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NFPA 8505
Stoker Operation
1992 Edition

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The Board of Directors reaffirms that the National Fire Protection Association recognizes that the toxicity of the products of combustion is an important factor in the loss of life from fire. NFPA has dealt with that subject in its technical committee documents for many years.

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NFPA 8505

Recommended Practice for

Stoker Operation

1992 Edition

This edition of NFPA 8505, *Recommended Practice for Stoker Operation*, was prepared by the Technical Committee on Boiler Combustion System Hazards and acted on by the National Fire Protection Association, Inc. at its Annual Meeting held May 18-21, 1992 in New Orleans, LA. It was issued by the Standards Council on July 17, 1992, with an effective date of August 14, 1992, and supersedes all previous editions.

The 1992 edition of this document has been approved by the American National Standards Institute.

Changes other than editorial are indicated by a vertical rule in the margin of the pages on which they appear. These lines are included as an aid to the user in identifying changes from the previous edition.

Origin and Development of NFPA 8505

In 1984 the Technical Committee on Boiler-Furnace Explosions started working on a document for stoker operations. The first edition of NFPA 85I was issued in 1989. This was developed through numerous task force, subcommittee, and Technical Committee meetings. The document was written to provide user requirements in order to limit the hazards associated with these special systems and to broaden the NFPA 85 series of standards, which deal with safe boiler operation.

This latest edition is a partial revision and includes a variety of changes. Foremost is the renumbering of the document to NFPA 8505. This is consistent with an initiative by the NFPA Boiler project to remove the letter designations and use shorter document titles.

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Contents

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NOTICE: Information on referenced publications can be found in Chapter 10.

Chapter 1 Purpose and Scope

1-1 Scope.

1-1.1 The purpose of this recommended practice is to establish guidelines for the design, installation, and operation of stoker fired boiler-furnaces, their fuel burning systems, and related control equipment to contribute to operating safety.

1-1.2 This document applies specifically to firing coal, wood, municipal waste, and other solid fuels in stoker-equipped units with a heat input rate greater than 400,000 Btu/hr (117 kW). When solid fuel is fired simultaneously with other fuels, additional controls and interlocks may be necessary but are not covered in this practice. When firing natural gas, fuel oil, or pulverized coal alone, use the NFPA standard that applies to that fuel.

1-1.3 This document does not address specific requirements of multiple fuel firing (e.g., solid fuel stoker fired in combination with gas, oil, or pulverized auxiliary fuel).

1-1.4 Requirements for auxiliary fuel firing equipment and interlocks should follow NFPA 8501, *Standard for Single Burner Boiler Operation*, and NFPA 85C; *Standard for the Prevention of Furnace Explosions/Implosions in Multiple Burner Boiler-Furnaces*.

Exception No. 1: The purge requirements of NFPA 8501 and NFPA 85C are not required when the stoker is firing and the boiler is on-line. In those cases, if no cooling air is being provided to the auxiliary burners, a purge of their associated air supply ducts should be provided.

Exception No. 2: When firing oil or gas in a supervised manual system in accordance with NFPA 8501, the excessive steam pressure interlock is not required.

1-2 Purpose.

1-2.1 While this document applies especially to units that have been placed in operation subsequent to July 15, 1992, its use can be helpful with units placed in operation earlier.

1-2.2 No document can be promulgated that will guarantee the elimination of boiler combustion hazards. Technology in this area is under constant development, which will be reflected in revisions to this document. The user of this document must recognize the complexity of firing fuel with regard to the type of equipment and the characteristics of the fuel. Therefore, the designer is cautioned that the document is not a design handbook. The document does not do away with the need for the engineer or for competent engineering judgment. It is intended that a designer capable of applying more complete and rigorous analysis to special or unusual problems should have latitude in the development of such designs. In such cases, the designer is responsible for demonstrating the validity of the approach.

1-2.3 Revisions to this document reflect the current state of knowledge and do not imply that previous editions were inadequate.

1-2.4 Because this document is based on the present state of the art, application to existing installations, while not mandatory, is encouraged, especially for those features that are considered applicable to and reasonable for existing installations.

1-2.5 Emphasis is placed on the importance of proper operation, maintenance, combustion control equipment, safety interlocks, alarms, trips, and other related controls that are essential to safe unit operation.

Chapter 2 General

2-1 Basic Cause of Furnace Explosions.

2-1.1 The basic cause of furnace explosions is the ignition of an accumulated combustible mixture within the confined space of the furnace or the associated boiler passes, ducts, and fans that convey the gases of combustion to the stack.

2-1.2 A dangerous combustible mixture within the boiler-furnace enclosure consists of the accumulation of an excessive quantity of combustibles mixed with air in proportions that will result in rapid or uncontrolled combustion when an ignition source is supplied. A furnace explosion may result from ignition of this accumulation if the quantity of combustible mixture and the proportion of air to fuel are such that an explosive force is created within the boiler-furnace enclosure. The magnitude and intensity of the explosion will depend on both the relative quantity of combustibles that has accumulated and the proportion of air that is mixed therewith at the moment of ignition. Explosions, including "furnace puffs," may be the result of improper procedures by operating personnel, improper design of equipment or control systems, equipment or control system malfunction, consistency of fuel, or moisture content of fuel.

2-1.3 Numerous situations that will produce explosive conditions can arise in connection with the operation of a boiler-furnace. The most common experiences are:

(a) An interruption of the fuel or air supply.

(b) Fuel leakage into an idle furnace and the ignition of the accumulation by a spark or other source of ignition.

(c) Attempts to light off without appropriate purging when firing gaseous, liquid, or pulverized fuels without stoker firing.

(d) Utilization of high volatile fuels such as gasoline for ignition purposes.

(e) The accumulation of an explosive mixture of fuel and air as a result of loss of flame or incomplete combustion.

(f) The accumulation of an explosive mixture of fuel and air as a result of a flameout and the ignition of the accumulation by a spark or other ignition source, such as attempting to light burner(s).

(g) Purging with too high an airflow, which stirs up combustibles smoldering in hoppers.

(h) Improper fuel consistency, especially when firing high volatile refuse fuels.

2-1.4 The conditions favorable to a boiler-furnace explosion described in 2-1.3 are typical examples. An examination of numerous reports of boiler-furnace explosions in stoker-fired units utilizing solid fuels suggests that the occurrence of small explosions or furnace puffs has been far more frequent than is usually recognized. It is believed that improved instrumentation, safety interlocks and protective devices, proper operating sequences, and a clearer understanding of the problem by both designers and operators can greatly reduce the risks and actual incidents of furnace explosions.

2-1.5 In a boiler-furnace, upset conditions or control malfunction may lead to an air/fuel mixture that may result in an unsafe condition. There may exist, in certain parts of the boiler-furnace enclosures or other parts of the unit, dead pockets susceptible to the accumulation of combustibles. These accumulations may ignite with explosive force in the presence of an ignition source.

2-2 Manufacture, Design, and Engineering.

2-2.1 The purchaser or the purchaser's agent should, in cooperation with the manufacturer, assure that the unit is not deficient in apparatus that is required for proper operation, so far as is practical, with respect to pressure parts, fuel burning equipment, and safe lighting and maintenance of stable conditions.

2-2.2 All fuel systems should include provisions to prevent foreign substances from interfering with the fuel supply.

2-2.3 An evaluation should be made to determine the optimum integration of manual and automatic safety features, considering the advantages and disadvantages of each trip function.

NOTE: The maximum number of automatic trip features does not necessarily provide for maximum overall safety. Some trip actions result in additional operations that increase exposure to hazards.

2-2.4 This guideline suggests a minimum degree of automation. The trend toward more complex plants or increased automation requires added provisions for:

(a) Information about significant operating events permitting the operator to make rapid evaluation of the operating situation. The operator should have available a continuous and useable display of critical trends, which will indicate conditions that may lead to unsafe operation.

(b) In-service maintenance and checking of system functions without impairing the reliability of the overall control system.

(c) An environment conducive to proper decisions and actions.

2-3 Installation. The boiler should not be released for operation before the installation and checkout of the safeguards and instrumentation system.

2-3.1 The constructor responsible for the erection and installation of the equipment should see that all pertinent apparatus is properly installed and connected.

2-3.2 The purchaser, the engineering consultant, the equipment manufacturer, and the operating company should avoid boiler operation until such safeguards have been tested to operate properly as a system. In some instances it may be necessary to install temporary interlocks and instrumentation. Any such temporary system should be reviewed by the purchaser, the engineering consultant, the equipment manufacturer, and the operating company, and agreement reached on its suitability in advance of start-up.

2-3.3 Testing and checkout of the safety interlock system and protective devices should be accomplished jointly by the organization with the system design responsibility and those who operate and maintain such systems and devices during the normal operating life of the plant. These tests should be accomplished before initial operation.

2-4 Coordination of Design, Construction, and Operation.

2-4.1 Statistics indicate that human error is a contributing factor in the majority of furnace explosions. Therefore, it is important to consider whether the error was the result of:

(a) Lack of proper understanding of, or failure to use, safe operating procedures.

(b) Unfavorable operating characteristics of the equipment or its control.

(c) Lack of functional coordination of the various components of the steam generating system, its controls, and the operator interaction.

2-4.2 In the planning and the engineering phases of plant construction, design should be coordinated with the operating company.

2-4.3 The proper integration of the various components consisting of boiler, fuel and air supply equipment, combustion controls, interlocks and safety devices, operator functions, operator communication, and training should be the responsibility of the operating company.

2-5 Maintenance Organization. A program should be provided for maintenance of equipment at intervals consistent with type of equipment, service requirements, and the manufacturers' recommendations. (*See Chapter 7.*)

2-6 Basic Operating Objectives.

2-6.1 Basic operating objectives should include the following:

(a) Establish operating procedures that will result in the minimum number of manual operations.

(b) Standardize all operating procedures. Where applicable, the use of interlocks is recommended to minimize improper operating sequences and to stop sequences when conditions are not proper for continuation. It is particularly important that purge and start-up procedures with necessary interlocks be established and rigidly enforced.

2-6.2 Written operating procedures and detailed check lists for operator guidance should be provided for achieving these basic operating objectives. All manual and automatic functions should be described.

Chapter 3 Definitions

3-1 These definitions apply to this recommended practice.

Agglomerating. A characteristic of coal that causes coking on the fuel bed during volatilization.

Air.

Cooling Air. Air supplied for cooling to tuyeres, feeders, or burners out of service.

Furnace Purge Air (Furnace Purge). See Purge.

Overfire Air. Air for combustion admitted into the furnace at a point above the fuel bed.

Seal Air. Air supplied to any device at pressure for the specified purpose of minimizing contamination.

Total Air. The total quantity of air supplied to the fuel and products of combustion. Percent total air is the ratio of total air to theoretical air expressed as percent.

Under Grate Air. Combustion air introduced below the grate.

Air/Fuel Ratio.

Air-Rich. A ratio of air to fuel supplied to a furnace that provides an amount of air appreciably greater than normal excess air requirements.

Bottom Air Admission. A method of introducing air to a chain or traveling grate stoker under the stoker.

Fuel-Rich. A ratio of air to fuel supplied to a furnace that provides an amount of air appreciably less than normal excess air requirements.

Excess Air. Air supplied for combustion in excess of theoretical air. (This is not "air-rich" as previously defined.)

Theoretical Air (Stoichiometric Air). The chemically correct amount of air required for complete combustion of a given quantity of a specific fuel.

Alarm. An audible or visible signal indicating an off-standard or abnormal condition.

Annunciator. A device that indicates an off-standard or abnormal condition by both visual and audible signals.

Approved. Acceptable to the "authority having jurisdiction."

NOTE: The National Fire Protection Association does not approve, inspect or certify any installations, procedures, equipment, or materials nor does it approve or evaluate testing laboratories. In determining the acceptability of installations or procedures, equipment or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization concerned with product evaluations which is in a position to determine compliance with appropriate standards for the current production of listed items.

Authority Having Jurisdiction. The "authority having jurisdiction" is the organization, office or individual responsible for "approving" equipment, an installation or a procedure.

NOTE: The phrase "authority having jurisdiction" is used in NFPA documents in a broad manner since jurisdictions and "approval" agencies vary as do their responsibilities. Where public safety is primary, the "authority having jurisdiction" may be a federal, state, local or other regional department or individual such as a fire chief, fire marshal, chief of a fire prevention bureau, labor department, health department, building official, electrical inspector, or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the "authority having jurisdiction." In many circumstances the property owner or his designated agent assumes the role of the "authority having jurisdiction"; at government installations, the commanding officer or departmental official may be the "authority having jurisdiction."

Banking. Burning solid fuels on a grate at low rates sufficient only to maintain ignition.

Banking (Live). Operating boilers at combustion rates just sufficient to maintain normal operating pressure under conditions of no load demand.

Boiler. A closed vessel in which water is heated, steam is generated, steam is superheated, or any combination thereof by the application of heat from combustible fuels in a self-contained or attached combustion chamber.

Boiler Control System. The group of control systems that regulates the boiler process including the combustion control.

Boiler-Furnace Enclosure. The physical boundary for all boiler pressure parts and the combustion process.

Burner. A device or group of devices for the introduction of fuel and air into a furnace at the required velocities, turbulence, and concentration to maintain ignition and combustion of the fuel within the furnace.

Cinder Return. Apparatus for the return of collected cinders to the furnace, either directly or with the fuel.

Coal. The general name for the natural, rock-like, brown to black derivative of forest-type plant material. By subsequent underground geological processes, this organic material is progressively compressed and indurated, finally altering into graphite and graphite-like material. Coal contains carbon, hydrogen, oxygen, nitrogen, and sulfur, as well as inorganic constituents that form ash after burning. There is no standard coal, but an almost endless variety as to character and composition. Starting with lignite (brown coal) at one extreme, the other basic classifications are sub-bituminous, bituminous, and anthracite. (*For greater detail, see ASTM D388, Specifications for Classification of Coal by Rank.*)

Coking Plate. A plate adjacent to a grate through which no air passes and on which coal is placed for distilling the coal volatiles before the coal is moved onto the grate.

Combustion Control System. The control system that regulates the furnace fuel and air inputs to maintain air/fuel ratio within the limits required for continuous combustion throughout the operating range of the boiler in accordance with demand. This control system includes the furnace draft control where applicable.

Damper. A device for introducing a variable resistance for regulating the volumetric flow of gas or air.

Butterfly Type. A single blade damper pivoted about its center.

Curtain Type. A damper, composed of flexible material, moving in a vertical plane as it is rolled.

Flap Type. A damper consisting of one or more blades, each pivoted about one edge.

Louvre Type. A damper consisting of several blades, each pivoted about its center and linked together for simultaneous operation.

Slide Type. A damper consisting of a single blade that moves substantially normal to the flow.

Dead Plate. A grate or plate through which no air passes.

Drag Seal. In a chain grate stoker, the hinged plate resting against the returning chain and used to seal the air compartments.

Dump Plate. An ash-supporting plate from which ashes may be discharged by rotation from one side of the plate.

Feeder, Raw Fuel. A device for supplying a controlled amount of raw fuel.

Fixed Grate. A grate that does not have movement.

Flame. The visible or other physical evidence of the chemical process of rapidly converting fuel and air into products of combustion.

Fly Carbon Reinjection. The process of removing the coarse carbon-bearing particles from the particulate matter carried over from the furnace and returning the carbonaceous material to the furnace to be combusted. (*See also Cinder Return.*)

Friability. The tendency of coal to crumble or break into small pieces.

Fuel Cutback. An action of the combustion control system to reduce fuel flow when the air/fuel ratio is less than a prescribed value.

Furnace. An enclosure for the combustion of fuel.

Gate, Raw Fuel (Gate, Silo; Gate, Bunker). A shutoff gate between the raw fuel bin and the raw fuel feed mechanism.

Grate. The surface on which fuel is supported and burned and through which air is passed for combustion.

Grate Bars or Keys. Those parts of the fuel supporting surface arranged to admit air for combustion.

Hand-Fired Grate. A grate on which fuel is placed manually, usually by means of a shovel.

Hogged Fuel. Wood refuse after being chipped or shredded by a machine known as a hog.

Interlock. A device or group of devices arranged to sense a limit or off-limit condition or improper sequence of events and to shut down the offending or related piece of equipment, or to prevent proceeding in an improper sequence in order to avoid a hazardous condition.

Labeled. Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization acceptable to the "authority having jurisdiction" and concerned with product evaluation, that maintains periodic inspection of production of labeled equipment or materials and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

Ledge Plate. A form of plate that is adjacent to, and overlaps, the edge of a stoker.

Link. An element of the chain of a chain grate stoker.

Listed. Equipment or materials included in a list published by an organization acceptable to the "authority having jurisdiction" and concerned with product evaluation, that maintains periodic inspection of production of listed equipment or materials and whose listing states either that the equipment or material meets appropriate standards or has been tested and found suitable for use in a specified manner.

NOTE: The means for identifying listed equipment may vary for each organization concerned with product evaluation, some of which do not recognize equipment as listed unless it is also labeled. The "authority having jurisdiction" should utilize the system employed by the listing organization to identify a listed product.

Logic System. The decision making and translation elements of the stoker management system.

(a) *Hardwired Systems.* Individual devices and interconnecting wiring.

(b) *Microprocessor Based Systems.*

1. Computer hardware, power supplies, I/O devices, and interconnections between these.

2. Operating system and logic software.

Monitor. A device that senses and alarms a condition requiring attention, without initiating corrective action.

Natural Gas. A gaseous fuel occurring in nature consisting mostly of a mixture of organic compounds (normally methane, butane, propane, and ethane). The Btu value of natural gases varies between 700 and 1500 Btu per cu ft (26.1 and 55.9 MJ/m^3), the majority averaging 1000 Btu per cu ft (37.3 MJ/m^3).

Open Flow Path. A continuous path for movement of an air stream from the forced draft fan inlet to the stack.

Purge. A flow of air through the furnace, boiler gas passages, and associated flues and ducts that will effectively remove any gaseous combustibles and replace them with air. Purging may also be accomplished by an inert medium.

Recommended Practice. A document similar in content and structure to a code or standard but containing only nonmandatory provisions using the word "should" to indicate recommendations in the body of the text.

Refuse-Derived Fuel (RDF). A solid fuel prepared from municipal solid waste. The waste material is usually refined by shredding, air classification, magnetic separation, or other means. The fuel may be packed, chopped, pelletized, pulverized, or subject to other mechanical treatment.

Register (Burner Air). A set of dampers for a burner or air supply system used to distribute the combustion air admitted to the furnace. It may also control the direction and velocity of the air stream for efficient mixing with the incoming fuel.

Reinjection. (*See definition of Fly Carbon Reinjection.*)

Retort. A trough or channel in an underfeed stoker, extending within the furnace, through which fuel is forced upward into the fuel bed.

Should. Indicates a recommendation or that which is advised but not required.

Side Air Admission. Admission of air to the underside of a grate from the sides of a chain or traveling grate stoker.

Stoker.

Chain Grate Stoker. A stoker that has a moving endless chain as a grate surface, onto which coal is fed directly from a hopper.

Dump Grate Stoker. A stoker equipped with movable ashtrays, or grates, by means of which the ash can be discharged at any desirable interval.

Forced Draft Stoker. A stoker in which the flow of air through the grate is caused by a pressure produced by mechanical means.

Front Discharge Stoker. A stoker so arranged that refuse is discharged from the grate surface at the same end as the coal feed.

Gate Stoker. An element of a stoker placed at the point of entrance of fuel into the furnace and by means of which the depth of fuel on the stoker grate may be controlled. It is generally used in connection with chain or traveling grate stokers and has the form of a guillotine.

Mass Burning Stoker. See Overfeed Stoker.

Mechanical Stoker. A device consisting of a mechanically operated fuel feeding mechanism and a grate, used for the purpose of feeding solid fuel into a furnace, distributing it over a grate, admitting air to the fuel for the purpose of combustion, and providing a means for removal or discharge of refuse.

Multiple Retort Stoker. An underfeed stoker consisting of two or more retorts, parallel and adjacent to each other, but separated by a line of tuyeres, and arranged so that the refuse is discharged at the ends of the retorts.

Overfeed Stoker. A stoker in which fuel is fed onto grates above the point of air admission to the fuel bed. Overfeed stoker grates include:

(a) *Front Feed, Inclined Grate.* Fuel is fed from the front onto a grate inclined downwards toward the rear of the stoker.

(b) *Chain or Traveling Grate.* A moving endless grate that conveys fuel into and through the furnace where it is burned, after which it discharges the refuse.

(c) *Vibrating.* An inclined vibrating grate in which fuel is conveyed into and through the furnace where it is burned, after which it discharges the refuse.

Rear Discharge Stoker. A stoker so arranged that ash is discharged from the grate surface at the end opposite the solid fuel.

Reciprocating Grate. A grate element that has reciprocating motion, usually for the purpose of fuel agitation or ash removal.

Side Dump Stoker. A stoker so arranged that refuse is discharged from a dump plate at the side of the stoker.

Single Retort Stoker. An underfeed stoker using one retort only in the assembly of a complete stoker. A single furnace may contain one or more single retort stokers.

Spreader Stoker. A stoker that distributes fuel into the furnace from a location above the fuel bed with a portion of the fuel burned in suspension and a portion on the grates. Spreader stoker grates include:

(a) *Stationary Grate.* A grate in which fuel is fed onto a fixed position grate.

(b) *Dump Grate.* A grate in which fuel is fed onto a nonmoving grate that is arranged to allow intermittent discharge of refuse through tilting action of the grate bars.

(c) *Continuous Discharge or Traveling Grate.* A grate that continuously discharges the refuse from the end after burning the fuel.

Traveling Grate Stoker. A stoker similar to a chain grate stoker with the exception that the grate is separate from but is supported on and driven by chains.

Underfeed Stoker. A stoker in which fuel is introduced through retorts at a level below the location of air admission to the fuel bed. Underfeed stokers are divided into three general classes.

(a) *Side Ash Discharge Underfeed Stoker.* A stoker having one or more retorts that feed and distribute fuel onto side tuyeres or a grate through which air is admitted for combustion and over which the ash is discharged at the side parallel to the retorts.

(b) *Rear Discharge Underfeed Stoker.* A stoker having a grate composed of transversely spaced underfeed retorts, which feed and distribute solid fuel to intermediate rows of tuyeres through which air is admitted for combustion. The ash is discharged from the stoker across the rear end.

(c) *Continuous Ash Discharge Underfeed Stoker.* A stoker in which the refuse is discharged continuously from the normally stationary stoker ash tray to the ash pit, without the use of mechanical means other than the normal action of the coal feeding and agitating mechanism.

Water Cooled Stoker. A stoker having tubes in or near the grate surface through which water is passed for cooling the grates.

Start-up Combustion Control System. A control system used to regulate and maintain air/fuel ratio during the start-up period when the customary indexes, such as pressure, temperature, load, or flow, that motivate the normal automatic combustion control system are not available or suitable.

Tuyeres. Forms of grates, located adjacent to a retort, feeders, or grate seals through which air is introduced.

Chapter 4 Fuels

4-1 Coals.

4-1.1 General. Depending on the method of stoker firing, all ASTM classifications of coals can be burned. These include Class I "Anthracite," Class II "Bituminous," Class III "Sub-Bituminous," and Class IV "Lignite." In choosing an appropriate stoker type, there are several properties of coal that must be considered. These are, in part, the relationship between fixed carbon and volatile matter, the moisture content, the percent ash, the ash fusion temperature, and the free swelling index.

4-1.2 Classification.

4-1.2.1 Class I, "Anthracite Coal," is divided into three groups. These are Group 1, "Meta-Anthracite," in which the fixed carbon on a dry and mineral matter-free basis is equal to or greater than 98 percent; Group 2, "Anthracite," which has a range of fixed carbon limits on a dry and mineral matter-free basis of greater than 92 percent and less than 98.2 percent; and Group 3, "Semi-Anthracite," which has a fixed carbon limit on a dry and mineral matter-free basis equal to or greater than 86 percent and less than 92.8 percent.

4-1.2.2 Class II, "Bituminous Coal," is subdivided into five groups. Group 1, "Low Volatile Bituminous Coal," has fixed carbon limits greater than 78 percent but less than 86 percent. Group 2, "Medium Volatile Bituminous Coal," has fixed carbon limits greater than 69 percent but less than 78 percent. Group 3, "High Volatile 'A' Bituminous Coal," has a fixed carbon quantity of less than 69 percent and greater than 14,000 Btu/lb (32,564 kJ/kg) calorific value on a moist mineral matter-free basis. Group 4, "High Volatile 'B' Bituminous Coal," has a calorific value equal to or greater than 13,000 Btu/lb (30,238 kJ/kg) and less than 14,000 Btu/lb (32,564 kJ/kg). All of the above bituminous coals are considered commonly agglomerating. Group 5, "High Volatile 'C' Bituminous Coal," has a calorific value equal to or greater than 11,500 Btu/lb (26,749 kJ/kg) and less than 13,000 Btu/lb (30,238 kJ/kg) when it is commonly agglomerating and a calorific value limit equal to or greater than 10,500 Btu/lb (24,423 kJ/kg) but less than 11,500 Btu/lb (26,749 kJ/kg) when it is always agglomerating.

4-1.2.3 Class III, "Sub-Bituminous Coal," is divided into three groups. All three groups are considered nonagglomerating. Group 1, "Sub-Bituminous 'A' Coal," has a calorific value equal to or greater than 10,500 Btu/lb (24,423 kJ/kg) but less than 11,500 Btu/lb (26,749 kJ/kg). Group 2, "Sub-Bituminous 'B' Coal," has a calorific value limit equal to or greater than 9,500 Btu/lb (22,097 kJ/kg) but less than 10,500 Btu/lb (24,423 kJ/kg). Group 3, "Sub-Bituminous 'C' Coal," has a calorific value equal to or greater than 8,300 Btu/lb (19,306 kJ/kg) but less than 9,500 Btu/lb (22,097 kJ/kg).

4-1.2.4 Class IV, "Lignite Coal," is divided into two groups. Both are considered nonagglomerating. Group 1, "Lignite A," has a calorific value limit equal to or greater than 6,300 Btu/lb (14,654 kJ/kg) and less than 8,300 Btu/lb (19,306 kJ/kg). Group 2, "Lignite B," has a calorific value less than 6,300 Btu/lb (14,654 kJ/kg).

4-1.3 Sizing. Sizing characteristics vary with stoker type as outlined in the ABMA *Recommended Design Guidelines for Stoker Firing of Bituminous Coal.* Different coals have varying tendencies to break down during mining processes and in handling. Western sub-bituminous coals are considered friable and are generally delivered to the boiler with high percentages of particles less than 1/4 in. (6.35 mm) in size. These can be burned satisfactorily using the correct equipment. Each plant should carefully analyze the fuel characteristics and associated handling and combustion problems for the best overall operation. Anthracite is generally burned in finer sizes, generally less than $^5/_{16}$ in. (7.94 mm), to expose more surface of the very high fixed carbon fuel to the oxygen in the air.

Sizing in the hopper should be within the two limits as set forth in the ABMA *Recommended Design Guidelines for Stoker Firing of Bituminous Coal.* Means should be provided for the delivery of coal to the stoker hopper without size segregation.

4-1.4 Coal Special Problems.

4-1.4.1 The term *coal* refers to solid fuels with widely differing characteristics. A coal-burning fuel system is designed for a specific range of coal characteristics. Coals that differ widely from the design range of characteristics can cause serious operating difficulties and become a potential safety hazard. The coal, as mined, transported, and delivered to the plant, can vary in size and in impurities to a degree that exceeds the capability of the plant equipment. When coals are received from more than one source, care should be exercised to make sure that all coals received are within the specific range of the coal-handling and coal-burning equipment.

4-1.4.2 To ensure that the type of coal and its preparation are suitable for the equipment, there should be a coal specification that is acceptable to the equipment designer, the purchasing agency responsible for procuring the fuel, and the operating department that burns the fuel. Volatility, moisture and ash content, size of raw coal, and other characteristics should be given close attention.

4-1.4.3 The following factors have a bearing on coal handling, storage, and preparation:

(a) Coal is an abrasive and corrosive substance. Equipment maintenance therefore may be several orders of magnitude greater than with liquid and gaseous fuels.

(b) Coal changes when it is exposed to the atmosphere. It is common practice to ship and stockpile coal without protection from the weather. The properties of stored coal may change. This may require special considerations. Coal with high surface moisture may freeze in shipment or in storage. This may require special handling equipment.

(c) Since coal has a high ash content, special attention should be given to problems associated with slag and ash deposits.

(d) Coal is capable of spontaneous combustion and self-heating from normal ambient temperature. This tendency increases radically when the temperature is increased. Blended or mixed coals may heat more rapidly than any of the parent coals.

(e) Volatile matter is given off by the coal. This volatile matter is a gaseous fuel that causes additional hazards.

4-2 Peat. Peat is a high-moisture fuel characterized by high volatile matter typically 50 to 70 percent on a dry, ash-free basis. The harvesting of peat bogs includes air drying to a moisture less than 50 percent, which allows it to be burned on stokers with preheated air.

4-3 Wood. Wood is a fuel derived either from the forest products industries, such as lumbering or pulp and paper mills, or from the direct harvesting of trees to be used as fuel. Wood is characterized by a high percentage of volatile matter, from 75 percent to an excess of 80 percent on a dry and ash-free basis. Wood releases its energy at a more rapid rate than coal.

Two characteristics of wood fuel vary greatly depending on the source of the fuel. One is the size consist and the other is moisture content. Size consist can vary from sander dust to coarse chips or bark, the size of which will depend on sizing preparation equipment, and in the case of bark, its tendency to remain in a long, stringy, fibrous form. Wood moisture can vary from less than 10 percent to an excess of 60 percent. Wood chips, hogged fuel, or green lumber mill waste will normally have moisture contents varying from 40 to 55 percent.

The source of wood fired on stokers can vary considerably. It is necessary for efficient and safe operation that the fuel be completely mixed without side variations in sizing or moisture content. These variations can cause rapid and severe furnace pulsations resulting in a dangerous condition as well as inefficient operation. Normally, wood having a moisture content up to 55 percent can be burned stably without auxiliary fuel as long as proper attention has been given to furnace design, preheated air temperature, stoker heat releases, and proper fuel handling and metering. The vast majority of wood is burned on overfeed spreader stokers.

4-4 Municipal Waste. Municipal waste is burned with stokers in two forms — one is known as municipal solid waste (MSW), which is delivered without preparation. This is normally burned as a deep fuel bed on an overfeed mass burning-type stoker specially constructed for this service. The other form of municipal waste is known as RDF or "refuse-derived fuel," in which the MSW is shredded and classified for size and to remove tramp material such as metals and glass and then is normally burned on an overfeed spreader stoker.

Municipal waste has a high volatile matter to fixed carbon ratio. Normally, it readily releases its energy. The effects of large sizing in the case of MSW and RDF can lead to improper burning. With the potential for high moisture content, the use of preheated air is generally advocated.

In the case of an MSW-fired unit, furnace explosions may result from aerosol cans, propane bottles, etc., contained in the fuel supply. Pulsations from concentrations of extremely volatile wastes may also result.

4-5 Other Waste. Other waste can include a multiplicity of discarded solids that could be considered stoker fuel. Wood waste that has been impregnated with resins or additives for adhesions or other purpose come into the category of other wastes. These additives, along with a consideration for size consist, could greatly reduce the flash point of the wood waste and increase concern for attention to stable furnace conditions. Other common waste might be bagasse from sugar cane processing, furfural residue from the production of phenolic resins, coffee grounds from the production of instant coffee, and peanut shells. All of these wastes, with proper attention to sizing, moisture, and continuous metering, can be successfully burned on overfeed spreader stokers. The vast majority of waste fuels are further characterized by a high volatile matter-to-fixed carbon ratio.

4-6 Solid Fuel Firing — Special Characteristics.

4-6.1 Solid Fuels.

4-6.1.1 Solid 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 applicable. There are also several types of feeders available. Feeders are specified according to fuel type and method of burning, e.g., suspension, in mass, etc.

4-6.1.2 Some solid fuels have a high moisture content. For instance, bark has a moisture content of 35 to 50 percent; bagasse, 40 to 60 percent; and coffee grounds, 60 percent. As a result, these fuels may be dried before burning with some of the final drying taking place as the fuel enters the furnace and falls to the grate. Manufacturer's recommendations should be followed.

4-6.1.3 The size consist of solid fuels should be in accordance with the stoker manufacturer's recommendations.

4-6.2 Specific Fuels.

4-6.2.1 Bagasse.

4-6.2.1.1 Bagasse is the portion of sugar cane left over after sugar is extracted. It consists of cellulose fibers and fine particles.

4-6.2.1.2 Variations in refining and handling can lead to variations in fuel particle size. This can create some firing problems. These variations can cause rapid and severe furnace pulsations, resulting in a dangerous condition as well as inefficient operation.

4-6.2.2 Refuse-Derived Fuel.

4-6.2.2.1 Refuse-derived fuel (RDF) 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 the large amounts of cardboard, plastics, and other synthetic materials used. Typical components of RDF are paper and paper products, plastics, wood, rubber, solvents, oils, paints, and other organic materials.

4-6.2.2.2 Other conventional fuels can be burned in the same furnace along with RDF. Older installations may also be converted to burn RDF.

4-6.2.2.3 A number of complex factors must be considered before attempting conversion to RDF firing. Additional information can be obtained from the boiler manufacturer.

4-7 Special Considerations. For special problems in handling refuse fuels, refer to NFPA 850, *Recommended Practice for Fire Protection for Electric Generating Plants.*

Chapter 5 Equipment

5-1 Single or Multiple Retort Underfeed Stoker. [*See Figures 5-1(a) and (b).*]

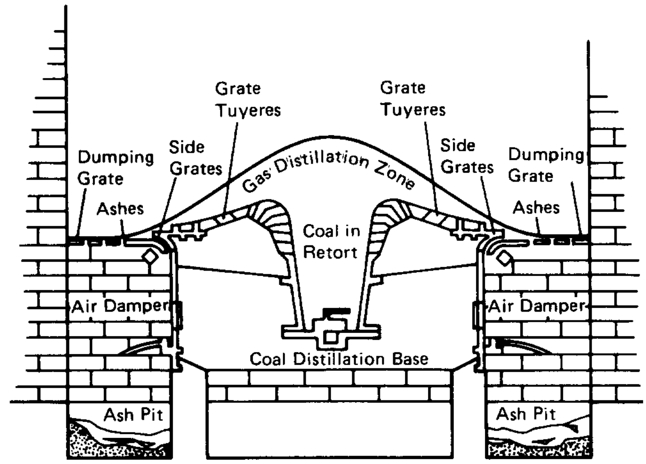

Figure 5-1(a) Cross-sectional view of single retort underfeed stoker in operation. (*Reprinted with permission of Detroit Stoker Company*)

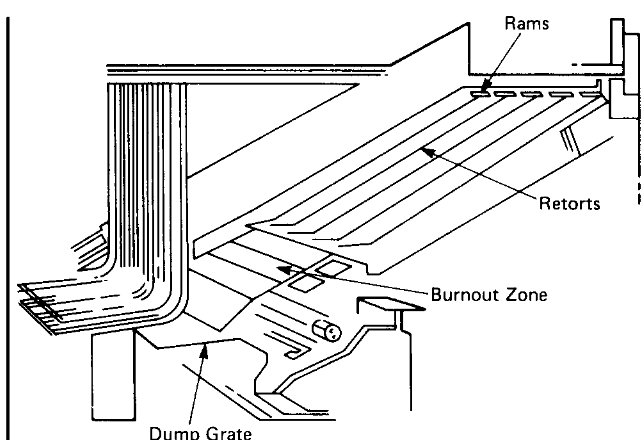

Figure 5-1(b) Multiple retort underfeed stoker showing components. (*Reprinted with permission of Detroit Stoker Company*)

5-1.1 Fuel Subsystem. The fuel combusted with an underfeed stoker is typically coal or wood. The fuel system can be as simple as a manual loading of a live hopper or automatic loading from a fuel storage facility. Either way fuel must be delivered at proper sizing and quantity to the live hopper to maintain an adequate fuel supply in the hopper. The live hopper has an open bottom that delivers fuel by gravity to the feed screw. Fuel is conveyed to the grate area by means of the feed screw at a variable speed, based on boiler demand. Some underfeed stokers use a reciprocating ram instead of a feed screw. Fuel is forced upward and outward through the retort, onto the tuyeres, at which point it is combusted.

5-1.2 Air Subsystem. Air is supplied under the grate (undergrate air plenum) by means of a forced draft fan (undergrate air fan). Overfire air is optional and is supplied in any or all of the furnace walls. Underfeed stokers must be balanced draft units.

5-1.2.1 At least 10 percent of the total air required for combustion at maximum continuous rating should be provided as overfire air when used.

5-1.3 Ash Subsystem. A dump grate is used to deposit ash into an ash pit. Ash is typically manually removed from the ash pit through ash doors on the front of the unit.

5-2 Overfeed Mass Burning Stoker. Overfeed mass burning stokers include not only chain and traveling grate stokers for coal firing, but also the MSW stoker for mass burning of unprepared municipal waste.

5-2.1 Overfire air should be provided in a quantity not less than 15 percent of the total air required for combustion (theoretical plus excess) at maximum continuous rating. This overfire air should be arranged to effectively cover the active burning area of the grate.

5-2.2 The recommended grate heat release should not exceed 450,000 Btu/hr per ft^2 (1420 kW per m^2) of effective air admitting grate area. Maximum grate heat release rates per foot of stoker width should be 9.0×10^6 Btu/hr per linear foot (8660 kW/m^2 per linear meter) of stoker width without arches and 10.8×10^6 Btu/hr per linear foot (10,393 kW/m^2 per linear meter) with arches.

5-2.3 This stoker is sensitive to changes in fuel sizing and distribution.

5-2.4 Means should be provided for the delivery of fuel to the stoker hopper without size segregation.

5-2.5 Ash softening temperature should be 2200°F (1204°C) or higher.

5-2.6 The as-fired total moisture in the coal should be a maximum of 20 percent by weight.

5-2.7 Means should be provided for tempering coals having free-swelling indices above 5 by adding moisture to a maximum of 15 percent by weight.

5-2.8 The volatile matter on a dry basis should be not less than 22 percent without special arch construction.

5-2.9 Coal should have a minimum ash content of 4 percent and a maximum of 20 percent (dry basis) to protect the grates from overheating and to maintain ignition.

5-2.10 Chain and Traveling Grate Stoker. (*See Figure 5-2.10.*)

5-2.10.1 Chain and traveling grate stokers are normally used for coal firing and are similar except for grate construction. The grate in these stokers resembles a wide belt conveyor, moving slowly from the feed end of the furnace to the ash-discharge end. Coal feeds from a hopper under control of a manually controlled gate, which establishes fuel bed thickness. Furnace heat ignites the coal and distillation begins. As the fuel bed moves along slowly, the coke formed is burned and the bed gets progressively thinner as the ash is automatically discharged at the rear of the stoker. To control the combustion air requirements and fuel bed resistances along the grate length, the stoker is zoned or sectionalized with a damper in each section that is manually operated. Air for combustion can enter from the bottom through both grates or from the side between the top and bottom grates. An automatic combustion control system is furnished with this firing system. However, the coal feed gate and the distribution of undergrate air and overfire air may be adjusted manually to meet the varying characteristics of the fuel.

5-2.10.2 These stokers are mainly used for medium-sized industrial boilers with heat inputs from 40,000,000 Btu/hr (11,720 kW) to 170,000,000 Btu/hr (49,800 kW). Coal sizing should be 1 in. (25.4 mm) × 0 in. with approximately 20 to 50 percent passing through a ¼ in. (6.35 mm) round mesh screen. This stoker will handle such fuels as bituminous coals, anthracite coals, coke breeze, sub-bituminous coals, and lignite. This stoker produces low particulate emission.

5-2.10.3 The coal requirements of this stoker, especially sizing and chemical composition, are important for successful operation. The free-swelling index should not exceed 5 on a scale of 1 to 10 without coal tempering, or 7 with coal tempering.

5-2.11 Vibrating Grate Stoker. (*See Figure 5-2.11.*)

5-2.11.1 The vibrating grate stoker is water cooled with an inclined grate surface with intermittent grate vibration for slowly moving the fuel bed down the inclined grate from the feed end of the furnace to the ash discharge end. Coal is fed from a hopper onto the inclined grate surface to form the fuel bed. The fuel bed thickness is established by a coal gate at the fuel hopper outlet and adjustable ash dam at the ash discharge end.

5-2.11.2 Furnace heat ignites the coal and distillation begins. As the fuel bed moves along slowly, the coke formed is burned and the bed gets progressively thinner as the ash is automatically discharged at the rear of the stoker. To control the combustion air requirements in relation to varying fuel bed resistances along the grate length, combustion air enters from the bottom of the grates through zoned or sectionalized plenum chambers. Each zoned section is furnished with a manually operated control damper. An automatic combustion control system is furnished with this firing system. The vibration generator that conveys the fuel bed is controlled automatically by cycle timers connected to the combustion control system. However, the coal feed gate and the distribution of undergrate air and overfire air may be adjusted manually to meet the varying characteristics of the fuel.

5-2.11.3 These stokers are mainly used for medium-sized industrial boilers with heat inputs from 70,000,000 Btu/hr (20,500 kW) to 140,000,000 Btu/hr (41,000 kW). They are designed to burn low-ranking coals. Coal sizing should be 1 in. (25.4 mm) × 0 in. with approximately 20 percent to 50 percent through a ¼ in. (6.35 mm) round mesh screen.

5-2.11.4 Response to load changes is slow, faster than the underfeed — but much slower than the spreader stoker.

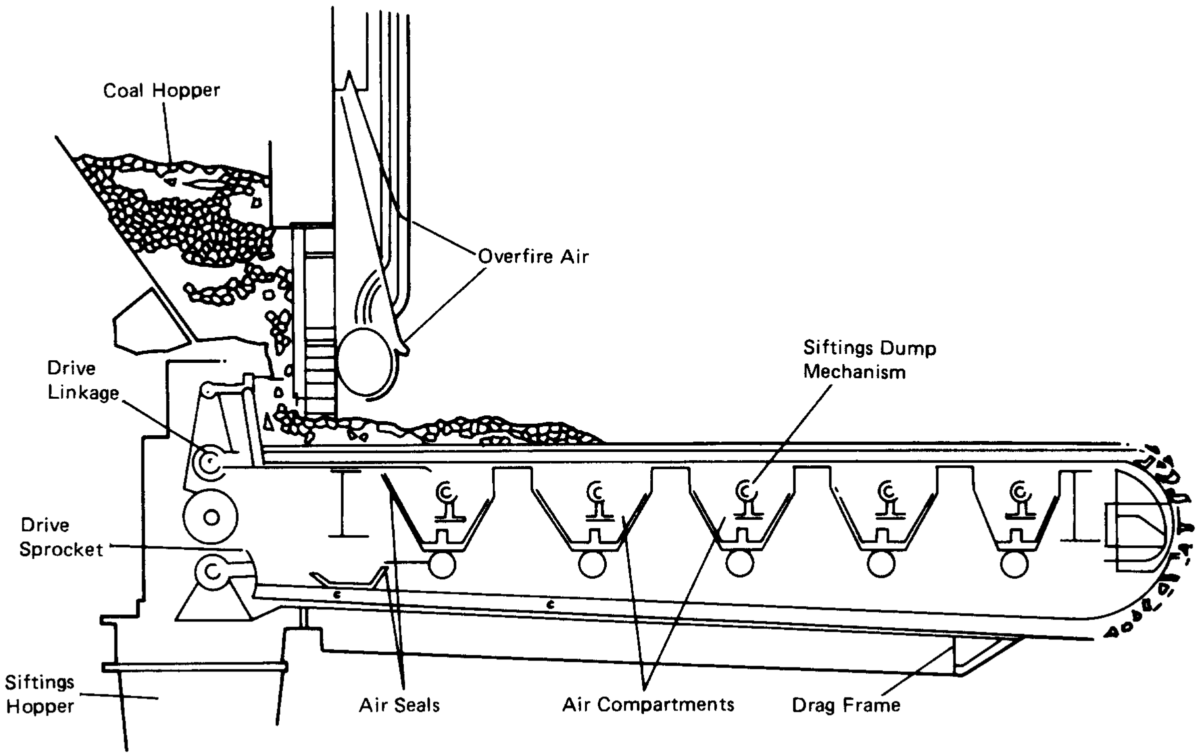

Figure 5-2.10 Side view of chain grate overfeed stoker. (*Reprinted with permission of Detroit Stoker Company*)

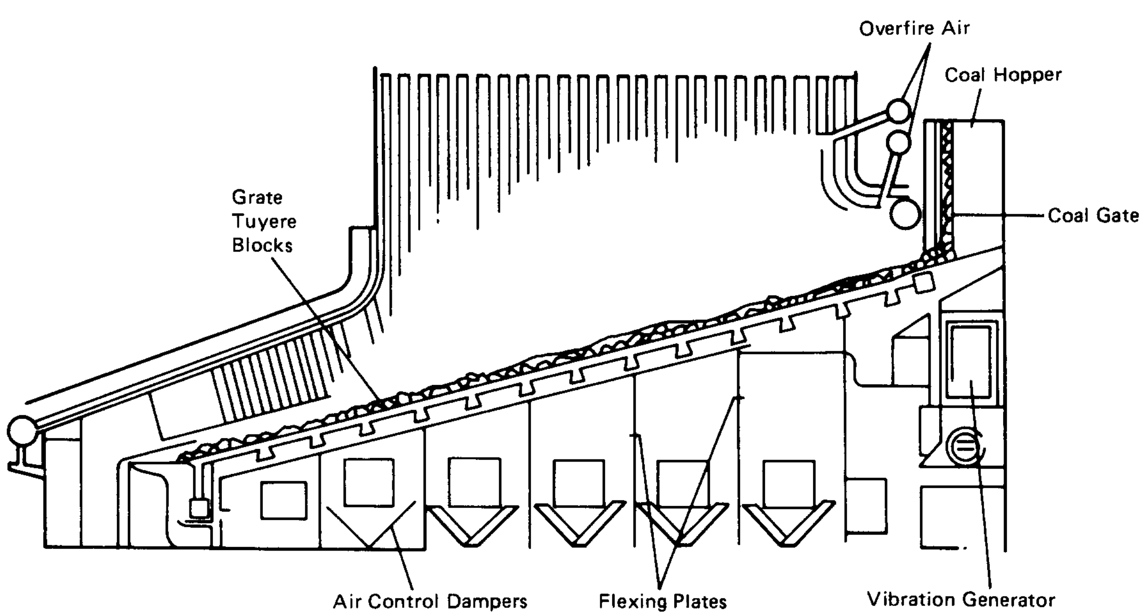

Figure 5-2.11 Side view of a water-cooled vibrating grate stoker. (*Reprinted with permission of Detroit Stoker Company*)

5-2.12 MSW Stoker.

5-2.12.1 The grate of an inclined stoker resembles a staircase and is used to move refuse from the feed end of the furnace to the ash discharge end. Refuse is fed from a charging hopper under control of a mechanical system, which establishes fuel bed thickness. A mechanical system then agitates and conveys the refuse down this incline by continuous agitation. This agitation is required to expose all of the refuse to the air in order to increase the burning rate and complete combustion. The individual plenums under the grates provide a means of distributing air to a particular location. This undergrate air system, coupled with the overfire air, complete the air requirements for combustion.

5-2.12.2 The constantly changing firing conditions associated with the variation in the density and composition of the refuse requires constant operator attention and manual adjustments.

5-2.12.3 Since feed rate is directly proportional to the stoker grate speed, the feed rate must be correlated very closely with the stoker burning rate and, in turn, with combustion air supply and distribution. Since an automatic grate speed control to match actual burning rates is not always practical, the operator's duties consist of constant visual monitoring of the combustion process and readjustments in combustion air distribution and grate speed with manually controlled systems.

5-2.12.4 This stoker is currently used for medium-sized boilers with heat inputs from 30,000,000 Btu/hr (8,800 kW) to 340,000,000 Btu/hr (99,600 kW).

5-2.12.5 Due to the nonuniform sizing of the refuse, the response to load change is slow. Due to the nonhomogeneous nature of raw refuse, high excess air requirements can result in lower thermal efficiency of the generating system.

5-2.12.6 This type of stoker is designed to burn unprepared raw municipal waste refuse with most of the combustion occurring on or near the grate surface. Generally, the stoker is sized for the highest anticipated refuse heat value. The heat values for refuse can vary from 3000 Btu/lb (6,978 kJ/kg) to 6000 Btu/lb (13,956 kJ/kg).

5-3 Spreader Stoker. (*See Figure 5-3.*)

5-3.1 General.

5-3.1.1 The spreader stoker distributes fuel into the furnace from a location above the fuel bed with a portion of the fuel burned in suspension and a portion on the grates. Theoretically, equal energy is released from each square foot of active grate area. To accomplish this equal energy release, it is necessary to have even fuel distribution over the grate surface and even airflow through the grates from the air plenum beneath.

5-3.1.2 There are five spreader stoker grate types in general use today. The first type is a traveling grate with a continuous forward moving grate in which the return portion is on the underside, within the air plenum chamber. Ashes are conveyed to the front end. The second type is a reciprocating grate, which is a stepped grate having a slow reciprocating action to convey the ashes to the front end. The third type is a vibrating grate, either air-cooled or water-cooled, having an intermittent vibrating action to convey the ashes to the front end. The fourth type, the dumping grate, manually intermittently discharges all of the ashes on the grate vertically downward to the ash pit.

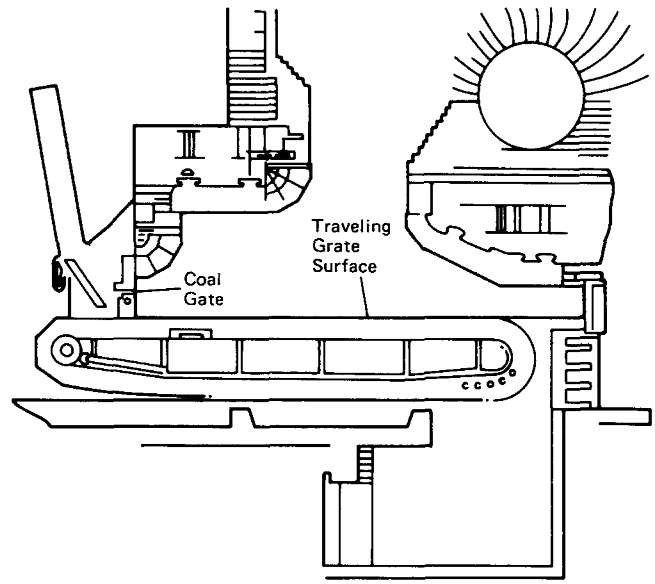

Figure 5-2.12 Side view of a traveling grate overfeed stoker. (*Reprinted with permission of Riley Stoker Corporation*)

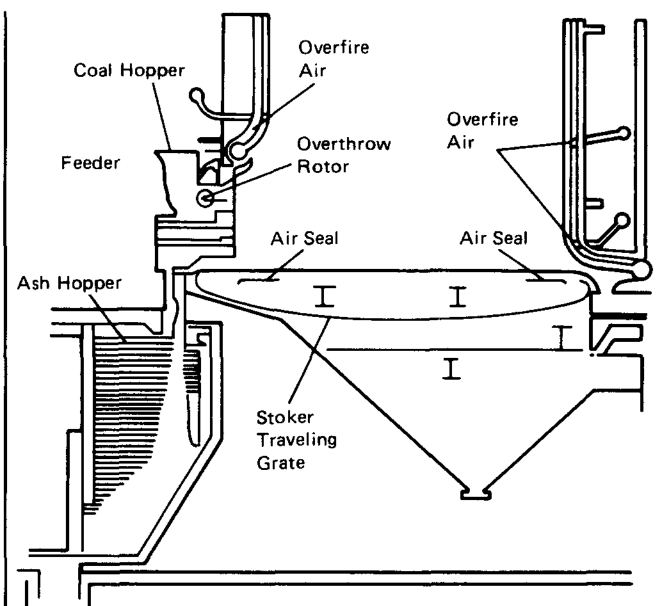

Figure 5-3 Side view of a spreader stoker with traveling grate. (*Reprinted with permission of Detroit Stoker Company*)

The dumping grate is seldom supplied today. The fifth grate type is the stationary grate, which is typically used for low-ash fuels.

5-3.1.3 The spreader stoker contains fuel feeders that are located in the front wall in sufficient quantity to ensure even lateral distribution of the fuel across the width of the grate. The design of the fuel feeder also incorporates methods to achieve even longitudinal distribution of fuel. These feeders take on many different designs and shapes, depending on the fuel and the manufacturer.

5-3.1.4 A spreader stoker system may include a cinder return system. Its function is to return a portion of cinders leaving the furnace and collected in various cinder hoppers to the furnace for reburning.

5-3.1.5 A spreader stoker includes an overfire air turbulence system. Its function is to provide mixing of the fuel and oxygen. Overfire air nozzles are located in the area of the furnace of highest temperature for highest efficiency and burnout of volatiles and carbon particles.

5-3.1.6 Spreader stokers are utilized on boilers having heat inputs from 30,000,000 Btu/hr (8,800 kW) to 820,000,000 Btu/hr (240,300 kW), depending on the fuel and type of spreader stoker grate. Spreader stokers have a very thin, active fuel bed and thus can respond to load changes quite rapidly.

5-3.2 Spreader stokers are not normally applied to coals having a volatile matter on a dry and ash-free basis of less than 20 percent. Moisture content affects the burning of sub-bituminous and lignitic coals on a spreader stoker. Preheated air is recommended with moisture contents greater than 25 percent. Ash content in excess of that required for grate protection has little effect on a selection of fuels for spreader stoker, as it only affects grate speed. Ash softening temperature is a consideration only on reciprocating, vibrating, or dump grate spreader stokers.

5-3.3 All wood, municipal waste, and other wastes listed in Chapter 4 can be burned on spreader stokers. Wood with moisture contents up to 55 percent can be burned without auxiliary fuel as long as preheated air temperature is sufficiently high. Municipal waste can be burned on an overfeed spreader stoker only as RDF. Of greatest importance in looking at refuse fuels is size consist.

5-4 Fuel Burning System.

5-4.1 Functional Requirements.

5-4.1.1 The fuel burning system should function to continuously convert any ignitible furnace input into unreactive products of combustion at the same rate the fuel and air reactants enter the furnace.

5-4.1.2 The fuel burning system should be properly sized to meet the operating requirements of the unit, should be compatible with other boiler component systems, and should be capable of being controlled over the full operating range of the unit.

5-4.2 System Requirements.

5-4.2.1 The fuel burning system should consist of the following subsystems: air supply, fuel supply, grate, furnace, combustion products removal, and ash removal. Each should be properly sized and interconnected to satisfy the functional requirements and not interfere with the combustion process.

5-4.2.2 The fuel burning system should provide means for safe start-up, operation, and shutdown of the combustion process. This should include appropriate openings and configurations in the components' assemblies to permit suitable observation, measurement, and control of the combustion process.

5-4.2.3 The fuel burning system should include the following:

(a) *Air Supply Subsystem.*

1. The air supply equipment should be properly sized and arranged to ensure a continuous steady airflow for all operating conditions of the unit.

2. The arrangement of air inlets and ductwork should minimize contamination of the air supply by such materials as water and fuel. Appropriate drains and access openings should be provided.

(b) *Fuel Supply Subsystem.*

1. The fuel supply equipment should be properly sized and arranged to ensure a continuous, controlled fuel flow adequate for all operating requirements of the unit.

2. The fuel unloading, storage, transfer, and preparation facilities should be designed and arranged to properly size the fuel, to remove foreign material, and to minimize interruption of fuel supply. This includes fuel sizing equipment and magnetic separators where necessary.

3. Mass fired municipal solid waste fired systems should incorporate detection and fire extinguishing systems into and over the feed system to extinguish and control the flashbacks of fuel as it is being fed into the furnace. Extinguishing systems should be capable of being used repeatedly without taking the unit out of service. See NFPA 850 for additional requirements.

(c) *Furnace Subsystem.*

1. The furnace should be properly sized and arranged with respect to the grate subsystem so that the grate can be fired to maintain stable combustion and minimize furnace pressure fluctuation.

2. Properly placed observation ports should be provided to permit inspection of the furnace and grate. Refer to Section 9-9.

3. Observation ports and lancing doors for mass fired MSW units should be provided with vision ports that will permit observation and operation of the unit while puffs are expected and occurring. Glasses should be replaceable without taking the unit out of service. Lancing ports should be equipped with aspirators or other devices to safely permit lancing of the fuel bed without restricting operations.

4. The stoker fired boiler is inherently less prone to furnace implosions because of the absence of the sudden "flame collapse" phenomenon that exists on fluid or pulverized fuel fired boilers.

5. The relatively high ID fan head capabilities brought about by the requirements of flue gas cleaning

equipment may result in high negative pressures in the duct and furnace due to improper ID fan start-up or malfunction of the furnace draft controlling equipment.

6. Although no specific values for the structural design of the furnace and ducts are given in this recommended practice, the designer should give consideration to the high head capability of the fans in the structural design and to the use of protective control loops similar to those shown in Chapter 5 of NFPA 85C, modified or simplified to fit the application.

7. The use of protection control loops is encouraged. The provisions of Chapter 5 of NFPA 85C may be used for general guidance; however, they must be modified or simplified by the designer in accordance with the manufacturer's recommendations to apply to stoker usage.

(d) *Combustion Products Removal Subsystem.*

1. The flue gas duct, fan(s), and stack should be properly sized and arranged to remove the products of combustion at the same rate that they are generated by the fuel burning process.

2. Convenient, appropriate access and drain openings should be provided.

3. The flue gas duct system should be designed so that it will not contribute to furnace pulsations.

(e) *Ash Removal Subsystem.*

1. The grate subsystem and flue gas cleaning subsystem should be sized and arranged to remove the ash at least at the same rate it is generated by the fuel burning process during unit operation.

2. Convenient access and drain openings should be provided.

5-5 Combustion Control System.

5-5.1 Functional Requirements.

5-5.1.1 The combustion control system should maintain furnace fuel and air input in accordance with demand.

5-5.1.2 The combustion control system should control furnace inputs and their relative rates of change so as to maintain the air/fuel mixture within the limits required for continuous combustion and stable furnace pressure throughout the controllable operating range of the unit.

5-5.2 System Requirements.

5-5.2.1 Furnace input should be controlled to respond to the energy demand under all operating conditions.

5-5.2.2 The air/fuel mixture should be maintained within safe limits as established by test under any boiler output condition within the controllable operating range of the subsystem.

5-5.2.3 When changing the rate of furnace input, the airflow and fuel flow should be changed simultaneously at the proper rates to maintain safe air/fuel ratio during and after the change. This does not prohibit provisions for air lead and lag of fuel during changes in firing rate. The practice of placing either fuel or airflow control on automatic without the other also being on automatic should be discouraged.

5-5.2.4 Furnace draft should be maintained at the desired set point in the combustion chamber.

5-5.2.5 A means should be provided to prevent the control system from demanding a fuel-rich mixture.

5-5.2.6 A means of permitting as much on-line maintenance of the combustion control equipment as possible should be provided.

5-5.2.7 A means should be provided for calibration and check testing of combustion control and associated safeguard equipment.

5-5.3 If applicable, the high-pressure overfire air turbulence system should also be controlled in either of two methods: (a) control the outlet pressure of the blower using a manual set point; or (b) control overfire air in parallel with forced draft flow.

5-5.4 The flue gas analyzer may be used as an operating aid. Caution should be used in interpreting the readings.

Chapter 6 Operation

6-1 General. This chapter addresses typical stoker operation. In all cases, manufacturers' recommendations should be consulted and followed.

6-2 Start-Up, General. After an overhaul or other maintenance, a complete functional check of the safety interlocks should be made. Preparation for starting should include a thorough inspection and check, not exclusively but particularly, for the following:

(a) Furnace and gas passages in good repair and free of foreign material.

(b) Boiler-furnace enclosure and associated ductwork evacuated by all personnel and all access and inspection doors closed.

(c) Energy supplied to control system and to safety interlocks.

(d) Fuel feed and grate system.

(e) Feed mechanism variable speed control operational through full range.

(f) All air and flue gas control dampers operational through full range.

(g) Proper drum level established.

(h) Oxygen and combustible analyzers, if provided, operating satisfactorily. Check that combustibles indication is zero and oxygen indication is at a maximum.

6-3 Start-Up Procedures (Cold Start). The cold start procedure is as follows:

(a) Prior to starting induced draft (ID) fans, verify an open flow path from the inlet of the forced draft (FD) fan to the stack. Unless there is sufficient natural draft for initial firing, the induced draft fan should be started and normal furnace draft maintained.

(b) Verify that grate is clear of ash and debris.

(c) Fill feeder hopper with fuel, start feed mechanism, and establish a bed of fuel on the grate.

(d) Place kindling on fuel bed. Spray the kindling from outside the furnace with a light coat of distillate oil.

CAUTION: Gasoline, alcohol, or other highly volatile material must not be used for light-off.

(e) Open furnace access door, light a torch, and ignite wood by passing torch through the door.

(f) When wood on bed of fuel is burning, start ID fan, if not in operation, and place in automatic mode of operation.

(g) The overfire air fan should be started immediately to prevent damage from gases passing through the ductwork.

CAUTION: Undergrate air pressure should always be greater than furnace pressure to prevent reverse flow and potential unit damage.

(h) When fuel bed is actively burning, start FD fan with dampers at minimum position.

(i) Start fuel feed. Observe operation and adjust fuel rate and air as required until boiler steam pressure is at normal operating pressure.

(j) Place fuel and air in automatic mode of operation.

6-3.1 Operation of auxiliary fuel burners may be required when starting up and firing high moisture fuel.

6-3.2 If a boiler is equipped with auxiliary gas or oil burners, it is possible to put the boiler on the line using this auxiliary fuel and then feed the solid fuel up on the grate, where it will ignite from radiant heat of the auxiliary burners. Care should be taken to protect the grate from overheating.

6-3.3 Start-up procedures for other wastes, as described in Chapter 4, would be dependent on the characteristics of the particular waste. In all cases, manufacturer's instructions should be consulted and followed.

6-4 Normal Operation.

6-4.1 The firing rate should be regulated by increasing or decreasing the fuel and air supply simultaneously to the grate(s), maintaining normal air/fuel ratio at all firing rates.

6-4.2 Each stoker has adjustments for the distribution of the fuel. Manual adjustments for distribution of fuel are made from visual appearance of the fuel bed, furnace, and oxygen analyzer and smoke monitor readings at the boiler outlet.

CAUTION: Visual observations of the fuel bed conditions through open doors should be made with extreme care. (*See Section 9-9.*)

6-4.3 Manual adjustments to the individual rows of overfire turbulence air nozzles for maximum furnace efficiency and minimum emission discharge may be required.

6-4.4 Fuel should be fed to maintain an even depth of ash. As the percent of ash in the fuel changes, it may be necessary to make adjustments. It is necessary to observe the depth of ash at the discharge end of the grates.

6-5 Normal Shutdown. Normal shutdown procedure is as follows:

(a) Manually reduce the boiler load to minimum normal load.

(b) Fuel shutoff gates, if furnished above the fuel feeders, should be closed.

(c) Remaining fuel in the system adjacent to the boiler should be burned out.

(d) Normal furnace draft should be maintained throughout this process and overfire air fan should be left running.

(e) After fuel feed ceases and the fire is burned out, the overfire air and forced draft fan can be shut off or left running depending on the desired rate of boiler cool-down. However, the overfire air fan should be left running until the furnace and boiler are sufficiently cool to prevent damage to the overfire system from a back flow of hot gases.

(f) If the forced draft fan is shut off, ensure that a natural draft flow of air through the grates is provided.

(g) For spreader stokers, fuel feeders with rotating devices should be left running to maintain even temperature until the furnace has cooled sufficiently to prevent damage to these rotating devices.

6-6 Normal Hot Start. When it is desired to restart the unit after it has been bottled up under pressure for a short time, and grate burning has stopped, follow cold start procedure: 6-2(d) through (g) and 6-3(a) through (j). If grate fire continues, follow the cold start procedure: 6-3(a) through (j), omitting (b), (d), and (e).

6-7 Emergency Shutdown.

6-7.1 For emergency shutdown caused by an interruption of fuel when the fuel supply cannot be restarted in a very short length of time, follow the same procedure as for a normal shutdown.

6-7.2 Loss of the induced draft fan would require that the uptake damper go into the full open position, the fuel feed immediately shut off, the forced draft damper go into the closed position, and a forced draft fan shut down. Overfire air fan should remain running, and overfire airflow dampers placed in the closed position. The operator should manually open fire doors above the grate only if there is sufficient furnace draft.

6-7.3 Loss of the forced draft fan would require immediate shutdown of the fuel feed and maintenance of normal furnace draft.

6-7.4 An emergency shutdown caused by loss of feedwater would require immediate shutdown of fuel feed, and forced draft fan. Normal furnace draft should be maintained. The overfire air fan should be left running and associated dampers closed if overfire air fan suction is taken from the forced draft fan discharge. The operator should manually open all fire doors above the stoker grate to assist in rapid cool-down of the furnace and boiler. This emergency shutdown procedure may vary. See manufacturer's recommendations.

6-7.5 Critical Emergency Situations. Critical emergency situations requiring action are:

(a) Low Drum Level.

1. Stop all fuel feed(s).

2. Stop fan(s) that supply combustion air to the unit.

3. Continue running ID fan with combustion air damper at minimum setting. This is recommended to limit continued combustion of the residual fuel bed.

(b) High Operating Steam Pressure.

1. Stop all fuel feed(s).

2. Decrease combustion air to minimum and maintain furnace draft.

3. When steam pressure is in normal operating range, start fuel feed and place combustion air for normal air/fuel ratio.

6-7.6 In all of the above situations, manufacturer's emergency procedures must be followed.

6-8 Multifuel Firing. In all cases, only one fuel should follow steam demands or respond to pressure changes. Secondary fuels should be base loaded at a constant air/fuel ratio basis.

6-9 Air/Fuel Ratio Control. With multifuel arrangements, it is necessary to measure the airflow to the stoker as well as the auxiliary fuel supply. When the auxiliary fuel is fired through burners and the auxiliary is following boiler demand, the forced draft system should have a controller upstream from the burner control damper that maintains a constant pressure to the supply duct. This will ensure a repeatable supply of air to the stoker. Conversely, it will ensure a repeatable supply of air to the auxiliary burners. Care must be taken to maintain an adequate amount of excess air at all times by continuously observing the flame or the air/fuel ratio or the oxygen indicator, if provided. When firing multiple fuels, care should be taken in interpreting the oxygen analyzer readings, especially with systems having a single point measurement.

6-10 Purge Cycle. Dual fuel fired boilers with stoker and auxiliary burners may require purge cycles under certain conditions prior to lighting off the burner. If boiler load is being carried by the stoker with an active fire and a satisfactory response from a combustible analyzer, then auxiliary fuel burners can be lit without a furnace purge cycle. If no cooling air is supplied to the auxiliary burner, a purge of its associate air supply ducts should be provided. However, upon loss of a burner on an emergency trip in the absence of sufficient stoker luminescence, a burner purge cycle should be required.

Chapter 7 Maintenance

7-1 Maintenance Objective. The objective of a maintenance program is to identify and correct conditions relating to the safety, continued reliable operation, and efficient performance of equipment. A program should be provided for maintenance of equipment at intervals consistent with the type of equipment, service requirements, and manufacturer's recommendations.

7-2 Maintenance Programs. As a minimum, the maintenance program should include the following:

(a) In-service inspections to identify conditions requiring corrective action or further study.

(b) Detailed, knowledgeable planning to allow use of qualified personnel, procedures, and equipment for an efficient safe repair or modification.

(c) Use of a comprehensive equipment history that records conditions found, maintenance work done, changes made, and the date of each.

(d) Written comprehensive maintenance procedures incorporating manufacturer's instructions to define the tasks and skills required. Any special techniques, such as nondestructive testing or those tasks requiring special tools, should be defined. Special environmental factors should be covered, such as temperature limitations, dusts, contaminated or oxygen-deficient atmosphere, and limited access or confined space requirements.

(e) Shutdown maintenance inspections, comprehensive in scope, to cover all problem areas.

(f) Adequate spare parts available meeting manufacturer's specifications to provide reliable service without necessitating unsafe makeshift repairs.

7-3 Equipment Inspections.

7-3.1 General.

7-3.1.1 An inspection and maintenance schedule should be established and followed.

7-3.1.2 Operation, set-points, and adjustments should be verified by periodic testing with the results documented.

7-3.1.3 Defects should be reported and corrected and the repairs documented.

7-3.1.4 System configuration, including logic, set-points, and sensing hardware, should not be changed without the effect being evaluated and approved.

7-3.1.5 Inspections, adjustments, and repairs should be performed by trained personnel, using tools and instruments suitable for the work. Maintenance and repairs should be performed in accordance with the manufacturer's recommendations and applicable standards and codes.

7-3.2 In-Service Inspections. In-service inspection of equipment should be done on a continual basis to evaluate operation and abnormal conditions that need corrective action.

7-3.3 Shutdown Inspection. The frequency of thorough maintenance inspections of shutdown boilers should be based on local and state law and recognized industrial practice.

7-4 Common Problem Areas. Several areas of stoker fired boilers routinely require maintenance attention. These are listed below:

7-4.1 Undergrate Air Distribution. Air must be distributed evenly through the grate in order to come in contact with the fuel at the desired location. Air distribution holes in the grates must be kept clear. Some grates are sectioned into zones to allow control of burning and improve efficiency. Grate air seals and air zone dampers must be in good repair to prevent air from bypassing around the fuel bed and to distribute air properly between zones.

7-4.2 Fuel Feed Mechanism. The fuel feed mechanism must be properly adjusted to provide an even fuel bed. Uneven fuel beds lead to poor combustion, clinker formation, inefficient operation, and potential grate damage.

7-4.3 Casing and Ductwork. Air infiltration into the furnace can cause improper fuel combustion due to insufficient air distribution to the fuel and erroneous oxygen analyzer readings. This can result in grate damage, smoking conditions, and reduced efficiency. All potential leak areas should be periodically checked. These areas include access doors, casing and brickwork, and expansion joints.

7-4.4 Grate. Grate drive mechanisms require periodic maintenance to ensure proper lubrication and operation. Grate alignment and tension must be checked to prevent binding and potential hang-up. Grate drive shear pins should be replaced with identical pins. Substituting harder shear pins may result in damage to other components. Air distribution holes in the grate should be kept clear.

7-4.5 Tuyeres. Air tuyeres must be checked for plugging and burnout. These are necessary for proper air sealing and feeder cooling.

7-4.6 Nozzles. Overfire air and cinder return nozzles must be checked for plugging and burnout.

7-4.7 Air Dampers. Air dampers should be checked for proper stroke and position.

7-4.8 Combustion Control System. Boiler controls should be kept in proper operating condition through regular operation and calibration checks.

Chapter 8 Training

8-1 Operator Training.

8-1.1 A formal training program should be established to prepare personnel to safely and effectively operate equipment. This program can consist of review of operating manuals, videotapes, programmed instruction, testing, and field training, among others. The training program should be consistent with the type of equipment and hazards involved.

8-1.2 Operating procedures should be established that cover normal and emergency conditions. Start-up and shutdown procedures, normal operating conditions, and lockout procedures should be covered in detail.

8-1.3 Operating procedures should be directly applicable to the equipment involved and consistent with safety requirements and manufacturer's recommendations.

8-1.4 Procedures should be periodically reviewed to keep them current with changes in equipment and personnel.

8-2 Maintenance Training.

8-2.1 A formal maintenance training program should be established to prepare personnel to safely and effectively perform any required maintenance tasks. This program can consist of review of maintenance manuals, videotapes, programmed instruction, testing, field training, and equipment manufacturer training, among others. The training program should be specific to the equipment involved, and to potential hazards.

8-2.2 Maintenance procedures should be established to cover routine and special techniques. Any potential environmental factors such as temperature, dust, contaminated or oxygen-deficient atmosphere, internal pressures, and limited access or confined space requirements should be included.

8-2.3 Procedures should be consistent with safety requirements and manufacturer's recommendations.

8-2.4 Procedures should be periodically reviewed to keep them current with changes in equipment and personnel.

Chapter 9 Additional Safety Requirements

9-1 General. Protective clothing, including but not limited to hard hats and safety glasses, should be used by personnel during maintenance operations.

9-2 Confined Spaces.

9-2.1 A confined space is any work location or enclosure in which any of the following may exist:

(a) The dimensions are such that a person 6 ft (1.8 m) tall cannot stand up in the middle of the space or extend his or her arms in all directions without hitting the enclosure.

(b) Access to or from the enclosure is by manhole, hatch, port, or other relatively small opening that limits ingress and egress to one person at a time.

(c) Confined spaces may include but are not limited to ducts, heaters, windboxes, cyclones, dust collectors, furnaces, bunkers or bins, etc.

9-2.2 Specific procedures should be developed and used for personnel entering confined spaces and should:

(a) Positively prevent inadvertent introduction of fuel, hot air, steam, or gas.

(b) Positively prevent inadvertent starting or moving of mechanical equipment or fans.

(c) Prevent accidental closing of access doors or hatches.

(d) Include tags, permits, or locks to cover confined space entry.

(e) Determine need for ventilation or self-contained breathing apparatus where the atmosphere may be stagnant, depleted of oxygen, or contaminated with irritating or combustible gases. Tests for an explosive or oxygen-deficient atmosphere should be made.

(f) Provide for a safety attendant. The safety attendant should remain outside of the confined space with appropriate rescue equipment and should be in contact (preferably visual contact) with those inside.

(g) Provide for use of proper safety belts or harnesses, which should be properly tied off when such use is practical.

9-3 Raw Fuel Bunkers.

9-3.1 In addition to the general provisions of Section 9-1, additional specific provisions for entering and working in fuel bunkers or bins should be made, recognizing the high probability of the presence of combustible or explosive gases and the hazards associated with shifting or sliding fuel.

9-3.2 No one should be permitted to enter fuel bunkers or bins without first notifying the responsible supervisor and obtaining appropriate permits, tags, clearances, etc.

9-3.3 The responsible supervisor should inspect the bunker, see that all necessary safety equipment is on hand, and see that a safety attendant, who will have no other duties during the job, is also on hand. The supervisor should review with the safety attendant and the workers the scope of the job and safety procedures to be followed.

9-3.4 No smoking, flames, or open lights should be permitted. All lamps should be suitable for Class II, Division 1 locations as defined in NFPA 70, *National Electrical Code.*®

9-3.5 Tests should be made for the presence of an explosive and oxygen-deficient atmosphere in a bunker or bin. If such an atmosphere is found, positive ventilation should be provided and entry prohibited until the atmosphere returns to safe limits. Sufficient retests should be made during the course of the work to ensure a safe atmosphere, and if it is not maintained, the bunker should be evacuated.

9-3.6 No person should enter a bunker containing burning fuel.

9-3.7 No person should enter a bunker or walk on the fuel unless the safety attendant is present and the person is equipped with a safety belt or harness and lifeline. The lifeline should be secured to an adequate support above the person and should have only sufficient slack to permit limited movement necessary to perform on the job. The lifeline should be manila rope at least ½ in. (12.7 mm) in diameter, or equivalent, in good condition.

9-3.8 The safety attendant should remain outside and/or above the bunker and should keep the workers in full view at all times. An adequate means of communication should be provided to the safety attendant in case additional help is needed.

9-3.9 Whenever practical, work should be done from platforms, ladders, scaffolds, etc., rather than from the surface of the fuel itself.

9-3.10 No one should walk on or work on a fuel surface that is more than 3 ft (0.9 m) lower than the highest point of the surrounding fuel, in order to avoid the possibility of being covered by sliding fuel.

9-3.11 Full-face respirators or respirators and goggles should be worn where dust conditions make them necessary, as directed by the responsible supervisor or the safety attendant.

9-4 Housekeeping.

9-4.1 Good housekeeping is essential for safe operation and prevention of fires or explosions; therefore, provisions should be made for periodic cleaning of horizontal ledges or surfaces of buildings and equipment to prevent the accumulation of appreciable dust deposits.

9-4.2 Creation of dust clouds should be minimized during cleaning. Compressed air should not be used to dislodge fuel dust accumulations; water washing or vacuum cleaning methods are preferred.

9-5 Welding and Flame Cutting. (*See also NFPA 51, Standard for the Design and Installation of Oxygen-Fuel Gas Systems for Welding, Cutting, and Allied Processes, and NFPA 51B, Standard for Fire Prevention in Use of Cutting and Welding Processes.*)

9-5.1 Fire-resistant blankets or other approved methods should be used in such manner as to confine weld spatter or cutting sparks.

9-5.2 A careful inspection of all areas near where welding or cutting has been done, including the floors above and below, should be made when the job is finished or interrupted, and such areas patrolled for a period long enough to make certain that no smoldering fires have developed.

9-6 Electrical Tools and Lighting.

9-6.1 Where flammable dust or dust clouds are present, sparking electrical tools should not be used. All lamps should be suitable for Class II, Division 1 locations as defined in NFPA 70, *National Electrical Code.*

9-6.2 Either ground fault protected or specially approved low voltage (6 or 12 volt) extension cords and lighting should be used for all confined spaces and where moisture may be a hazard.

9-7 Explosion-Operated Tools. Explosion-operated tools and forming techniques should not be used where combustible dust or dust clouds are present. When these operations become necessary, all equipment, floors, and walls should be cleaned and all dust accumulation removed by an approved method. A careful check should be made to be sure that no cartridges or charges are left in the work area. (*See 9-4.2.*)

9-8 Furnace Inspection.

9-8.1 Personnel should be prevented from entering the furnace until slag deposits have been removed. Care should be exercised to protect personnel from falling objects.

9-8.2 On overfeed mass burning stokers, the feed gate should be blocked open to prevent accidental dropping of the gate.

9-9 On-Line Maintenance. Extreme care should be exercised and furnace draft should be increased and held while performing any maintenance that requires personnel exposure to the furnace, such as grate and feeder work. Appropriate protective clothing should be worn while performing such maintenance. When possible, such repairs should be performed with the unit shut down. Any work that would require the presence of personnel inside the undergrate plenum chamber while the unit is in operation is prohibited.

9-10 Access Doors or Observation Ports.

9-10.1 Proper protective clothing and face shields should be used while viewing the furnace through access doors or observation ports and while manipulating the fuel or ash bed.

9-10.2 The furnace draft should be increased before access doors or observation ports are opened, to prevent any potential blowback.

9-11 Ash Hopper Access Doors.

9-11.1 Fly ash hopper access doors should not be opened while the boiler is operating. Hot or smoldering fly ash that may have bridged over the ash removal connection could cascade out of the door. Small capped clean-out connections should be used at the hopper bottom for unplugging bridged fly ash.

9-11.2 Care should be taken when opening ash hopper access doors after shutdown. Hot or smoldering fly ash that may have bridged over the ash removal connection could cascade out of the door. Care should be taken to avoid stepping into accumulated ash while inspecting equipment. Fly ash may be smoldering long after unit shutdown.

9-11.3 Vertical lifting ash pit doors should be securely blocked open prior to personnel entry.

9-12 Ash Handling. Hazards associated with ash handling include high temperature materials and dust. Appropriate protective equipment should be utilized.

9-13 Finely Divided Solid Fuels.

9-13.1 Characteristics of finely divided solid fuel approach those of pulverized fuel. Care should be taken in the handling of these to prevent accumulations that could ignite spontaneously.

9-13.2 These fuels should be handled separately from other solid fuels, and, therefore, special care should be taken to follow safe design and operating procedures. Recommendations of the equipment manufacturer should be followed.

Chapter 10 Referenced Publications

10-1 The following documents or portions thereof are referenced within this recommended practice and should be considered part of the recommendations of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

10-1.1 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 51, *Standard for the Design and Installation of Oxygen-Fuel Gas Systems for Welding, Cutting, and Allied Processes*, 1992 edition

NFPA 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes*, 1989 edition

NFPA 70, *National Electrical Code*, 1993 edition

NFPA 85C, *Standard for the Prevention of Furnace Explosions/Implosions in Multiple Burner Boiler-Furnaces*, 1991 edition

NFPA 850, *Recommended Practice for Fire Protection for Electric Generating Plants*, 1992 edition

NFPA 8501, *Standard for Single Burner Boiler Operation*, 1992 edition.

10-1.2 Other Publications.

10-1.2.1 ABMA Publication. American Boiler Manufacturers Association, 950 N. Glebe Road, Arlington, VA 22203.

Recommended Design Guidelines for Stoker Firing of Bituminous Coal.

10-1.2.2 ASTM Publication. American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM D388-91, *Specifications for Classification of Coal by Rank.*

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