NFPA 8505

Standard for Stoker Operation

1998 Edition

National Fire Protection Association, 1 Batterymarch Park, PO Box 9101, Quincy, MA 02269-9101
An International Codes and Standards Organization

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This edition of NFPA 8505, *Standard for Stoker Operation,* was prepared by the Technical Committee on Stoker Operations, released by the Technical Correlating Committee on Boiler Combustion System Hazards, and acted on by the National Fire Protection Association, Inc., at its Fall Meeting held November 17–19, 1997, in Kansas City, MO. It was issued by the Standards Council on January 16, 1998, with an effective date of February 6, 1998, and supersedes all previous editions.

This edition of NFPA 8505 was approved as an American National Standard on February 6, 1998.

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 dealt with safe boiler operation.

The 1989 edition was a partial revision and included a variety of changes. Foremost was the renumbering of the document to NFPA 8505.

The 1998 edition is a complete revision of the document. The document has been revised to change the language to mandatory text and to rename the document as a standard. Additional changes have been made to correlate this standard with the other five NFPA 8500 series standards.

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NOTE: Membership on a committee shall not in and of itself constitute an endorsement of the Association or any document developed by the committee on which the member serves.

Committee Scope: This Committee shall have primary responsibility for documents on the reduction of combustion system hazards in single- and multiple-burner boilers with a heat input rate of 12,500,000 Btu/hr and above. This includes all fuels. This Committee also is responsible for documents on the reduction of hazards in pulverized fuel systems, fluidized-bed boilers, heat recovery steam generators, and stoker-fired boilers at any heat input rate.

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Committee Scope: This Committee shall have primary responsibility for documents covering the operation of stokers and related fuel-burning equipment. This includes all fuels at any heat input rate.

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NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates that explanatory material on the paragraph can be found in Appendix A.

Information on referenced publications can be found in Chapter 8 and Appendix D.

Chapter 1 Introduction

1-1 Scope.

1-1.1 This standard shall apply to boilers with a heat input rating of 12,500,000 Btu/hr (3663 kW) or greater. This standard shall apply only to boilers using a stoker to fire the following fuels:

(a) Coal, as defined in Chapter 3

(b) Wood

(c) Refuse-derived fuel (RDF), as defined in Chapter 3

(d) Municipal solid waste (MSW) as defined in Chapter 3

(e) Other solid fuels

When solid fuel is fired simultaneously with other fuels (e.g., solid fuel stoker fired in combination with gas, oil, or pulverized auxiliary fuel), additional controls and interlocks might be necessary; however, these are not covered in this standard. When firing gas, oil, or pulverized fuel alone, the NFPA standard that applies to that fuel shall be used.

1-1.2 Requirements for auxiliary fuel-firing equipment and interlocks shall comply with NFPA 8501, *Standard for Single Burner Boiler Operation,* or NFPA 8502, *Standard for the Prevention of Furnace Explosions/Implosions in Multiple Burner Boilers.*

Exception No. 1: The purge requirements of NFPA 8501 or NFPA 8502 shall not be required when the stoker is firing and the boiler is online. In those cases, if no cooling air is being provided to the auxiliary burners, a purge of their associated air supply ducts shall 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 shall not be required.

1-1.3 This standard is not retroactive. This standard shall apply to new installations and to major alterations or extensions that are contracted subsequent to the effective date of this standard.

1-1.4 Since this standard is based on the present state of the art, its application to existing installations is not mandatory. Nevertheless, operating companies are encouraged to adopt those features of this standard that are considered applicable and reasonable for existing installations.

1-1.5 Revisions to this document reflect the current state of knowledge and do not imply that previous editions were inadequate.

1-2 Purpose.

1-2.1 The purpose of this standard shall be to establish minimum standards for the design, installation, operation, and maintenance of stoker-fired boilers, their fuel-burning systems, and related control equipment, to contribute to operating safety.

1-2.2 No standard can guarantee the elimination of furnace explosions and implosions in boilers. Technology in this area is evolving constantly, as reflected in revisions to this standard. The user of this standard needs to 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 this standard is not a design handbook. This standard shall not eliminate 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 is to be given latitude in the development of such designs. In such cases, the designer shall be responsible for demonstrating the validity of the proposed design.

1-2.3 Emphasis is placed on the importance of adequate strength of the structure, proper operation and maintenance procedures, combustion and draft control equipment, safety interlocks, alarms, trips, and other related controls that are essential to proper boiler operation.

1-2.4 The effect of gas cleanup systems located downstream of the post-combustion gas passes of the boiler furnace is known to be significant. Coordination of the operating procedures and design of the boiler furnace system and air quality system air-flue gas path shall be required. Such coordination shall include requirements for ensuring a continuous flow path from the forced draft fan inlet through the stack. This standard provides only the general requirements for these systems because of the multiplicity of their designs.

Chapter 2 General

2-1 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 enclosure consists of the accumulation of an excessive quantity of combustibles mixed with air in proportions that result in rapid or uncontrolled combustion where an ignition source is supplied. A furnace explosion can 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 enclosure. The magnitude and intensity of the explosion depends on both the relative quantity of combustibles that have accumulated and the proportion of air that mixes with the combustibles at the moment of ignition. Explosions, including "furnace puffs," are the result of improper operating procedures by personnel; improper design of equipment or control systems; or malfunction of the equipment or control system, consistency of fuel, or moisture content of fuel.

2-1.3 Numerous conditions can arise in connection with the operation of a boiler that produce explosive conditions. The most common of these are as follows:

(a) An interruption of the fuel or air supply sufficient to result in momentary loss of flames, followed by restoration and delayed reignition of an accumulation

(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 highly 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 highly volatile refuse fuels

2-1.4 The conditions favorable for a boiler explosion described in 2-1.3 are typical examples. An examination of numerous reports of boiler 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, 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 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 Furnace Implosions.

2-2.1 Stoker-fired boilers are inherently less prone to furnace implosions because of the absence of the sudden "flame collapse" phenomenon that exists on fluid bed or pulverized fuel-fired boilers.

2-2.2 A furnace implosion is the result of the occurrence of excessively low gas-side pressure, which causes equipment damage.

2-2.3 Two conditions that have caused furnace implosions include the following:
(a) A misoperation of the equipment regulating the boiler gas flow, including air supply and flue gas removal, resulting in furnace exposure to excessive induced-draft fan head capability
(b) The rapid decay of furnace gas temperatures and pressure resulting from either a rapid reduction in fuel input or a master fuel trip

2-2.4 A combination of the two conditions indicated in 2-2.3 has resulted in the most severe furnace implosion incidents.

2-3 Manufacture, Design, and Engineering.

2-3.1 The purchaser or the purchaser's agent shall, in cooperation with the manufacturer, ensure that the unit is not deficient in apparatus required for proper operation, so far as is practical, with respect to pressure parts, fuel-burning equipment, safe lighting, and maintenance of stable conditions.

2-3.2 All fuel systems shall include provisions to prevent foreign substances from interfering with the fuel supply.

2-3.3* An evaluation shall be made to determine the optimum integration of manual and automatic safety features, taking into consideration the advantages and disadvantages of each trip function.

2-3.4 This standard necessitates a minimum degree of automation. The trend toward more complex plants or increased automation shall require additional provisions for the following:
(a) Information regarding significant operating events that allow the operator to make a rapid evaluation of the operating situation; provision of continuous and usable displays of variables that allow the operator to avoid unsafe conditions
(b) In-service maintenance and checking of system functions without impairment of the reliability of the overall control system
(c) An environment conducive to proper decisions and actions

2-3.5 On the basis of reported incidents and field tests, the maximum negative furnace pressure is determined primarily by the maximum head characteristic of the induced draft fan. A major objective of the final design shall be to limit the maximum head capacity of draft equipment to that necessary for satisfactory operation. Special consideration shall be given to fan selection and arrangement of ductwork to limit the effect of negative head.

2-3.6 With scrubbers or other high-draft-loss equipment for removing flue gas contaminants, a booster fan might be necessary. A bypass or other appropriate means shall be provided to counteract the potentially excessive negative pressure conditions resulting from combining the suction heads of both the induced draft fan and booster fan.

2-4 Installation.

2-4.1 The boiler shall not be permitted to be operated before the installation and check of the required safeguards and instrumentation system.

2-4.2 The party responsible for the erection and installation of the equipment shall ensure that all apparatus are installed and connected properly.

2-4.3 The purchaser, the engineering consultant, the equipment manufacturer, and the operating company shall avoid boiler operation until such safeguards have been tested and operated properly as a system. In some instances, it might be necessary to install temporary interlocks and instrumentation to meet these requirements. Any such temporary system shall be reviewed by the purchaser, the engineering consultant, the equipment manufacturer, and the operating company, and agreement shall be reached on its suitability in advance of start-up.

2-4.4 The safety interlock system and protective devices shall be tested jointly by the organization responsible for the system design and by those who operate and maintain such a system and devices during the normal operating life of the plant. After installation, coordinated tests of all systems shall be accomplished before initial operation.

2-5 Coordination of Design, Construction, and Operation.

2-5.1 Statistics indicate that human error is a contributing factor in the majority of furnace explosions. It is important to consider whether the error was the result of the following factors:

(a) Lack of understanding of or failure to use proper operating procedures, safeguards, and equipment

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

(c) Lack of functional coordination of the various components of the steam-generating system and its controls

2-5.2 Furnace explosions have occurred as a result of unfavorable functional design. The investigation frequently has revealed human error and has completely overlooked the chain of causes that triggered the operating error. Therefore, the design, installation, and functional objectives of the overall system of components and their controls shall be integrated. Consideration shall be given to the existing ergonomics that can affect operation of the system.

2-5.3 In the planning and the engineering phases of plant construction, design shall be coordinated with the operating personnel.

2-5.4 The proper integration of the various components consisting of boiler, burner, fuel and air supply equipment, controls, interlocks and safety devices, operator and maintenance functions, and communication and training shall be the responsibility of the operating company and shall be accomplished by the following:

(a) Design and operating personnel who possess a high degree of competence in this field and who are mandated to achieve these objectives

(b) Periodic analysis of the plant with respect to evolving technology so that improvements can be made to make the plants safer and more reliable

(c) Documentation of the plant equipment, the system, and maintenance

2-6 Maintenance Organization. A program shall be provided for maintenance of equipment at intervals consistent with type of equipment, service requirements, and the manufacturers' recommendations. *(See Chapter 6.)*

2-7 Basic Operating Objectives.

2-7.1 Basic operating objectives shall include the following:

(a) Operating procedures shall be established that will result in the minimum number of manual operations.

(b) Standardization of all operating procedures shall be established. Where applicable, the use of interlocks is essential to minimize improper operating sequences and to interrupt 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.

2-7.2 Written operating procedures and detailed checklists for operator guidance shall be provided for achieving these basic operating objectives. All manual and automatic functions shall be included.

2-7.3 Proper procedures shall be established for taking appropriate and timely action. These include reducing load, tripping equipment, and calling for outside assistance in case of emergency.

Chapter 3 Definitions

3-1 Definitions. These definitions shall apply to this standard.

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

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

Air, Excess. Air supplied for combustion in excess of theoretical air.

Air, Furnace Purge (Furnace Purge). See Purge.

Air, Overfire. Air for combustion admitted into the furnace at a point above the fuel bed. This can also be referred to as secondary air.

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

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

Air, Total. 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.

Air, Under Grate. Combustion air introduced below the grate. This can also be referred to as primary air.

Air/Fuel Ratio. A ratio of air to fuel supplied to a furnace.

Air-Rich. Indicates a ratio of air to fuel supplied to a furnace that provides more than the minimum excess air needed for optimum combustion of the fuel.

Alarm. An audible or visible signal that indicates 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.

Authority Having Jurisdiction.* The organization, office, or individual responsible for approving equipment, an installation, or a procedure.

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, or steam is superheated, or in which any combination thereof takes place by the application of heat from combustible fuels, in a self-contained or attached furnace.

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

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

Bunker. An enclosure to store raw fuel.

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.

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

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 D 388, 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 an air/fuel ratio within the limits necessary for continuous combustion and stable flame 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.

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

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

Extension. An addition to the boiler system or additional subsystems, such as, but not limited to, air quality control.

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.)*

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

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

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

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

Fuel-Rich. Indicates a ratio of air to fuel supplied to a furnace that provides less than the minimum excess air needed for optimum combustion of the fuel.

Furnace. The portion of the boiler enclosure within which the combustion process takes place and wherein heat transfer occurs predominantly by radiation.

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

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.

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.

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 related 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 that is 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, materials, or services included in a list published by an organization that is acceptable to the authority having jurisdiction and concerned with evaluation of products or services, that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services, and whose listing states that either the equipment, material, or service meets identified standards or has been tested and found suitable for a specified purpose.

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

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.

Monitor. To sense and indicate a condition without initiating automatic corrective action.

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.

Municipal Solid Waste (MSW). Untreated solid waste material as collected from household and commercial establishments. It is highly variable in appearance, density, and BTU content.

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/ft^3 (26.1 and 55.9 MJ/m^3), the majority averaging 1000 Btu/ft^3 (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.

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 the following:

(a) *Front Feed, Inclined Grate.* A grate, inclined downward toward the rear of the stoker, onto which fuel is fed from the front

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

Purge. A flow of air through the furnace, boiler gas passages, and associated flues and ducts that effectively removes any gaseous or suspended combustibles and replaces them with air. Purging can also be accomplished by an inert medium.

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.

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 Fly Carbon Reinjection.

Repair. A process that returns the boiler system or subsystem to its original design specifications or criteria.

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

Shall. Indicates a mandatory requirement.

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.

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 the following:

(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

Standard. A document, the main text of which contains only mandatory provisions using the word "shall" to indicate requirements and which is in a form generally suitable for mandatory reference by another standard or code or for adoption into law. Nonmandatory provisions shall be located in an appendix, footnote, or fine-print note and are not to be considered a part of the requirements of a standard.

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.

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.

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

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.

Chapter 4 Equipment Requirements

4-1 Fuel-Burning System.

4-1.1 Functional Requirements.

4-1.1.1 The fuel-burning system shall function to continuously convert any ignitible furnace input into substantially unreactive products of combustion at the same rate the fuel and air reactants enter the furnace.

4-1.1.2 The fuel-burning system shall be properly sized to meet the operating requirements of the unit, shall be compatible with other boiler component systems, and shall be capable of being controlled over the full operating range of the unit.

4-1.2 System Requirements.

4-1.2.1 The fuel-burning system shall consist of the following subsystems: air supply, fuel supply, grate, furnace, combustion products removal, and ash removal. Each subsystem shall be properly sized and interconnected to satisfy the functional requirements and not to interfere with the combustion process.

4-1.2.2 The fuel-burning system shall provide means for safe start-up, operation, and shutdown of the combustion process. This shall include appropriate openings and configurations in the components' assemblies to permit suitable observation, measurement, and control of the combustion process.

4-1.2.3 The fuel-burning system shall include the following:

(a) Air Supply Subsystem

1. The air supply equipment shall 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 shall minimize contamination of the air supply by materials such as water and fuel. Appropriate drains and access openings shall be provided.

(b) Fuel Supply Subsystem

1. The fuel supply equipment shall 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 shall be designed and arranged to size the fuel properly, 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 (MSW) systems shall incorporate fire-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 shall be capable of being used repeatedly without taking the unit out of service.

(c) Furnace Subsystem

1. The furnace shall be properly sized and arranged with respect to the grate subsystem so that the grate can be fired to maintain stable combustion and to minimize furnace pressure fluctuation.
2. Properly placed observation ports shall be provided to permit inspection of the furnace and grate. Refer to Section 7-10.
3. Observation ports and lancing doors for mass-fired MSW units shall be provided with vision ports that will permit observation and operation of the unit while puffs are expected and occurring. Glasses shall be replaceable without taking the unit out of service. Consideration shall be given to equipping lancing ports with aspirators or other devices to safely permit lancing of the fuel bed without restricting operations.
4. Relatively high induced draft fan head capability can be required by flue gas cleaning equipment. The maximum negative furnace pressure is determined primarily by the maximum head characteristic of the induced draft fan; an objective of the final design shall be to limit the maximum head capability of draft equipment to that necessary for satisfactory operation. Special consideration shall be given to fan selection and arrangement of ductwork to limit the effect of negative head.
5. The furnace and flue gas removal system shall be designed so that the maximum head capability of the induced draft system with ambient air does not exceed the design pressure of the furnace, ducts, and associated equipment. This design pressure shall be defined the same as the wind and seismic stresses of the American Institute of Steel Construction (AISC) *Manual of Steel Construction,* Section A5.2.
6. Consideration shall be given to the potential effects resulting from improper induced draft fan start-up or malfunction of the furnace draft controlling equipment. Consideration also shall be given to the use of protective control loops similar to those shown in Chapter 5 of NFPA 8502, *Standard for the Prevention of Furnace Explosions/Implosions in Multiple Burner Boilers,* modified or simplified 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 shall 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 shall be provided.
3. The flue gas duct system shall be designed so that it will not contribute to furnace pulsations.

(e) Ash Removal Subsystem

1. The grate subsystem and flue gas cleaning subsystem shall 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 shall be provided.

4-2 Combustion Control System.

4-2.1 Functional Requirements.

4-2.1.1 The combustion control system shall maintain furnace fuel and air input in accordance with demand.

4-2.1.2 The combustion control system shall 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.

4-2.2 System Requirements.

4-2.2.1 Furnace input shall be controlled to respond to the energy demand under all operating conditions.

4-2.2.2 The air/fuel mixture shall be maintained within safe limits as established by test under any boiler output condition within the controllable operating range of the subsystem.

4-2.2.3 When changing the rate of furnace input, the airflow and fuel flow shall be changed simultaneously at the proper rates to maintain safe air/fuel ratio during and after the change. This shall not prohibit provisions for air lead and lag of fuel during changes in firing rate. Placing the fuel flow control on automatic without the air flow in automatic shall be prohibited.

4-2.2.4 Furnace draft shall be maintained at the desired set point in the combustion chamber.

4-2.2.5 A means shall be provided to prevent the control system from demanding a fuel-rich mixture.

4-2.2.6 Equipment shall be designed and procedures shall be established to allow as much on-line maintenance of combustion control equipment as practicable.

4-2.2.7 Provisions for calibration and check testing of combustion control and associated interlock equipment shall be furnished.

4-2.3 Overfire Air. If applicable, the high-pressure overfire air turbulence system shall be controlled in either of two methods:

(a) Control the outlet pressure of the blower using a manual set point

(b) Control overfire air in parallel with undergrate airflow.

4-2.4 Flue Gas Analyzers. Consideration shall be given to providing oxygen and combustibles meters for use as operating guides.

Chapter 5 Operation

5-1 General. This chapter shall apply to typical stoker operation. Manufacturers' recommendations shall be consulted.

5-2 Start-Up, General. After an overhaul or other maintenance, a complete functional check of the safety interlocks shall be made. Preparation for starting shall include a thorough inspection and check, to include but not be limited to the following:

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

(b) Boiler 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) Verification that the grate is clear of foreign material and operational

(e) Verification that the fuel feed system is clear of foreign material and operational

(f) Feeder control operational through full range

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

(h) Proper drum level established with clean, treated, and deaerated water

(i) Oxygen and combustible analyzers, where provided, operating satisfactorily

(j) The vent and drain valves set in accordance with the boiler manufacturer's instructions

5-3 Start-Up Procedures (Cold Start). The cold start procedure shall be as follows:

(a) Verify an open flow path from the inlet of the forced draft (FD) fan to the stack. Where there is not sufficient natural draft for initial firing, the induced draft fan shall be started and normal furnace draft maintained.

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

(c) From outside the furnace, spray the bed with a light coat of distillate oil or place oil-soaked rags or kindling on fuel bed.

(d) Do not use gasoline, alcohol, or other highly volatile material for light-off.

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

(f) Start induced draft (ID) fan (where the ID fan is not in operation) and place the draft control in automatic mode of operation when the bed of fuel has ignited.

CAUTION: Excessive negative draft can cause fuel to be pulled from the feeders onto the grate.

(g) Ensure that undergrate air pressure is always greater than furnace pressure to prevent reverse flow.

(h) Start FD fan with dampers at minimum position when fuel bed is actively burning.

(i) Start overfire air fan immediately to prevent damage from gases passing through the ductwork.

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

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

5-3.1 Consideration shall be given to the operation of auxiliary fuel burners when starting up and firing high-moisture fuel.

5-3.2 Where a boiler is equipped with auxiliary gas or oil burners, it shall be permitted 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 shall be taken to protect the grate from overheating.

5-3.3 Start-up procedures for other fuels as described in Appendix B are dependent on the characteristics of the particular fuel. In all cases, manufacturer's instructions shall be consulted.

5-4 Normal Operation.

5-4.1 The firing rate shall 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.

5-4.2 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. Visual observations of the fuel bed conditions through open doors shall be made with extreme care. *(See Sections 7-9 and 7-10.)*

5-4.3 Manual adjustments to the individual rows of overfire turbulence air nozzles for maximum furnace efficiency and minimum emission discharge shall be permitted.

5-4.4 Fuel shall be fed to maintain an even depth of ash. As the percent of ash in the fuel changes, it might be necessary to make adjustments. It is necessary to observe the depth of ash at the discharge end of the grates.

5-5 Normal Shutdown. Normal shutdown procedure shall be as follows:

(a) The boiler load shall be reduced manually to minimum load.
(b) Fuel shutoff gates, where furnished above the fuel feeders, shall be closed.
(c) Remaining fuel downstream from the shutoff gate shall be burned out.
(d) Normal furnace draft shall be maintained throughout this process.
(e) The overfire air fan shall be left running.

Exception: This rule may not apply to boilers where manufacturer's recommendations state otherwise.

(f) After fuel feed ceases and the fire is burned out, the overfire air and forced draft fan shall be operated in accordance with the manufacturer's recommended cooldown rate. The overfire air fan shall 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.
(g) Where the forced draft fan is shut off, a natural draft flow of air through the grates shall be provided.
(h) For spreader stokers, fuel feeders with rotating devices shall be left running to maintain even temperature until the furnace has cooled sufficiently to prevent damage to the rotating devices.

5-6 Normal Hot Start.

5-6.1 When it is desired to restart the unit after it has been bottled up under pressure for a short time and when grate burning has stopped, the start procedure shall be as follows:

(a) Verify that the fuel feed system is clear of foreign material and operational.
(b) Keep the feeder control operational through full range.
(c) Keep all air and flue gas control dampers operational through full range.
(d) Establish the proper drum level.
(e) Set the vent and drain valves in accordance with the boiler manufacturer's instructions.
(f) Verify an open flow path from the inlet of the FD fan to the stack. Where there is not sufficient natural draft for initial firing, the induced draft fan shall be started and normal furnace draft maintained.
(g) Fill the feeder hopper with fuel, start a feed mechanism, establish a bed of fuel on the grate, and ignite it.
(h) When the bed of fuel has ignited, start the ID fan (where the ID fan is not in operation) and place the draft control in automatic mode of operation.

CAUTION: Excessive negative draft can cause fuel to be pulled from the feeders onto the grate.

(i) Undergrate air pressure shall always be greater than furnace pressure to prevent reverse flow.
(j) When the fuel bed is actively burning, start the FD fan with dampers at minimum position.
(k) The overfire air fan shall be started immediately to prevent damage from gases passing through the ductwork.
(l) Start the fuel feed. Observe the operation and adjust the fuel rate and air as required until boiler steam pressure is at the desired operating pressure.
(m) Place the fuel and air in the automatic mode of operation.

5-6.2 When it is desired to restart the unit after it has been bottled up under pressure for a short time, and the grate fire continues, the hot-start procedure shall be as follows:

(a) Establish the proper drum level.
(b) Set the vent and drain valves in accordance with the boiler manufacturer's instructions.
(c) Verify an open flow path from the inlet of the FD fan to the stack. Where there is not sufficient natural draft for initial firing, the ID fan shall be started and normal furnace draft maintained.
(d) Fill the feeder hopper with fuel.
(e) Start the ID fan (where the ID fan is not in operation) and place the draft control in automatic mode of operation.

CAUTION: Excessive negative draft can cause fuel to be pulled from the feeders onto the grate.

(f) Ensure that undergrate air pressure is always greater than furnace pressure to prevent reverse flow.
(g) Start FD fan with dampers at minimum position when fuel bed is actively burning.
(h) Start the overfire air fan immediately to prevent damage from gases passing through the ductwork.
(i) Start fuel feed. Observe operation and adjust fuel rate and air as required until boiler steam pressure is at desired operating pressure.
(j) Place fuel and air in automatic mode of operation.

5-7 Emergency Shutdown. In all of the following situations, manufacturer's emergency procedures shall be considered.

5-7.1 For emergency shutdown caused by an interruption of fuel when the fuel supply cannot be restarted in a very short length of time, the normal shutdown procedure shall be followed.

5-7.2 Loss of the ID fan shall require the following:

(a) The ID damper going into the full open position
(b) The fuel feed being immediately shut off
(c) The forced draft fan being shut down
(d) The forced draft damper going into the closed position

(e) Overfire air fan remaining running and overfire airflow dampers being placed in the closed position

Exception: This rule may not apply to boilers where manufacturer's recommendations state otherwise.

5-7.3 Loss of the forced draft fan shall require the immediate shutdown of the fuel feed and maintenance of normal furnace draft.

CAUTION: Excessive negative draft can cause fuel to be pulled from the feeders onto the grate.

5-7.4 An emergency shutdown caused by loss of feedwater shall require immediate completion of the following:

(a) Fuel feed shall be shut down.

(b) Forced draft fan shall be shut down.

(c) Normal furnace draft shall be maintained.

(d) Overfire air fan shall remain running and overfire airflow dampers placed in the closed position.

Exception: This rule may not apply to boilers where manufacturer's recommendations state otherwise.

This emergency shutdown procedure may vary. See manufacturer's recommendations.

5-7.5 Critical Emergency Situations. The following critical emergency situations shall require action:

(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 to limit continued combustion of the residual fuel bed.

CAUTION: Excessive negative draft can cause fuel to be pulled from the feeders onto the grate.

(b) *High Operating Steam Pressure*

1. Reduce all fuel feed(s).
2. Decrease combustion air, and maintain furnace draft.

5-8* Multifuel Firing.

5-8.1 The total fuel input shall be limited to the maximum design steaming capacity of the boiler.

5-8.2 An adequate amount of excess air shall be maintained at all times by continuously observing the burner flames, the air/fuel ratio, or an oxygen indicator, where provided.

Chapter 6 Maintenance, Inspection, Training, and Safety

6-1 Maintenance and Equipment Inspection.

6-1.1 The objective of a maintenance program shall be to identify and correct conditions that adversely affect the safety, continued reliable operation, and efficient performance of equipment. A program shall be provided for maintenance of equipment at intervals consistent with the type of equipment used, service requirements, and manufacturers' recommendations.

6-1.2* As a minimum, the maintenance program shall include the following:

(a) In-service inspections to identify conditions that need corrective action or further study shall be performed.

(b) Detailed, knowledgeable planning for effecting repair or modifications using qualified personnel, procedures, and equipment shall be implemented.

(c) A comprehensive equipment history shall be used to record conditions found, maintenance work done, changes made, and dates of each.

(d) Written comprehensive maintenance procedures incorporating the manufacturer's instructions to define the tasks and skills required shall be provided. Any special techniques, such as nondestructive testing or those tasks necessitating special tools, shall be specified. Special environmental factors such as temperature limitations, dusts, contaminated or oxygen-deficient atmospheres, and limited access or confined space restrictions shall be included.

(e) Comprehensive shutdown maintenance inspections shall be performed.

(f) Sufficient spare parts meeting specifications shall be available to provide reliable service without necessitating makeshift repairs.

6-1.3 An inspection and maintenance schedule shall be established and followed.

6-1.4 Operation, set points, and adjustments shall be verified by periodic testing, and the results shall be documented.

6-1.5 Defects shall be reported and corrected, and the repairs shall be documented.

6-1.6 System configuration, including logic, set points, and sensing hardware, shall not be changed without evaluation and approval of the effect.

6-1.7 Inspections, adjustments, and repairs shall be performed by trained personnel, using tools and instruments suitable for the work. Maintenance and repairs shall be performed in accordance with the manufacturer's recommendations and applicable standards and codes.

6-2 Training.

6-2.1 Operator Training.

6-2.1.1 A formal training program shall be established to prepare personnel to operate equipment safely and effectively. This program can consist of a review of operating manuals and videotapes, programmed instruction, testing, use of simulators, and field training, among others. The training program shall be consistent with the type of equipment and hazards involved.

6-2.1.2 Operating procedures shall be established that cover normal and emergency conditions. Start-up and shutdown procedures, normal operating conditions, and lockout procedures shall be covered in detail.

6-2.1.3 Operating procedures shall be directly applicable to the equipment involved and consistent with safety requirements and the manufacturer's recommendations.

6-2.1.4 Operating procedures shall be reviewed periodically to keep them current with changes in equipment and personnel.

6-2.2 Maintenance Training.

6-2.2.1 A formal maintenance training program shall be established to prepare personnel to perform any required maintenance tasks safely and effectively. This program shall be permitted to consist of a review of maintenance manuals and videotapes, programmed instruction, testing, field training, and equipment manufacturer training, among other items. The training program shall be specific to the equipment and potential hazards involved.

6-2.2.2 Maintenance procedures shall be established to cover routine and special techniques. Any potential environmental factors such as temperature limitations, dusts, contaminated or oxygen-deficient atmospheres, internal pressures, and limited access or confined space restrictions shall be included.

6-2.2.3 Procedures shall be consistent with safety requirements and the manufacturer's recommendations.

6-2.2.4 Procedures shall be reviewed periodically to keep them current with changes in equipment and personnel.

Chapter 7 Personnel Safety

7-1 General. Protective clothing, including but not limited to hard hats and safety glasses, shall be used by personnel during maintenance operations.

7-2 Confined Spaces.

7-2.1 A confined space is any work location or enclosure in which any of the following exist:

(a) The dimensions are such that a person 6 ft (1.8m) tall cannot fully 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 include but are not limited to ducts, heaters, windboxes, cyclones, dust collectors, furnaces, bunkers, or bins.

7-2.2 Specific procedures shall be developed and used for personnel entering confined spaces and shall include the following:

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

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

(c) Preventing accidental closing of access doors or hatches

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

(e) Determining the 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 shall be made.)

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

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

7-3 Raw Fuel Bunkers.

7-3.1 In addition to the general provisions of Section 7-1, additional specific provisions for entering and working in fuel bunkers or bins shall be made, recognizing the high probability of the presence of combustible or explosive gases and the hazards associated with shifting or sliding fuel.

7-3.2 No one shall be permitted to enter fuel bunkers or bins without first notifying the responsible supervisor and obtaining appropriate permits, tags, clearances, and so forth.

7-3.3 The responsible supervisor shall inspect the bunker, see that all necessary safety equipment is on hand, and see that a safety attendant, who shall have no other duties during the job, is also on hand. The supervisor shall review with the safety attendant and the workers the scope of the job and safety procedures to be followed.

7-3.4 No smoking, flames, or open lights shall be permitted. All lamps shall be suitable for Class II, Division 1 locations as defined in NFPA 70, *National Electrical Code®*.

7-3.5 Tests shall 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 shall be provided and entry shall be prohibited until the atmosphere returns to safe limits. Sufficient retests shall be made during the course of the work to ensure a safe atmosphere. If a safe atmosphere is not maintained, the bunker shall be evacuated.

Exception: A nonexplosive, oxygen-deficient atmosphere shall be permitted to be entered with suitable breathing apparatus.

7-3.6 No person shall enter a bunker containing burning fuel.

7-3.7 No person shall 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 shall be secured to an adequate support above the person and shall have only sufficient slack to permit limited movement necessary to perform the job. The lifeline shall be manila rope at least $^1/_2$ in. (12.7 mm) in diameter, or equivalent, in good condition.

7-3.8 The safety attendant shall remain outside or above the bunker and shall keep the workers in full view at all times. An adequate means of communication shall be provided to the safety attendant in case additional help is needed.

7-3.9 Whenever practical, work shall be done from platforms, ladders, scaffolds, and the like, rather than from the surface of the fuel itself.

7-3.10 No one shall 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.

7-3.11 Full-face respirators or respirators and goggles shall be worn where dust conditions make them necessary, as directed by the responsible supervisor or the safety attendant.

7-4 Housekeeping.

7-4.1 Good housekeeping is essential for safe operation and prevention of fires or explosions; therefore, provisions shall be made for periodic cleaning of horizontal ledges or surfaces of buildings and equipment to prevent the accumulation of appreciable dust deposits.

7-4.2 Creation of dust clouds shall be minimized during cleaning. Compressed air shall not be used to dislodge fuel dust accumulations; water washing or vacuum cleaning methods are preferred.

7-5* Welding and Flame Cutting.

7-5.1 Fire-resistant blankets or other approved methods shall be used in such a manner as to confine welding spatter or cutting sparks.

7-5.2 A careful inspection of all areas near where welding or cutting has been done, including the floors above and below, shall be made when the job is finished or interrupted, and such areas shall be patrolled for a period long enough to make certain that no smoldering fires have developed.

7-6 Electrical Tools and Lighting.

7-6.1 Where flammable dust or dust clouds are present, sparking electrical tools shall not be used. All lamps shall be suitable for Class II, Division I locations as defined in NFPA 70, *National Electrical Code.*

7-6.2 Either ground-fault-protected or specifically approved low-voltage (6–12 V) extension cords and lighting shall be used for all confined spaces and where moisture may be a hazard.

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

7-8 Furnace Inspection.

7-8.1 Personnel shall be prevented from entering the furnace until slag deposits have been removed. Care shall be exercised to protect personnel from falling objects.

7-8.2 On overfeed mass burning stokers, the feed gate shall be blocked open to prevent accidental dropping of the gate.

7-9 On-Line Maintenance. Extreme care shall be exercised and furnace draft shall be increased and maintained while performing any maintenance that requires personnel exposure to the furnace, such as grate and feeder work. Appropriate protective clothing shall be worn while performing such maintenance. When possible, such repairs shall be performed with the unit shut down. Any work that requires the presence of personnel inside the undergrate plenum chamber while the unit is in operation shall be prohibited.

7-10 Access Doors or Observation Ports.

7-10.1 Proper protective clothing and face shields shall be used while viewing the furnace through access doors or observation ports and while manipulating the fuel or ash bed.

7-10.2 The furnace draft shall be increased before access doors or observation ports are opened in order to prevent any potential blowback.

7-11 Ash Hopper Access Doors.

7-11.1 Fly ash hopper access doors shall 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 shall be used at the hopper bottom for unplugging bridged fly ash.

7-11.2 Care shall 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 the door. Care shall be taken to avoid stepping into accumulated ash while inspecting equipment. Fly ash may be smoldering long after unit shutdown.

7-11.3 Vertical-lifting ash pit doors shall be securely blocked open prior to personnel entry.

7-12 Ash Handling. Appropriate protective equipment shall be utilized for hazards associated with ash handling that involves high-temperature materials and dust.

7-13 Finely Divided Solid Fuels.

7-13.1 Characteristics of finely divided solid fuel approach those of pulverized fuel. Care shall be taken in the handling of these to prevent accumulations that could ignite spontaneously.

7-13.2 These fuels shall be handled separately from other solid fuels; therefore, special care shall be taken to follow safe design and operating procedures. Recommendations of the equipment manufacturer shall be followed.

Chapter 8 Referenced Publications

8-1 The following documents or portions thereof are referenced within this standard as mandatory requirements and shall be considered part of the requirements of this standard. The edition indicated for each referenced mandatory document is the current edition as of the date of the NFPA issuance of this standard. Some of these mandatory documents might also be referenced in this standard for specific informational purposes and, therefore, are also listed in Appendix D.

8-1.1 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 70, *National Electrical Code®,* 1996 edition.
NFPA 8501, *Standard for Single Burner Boiler Operation,* 1997 edition.
NFPA 8502, *Standard for the Prevention of Furnace Explosions/Implosions in Multiple Burner Boilers,* 1995 edition.

8-1.2 AISC Publication. American Institute of Steel Construction, 1 East Wacker Drive, Suite 3100, Chicago, IL 60601.

AISC Manual of Steel Construction, 1992.

8-1.3 ASTM Publication. American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM D 388, *Specifications for Classification of Coal by Rank,* 1992.

Appendix A Explanatory Material

Appendix A is not a part of the requirements of this NFPA document but is included for informational purposes only. This appendix contains explanatory material, numbered to correspond with the applicable text paragraphs.

A-2-3.3 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.

A-3-1 Approved. 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, 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 that is concerned with product evaluations and is thus in a position to determine compliance with appropriate standards for the current production of listed items.

A-3-1 Authority Having Jurisdiction. 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, or 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 or her 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.

A-3-1 Listed. The means for identifying listed equipment may vary for each organization concerned with product evaluation; some organizations 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.

A-4-1.2.3(b)3 See NFPA 850, *Recommended Practice for Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations,* for additional information.

A-5-8 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, where provided. When firing multiple fuels, care should be taken in interpreting the oxygen analyzer readings, especially with systems having a single point measurement.

A-6-1.2 Several areas of stoker-fired boilers routinely require maintenance attention. These are listed below:

(a) *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 the fuel bed and to distribute air properly between zones.

(b) *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.

(c) *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.

(d) *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.

(e) *Tuyeres.* Air tuyeres must be checked for plugging and burnout. These are necessary for proper air sealing and feeder cooling.

(f) *Nozzles.* Overfire air and cinder return nozzles must be checked for plugging and burnout.

(g) *Air Dampers.* Air dampers should be checked for proper stroke and position.

(h) *Combustion Control System.* Boiler controls should be kept in proper operating condition through regular operation and calibration checks.

A-7-5 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.*

Appendix B Fuels

This appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

B-1 Coals.

B-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.

B-1.2 Classification.

B-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.

B-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.

B-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 8300 Btu/lb (19,306 kJ/kg) but less than 9500 Btu/lb (22,097 kJ/kg).

B-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 6300 Btu/lb (14,654 kJ/kg) and less than 8300 Btu/lb (19,306 kJ/kg). Group 2, "Lignite B," has a calorific value less than 6300 Btu/lb (14,654 kJ/kg).

B-1.3 Sizing. Sizing characteristics vary with stoker type as outlined in the ABMA #202, *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 #202, *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.

B-1.4 Coal Special Problems.

B-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 can 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.

B-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.

B-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, which could require special considerations. For example, 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 coal. This volatile matter is a gaseous fuel that causes additional hazards.

B-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.

B-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.

B-4 Municipal Waste. Municipal waste is burned with stokers in two forms — the first is known as municipal solid waste (MSW), which is delivered without preparation. It 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. It is then 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, and so forth, contained in the fuel supply. Pulsations from concentrations of extremely volatile wastes may also result.

B-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 purposes falls 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 include 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.

B-6 Solid Fuel Firing — Special Characteristics.

B-6.1 Solid Fuels.

B-6.1.1 Solid fuels can be burned in three ways: in suspension, in partial 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, for example, suspension, in mass, and so forth.

B-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.

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

B-6.2 Specific Fuels.

B-6.2.1 Bagasse.

B-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.

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

B-6.2.2 Refuse-Derived Fuel.

B-6.2.2.1 Refuse-derived fuel 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. The 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.

B-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.

B-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.

B-7 Special Considerations. For special problems in handling refuse fuels, refer to NFPA 850, *Recommended Practice for Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations.*

Appendix C Stoker Descriptions

This appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

C-1 Single or Multiple Retort Underfeed Stoker. See Figures C-1(a) and (b).

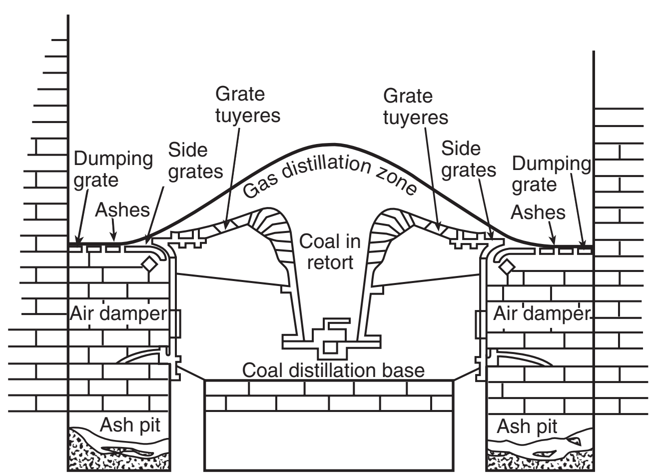

Figure C-1(a) Cross-sectional view of single retort underfeed stoker in operation. *(Reprinted with permission of Detroit Stoker Company)*

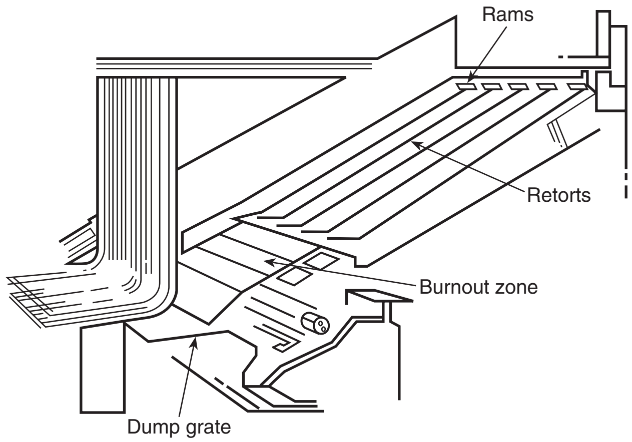

Figure C-1(b) Multiple retort underfeed stoker showing components. *(Reprinted with permission of Detroit Stoker Company)*

C-1.1 Fuel Subsystem. The fuel combusted with an underfeed stoker is typically coal or wood. The fuel system can be as simple as 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.

C-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.

C-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.

C-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.

C-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.

C-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.

C-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.

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

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

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

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

C-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.

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

C-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.

C-2.10 Chain and Traveling Grate Stoker. See Figure C-2.10.

C-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.

C-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 $^1/_4$-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.

C-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.

C-2.11 Vibrating Grate Stoker. See Figure C-2.11.

C-2.11.1 The vibrating grate stoker is water cooled, with an inclined, intermittently vibrating grate surface to slowly move 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.

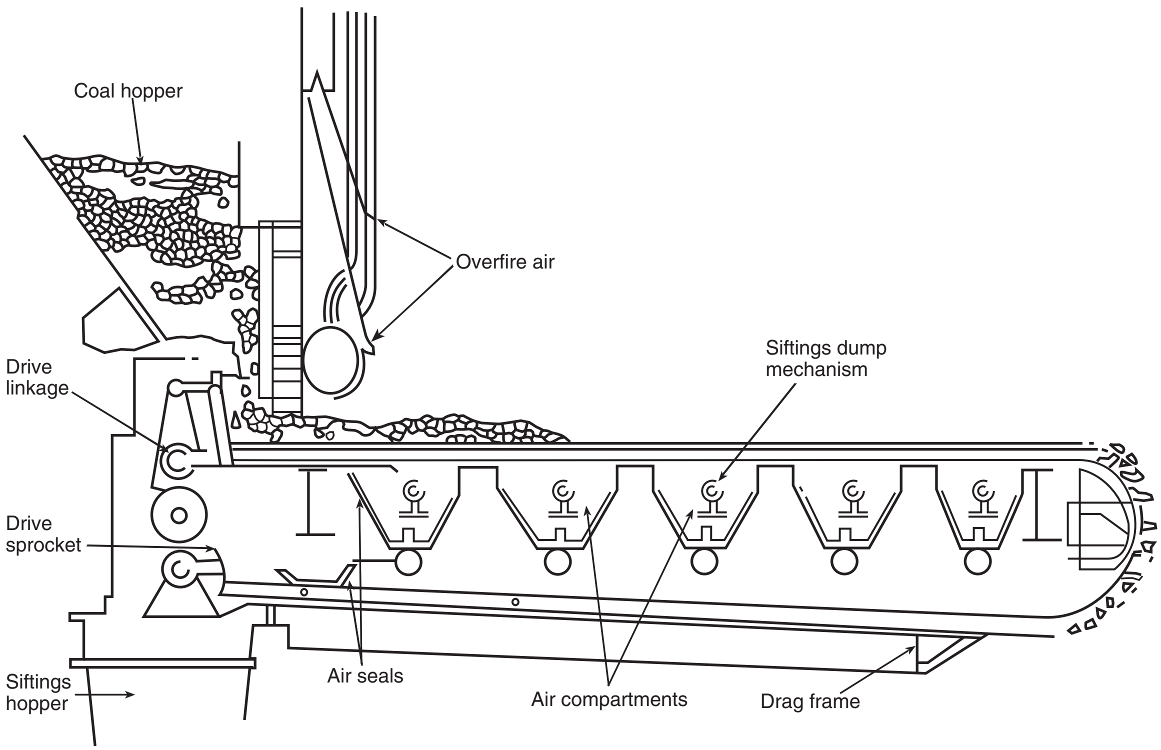

Figure C-2.10 Side view of chain grate overfeed stoker. *(Reprinted with permission of Detroit Stoker Company)*

C-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.

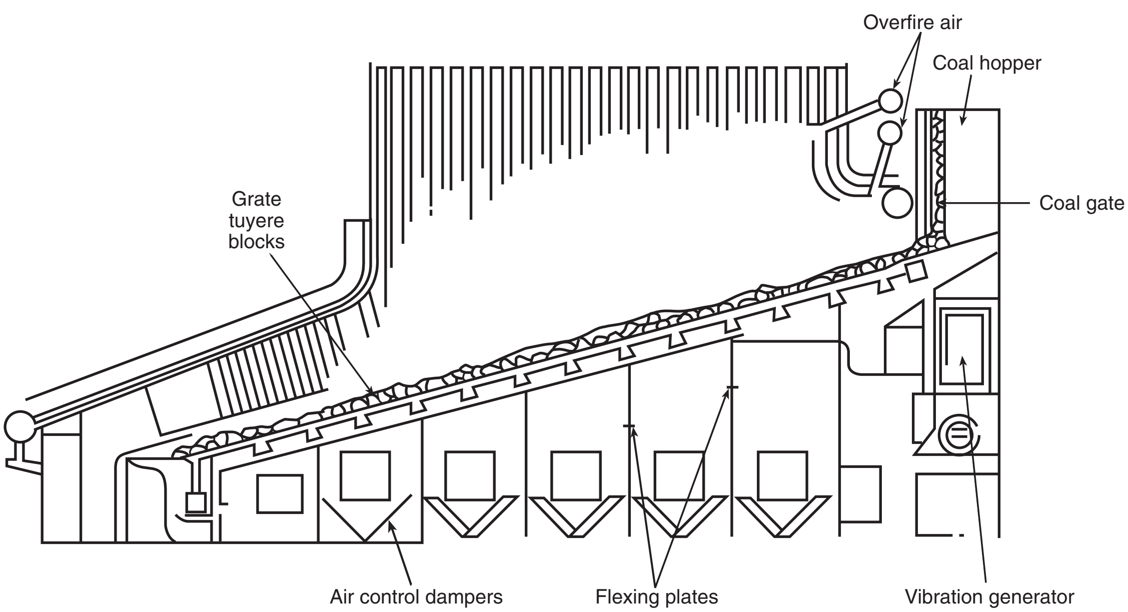

Figure C-2.11 Side view of a water-cooled vibrating grate stoker. *(Reprinted with permission of Detroit Stoker Company)*