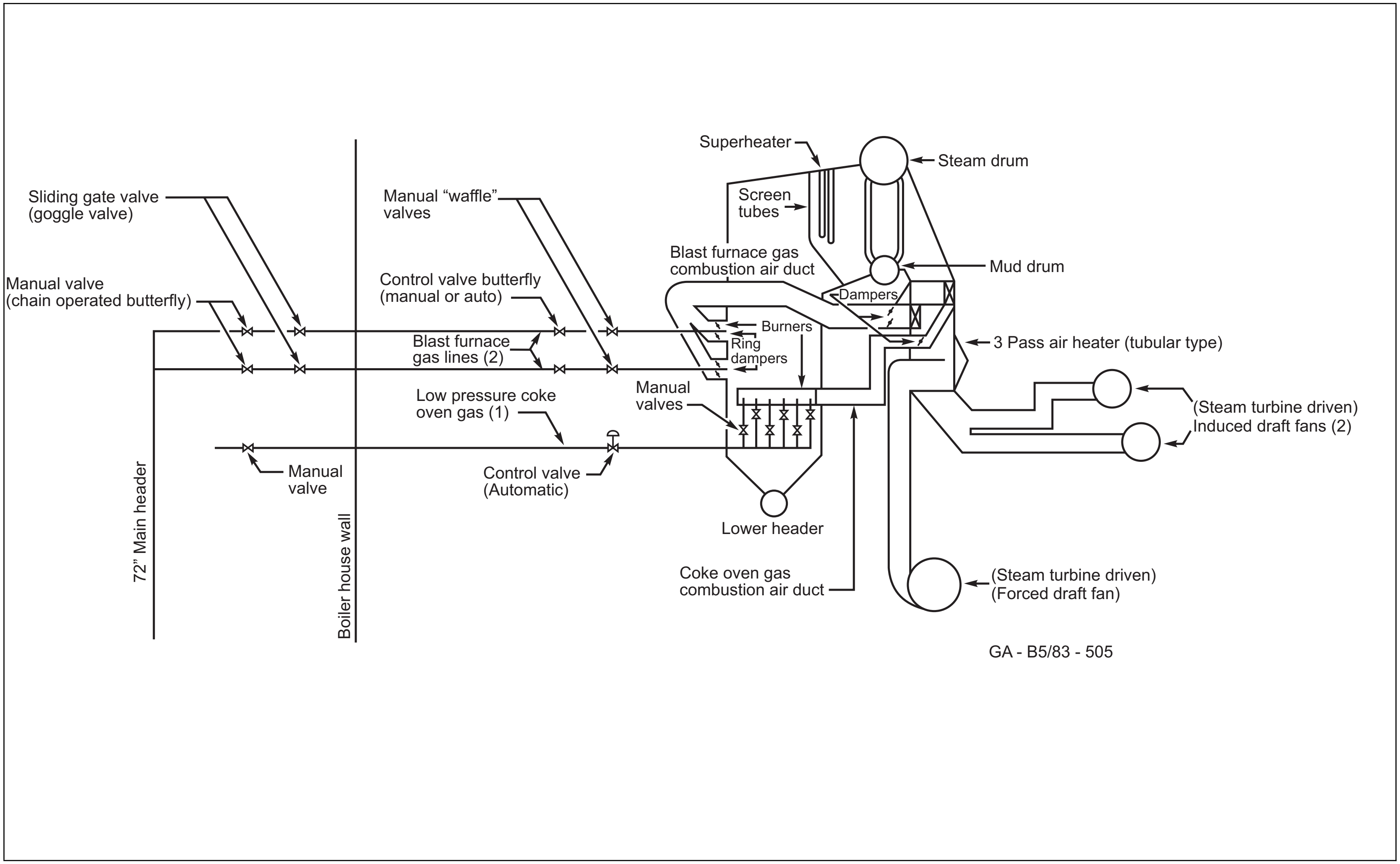

Fig. 4. Schematic of blast furnace gas and coke oven gas fuel piping

wastes usually fall into one of two categories: high Btu wastes 8000 to 9000 Btu/lb (18600-21000 kJ/kg), or low Btu wastes. Sometimes entire waste streams are burned in the boiler if undesirable components are difficult to remove.

High Btu liquid wastes can be burned in the same manner as conventional liquid fuels. Low Btu liquid wastes, however, may require an auxiliary burner for stabilization. Liquid wastes must be atomized the same as conventional liquid fuels. Combustion chambers and burners must be adjusted according to the fuel to be fired. They must be arranged to provide time for proper suspension to drive off any water and expose all organic portions for complete oxidation.

C.1.2.2 Slurries

Slurries as defined in this data sheet are coal and oil mixtures. Pulverized coal, 80% passing a 200 mesh screen, is mixed with an oil and a surfactant. Mixing equipment and the surfactant help to keep the coal in suspension. Slurries are economical for use on boilers that were originally designed to burn coal and then were converted to oil, but which cannot be converted back to coal because of lack of storage capacity or proper equipment. Units originally designed for oil and gas can also fire slurries if several modifications are made. These modifications include the addition of coal and ash handling equipment, burner modification, addition of soot blowers, and provisions for balanced draft operation.

Test firing of slurries to date has resulted in the following information on handling and burning:

1. Air atomization is preferred over steam atomization. Coking and plugging problems can arise on steam-atomized burners.

2. Recirculation of slurries is essential to avoid stratification, which can lead to fuel flow problems.

3. Storage and burning temperature should be the same as for #6 oil to a maximum of 180°F (82°C). Temperatures beyond 180°F (82°C) are avoided because of accelerated stratification.

C.1.3 Solids

Types of solid wastes commonly used are: wood and wood wastes, bagasse and other solid biomass materials, refuse-derived fuel (RDF or trash), and coal tailings. Other fuels, such as coffee grinds and cotton lint, may be encountered. In general, the hazards and problems associated with these are the same as other solid waste fuels.

Solid waste fuels can be burned in three ways: in suspension, partially in suspension with final burnout on a grate, or in mass on a grate. Different types of grates can be used depending on what kind of a system is most convenient. There are also several types of feeders available. Feeders are specified according to fuel type and method of burning, suspension, in mass, etc.

Solid waste fuels typically have a high moisture content. For instance, bark has a moisture content of 35% to 50%, bagasse 40% to 60%, and coffee grounds 60%. As a result, these fuels are usually dried before burning with some of the final drying taking place as the fuel enters the furnace and falls to the grate. Other solid fuels, such as cotton lint and RDF, can be burned without pre-drying.

Solid waste fuel particles should be relatively the same size for proper burning. This may require shredding or hogging the fuel.

C.1.3.1 Bagasse

Bagasse is the portion of sugar cane left over after sugar is extracted. It consists of cellulose fibers and fine particles. It also has a high ash content.

Older bagasse-burning installations were very inefficient. Because of the nature of the sugar refining business, large amounts of bagasse were available for a short period of time, and plants burned it to dispose of it. Older boilers did not have superheaters. They usually had large furnaces to provide the air necessary to burn the large volume of fuel. Soot blowers were rare because of the short operating time. After the season peak, boilers were brought down and completely overhauled. Newer installations are more efficient, primarily because other uses for bagasse, such as papermaking, have been developed. Sugar mills can burn what they need for fuel and sell excess for otherprocesses.

Variations in refining and handling can lead to variations in fuel particle size. This can create some firing problems. Bagasse is fired on a grate with an average moisture content of about 50%. Therefore, bagasse is usually fired along with an auxiliary fuel for stability.

C.1.3.2 Refuse-Derived Fuel (RDF)

Refuse-derived fuel (RDF) consists largely of combustible components of municipal solid waste and has many of the same characteristics as wood and bagasse, and receives its heating value from the cellulose contained in it. If given proper preparation, RDF can have a heating value as high as lignite. RDF has a high ash but low sulfur content. Heating value of RDF has increased in recent years because of large amounts of cardboard, plastics, and other synthetic materials. Typical components of RDF are paper and paper products, plastics, wood, rubber, solvents, oils, paints, and various organic materials. Table 3 is a breakdown of a sample of typical RDF.

Table 3. Typical RDF Breakdown (By Volume)

Paper	34
Textiles, rubber, plastic	8
Food waste	17
Wood	6
Glass	10
Metal	11
Grass, leaves, dirt	14
	100

Refuse derived fuel can be burned in suspension firing, which requires a good deal of fuel preparation; or in spreader-stoker firing (semi-suspension), which requires some preparation. The greater the degree of preparation, the lower the ash content of the fuel.

Refuse fuel-fired in suspension has a nominal size of 1½ in. (38 mm) in diameter. The resulting ash content runs approximately 10%. Refuse fuel-fired in semi-suspension can have a particle size as large as 4 in. (102 mm) in diameter and an ash content of about 15%. There is no limit on fuel particle size for mass burning. However, because some of the fuel particles may be quite large, the burn time on the grate is longer. The longer burn time is needed to expose all of the fuel to the combustion air. Figure 5 shows the refuse handling and burning system for RDF burned in suspension.

Other conventional fuels can be burned in the same furnace along with RDF. Also, older installations may be converted to burn RDF. Factors that need to be considered when designing any installation for RDF firing are:

1. Flue gas velocities must be kept low (typically less than 75 fps [23 m/sec] to avoid erosion.

2. Spacing between convection pass tubing must be adequate to prevent ash bridging (typically at least 2 in. [51 mm] clearance between tubes.

3. Particulate matter in flue gases must be removed before entering a stack.

4. Soot blower spacing and operating pressure must be adequate to remove ash accumulations.

5. Ash handling systems must be adequate to cope with the quantities of ash produced by RDF.

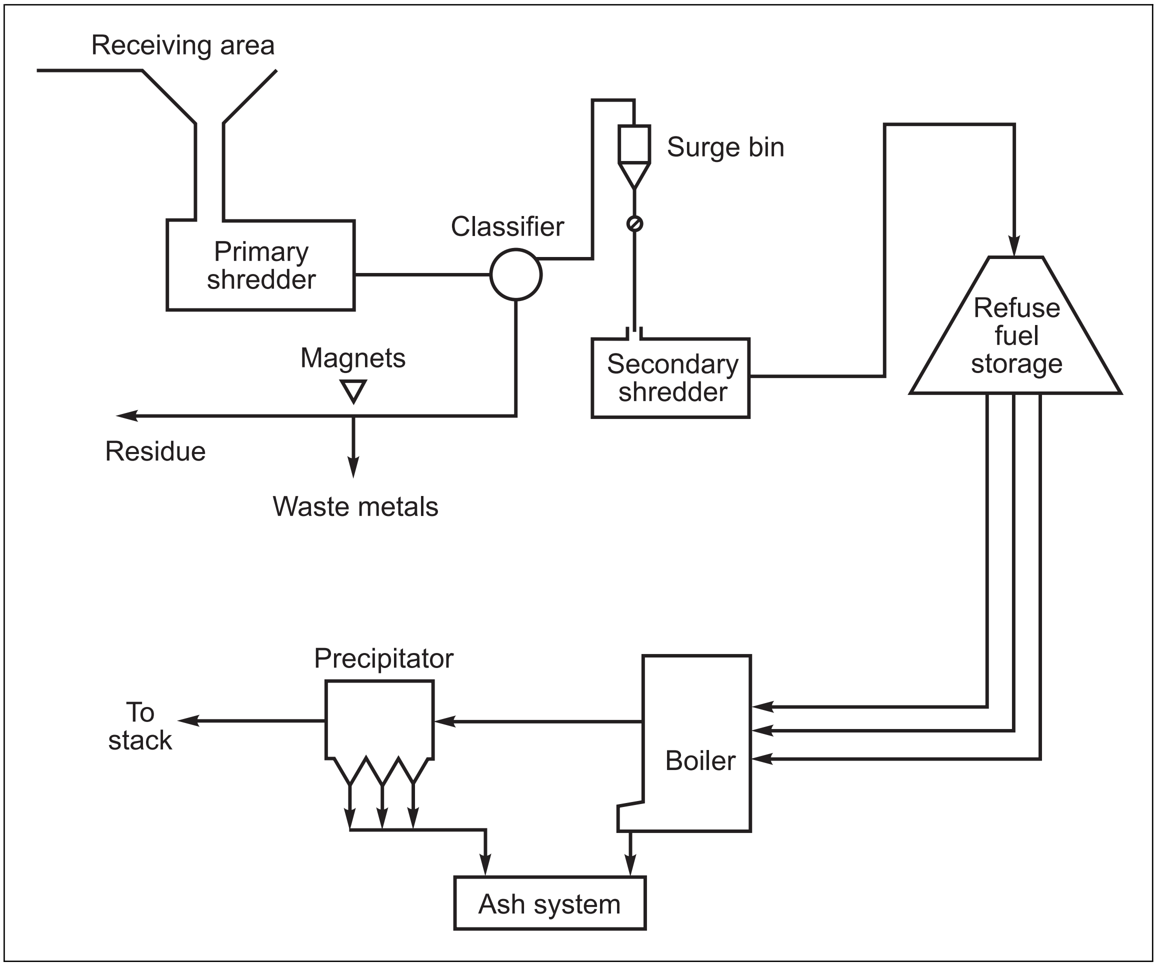

Fig. 5. Handling and burning system for RD fuel.

C.1.3.3 Municipal Solid Waste (MSW) Mass Burning

Unprepared MSW is burned in specially designed stoker grate boilers. These boilers have grates specifically created to handle MSW ash, large furnaces to lower flyash temperature to below 1700°F to reduce slag formation on convection surfaces, wide spacing of convection section tubes to control bridging, and specially designed cleaning systems to remove accumulated ash from convection section tubes. It is not used as a supplementary or additional fuel in boilers not specifically designed for MSW. They operate at high excess air, typically at least 7.5% O_2 (dry basis).

Attempting to burn MSW in a boiler not designed for this fuel will be subject to severe ash corrosion and plugging in the convection area, requiring frequent shutdowns for cleaning. Also, materials of construction in MSW boilers are specifically selected to resist corrosion.

For MSW boilers, combustion safeguards related to auxiliary fuel firing are consistent with oil or gaseous startup/auxiliary burners. The auxiliary fuel burners typically supplement the burn-down of waste from the fuel bed to mitigate the production of CO; once extinguished the auxiliary burners should follow the functioning flame safety shutdown steps.

Guidance for low water protection for stoker boilers in DS 6-12 should be followed. Purging, startup, and shutdown are mostly consistent with solid fuel firing in stoker boilers. Boiler tube monitoring programs should follow the guidance in DS 6-23, *Watertube Boilers*.

Soot blowing, Intervals, and pressures are a site-specific determination based on fuel-fouling tendencies and balance against soot-blower-induced erosion potential and the condition of any tube shielding or cladding that may be applied.

Typical alarms and trips are related to steam pressure, drum level, and aux burner controls. Loss of induced draft fans initiate a trip of the primary (under-grate) or forced draft fan. Facilities equipped with Fabric filter bag houses will also be equipped with a high inlet gas temperature trip of the FD fan. There are typically no furnace pressure trips due to the releases associated with occasional compressed gas canister combustion.

C.1.4 Wood

C.1.4.1 General

Wood, although it is a very complex material, is primarily made up of cellulose. Compounds that are also found in wood are resins, gums, and other substances. These compounds vary in amount, depending on the type of wood. This variation of compounds causes different types of wood to have different heating values.

Moisture content of wood also varies by type. It is the moisture content of wood that is the single biggest factor in boiler design. Moisture content of freshly cut wood varies from 30% to 50%. Table 4 relates percentage of moisture to gross heating value of fuel.

Table 4. Moisture Content vs. Heating Value

Moisture Content	*As Fired Gross Heating Value Btu/lb*	*kJ/kg*
15	7400	17,205
30	6100	14,183
40	5200	12,090
50	4400	10,230
60	3500	8,138

Proximate analyses express the different principal characteristics of wood. Proximate differs from ultimate analysis in that the ultimate analysis relates the exact chemical composition of the fuel. The major components of a proximate analysis are percentages of moisture, volatile matter, ash content, and fixed carbon. Table 5 represents the proximate and ultimate analyses and a comparison to some types of coal.

Table 5. Proximate-Ultimate Analysis of Wood as Compared to Coal

Fuel	*Wood*			*Coal*	
Characteristics	*Redwood*	*Pine*	*Maple*	*Sub-bituminous*	*Bituminous*
Proximate					
Volatile matter	82.5	79.4	N/A	39.7	35.4
Fixed carbon	17.3	20.1	N/A	53.6	56.2
Ash	0.2	0.5	N/A	6.7	8.4
Ultimate					
Hydrogen	5.9	6.3	6.02	5.2	4.8
Carbon	53.5	51.8	50.64	67.3	74.6
Sulfur	0	0	0	2.7	1.8
Nitrogen	0.1	0.1	0.25	1.9	1.5
Oxygen	40.3	41.3	41.74	16.2	8.9
Ash	0.2	0.5	1.35	6.7	8.4
Heating Value Dry Basis,					
Btu/lb	9220	9130	8580	12,096	13,388
kJ/kg	21,437	21,227	19,949	28,123	31,127

Almost all wood used for steam generation is a waste or byproduct of some other manufacturing process. Sawmills produce a byproduct consisting of sawdust, shavings, and bark. The percentage of each depends on the prime product of a given mill. Paper mills produce a byproduct principally composed of wet bark. Many mills have also explored the use of biomass, a fuel made up of remnants of trees used in making paper. Other mills may buy wood fuel. When wood is purchased for fuel, it is primarily received in chip form. It may also be received as wood pellets. The latter form is more likely to be found in smaller industrial locations not equipped with extensive fuel preparation and handling systems.

C.1.4.2 Fuel Preparation

The wood fuel must be cleaned and properly sized before it can be fired in a furnace. The first step in handling the fuel is to divert it through a series of screens. The screens classify the material. Any chips that are oversized are diverted to the hog mill for further breakdown. Screens may also be capable of removing dirt.

Tramp iron also must be removed. This is usually done before the chips enter the hogger. It can be removed in several ways. One method is to use a magnet. Another is to use a metal detector and divert the fuel stream to a point where the metal can be removed. After the fuel has been through the hog mill, it is rerouted to the screens. All material that passes through the screens is then diverted to storage, or is sent directly to the burning system by belt, drag, screw conveyer, or pneumatic conveyors.

C.1.4.3 Fuel Burning

The two ways to burn wood fuel are in pile or in suspension. Pile burning can be broken into two categories: pile burning, where the burning is in a large pile on a surface, and semipile burning, in which the burning is in a thick bed spread out over a surface. Suspension burning also has two categories: suspended and semi-suspended firing. Suspension firing allows the fuel particle to be burned completely while it is suspended, whereas semi-suspension firing allows the fuel particle to be burned partially suspended and partially on a grate.

C.1.4.3.1 Pile Burning

Pile burners are simple in design. They often take the form of a combustion chamber that is separate but attached to a boiler furnace, such as a Dutch oven. They have three distinct advantages: (1) pile burners are not affected by minor fluctuations in or interruptions to fuel supplies; (2) they require little operator attention; and (3) they need very little flue gas cleaning equipment. Some disadvantages are high maintenance of refractory, manual ash removal, and a poor ability to respond to load changes.

Pile burners are just what the name implies, units that burn fuel in a pile. They are especially good for handling fuels of very high moisture, such as bark. They are also used when fuel size varies. Most pile burners are generally good for fuel sized up to 3 in. (75 mm). Some units, such as Dutch ovens, have no limit on fuel size. Pile burning results in a large amount of ash that must be manually removed. The unit must be shut down, to do this. As a result, auxiliary burners are used on the boiler to handle the load during the minor interruptions.

Semipile combustion systems are also used for fuel that has a high moisture content. The biggest difference between pile and semipile systems is that semipile systems have continuous burning and ash removal. Typically, there is no need for auxiliary firing in the boiler.

Figures 6 and 7 show two types of inclined grates that are used in a semipile burning system. In both instances fuel is fed to the grate, where it is dried and burned as it slides down the grate. When the fuel reaches the bottom of the incline, the final combustion and eventual ash dumping is accomplished on a relatively flat grate.

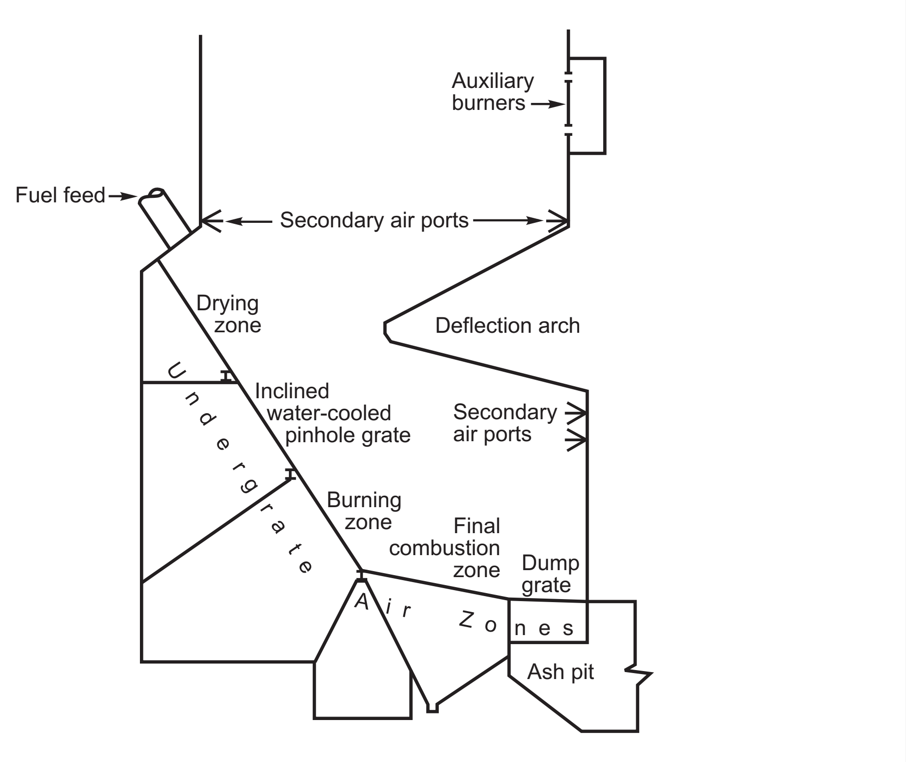

Fig. 6. Inclined water-cooled pinhole grate for semipile burning.

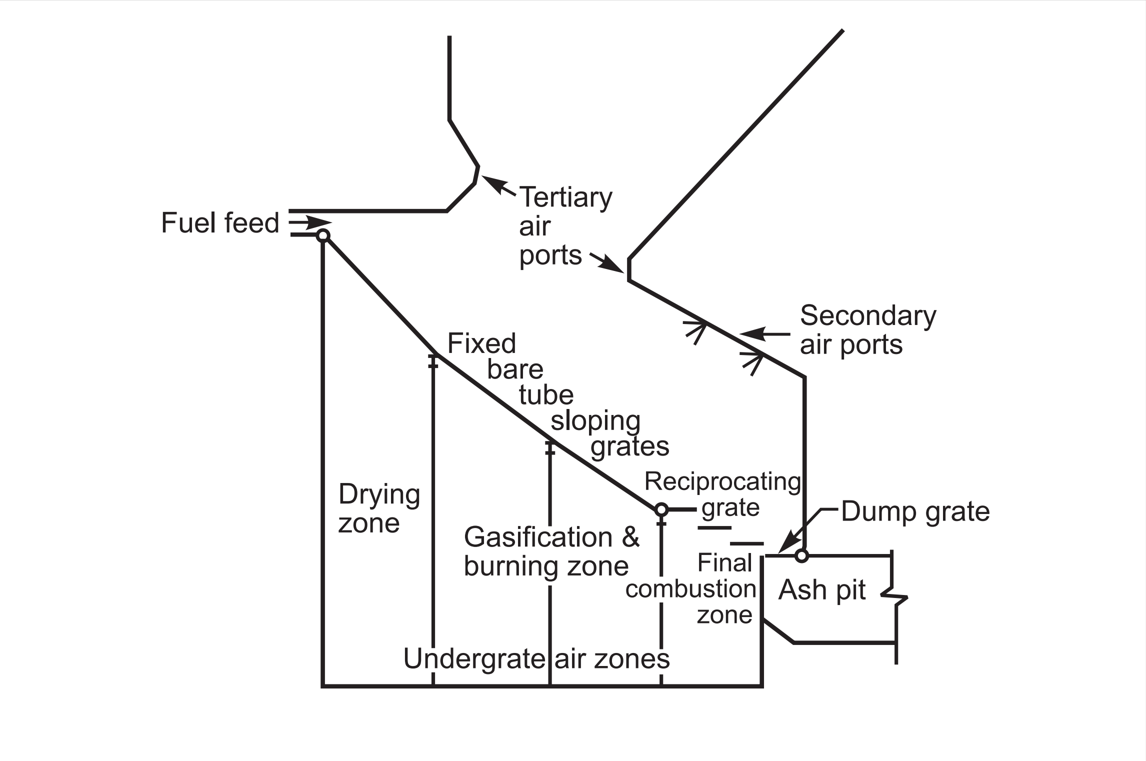

Fig. 7. Semipile burning on sloping and reciprocating grates.

Primary combustion air, also known as under-grate air, is fed to the grate through zones that extend the length of the grate. Secondary air, and tertiary air if needed, is supplied above the grate and is used to complete the combustion of gaseous vapors that are given off in the grate burning.

C.1.4.3.2 Semi-suspension Burning

Semi-suspension burning is fuel that is partially burned in suspension with final combustion taking place on the grates. Usually, the smaller particles of fuel are burned in suspension and the larger particles are dried in suspension and burned on the grate. Wood fuel must be hogged so the largest dimension of the fuel particle is no larger than 3 in. (75 mm). Pneumatic and mechanical distributors are used to spread the fuel onto the grate. Mechanical distributors are not used as much because of jamming and fouling problems that can be created by stringy wood particles or tramp iron. Figures 8 and 9 illustrate pneumatic and mechanical feeders.

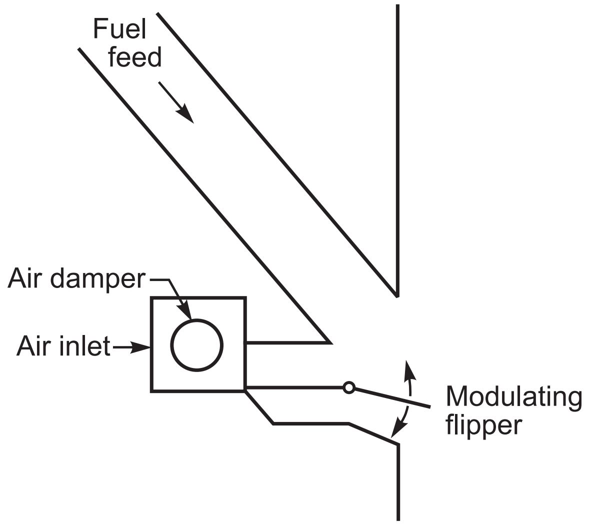

Fig. 8. Pneumatic feeder.

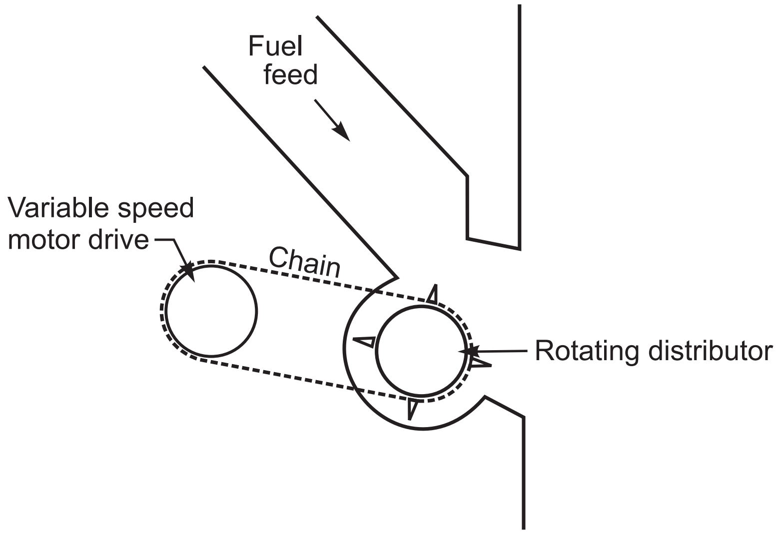

Fig. 9. Mechanical feeder

In the pneumatic feeder, air under pressure is blown into the furnace. The feeder air pressure is higher than the furnace pressure. The fuel drops down the fuel chute and is picked up by the air. There is also a flipping mechanism that modulates and controls the angle at which the fuel air mixture is blown into the furnace area. The mechanical feeder is similar except there is a rotating distributor that picks up the fuel and throws it into the furnace.

Whichever is used, the feeder must be low in the furnace to minimize carryover of unburned fuel but high enough to distribute the fuel to the back of the furnace. Proper design results in an even bed of fuel distributed over the entire grate.

Traveling grates are the most popular type of grate for steaming rates of 200,000 lb steam/hr (91,000 kg steam/hr) or more. There are several advantages to the traveling grate. It has the ability to burn multiple fuels, such a coal and wood simultaneously. It responds rapidly and accurately to load changes and has continuous ash disposal. Fuel on a traveling grate is usually burned in a thin bed, 5 to 6 in. (125 to 150 mm) deep. Figure 10 illustrates a boiler with a traveling grate.

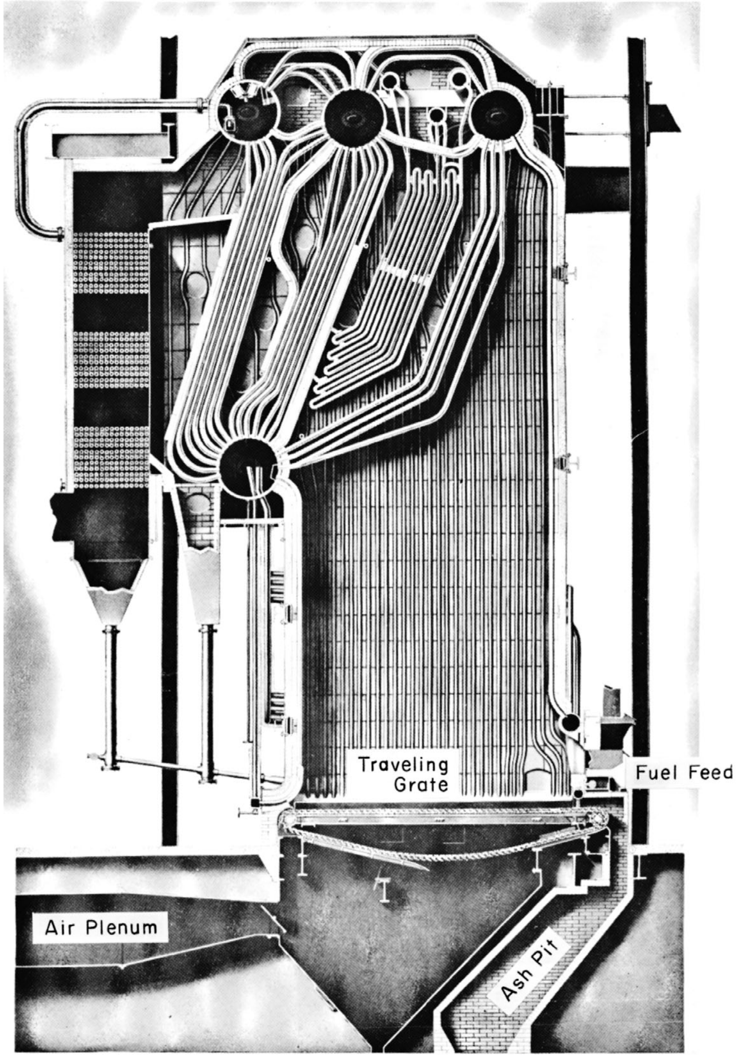

Fig. 10. Boiler with traveling grate

One of the most important aspects of grate operation is overfire air to supply the oxygen necessary to burn off any volatiles rising from the fuel bed. It also supplies the turbulence to complete the reaction. Excess air for semi-suspended, thin bed burning is typically supplied at 25% to 35%. However, for cases when fuel is extra wet or some other abnormal condition exists, the air system may be required to supply 50% excess air.

Fly ash re-injection is also of major concern in grate-fired boilers. A certain amount of fly ash is re-injected to increase boiler efficiency and decrease dust loadings. Usually, only fly ash collected in the boiler bank and air heater hoppers is re-injected. Typical re-injection equipment consists of an air lock for each hopper, hoppers sloped at 60 degree minimum, sand classifiers, a second air lock, and transport piping. Air locks provide a seal that keeps air from contacting hot char particles.

Char particles are coke-like in nature. They require high temperature and long burning times to burn completely. They also glow upon contact with air. They have been known to start fires in the back end of boilers if air is introduced and hoppers are allowed to fill up. For best operation, hoppers should be emptied continuously.

C.1.4.3.3 Suspension Firing

There are two basic types of burners used for suspension burning: cyclone and solid fuel. Cyclone burners are just cylindrical furnaces attached to the side of boiler furnace. Fuel and air enter the cyclone tangentially. The burners are designed so combustion is complete before the products of combustion enter the boiler furnace.

Solid-fuel burners mix the fuel and air and then introduce the mixture to be burned. Complete combustion takes place in the boiler furnace. Solid-fuel burners are also used in combination with semi-suspension grate burning.

Efficiency of suspension burners depends entirely on having clean, dry wood fines, preferably in the range of 1⁄32 in. to 1⁄8 in. (0.8 mm to 3 mm) in diameter. They should not be used for grate-fired units because of the possibility of blowing unburned particles into the back end where there is a fire or explosion potential.

C.1.5 Coal

The equipment used to fire coal on a grate is similar to the equipment used for semi-suspended firing of wood. Coal fuel size is limited to ¾ in. (19 mm) in diameter. If larger sized coal is delivered to the mill, crushers may be needed to achieve optimum fuel size. The fuel bed is limited to 2 or 4 in. (50 to 100 mm) in thickness. Typical carbon loss for stoker fired coal is 4% to 8%, depending on the amount of reinjection. Coal fines should be controlled. If the amount of fines is too great, boiler safety and performance will be affected because of the increase in suspension burning. Furnace pulsations and higher dust loadings may be experienced. If too little coal fines are in the fuel, flame stability may be affected.

C.2 Other Standards

Additional information concerning explosion prevention in boilers 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. With minor exceptions as to fuel gas-train arrangements, there are no known conflicts with these standards.

Other related standards include NFPA 120, *Coal Preparation Plants;* NFPA 54, *National Fuel Gas Code;* NFPA 30, *Flammable and Combustible Liquids Code;* and NFPA 70, *National Electric Code.*