Report of Committee on Boiler-Furnace Explosions

James K. Lafontaine, Chairman
Penelec

Courtney D. Alvey, Lutherville, MD
R. B. Beal, Bailey Controls Inc.
Paul L. Cioffi, Babcock & Wilcox
C. W. Conaway, Industrial Risk Insurers
William E. Cunningham Jr., Riley Stoker Corp.
John L. Edler, Baltimore Gas & Electric Co.
Humphrey Fedorak, E T duPont de Nemours & Co.
Frank M. Fishlock, Fenwal Inc.

Kenneth N. Lawrence, Honeywell Inc.
Albert L. Loom, Intl Union of Operating Engineers
Thomas B. Hamilton, Hamilton Consulting Services, Inc.
C. W. Conaway, Industrial Risk Insurers
C. Dudley Orr, American Petroleum Institute
Tommy E. England, Industrial Risk Insurers
J. H. Simmons, Factory Mutual Research Corp.
J. J. McCauley, Public Service Electric & Gas Co.
Raymond J. Murphy, Fornay Engineering
Robert P. Richmond, Exxon Co. USA
J. M. Simmons, Factory Mutual Research Corp.
Robert F. Tomczak, Tampa Electric Co.
Nell H. Johnson, Detroit Stoker Company

Enno Toomsalu, Underwriters Laboratories Inc.

Alternates

Phillip A. Davis, Kemper Group
(Alternate to R. L. Gruenl)
Tommy E. England, Industrial Risk Insurers
(Alternate to C. W. Conaway)
Roger W. Malone, Union Carbidie Corp.
(Alternate to W. G. Hudson)
Jerry J. Moskal, Combustion Engineering Inc.
(Alternate to Combustion Engineering Rep.)
C. Dudley Orr, American Petroleum Institute
(Alternate to API Rep.)
J. C. Haung, Babcock & Wilcox Co.
(Alternate to P. L. Cioffi)

Stoker Fired Boilers Task Force
Richard Leone, Chairman
Factory Mutual Research

John C. DeRuyter, E. I. duPont
Neil E. Johnson, Detroit Stoker Company
William B. McBurney, The McBurney Corporation
Robert A. Santos, Zurn Industries, Inc.
Francisco Palacios, Riley Stoker Corporation

Fluidized Bed Task Force
Francisco Palacios, Chairman
Riley Stoker Corporation

Paul M. Chase, Combustion Engineering.
Terry Cooper, American Electric Power
Ronald L. Garrell, Babcock & Wilcox Company
Walter A. Hansen, Babcock & Wilcox Company
Robert S. Rand, Bailey Controls Company
Gary R. Rossman, Honeywell, Inc.
Edward S. Taylor, Pyropower Corporation
Jim Toutz, Forney Engineering Co.
James M. Witt, Jr., Southern Company Ser.

This list represents the membership at the time the Committee was balloted on the text of this edition. Since that time, changes in the membership may have occurred.

The Report of the Committee on Boiler-Furnace Explosions is presented for adoption in 2 parts.

Part I of this Report was prepared by the Technical Committee on Boiler-Furnace Explosions and proposes for adoption a new document entitled NFPA 85H, Standard for Prevention of Combustion Hazards in Atmospheric Fluidized Bed Combustion System Boilers.

Part I of this Report has been submitted to letter ballot of the Technical Committee on Boiler-Furnace Explosions which consists of 26 voting members; of whom 18 voted affirmatively, 1 negatively (Mr. Cioffi), 2 abstained (Messrs. Lawrence and Tomczak) and 5 ballots were not returned (Messrs. Lafontaine, Conaway, Gruenl, Lin and Orri).

Mr. Cioffi voted negatively stating: "1) Commercially available duct burners currently in use for air preheating do not meet the NFPA 85 requirements with respect to flame detection, lighter classification and valving. Paragraph 3-7.3.1 should be revised as follows: "When using natural gas or fuel oil to fire start-up and warn up auxiliary burners the requirements of NFPA 85A (single burner oil and gas), NFPA 85B (multi-burner, oil) shall be followed. When using natural gas or fuel oil fired duct burners for air preheating, the requirements of NFPA 85B shall be followed."

2) By their nature, submerged in-bed liquid or gaseous fuel lances cannot be optically flame detected. Paragraph 4-1.2.2(f)2 should be revised to specifically state that flame detection requirements of NFPA 85E are not applicable to in-bed lances and that minimum bed temperature interlocks are sufficient to ensure combustion of the fuel."

Mr. Lawrence abstained from voting due to lack of current knowledge on the proposed standard.

Mr. Tomczak abstained from voting stating: "As a new member I did not have the opportunity to participate in the discussion of this proposal."

Part II of this Report was prepared by the Technical Committee on Boiler-Furnace Explosions and proposes for adoption a new document entitled NFPA 85I, Recommended Practice for Stoker Operation.

Part II of this Report has been submitted to letter ballot of the Technical Committee on Boiler-Furnace Explosions which consists of 26 voting members; of whom 18 voted affirmatively, 1 negatively (Mr. Moskal), 2 abstained (Messrs. Lawrence and Tomczak) and 5 ballots were not returned (Messrs. Lafontaine, Conaway, Gruenl, Lin and Orri).

Mr. Moskal voted negatively stating: "Procedures in 6-5.2 and 6-5.4 are unsafe because: 1) they promote furnace accumulations of volatilized and incompletely burned combustibles from the hot fuel bed on the grate; 2) subsequent air admission through fire doors above grate can cause sudden uncontrolled combustion of accumulated combustibles resulting in furnace pressurization which could damage equipment and be hazardous to personnel, especially in vicinity of fire doors."

Mr. Lawrence abstained from voting due to lack of current knowledge on the proposed document.

Mr. Tomczak abstained from voting stating: "As a new member, I did not have the opportunity to participate in the discussion of this proposal."

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PART I

NFPA 85H - Standard for Prevention of Combustion Hazards in Atmospheric Fluidized Bed Combustion System Boilers

Chapter 1 Purpose and Scope

1-1 The purpose of this standard is to establish minimum requirements for the design, installation and operation of atmospheric fluidized bed system boilers, their fuel preparation and burning systems, and related control equipment, to contribute to operating safety, and to prevent combustion hazards.

1-2 This standard is applicable to new installations and to major alterations or extensions of existing equipment contracted for subsequent to December, 1988. This standard is not retroactive.

1-3 Because this standard is based upon the present state of the art, 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.

1-4 Emphasis is placed upon the importance of combustion control equipment, safety interlocks, alarms, trips and other related controls that are essential to proper boiler operation.

Chapter 2 Definitions

Alternate Fuel. A fuel other than the main fuel, also used to carry load.

Bed Burner. A burner that is fired into a fluidized bed boiler furnace, having its own air supply, used for warming up the bed to auto-ignition temperature and for partial load carrying, and complying with applicable NFPA 85 standards.

Bed Compartment. Segments of a fluidized bed which may be individually controlled with respect to combustion air flow and fuel feed.

Bed Drain. An opening provided in the enclosure of a fluidized bed for removal of spent bed material and any tramp material.

Bed Material. Granular particles which compose the fluidized bed.

Bed Temperature. The mean average temperature of the fluidized bed.

Bubbling Bed (BBF). A fluidized bed in which the fluidizing velocity is less than the terminal velocity of individual bed particles where part of the fluidizing gas passes through the bed as bubbles.

Char. The unburned combustibles in solid form combined with a portion of the fuel ash.

Circulating Bed (CFB). A fluidized bed in which the fluidizing velocities exceed the terminal velocity of individual bed particles.

Crusher. A device for reducing the size of solid fuels.

Elutriation. The selective removal of fine solids from a fluidized bed by entrainment in upflowing gas.

Fluidize. To blow air or gas through a bed of finely divided solid particles at such a velocity that the particles separate and behave much like a fluid.

Fluidized Bed. A process in which a bed of granulated particles are maintained in a mobile suspension by an upward flow of air or gas.

Freeboard. The space or volume above the upper surface of the bubbling bed and below the furnace exit.

In Bed. Volume within the fluidized bed zone.

Lance. A burner, without its own air supply, providing fuel input directly into the bed.

Lock Hopper. A feeding device that incorporates a double pressure seal, thus enabling solids to be fed into a system with a higher pressure than that existing in the solids storage area. Also, a letdown device that incorporates a double pressure seal that enables solids to be withdrawn from a system with a higher pressure than that existing downstream of the lock hopper.

Main Fuel Temperature Permit. The bed temperature at which main fuel can be introduced with resulting stable combustion.

Minimum Fluidization Velocity. The lowest velocity sufficient to cause fluidization (incipient fluidization).

Primary Air. In a bubbling bed, that portion of total air used to transport or inject fuel, sorbent, and recycle material to the bed. In a circulating bed, that portion of total air introduced at the base of the combustor through the air distributor.

Recirculation (Solids or Recycle). The reintroduction of solid material extracted from the products of combustion into a fluid bed.

Secondary Air. Air for combustion supplied to the boiler to supplement the primary air.

Sorbent. A constituent in a fluidized bed that reacts with and captures a pollutant.

Sulfur Capture. The fraction of sulfur in the fuel that is "captured" by the sorbent.

Transport Air. The air used to convey or inject solid fuel, sorbent, or recycle material (also see Primary Air).

Warm-Up Burner. A burner fired into a duct or chamber that is external to the fluid bed boiler furnace, having its own air supply, used to warm up the bed to auto-ignition temperature, and complying with applicable NFPA 85 standards.

Chapter 3 General

3-1 Basic Cause of Combustion Hazards.

3-1.1 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.
enclosure. The magnitude and intensity of the explosion will depend upon both the relative quantity of combustibles that have accumulated and the proportion of air which is mixed therewith at the moment of ignition. Explosions, including "furnace puffs," are the result of improper procedures by operating personnel, improper design of equipment or control systems, or equipment or control system malfunction.

3-1.2 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, which convey the gases of combustion to the stack.

3-1.3 Numerous situations that will produce explosive conditions can arise in connection with the operation of a fluidized bed system. The most common experiences are:

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

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

(c) Repeated unsuccessful attempts to light off auxiliary fuel without appropriate purging, resulting in the accumulation of an explosive mixture.

(d) The accumulation of an explosive mixture of fuel and air as a result of main fuel entering a bed whose temperature is below the ignition temperature for the main fuel and the ignition of the accumulation by a spark or other source of ignition.

(e) Purging with too high an air flow, which stirs up combustibles smoldering in hoppers.

(f) Insufficient air to all or some bed compartments, causing incomplete combustion and accumulation of combustible material.

3-1.4 Fluidized bed combustion by virtue of the more consistent ignition source available from the mass of high temperature bed material is less susceptible to "furnace puffs" and "flameouts" than burner combustion.

Instrumentation, safety interlocks, protective devices, proper operating sequences and a clearer understanding of the problem by both designers and operators can further reduce the risks and actual incidence of furnace explosions.

3-1.5 There may exist, in certain parts of the boiler-furnace enclosure 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.

3-2 Manufacturer, Design and Engineering.

3-2.1 The purchaser or his/her agent shall, in cooperation with the manufacturer, assure that the unit is not deficient in apparatus that is required for proper operation, so far as practical, with respect to pressure parts, fuel burning equipment, air and fuel metering, and safe lighting and maintenance of stable fluidized bed operation.

3-2.2 All fuel systems shall include provisions to prevent foreign substances interfering with the fuel supply to the bed.

3-2.3 An evaluation shall 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.

3-2.4 Although this standard requires a minimum degree of automation (see 6-1.2), the trend toward more complex plants with increased automation requires added provisions for:

(a) Information about significant operating events, which permits the operator to make a rapid evaluation of the operating situation.

(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.

3-2.5 Fuel feeding piping and equipment shall be designed and constructed to prevent the formation of hazardous concentrations of combustible gases that may exist under normal operating conditions.

3-3 Installation.

3-3.1 The boiler shall not be released for operation before the installation and checkout of the required safeguards and instrumentation system.

(a) The constructor responsible for the erection and installation of the equipment shall see that all pertinent apparatus is properly installed and connected.

(b) The purchaser, the engineering consultant, the equipment manufacturer and the operating company shall 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 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 reached on its suitability in advance of start-up.

(c) Testing and checkout of the safety interlock system and protective devices shall be accomplished jointly by the organization with the system design responsibility and those who operate and maintain such system and devices during the normal operating life of the plant. These tests shall be accomplished before the initial operation.

3-4 Coordination of Design, Construction and Operation.

3-4.1 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 and its controls.

3-4.2 Furnace explosions have occurred as a result of unfavorable functional design. Frequently, the investigation has identified human error, and has completely overlooked the contributing causes that resulted in the incident. 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 human-machine relationships that will exist during the operating life of the system.

3-4.3 In the planning and the engineering phases of plant construction, design shall be coordinated with operating personnel.
3-4.4 The proper integration of the various components consisting of boiler, fuel and air supply equipment, combustible controls, interlocks and safety devices, operator functions, operator communication and training shall be the responsibility of the operating company, and shall be accomplished by:

(a) Providing design and operating personnel who possess a high degree of competence in this field, and who are required to bring about these objectives.

(b) Periodic analysis to compare the plant to evolving technology so that deficiencies can be corrected to make the plants safer and more reliable.

3-5 Maintenance Organization.

3-5.1 A program shall be provided for maintenance of equipment at intervals consistent with type of equipment, service requirements and the manufacturers' recommendations.

3-6 Basic Operating Objectives.

3-6.1 Basic operating objectives shall include the following:

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

(b) Standardize all operating procedures. The use of interlocks is essential 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. Chapter 5 describes operating sequences that have proved to be effective in unit operation.

3-6.2 Written operation procedures and detailed checklists for operator guidance shall be provided for achieving these basic operating objectives. All manual and automatic functions shall be described.

3-7 Fluidized Bed Combustion - Special Problems.

3-7.1 Heating the Bed. The bed material must be heated to a temperature above the ignition temperature of the main fuel prior to admitting main fuel to the bed. This is normally accomplished by auxiliary fuel-fired burners that heat the fluidizing air. Users of this document shall comply with the requirements of the appropriate NFPA bodies for the type of auxiliary fuel(s) used for bed warm-up burners.

3-7.2 Char Carryover. Elutriation of char from the bed is a characteristic of fluidized bed combustion. Although most boiler designs provide for re-injection of elutriated char into the bed, a certain amount of unburned carbon will be carried in the flue gas through the boiler's heat transfer surfaces and duct work to the baghouse or other dust collection equipment. The system design shall include provisions to minimize such accumulations in the flue gas duct work and dust collection equipment.

3-7.3 Coal Firing. Common hazards are involved in the combustion of solid, liquid and gaseous fuels. Each of these fuels has special hazards related to its physical characteristics. The following items shall be considered in the design of the coal firing systems:

(a) Coal requires considerable processing in several independent subsystems that must operate in harmony. Failure to process the fuel properly in each subsystem increases the potential explosion hazard.

(b) Methane gas released from freshly crushed or pulverized coal may accumulate in enclosed spaces.

(c) The raw coal delivered to the plant may contain foreign substances: scrap iron, wood shoring, rags, excelsior, rock, etc. Much of this foreign material can interrupt coal feed, damage or jam equipment, or become a source of ignition within the fuel feeding equipment. The presence of foreign material may constitute a hazard by interrupting coal flow. Wet coal can cause a coal hangup in the raw coal supply system. Wide variations in the size of raw coal may cause erratic or uncontrollable coal feeding.

(d) Explosions or fires can result from the back flow of hot flue gas or bed material into the fuel feeding equipment. Provisions shall be made in the design to prevent back flow.

(e) Caution shall be exercised in the interpretation of combustibles meter indication. Most meters and associated sampling systems measure only volatile combustibles. Thus, the lack of meter indication of combustibles does not prove that unburned coal particles or other combustibles are not present.

(f) Coal is subject to wide variations in analysis and characteristics. The change in percent of volatile constituents affects the ignition characteristics of the coal and may affect the minimum bed temperature required prior to admission of coal into the bed. The amount of fines in the coal can also affect its ignition and burning characteristics. The minimum bed temperature permitting the admission of coal into the bed shall account for the range of the ignition characteristics.

3-7.4 Waste Fuel Firing. Common hazards are involved in the combustion of waste fuels.

(a) The items listed in 3-7.3 above also apply to waste fuels.

(b) Waste fuels may contain volatile solvents or liquids, therefore, special consideration shall be taken in the design of the fuel handling and storage system.

(c) Waste fuels may be even more variable in analysis and burning characteristics than conventional fuels, requiring greater special consideration in fuel handling and burning.

3-7.5 Gas or Oil-fired Start-up, Auxiliary and Air Preheating Burners.

3-7.5.1 When using natural gas or fuel oil to fire start-up, warm-up auxiliary and air preheating burners, the requirements of NFPA 85A (single burner oil and gas), NFPA 85B (multiple burner, oil) or NFPA 85D (multiple burner, oil) shall be followed.

3-7.6 Hot Bed Material. Hot bed material can be removed from the bed to maintain the desired inventory of bed material. This bed material exists at or near the bed operating temperature (1400 to 1600°F) and must be cooled prior to disposal.

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 ignitable furnace input into unreactive products of combustion at the same rate that the fuel and air reactants enter the furnace.

4-1.1.2 The fuel burning system shall be properly sized, adequate to meet the operating requirements of the unit, compatible with other boiler component systems and 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 typically consists of the following subsystems: boiler-furnace enclosure, air supply, coal and alternate solid fuel supply, crusher (when utilized), bed feed, liquid or gaseous fuel lines, bed warm-up, burner, ash removal, ash re-injection, and combustion products removal. Each must
be properly sized and interconnected to satisfy the functional requirements and not interfere with the combustion process.

4.1.2.2 The fuel burning system shall provide means for proper start-up, operation and shutdown of the combustion process. This shall include appropriate drain and access openings in the component assemblies to permit safe operation, measurement and control of the combustion process.

The fuel burning system design shall be predicated on the following fundamentals:

(a) Boiler-Furnace Enclosure.
1. The boiler-furnace enclosure shall be designed to size and arranged so that fuel can be fired to maintain stable combustion.
2. The boiler-furnace enclosure shall be free of dead pockets when prescribed purge procedures are followed.
3. Observation ports shall be provided to permit inspection of the furnace and burners.
4. Means shall be provided for adequate monitoring of conditions at the bed and its ignition zone. Accessibility for maintenance shall be provided.

(b) Air Supply Subsystem.
1. The air supply equipment shall be sized and arranged to ensure a continuous air flow adequate for all operating conditions of the unit.
2. The arrangement of air inlets, duct work and air preheaters shall minimize contamination of the air supply by such materials as flue gas, water, and fuel. Appropriate drain and access openings shall be provided.

(c) Coal or Alternate Solid Fuel Supply.
1. The solid fuel supply subsystem shall be properly sized and arranged to ensure a steady fuel flow for all operating requirements of the unit.
2. The solid fuel unloading, storage, transfer and preparation facilities shall be designed and arranged to size the fuel, to remove foreign material, and to minimize interruption of the fuel supply to the feeders. This design includes the installation of breakers, cleaning screens and magnetic separators where necessary. Detection of flow interruption and means of correction should be provided to ensure a steady flow to the boiler.
3. Solid fuel feeders shall be designed with a capacity range to allow for variations in size, quality and moisture content of the coal as specified by the purchaser. Fuel piping to and from feeders shall be designed for free flow within the design range of solid fuel size and moisture content. Means shall be provided for observation and detection of the solid fuel flow. Access shall be provided for clearing of obstructions and sampling of fuel.
4. A bed that operates at a lower pressure than the boiler furnace enclosure to which it is connected shall have a lock hopper or other suitable means to prevent back flow of combustion products.
5. Means shall be provided to assure adequate transport air for the required fuel input.

d) Crusher Subsystem (when utilized in the fuel feed system).
1. Fuel crushing equipment shall be designed to provide a range of capacity that will minimize starting and stopping of crushers during boiler load changes. It shall produce satisfactory fuel sizing over a specified range of fuel analysis and characteristics. The crushing system shall be designed to minimize the possibility of fires starting in the system and means shall be provided to extinguish fires.

2. Transport air systems provide for transport of the crushed coal from the crusher to the bed. The fans, their ducts, and dampers shall be sized and arranged so that proper transport velocity is provided throughout the crusher operating range. Positive means shall be provided to assure that all pipe velocities are equal to or above the minimum velocity required for fuel transport. Testing during initial start-up and retesting as appropriate shall be performed to verify that individual pipe velocities are adequate. Means shall be provided for positive isolation of the crusher systems from the bed and air supply system.
3. A bed feed system that operates at a lower pressure than the boiler furnace to which it is connected shall have a lock hopper or other suitable means to prevent back flow of combustion products.
4. Means shall be provided to control crusher outlet temperature within limits suitable for the fuel being fired.
5. Piping that connects the crushe system to the bed shall be kept to a minimum length. Where the air-fuel stream is directed into multiple pipes, the system shall divide the air/fuel mixture in the proper ratio among the various pipes.

(e) Bed Feed Subsystem. The limits of stable combustion for each bed feed subsystem producing a separate combustion envelope shall be determined by tests. These tests shall be performed without the bed warm-up subsystem in service. These tests shall consist of maximum credible deviations from normal flows including verification that transients generated in the fuel and air subsystems do not adversely affect the beds in operation. Such transients are generated by bed feed shutoff valves, dampers, etc., that operate at speeds faster than the speed of response of other components in the system. These tests shall include the expected range of available fuel.

(f) Liquid or Gas Fuel Lances.
1. The fuel piping system for lances shall comply with the applicable NFPA 85 standard.
2. The liquid or gaseous fuel lance subsystem shall be designed so that the fuel is supplied in a continuous manner and within the confines of stable combustion limits. Minimum bed temperature interlocks [see 5-1.5.1(h) and 6-3.1.1(g)] shall be furnished to ensure combustion of fuel in the bed at all times.
3. Provision shall be made for protecting and cleaning of the lance nozzles and tips.
4. The lance equipment shall be located in an appropriate environment with convenient access for maintenance. Special cognizance shall be taken of the fire hazards imposed by leakage or rupture of piping near the lance. Requirements of good housekeeping shall be recognized.

(g) Bed Warm-Up and Burner Subsystem.
1. The bed warm up and burner subsystem shall comply with the requirements of NFPA 85A, B or D as applicable.

(h) Ash Removal Subsystem.
1. The bed drain 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.
3. The removal equipment handling hot ash from the boiler shall be designed to provide effective material cooling before discharging material into conventional ash handling and storage equipment. Safety interlocks with a device to monitor cooling water flow or material discharge temperature shall be required to prevent fires or equipment damage.
(1) Combustion Products Removal Subsystem.

1. The flue gas ducts, fans and stack shall be sized and arranged to remove the products of combustion at least at the same rate that they are generated by the fuel burning process during credible operation of the unit.

2. Convenient access and drain openings shall be provided.

3. The flue gas ducts shall be designed so as not to contribute to furnace pulsations.

4. Components common to more than one boiler shall not limit the rate of removal of products of combustion during operation of all boilers.

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 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 stable combustion throughout the controlled operating range of the unit.

4-2.2 System Requirements.

(a) Furnace input shall be controlled to respond to the energy demand under all credible conditions.

(b) The air/fuel mixture shall be maintained within safe limits as established by test under any boiler output conditions within the controllable operating range of the subsystem.

(c) Provide means for setting minimum and maximum limits on the fuel and air control systems to prevent these systems from providing fuel and air flows beyond the stable combustion limits of the fuel burning system. These minimum and maximum limits shall be defined by the boiler manufacturer and verified by operating tests. [See 4-1.2.2(f)].

(d) A means shall be provided to control the crusher fuel-air temperature within the required limits (where applicable).

(e) A means shall be provided to assure adequate transport air for transporting the required fuel, sorbent, and recycled ash material where applicable.

(F) When changing the rate of furnace input, the air flow and fuel flow shall be changed simultaneously to maintain proper air/fuel ratio during and after the changes. This does not prohibit provisions for air lead and lag during changes in firing rate.

(g) Means shall be provided to prevent the control system from demanding a fuel-rich mixture.

(h) Means shall be provided to cut back fuel to available air.

(i) Oxygen analyzers shall be provided as an operator guide.

(j) Consideration shall be given to providing carbon monoxide and sulfur dioxide analyzers for use as operating guides.

(k) Combustion chamber furnace draft shall be maintained at the desired set point.

(I) Solid fuel flow devices on each Feeder are recommended as a part of the combustion control and bed feed control systems to provide indices of total fuel vs. total air flow. These devices are also a valuable operating guide.

(m) Provide means to permit as much on-line maintenance of combustion control equipment as possible.

(n) Provide a means for calibration and check testing of combustion control and associated safeguard equipment.

4-3 Combustion Monitoring and Tripping Systems.

4-3.1 Functional Requirements.

4-3.1.1 The basic requirements of any combustion monitoring and tripping system are:

(a) Bed temperature shall be monitored by redundant measurements and devices. The indication of any bed temperature shall be used for monitoring and interlocking. If the bed is compartmented, individual compartment temperatures shall be indicated.

(b) An indication of bed temperature outside the normal operating range shall be brought to the attention of the operator in order to permit remedial action.

(c) Upon detection of serious combustion problems emergency shutdown of the involved equipment shall be automatically initiated (see paragraph 5-2.1.1).

4-3.2 System Objectives.

4-3.2.1 Influence of Furnace Configuration. System design objectives shall address furnace configuration, bed feed system, and fuel characteristics. Such objectives shall be consistent with the particular manufacturer's design philosophy.

4-3.2.2 Tripping Philosophy. There are two separate tripping philosophies for fluidized bed boilers, one for the bed warm-up burners and auxiliary burners and one for main bed fuel.

1. Burners shall employ individual conventional flame detection devices to ensure flame safety. Loss of flame by individual burners shall isolate the fuel from the combustion chamber through a series of interlocks and permissives outlined in NFPA 85A, Single Burner Boiler Furnaces, NFPA 85B, Multiple Burner Gas, NFPA 85C, Multiple Burner Oil, or NFPA 86, Ovens and Furnaces, as applicable.

2. The combustion process receives its source of ignition energy from the bed temperature. Tripping philosophy for the main fuel shall be based on ensuring adequate bed temperature to ignite the fuel entering the combustion chamber. All main fuels shall be prevented from entering a bed or bed zone unless its temperature is above a preset minimum that will ensure combustion. This minimum temperature shall be verified by field test of the unit or experience with the same fuel in a similar boiler-furnace enclosure.

Chapter 5 Sequence of Operations

5-1 General.

5-1.1 The purpose of sequencing is to ensure that operating events occur in proper order. This will permit properly prepared fuel to be admitted to the fluidized bed combustion zone only when there is sufficient ignition energy and correct air flow to ignite the fuel as it enters the furnace, and to burn it continuously and as completely as possible within the confines of the combustion area.

5-1.2 The sequences are based on the typical fuel supply system shown in Figure 1. These sequences shall be followed whether the unit is operated manually or certain functions are accomplished by interlocks or automatic controls. Different arrangements are permissible if they provide equivalent protection and meet the intent of the following operating sequences.

5-1.3 The starting and shutdown sequences for fluidized bed boilers are designed to preserve the temperature of the bed material and refractory while providing safe operating conditions. As a result the
warm-up cycle for cold start-up and hot restart as well as a conventional coal or oil fire boiler. For example, on a cold start-up, after the normal purge period, air flow (depending on the process design) may be reduced below the purge value to provide for the proper warm-up rate. Another deviation from normal practice is during a hot restart. If the bed material is above a predetermined minimum ignition temperature (see 4-3.2.2), fuel may be admitted to the boiler, or warm-up burners may be started to preserve bed temperature without the normal boiler purge cycle. The third exception from standard practice is that tripping the fans or diverting air flow from previously active bed sections is allowed shortly after a master fuel trip without the normal post purge. Again, the object is to maintain bed temperature and protect the refractory against sudden temperature change by reducing the cooling effect from high volumes of air. Sufficient ignition energy remains in the bed material and refractory, provided the bed average temperature remains above the ignition point, to ensure total burn-out of combustible volatile matter, after the master fuel trip.

5-1.4 Fluidized bed boilers that have multiple beds (sometimes called zones, sections or compartments) may require a restorative pattern of bed start-up and shutdown and not allow random bed operation. In this case, bed sequence shall be defined by operating instructions and verified by actual experience with the unit in order to minimize damage to tube sections and excessive emissions. 

5-1.4.1 The first bed section shall be directly accessible by a source of ignition energy and shall have reached predetermined ignition temperature before fuel is introduced. 

5-1.4.2 Beds adjacent to an active bed shall have predetermined ignition temperature before fuel is introduced. 

5-1.4.3 A positive means shall be provided to prevent fuel leakage into idle beds. 

5-1.5 All registers and dampers in the combustion air flow path to the boiler will be open to the purge position during the purge procedure. Purge and light-off shall be performed in accordance with the following basic operating conditions, which will significantly improve the margin of operating safety, particularly during start-up. 

(a) Minimum number of required equipment modifications, thereby minimizing exposure to operating errors or equipment malfunction. 

(b) Minimize the hazard of dead pockets in the gas passes and the accumulation of combustibles by continuously diluting the furnace with large quantities of air:

5-1.5.1 The basic procedure shall incorporate the following operating objectives: 

(a) All of the bed air registers/dampers are placed in a predetermined open position. 

(b) Complete a unit purge with the bed air registers/dampers in the position specified in item (a). The bed must be purged while in the fluidized or semifluidized condition. A freeboard (above the bed) purge without air specifically going through the bed material is not sufficient. 

(c) Components (e.g. precipitators, fired reheaters) containing sources of ignition energy shall be purged for the greater of either: (1) a period of not less than 5 minutes or (2) five volume changes of that component, prior to being placed into operation. 

(d) Boilers that share a common component between the furnace outlet and the stack shall have provisions to bypass the common components for unit purge. 

(e) The bed warm-up cycle will start after purge is complete. Air flow may be reduced below the purge requirements depending on the process constraints. Multi-zone fluidized beds may require slumping beds that are not being heated for start-up. Fluidized beds may be warmed up with the bed in a slumped or fluidized mode. Air flow through a fluidized bed boiler during the warm-up cycle shall be determined by performance design requirements. 

(f) Fluidized bed boilers shall be warmed up following the procedures and warm-up rates recommended by the manufacturer. 

(g) Bed lances shall be "locked out" of operation until the average bed temperature has reached 1400°F. 

(h) Solid fuel shall be "locked out" until average bed temperature has reached 1400°F. A lower solids fuel temperature will be permitted (but not lower than 900°F) provided the temperature has been verified through test and actual experience to safely ignite the main solid fuel. 

5-1.5.2 Each boiler shall be tested during initial start-up to determine whether any modifications to the procedures specified in 5-1.5.1 are required in order to obtain satisfactory ignition or to satisfy other design limitations during light-off and warm-up. However, unnecessary modifications in the basic procedure shall be avoided, thereby satisfying the basic objectives set forth in 5-1.5, particularly that of keeping the number of equipment manipulations to a minimum. 

5-1.6 Improper water, steam, and flue gas temperatures in economizers and superheaters may require modifications in the mode of operations. Such modifications shall be made only after the necessity for changes has been determined by operating experience. 

5-2 Operational Requirements. 

5-2.1 Cold Start. 

5-2.1.1 Preparation for starting shall include a thorough inspection, particularly for the following: 

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

(b) All personnel evacuated from unit and associated equipment, and all access and inspection doors closed. Ensure all equipment and instrumentation are in proper operating condition. 

(c) All air and flue gas flow control dampers operated through full range to check operating mechanism and then set at a position that will allow the fans to be started at a minimum air flow and without over or under pressuring any part of the unit. 

(d) All normally adjustable individual burner dampers or registers operated through full range to check operating mechanism. 

(e) All safety shutoff valves operational and closed and spark deenergized. For gas ignition systems see NFPA 65B; for oil ignition systems see NFPA 65D. 

(f) Feeder equipment effectively isolated to prevent leakage of fuel or sorbent into the furnace and leakage of hot air or flue gas from the fluidized bed back into the feed system. 

(g) Proper drum water level shall be established. Circulating flow shall be established in forced circulation boilers. 

(h) Feeders and associated equipment shall be in good condition and adjusted properly ready for service. 

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

(j) Oxygen and CO analyzer(s), if provided, operating satisfactorily and obtaining a sample. CO indication at zero and oxygen indication at maximum.
A complete functional check of the safety interlocks has been made at least after an overhaul or other significant maintenance.

A complete periodic operational test of each igniter has been made. The frequency of testing will depend on the design and operating history of each individual unit and ignition system. As a minimum, the test shall be made during every startup following an overhaul or other significant maintenance. The test shall be integrated into the starting sequence and will follow the purge and precede the admission of any main fuel.

Starting Sequence. The starting sequence shall be performed in the following order:

(a) Prepare the unit for operation. Ensure adequate cooling water flow to critical components. Ensure that the plant air, instrument air and service steam systems are operational.

(b) Verify an open flow path from the inlets of the forced draft fans to the stack.

(c) Start the flue gas clean-up system, ash transportation system and gas recirculation fans in the manner recommended by the boiler manufacturer. When provided, start regenerative-type air heaters.

(d) Start an induced draft fan, then start a forced draft fan. Some systems may require starting additional equipment prior to starting fans. (Follow manufacturers recommended fan start procedure.) Start additional induced draft or forced draft fans in accordance with NFPA 8SG as required to achieve purge flow rate.

(e) Open dampers and air registers to purge position in accordance with open register/damper purge method objectives outlined in 5-1.5.

(f) Purge the bed and boiler enclosure with not less than five volumetric changes, but in any event for a continuous period of not less than five minutes. A freeboard purge without air specifically going through the bed material is not sufficient.

(g) Shut down gas recirculation fans subsequent to purge if recommended by the boiler manufacturer.

(h) Establish proper bed height if required at this time, by adding sorbent or inert solids or by draining excess bed material. FD and ID fans shall remain in operation; coal feeders off, and all fuel valves must be proven closed.

NOTE: At this point the BFB and CFB processes have different start-up procedures.

(i) The BFB starting procedures is as follows:

1. The BFB process may require two types of devices for warming the bed. One type is a duct burner that heats the combustion air and the other type heats the bed or portions of the bed. Duct burners are started first. The bed warm-up rate shall not exceed the manufacturer’s recommendations.

2. Burners shall be started in accordance with NFPA 8SA, B, or D as applicable.

3. Combustion air flow can be reduced to the level required for warming the bed sections.

4. Dampers may be closed on bed sections not to be fired.

5. Place bed burners in service (if applicable). Use guideline stated in (2) above with the following exception: if the burner (if used) fails to light within 10 seconds, the unit must be repurged before a second trial. If air flow has been reduced below purge requirements, if air flow has not been reduced below purge rate, one minute shall elapse between trials.

6. Continue heating the bed at a rate recommended by the manufacturer. Maintain proper bed level by adding sorbent or inert solids as needed.

7. Fuel feed to the warm-up section shall start when the bed reaches 1400°F. A lower solids fuel temperature permit may be used (but not lower than 900°F) if this temperature has been proven by test and verified by actual experience to safely ignite the solid fuel.

8. Maintain duct temperature within the manufacturer’s recommended limits.

9. Ensure that the fuel is igniting by watching for a steady increase in bed temperature and a decreasing O2. Increase fuel flow to maintain bed temperature as required. Increase air flow as necessary to maintain the desired O2 level.

10. Expand the active bed area by activating idle bed sections as steam load demands by following manufacturers suggested sequence.

(j) The CFB process initiates its warm-up cycle with the purge complete permissively. In general, the light off and warm-up recommendations of the manufacturer shall be followed. Warm-up may require less than purge air flow. Ensure that proper light-off and flame safeguard procedures are followed as recommended by the NFPA standard appropriate to the fuel to be used on the burners.

1. After placing the first bed warm-up burner in service, heat the bed slowly and refractory up at the manufacturer’s recommended rate.

2. Add warm-up burners if required to maintain the required bed heat-up rate. Place any fans and blowers that may have been shut down for the warm-up cycle back in service when the bed temperature reaches the required temperature permit. Prepare to admit main fuel.

3. Start the fuel and sorbent feed systems after the bed reaches the 1400°F main fuel temperature permit. A lower solids fuel main temperature permit may be used (but not less than 900°F) if this temperature has been proven by test and verified by actual experience to safely ignite the solid fuel. However, if the main fuel is oil or gas the temperature permit shall not be less than 1400°F.

4. Ensure that the fuel is igniting by watching for a steady increase in bed temperature and a decrease in O2. Remove warm-up burners and increase fuel flow to maintain bed temperature at the recommended level.

(k) The normal on-line metering combustion control (unless designed specifically for start-up procedures) shall not be placed in service until:

1. A predetermined minimum main fuel input has been exceeded.

2. Stable bed temperature conditions have been established.

3. All manual control loops are operating without significant error signal between their setpoint and process feedback.

4. Air flow control is on automatic.


5-2.1 The firing rate shall be regulated by increasing or decreasing the fuel and air supply simultaneously to all fuel ports or bed sections, maintaining normal air/fuel ratio continuously at all firing rates. This does not prohibit provisions for air lead and lag of the fuel during changes in firing rate.

5-2.2 For those applications firing gas or oil, the firing rate shall not be regulated by varying shutoff valves. Individual load carrying oil or natural gas fuel shutoff valves shall be wide open or completely closed (do not use at intermediate settings).
5-2.2.3 Fuel feed rates and transport air flow shall be maintained between the maximum and minimum limits specified by the boiler manufacturer or, preferably, as determined by trial. These trials shall test for minimum load under stable bed temperature, fluidization and proper combustion conditions:

1. With all feeders in service and combustion controls on automatic, and

2. With different combination of feeders in service and combustion controls on automatic. Where changes occur to the manufacturer's maximum and minimum limits because of various feeder combinations and different fuel conditions, additional testing shall be required to establish the new safe limits.

5-2.2.4 If lower minimum loads are required than can be obtained with all feeders at minimum speed, remove feeder(s) (and associated bed sections if applicable) from service. Operate the remaining feeder(s) at a fuel rate above the minimum required for stable operation. The minimum fuel rate shall be determined by tests with various combinations of fuel distribution and excess air. These tests shall reflect the most restrictive conditions.

5-2.2.5 The philosophy for a stable operating fluidized bed shall be a bed with a stable temperature greater than 1400°F. Temperatures below 1400°F shall initiate a master fuel trip.

Exception: A lower solids fuel temperature permit than 1400°F may be used if this temperature has been proven by test and verified by actual experience to safely maintain combustion of the solid fuel. However, if the main fuel is oil or gas, the temperature permit shall not be less than 1400°F.

5-2.2.6 Total air flow shall not be reduced below 25 percent of full load volumetric air flow when main fuel is being fired. Air flow shall not be reduced below that required to maintain stable fluidization conditions within active beds or bed compartments.

5-2.3 Normal Shutdown.

5-2.3.1 When taking the unit out of service, the boiler shall be brought down to a minimum load.

5-2.3.2 After the boiler load is reduced, there are two options for normal shutdown.

(a) If the unit is scheduled to be out of operation for a significant period of time, trip the main fuel and allow the FD and ID fans to remain in operation. Allow fans to operate until unit is sufficiently cooled for maintenance. Air flow can be reduced below purge air flow as required for cooling.

(b) If the unit is scheduled to be restarted soon, the fans can be tripped after a minimum short time period sufficient to remove volatiles from the furnace after the main fuel has been tripped. This will be typically indicated by a drop in bed temperature and increase in O2 reading. Fan tripping will effectively reduce start-up time by conserving the temperature of the bed and the refractory.

NOTE: Residual carbon in the bed, compared to inert solids, represents less than 3 percent of the bed material during normal operation. After a main fuel trip, the remaining carbon is consumed within minutes due to the high temperature level of the inert bed medium. Carbon does not represent a hazard, but the volatile gases driven off from the fuel particles must not be allowed to accumulate. Tests have shown that volatile gases are driven from the fuel shortly after entering the bed. A short time delay between the main fuel trip and fan trip plus the normal fan coast-down time shall be sufficient to purge remaining volatiles from the bed.

5-2.4 Normal Hot Restart.

5-2.4.1 When restarting a unit after it has been tripped or after the furnace has been bottled up, the purge cycle outlined in 5-1.5.1 should not be required prior to introduction of main fuel if the bed temperature is above the main fuel temperature permit established in 5-2.1.2(i)(7) or 5-2.1.2(j)(3).

5-2.4.2 If the bed temperature has dropped below the main fuel temperature permissive during the shutdown, a unit purge shall be required as outlined in subdivision 5-1.5.1.

5-2.5 Emergency Shutdown-Master Fuel Trip.

5-2.5.1 With the initiation of a master fuel trip (MFT) from any of the emergency conditions tabulated in 5-2.5.1.1 or 5-2.5.1.2, all fuel shall be stopped from entering the boiler. Oil and gas safety shutoff valves shall be tripped and igniter spark deenergized. The fuel and sorbent feed system and the bed drain system shall be tripped. Electrostatic precipitators, fired reheaters or other ignition sources shall be tripped. Master fuel trips shall operate in a manner to stop all fuel flow into the furnace within a period that will not permit a dangerous accumulation of fuel in the furnace. The owner shall have the option of allowing a master fuel trip to initiate a time delay FD and ID fan trip.

5-2.5.1.1 Mandatory Automatic Master Fuel Trips (see Chapter 6 for more details).

(a) Loss of all induced or all forced draft fans. (See NFPA 85G.)

(b) Furnace pressure greater than the normal operating pressure by a value recommended by the manufacturer. (See NFPA 85G.)

(c) High bed temperature.

(d) Bed temperature below main fuel permit and flame not proven (self-proving warm-up burners).

5-2.5.1.2 Mandatory master fuel trips with alarms, not necessarily automatic.

(a) Loss of boiler feedwater pumps.

(b) Low or high drum level.

(c) Loss of energy supply for combustion control and interlock systems.

(d) Cooling water flow for fluidized bed system components less than minimum.

(e) Plant air or instrument air pressure low (process requirement only).

(f) Air flow less than purge air flow requirements.

(g) Loss of boiler circulation pumps or flow.

5-2.5.2 If the option for tripping fans on a master fuel trip is not exercised, the following procedure shall be followed:

Fans that are operating after the master fuel trip shall be continued in service. Do not immediately increase the air flow by deliberate manual or automatic control action.

5-3 Emergency conditions not requiring shutdown or trip.

5-3.1 Many unit installations include multiple induced draft fans or forced draft fans or both. In the event of a loss of a fan or fans, the control system shall be capable of reducing the fuel flow to match the available air flow or else tripping of the unit is mandatory.

5-3.2 If an air deficiency should develop while firing main fuel, reduce the fuel until the proper air/fuel ratio has been restored. If fuel flow cannot be reduced, slowly increase air flow until proper air/fuel ratio has been restored.
5-3.3 Common emergencies that may arise when firing solid fuel include:

(a) Solid fuel hangups ahead of feeder causing an intermittent feed rate.
(b) Wet solid fuel or changing solid fuel quality causing bed temperature drift.

These conditions are not particularly hazardous because the massive thermal energy built up in the bed will usually forgive momentary intermittent fuel feed problems. If the bed temperature starts to drop, auxiliary firing equipment may be placed in service immediately in order to support combustion. If fuel feed to a malfunctioning feeder subsystem can be restored before bed temperature falls below the main fuel temperature permit limit, the subsystem may be continued in service.

5-4 General Operating Requirements - All Conditions.

5-4.1 Prior to entering a unit, positive action shall be taken to prevent fuel from entering the furnace.

5-4.2 Burners shall not be lighted one from another or from the hot refractory. The ignitor for the burner shall always be used.

5-4.3 When feeder or fuel transport line maintenance is being performed with the boiler in service, positive means to isolate the feeder or fuel transport line from the boiler shall be used.

Chapter 6 Interlock System

6-1 General.

6-1.1 The basic requirement of an interlock system for a unit is that it protect personnel from injury and also protect the equipment from damage. The interlock system functions to protect against improper unit operation by limiting actions to a prescribed operating sequence or by initiating trip devices when approaching an undesirable or unstable operating condition.

6-1.2 The mandatory automatic trips specified in 6-3.1 represent those automatic trips for which sufficient experience has been accumulated to demonstrate a high probability of successful application for all units. The use of additional automatic trips, while not mandated, is encouraged.

6-1.2.1 It is possible to achieve conditions conducive to a furnace explosion that will not be detected by any of the mandatory automatic trip devices, even though they are properly adjusted and maintained. Therefore, operating personnel shall be made aware of the limitations of the automatic protection system.

6-2 Functional Requirements.

6-2.1 The operation of any interlock that causes a trip shall be annunciated in order to indicate an abnormal condition.

6-2.2 An interlock system requires sound design, proper installation, adjustment and testing to confirm design function and proper timing. Periodic testing and maintenance shall be performed to keep the interlock system functioning properly.

6-2.3 The design of an interlock system shall be predicated on the following fundamentals:

(a) Supervise starting procedure and operation to ensure proper operating practices and sequences.
(b) Trip the minimum amount of equipment in the proper sequence when the safety of personnel or equipment is jeopardized.
(c) Indicate the initiating cause of the trip and prevent starting any portion of the system until proper conditions are established.

(d) Coordinate the necessary trip devices into an integrated system.

(e) Where automatic equipment is not available to accomplish the intended function, provide sufficient instrumentation to enable the operator to complete the proper operating sequence.

(f) Retain in the design as much flexibility with respect to alternate modes of operation as is consistent with good operating practice.

(g) Provide for proper preventive maintenance.

(h) Shall not require any deliberate defeating of an interlock in order to start or operate equipment. Whenever a safety interlock device has been temporarily removed from service, this action shall be noted in the log and announced if practicable, and a manual or other means shall be substituted to supervise this interlock function.

(i) The mandatory master fuel trip and circuits shall be independent of all other control system operation. Input sensors shall be either dedicated to the trip system or redundant when shared with other control systems.

(j) Misoperation of the interlock system due to interruption and restoration of the interlock power supply shall be prevented.

6-2.4 The actuation values and time of action of the initiating devices shall be tuned to the furnace and equipment on which they are installed. After adjustment, each path and the complete system shall be tested to demonstrate the adequacy of adjustment for that furnace.

6-3 System Requirements.

6-3.1 Interlocks (see Figures 1 through 4).

6-3.1.1 Figure 1 shows, in block form, the required system of interlocks that will provide the basic furnace protection for a fluidized bed boiler operated in accordance with this standard. The sequence of operation in Chapter 5 describes a fluidized bed boiler cold start and hot restart. Logic flow paths illustrated in Figure 1 show the interlocking logic required to satisfy those process requirements.

(a) The proper starting sequence shall be ensured by a series of purge-permissive interlocks shown in Block No. 1 (expanded block diagram in Figure 2).

(b) Block No. 2 represents warm-up burner flame protection, fuel pressure and atomizing medium pressure interlocks (expanded block diagram in Figure 3).

(c) Master Fuel Trip (MFT) logic, which initiates tripping both the main and ignition fuel supplies through an MFT device, resides in Block No. 3. An expanded block diagram listing required boiler trips is illustrated in Figure 4.

(d) Block No. 4 generates a Boiler Operate Logic permit signal by interlocking three blocks of logic:

1. The purge logic (Block No. 1) during a cold start-up before a bed warm-up burner is proven in operation.
2. The purge reset and bypass logic (Block No. 6) which signals the successful operation of a bed warm-up burner.
3. The MFT device logic block. This trip device shall be the type that stays "tripped" until the boiler purge system allows it to be reset or the bed temperature permits the fuel release logic (Block No. 7) to reset it.
(e) Block No. 5 shall permit the warm-up cycle to start by interlocking the boiler operate logic with the warm-up burner safety logic.

(f) Block No. 6 shall reset the purge timer after a warm-up burner (with flame detector protection) is proven in operation. Loss of a burner flame (Block No. 2) or a boiler operate permit (Block No. 4) shall require a boiler purge.

(g) Logic in Block No. 7 shall generate a permit for releasing fuel to the bed. This permit requires proper bed temperature and is interlocked with the boiler operate logic (Block No. 4). Also, a hot restart permit without the normal boiler purge cycle shall originate from this block by an interlock with the purge reset and bypass logic (Block no. 6).

6-3.1.2 The fluidized bed boiler purge logic illustrated in Figure 2 shall check for a proper starting sequence by a series of permissive interlocks. This system will assure that the unit purge has been completed with all sources of fuel proven off, all required air sources on, all air paths in a purge position, and that there are no boiler trip conditions during the purge cycle. The boiler shall require a minimum of 25 percent air flow for not less than 5 minutes before satisfying the purge logic.

6-3.1.3 Figure 3 illustrates the requirements for the warm-up burner safety logic (Block No. 2) as follows:

(a) Loss of individual warm-up burner flame shall close the individual warm-up burner safety shutoff valve, and deenergize the spark.

(b) Improper warm-up burner fuel header pressure shall be interlocked so as to initiate the tripping of the main and individual warm-up burner safety shutoff valves and deenergize the spark. When gas is used for fuel both high and low pressure shall be interlocked. When oil is used, low pressure shall be interlocked.

(c) When oil is used for burner fuel with air or steam atomization, improper atomization of an ignitor fuel shall trip the header and individual burner safety shutoff valves, and deenergize sparks as indicated.

(d) An interlock from the master fuel trip device shall also initiate tripping the header and individual burner safety shutoff valves and deenergize the spark.

6-3.1.4 Figure 4 represents conditions that shall initiate the tripping of both main and burner fuel supplies through a master fuel trip device. The master fuel trip device shall be the type that stays "tripped" until reset by either the purge complete and boiler operate logic (Block No. 4) or the main fuel temperature permit from the fuel release logic (Block no. 7, Figure 1). The operator shall initiate fuel input to the unit. Whenever the master fuel trip device is operated, it trips all feeders and safety shutoff valves, de-energizes all ignitor sparks and deenergizes all other ignition sources within the unit and flue gas path. These interlocks are as follows:

(a) Items 1 through 4 represent protection against loss of large quantities of combustion air. The loss of all ID or all FD fans shall operate the master fuel trip device. The loss of one ID or FD fan or other large loss of air shall shut the fuel in order to maintain the proper air/fuel ratio. This may be interlocked or made a part of the combustion control system (Item 5).

(b) Furnace pressure high (Item 6) shall be interlocked with the master fuel trip device to protect against abnormal furnace conditions such as that resulting from a tube rupture, damper failure, etc.

(c) A manual trip switch (Item 8) shall be used by the operator in an emergency to actuate the master fuel trip device. This manual switch shall actuate the final trip device(s) through not more than one level of isolated device.

(d) Bed temperature high trip prevents unit damage for excessive temperature.

(e) Bed temperature low and warm-up burner flame not proven (item 8) is the equivalent of a no boiler flame detection signal in a conventional boiler. It is interlocked to activate the master fuel trip device.

6-3.1.5 Each source of operation of the master fuel trip device shall actuate a "cause of trip" indication that will tell the operator the initiating cause of the tripping impulse.

6-3.1.6 In all cases following a master fuel trip, operator initiation of fuel input to the unit shall be required.

NOTE: Additional information for Blocks No. 1, 2 and 3 are on Figure 2, 3 and 4 respectively.

Figure 1 Fluidized Bed Boiler Safety Interlocks

Figure 2 Fluidized Bed Boiler Purge Logic

Figure 3 Warm-Up Burner Safety Logic
Chapter 7 Alarm System

7-1 Functional Requirements.

7-1.1 The functional requirement of the alarm system is to bring a specific abnormal condition to the attention of the operator. Alarms may be used to indicate equipment malfunction, hazardous conditions, and misoperation. For the purpose of this standard, the primary concern is with alarms that indicate abnormal conditions that may lead to impending or immediate hazards.

7-1.2 Alarm systems shall be designed so that for the alarm required by 7-2.1 the operator receives audible as well as visual indication of the abnormal condition. Means may be provided to silence the audible alarm, but the visual indication shall remain until the condition has been returned to normal.

7-1.3 The design shall make it difficult to manually defeat the alarm and, where equipment malfunction makes this necessary, it shall be done by authorized personnel and the alarm shall be tagged as inoperative.

7-2 System Requirements.

7-2.1 Required Alarms. In addition to the safety features of the interlock system, the separately annunciator alarms in 7-2.1(a) through (m) shall be provided.

(a) Burner Atomizing Steam or Air Pressure (Low). For steam or air assisted burners, an alarm shall be provided to warn that steam or air pressure and oil pressure is outside of operating range and poor oil atomization may result.

(b) Burner Fuel Header Pressure (High and Low). The burner fuel header pressure shall be monitored as close to the burners as possible in order to warn the operator of high or low pressure in advance of conditions that lead to a trip.

(c) Solid Fuel Feeder Tripped. Alarm when a feeder has tripped (not normal shutdown).

(d) Solid Fuel Transport Air Fan Tripped. Alarm when a transport air fan has tripped (not normal shutdown).

(e) Solid Fuel Pluggage. Alarm when the feeder is running and the fuel flow detecting device downstream of the feeder indicates no fuel flow.

(f) Furnace Pressure High or Low. It warns the operator of furnace pressure outside the region of normal operation and an approach to a trip condition.

(g) Loss of any Operating FD Fan. This shall be sensed and alarmed only when the fan is supposed to be running and it is not.

(h) Loss of Operating ID Fan. This shall be sensed and alarmed only when the fan is supposed to be running and is not.

(i) Boiler Air Flow (Low). This shall be sensed and alarmed when total air flow falls below purge rate.

(j) Loss of Interlock Energy. This shall be sensed and alarmed and shall include all sources of energy required to complete interlock functions. For example, if both a 125 VDC electric circuit and a compressed air circuit are required for an interlock scheme, then loss of either shall be annunciated separately.

(k) Loss of Control Energy. This shall be sensed and alarmed to include all sources of energy for the combustion control and fluidized bed boiler safety interlocks.

(l) Bed Temperature Out of Limits. The bed temperature shall be monitored and alarmed when it drifts out of the normal operating range and approaches a trip condition (not on shutdown).

(m) Ash Cooler Discharge Material Temperature High. Alarm when the material temperature about to be discharged from the ash cooler reaches a predetermined high limit.

Chapter 8 Referenced Publications

8-1 The following documents or portions thereof are referenced within this document and shall be considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

8-1.1 NFPA Publications. National Fire Protection Association, Batterymarch Park, Quincy, MA 02269.

NFPA 85A-1987, Standard For Explosion Prevention - Single Burner Boiler Furnaces Oil or Gas Fired or Simultaneous Firing of Oil and Gas.


NFPA 85D-198#, Standard for Prevention of Furnace Explosions in Fuel Oil-Fired Multiple Burner Boiler-Furnaces.


NFPA 86-1985, Standard for Ovens and Furnaces.
PART II

NFPA 85I - 1 - (Entire Document): Accept

SUBMITTER: Technical Committee on Boiler-Furnace Explosions

RECOMMENDATION: Establish a new document NFPA 85I, Recommended Practice for Stoker Operation, for the installation, design and operation of stoker fixed boilers.

SUBMISSION: It is the feeling of the Committee that special guidance is needed for those individuals involved with the installation of these units. The increased use of solid fuels such as coal, wood and refuse dry fuel in stoker fixed units may present some new situations that other NFPA 85 series standards do not cover.

COMMITTEE ACTION: Accept.

NFPA 85I
Recommended Practice for Stoker Operation
1988 Edition

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, refuse-dried fuel and other solid fuels in stoker-equipped units with a heat input rate greater than 400,000 Btu/hr. 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 85 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 85A, B, D or E except for purge requirements 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.

1.2 Purpose.

1.2.1 While this document applies especially to units that have been placed in operation subsequent to December, 1988, its use can be helpful with units placed in operation earlier.

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

1.2.3 Emphasis is placed upon 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, which 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 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 upon 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 examples 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) The accumulation of an explosive mixture of fuel and air as a result of loss of flame or incomplete combustion.

(e) 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).

(f) Purging with too high an air flow, which stirs up combustibles smoldering in hoppers.

(g) 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 of other situations. 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 enclosure, 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 their 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 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 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 Although this practice suggests a minimum degree of automation, the trend toward more complex plants with increased automation requires added provisions for:

(a) Information about significant operating events, which permits the operator to make a rapid evaluation of the situation.

(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.

2-3.1 The boiler should not be released for operation before the installation and checkout of the safeguards and instrumentation system.

(a) The constructor responsible for the erection and installation of the equipment should see that all pertinent apparatus is properly installed and connected.

(b) 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.

(c) 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 system and devices during 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.

2-5.1 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. When 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 checklists for operator guidance should be provided for achieving these basic operating objectives. All manual and automatic functions should be described.

Chapter 3 Definitions

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.

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 provide 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
material, moving in a vertical plane as it is rolled.

onto the grate.

which no air passes and on which coal is placed for burning, and through which air is passed for combustion.

Specifications for Classification of Coal by Rank.)

classifications are subbituminous, bituminous and anthracite. (For greater detail, see ASTM 0388-66, Specifications for Classification of Coal by Rank.)

compressed and indurated, finally altering into graphite and graphite-like material. Coal contains carbon, hydrogen, oxygen, nitrogen and sulphur, as well as inorganic constituents that form ash after burning. There is no standard coal, but almost endless variety as to character and composition. Starting with lignite (brown coal) at one extreme, the other basic classifications are subbituminous, bituminous and anthracite. (For greater detail, see ASTM D388-66, Specifications for Classification of Coal by Rank.)

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.

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

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.
Agitation or ash removal.

Reciprocating motion, usually for the purpose of fuel

where it is burned, after which it discharges the

which fuel is conveyed into and through the furnace

Purging may also be accomplished by an

effectively remove any gaseous combustibles and replace

passages and associated flues and ducts, which will

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.

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

tabled 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.

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. A device that senses and alarms a condition

requiring attention, without initiating 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.

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 (20.1 and 55.9 MJ/m³), the majority

averaging 1000 Btu per cu ft (37.3 MJ/m³).

Overfeed Stoker. A stoker in which fuel is fed onto

grates above the point of air admission to the fuel

bed. Overfeed stokers include:

(a) Front Feed, Inclined Grate. A stoker in which

fuel is fed from the front onto a grate inclined

downwards toward the rear of the stoker.

(b) Chain or Traveling Grate. A stoker having 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 stoker 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, which will

effectively remove any gaseous combustibles and replace

them with air. Purging may 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.

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 be 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.

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 Feed Grate Stoker. A stoker in which fuel is

furnished to the grate from the side of the grate.

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 stokers include:

(a) Stationary Grate. A stoker in which fuel is fed

to a fixed position grate.

(b) Dump Grate. A stoker in which fuel is fed onto a

nonmoving grate that is arranged to allow

intermittent discharge of refuse through lifting action

of the grate bars.

(c) Continuous Ash Discharge or Traveling Grate. A

stoker in which fuel is fed onto a moving endless grate

which conveys the fuel into and through the furnace

where it is burned, after which it discharges the

refuse.

Stable Flame. A flame envelope that retains its

continuity throughout the maximum rate of load change

within the operating range of the boiler.

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, which motivate the

normal automatic combustion control system, are not

available or suitable.

Stationary Grate. A grate having no moving parts.

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, as

follows:

(a) A side ash discharge underfeed stoker is 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) A rear discharge underfeed stoker is 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) A continuous ash discharge underfeed stoker is one 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 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 Coals" are subdivided into five groups. Group 1 "Low Volatile Bituminous Coal" has fixed carbon limits greater than 78 percent or less than 86 percent; Group 2 "Medium Volatile Bituminous Coal" has fixed carbon limits greater than 69 percent or less than 78 percent; Group 3 "High Volatile A" Bituminous Coal" has a fixed carbon quantity of less than 69 percent and greater than 64,000 Btu/lb 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 15,000 Btu/lb and less than 14,000 Btu/lb. 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 13,000 Btu/lb when it is commonly agglomerating, and a calorific value limit equal to or greater than 10,500 Btu/lb but less than 11,500 Btu/lb 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 but less than 11,500 Btu/lb. Group 2 "Sub-Bituminous B" Coal" has a calorific value limit equal to or greater than 9,500 Btu/lb but less than 10,500 Btu/lb. Group 3 "Sub-Bituminous B" Coal" has a calorific value equal to or greater than 8,300 Btu/lb but less than 9,500 Btu/lb.

4-1.2.4 Class IV "Lignite Coal" is divided into two groups. Group 1 "Lignite A" has a calorific value limit equal to or greater than 6,300 Btu/lb and less than 6,800 Btu/lb. Group 2 "Lignite B" has a calorific value less than 6,300 Btu/lb.

4-1.3 Sizing.

4-1.3.1 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 breakdown during mixing processes and in handling. Western subbituminous coals are considered friable and are generally delivered to the boiler with high percentages of particles less than 1/4 in. These can be burned satisfactorily using the correct equipment. The 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. 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 Guide for Stoker Firing of Bituminous Coal. Means should be provided for the delivery of coal to the stoker hopper without size segregation.

4-2 Peat.

4-2.1 Peat is a high-moisture fuel characterized by high volatile matter typically 50-70 percent on a dry ash-free basis. The harvesting of peat bog includes air drying to a moisture less than 50 percent, which allows it to be burned on stokers with preheated air.

4-3 Wood.

4-3.1 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.

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 undue 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 moisture contents 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 overflow spreader stokers.

4-4 Municipal Waste.

4-4.1 Municipal waste is burned with stokers in two forms - one known as RDF or "refuse derived fuel," which is delivered without preparation. This is normally burned as a deep fuel bed on an underfeed mass burning-type stoker specially constructed for this service. The other form of municipal waste is known as RBF 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 overflow 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. Pulsaions from concentrations of extremely volatile wastes may also result.

4-5 Other Waste

4-5.1 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 may be called for. 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 underfeed 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 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, suspension, in mass, etc.

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4-6.1.2 Some solid fuels have a high moisture content. For instance, bark has a moisture content of 35 percent to 40 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 manufacturers' recommendations.

4-6.2 Specific Fuels

4-6.2.1 Bagasse is the portion of sugar cane left over after sugar is extracted. It consists of cellulose fibers and fine particles.

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 (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 large amounts of cardboard, plastics, and other synthetic materials. Typical components of RDF are paper and paper products, plastics, wood, rubber, solvents, oils, paints, and other organic materials.

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

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

Chapter 5 Equipment

5-1 Single or Multiple Retort Underfeed Stoker. (See Figure 1).

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 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 (under grate air plenum) by means of a forced draft fan (under grate 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. Ash is typically manually removed either from an ash pit or directly from the sides of the grate. If removed from the ash pit, a dump grate is used. Ash removal is accomplished through ash doors on the front of the unit.

Cross-Sectional View of Single Retort Underfeed Stoker in Operation. (Reprinted with Permission of Detroit Stoker Company)
5-2 Overfeed Mass Burning Stoker. Overfeed mass burning stokers will encompass not only the 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 square foot of effective air admitting grate area. Maximum grate heat release rates per foot of stoker width should be $9.0 \times 10^6$ Btu/hr per linear foot of stoker width without arches and $10.8 \times 10^6$ Btu/hr per linear foot 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 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 2). 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 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.

These stokers are mainly used for medium-sized industrial boilers with loads 30,000 lbs steam/hr to 125,000 lbs steam/hr. Coal sizing should be 1 in. x 0 in. with approximately 20 percent to 50 percent passing through a 1/4 in. round mesh screen. This stoker will handle such fuels as bituminous coals, anthracite coals, coke breeze, subbituminous coals and lignite. This stoker produces low particulate emission.

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. (See Figure 3) or 7 with coal tempering.

5-2.11 Vibrating Grate Stoker. (See Figure 3) 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 ash at the ash discharge end.

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.

These stokers are mainly used for medium-sized industrial boilers with loads 50,000 lbs steam/hr to 100,000 lbs steam/hr. They are designed to burn low-ranking coals. Coal sizing should be 1 in. x 0 in. with approximately 20 percent to 50 percent through a 1/4 in. round mesh screen.

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

5-2.12 MSW Stoker. (See Figure 4). The grate in an incinerator stoker resembles a staircase that 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.

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

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 system 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.

This stoker is currently used for medium-sized boilers with loads 20,000 lbs steam/hr to 250,000 lbs steam/hr.

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.

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 to 6000 Btu/lb.

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

5-3.1 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 grate. Theoretically, equal energy is released from each square foot of active grate area. To accomplish this equal energy release, it is necessary for one to have even fuel distribution over the grate surface and secondly, even air flow through the grates from the air plenum to the grate surface.

There are five spreader stoker grate types in general use today. The first type is a traveling grate with a continuous forward moving grate having the return portion 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. The dumping grate is seldom supplied today. The fifth grate type is the stationary grate, which is typically used for low-ash fuels.

The spreader stoker contains fuel feeders that are located in the front wall in sufficient quantity to assure 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.

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.

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 burn-out of volatiles and carbon particles.

Spreader stokes are utilized on boilers having steam rates from 20,000 lbs of steam/hr up to 600,000 lbs of steam/hr, depending upon 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 subbituminous 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 ignitable 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. 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 air flow 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.

(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 furnace pressure.

2. Adequate, properly placed observation ports should be provided to permit inspection of the furnace and grate.

3. 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.

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.

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 NFPA 85G standard, modified, or simplified to fit the application.

The use of protection control loops is encouraged. The provisions of NFPA 85G 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.

5-5 Combustion Control System.

5-5.1 Functional Requirements.

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

5-5.1.2 It 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.

(a) Furnace input should be controlled to respond to the energy demand under all operating conditions.

(b) 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.

(c) When changing the rate of furnace input, the air flow 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 air flow control on automatic without the other also being on automatic should be discouraged.

(d) Furnace draft should be maintained at the desired set point in the combustion chamber.

(e) A means should be provided to prevent the control system from demanding a fuel-rich mixture.

(F) A means of permitting as much on-line maintenance of the combustion control equipment as possible should be provided.
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.

5-6.4 The flue gas analyzer may be used as an operating aide. Caution may be used in interpreting the readings.

Chapter 6 Operation

6-1 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.

6-1.1 Start-Up Procedures.

(a) Prior to starting ID fans verify an open flow path from the inlet of the 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) Fill feeder hopper with fuel, start feed mechanism and establish a bed of fuel on the grate.
(c) 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.
(d) Open furnace access door, light a torch and ignite wood by passing torch through the door.
(e) When wood on bed of fuel is burning, start ID fan, if not in operation, and place in automatic mode of operation.
(f) 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.
(g) When fuel bed is actively burning, start FD fan with dampers at minimum position.
(h) Start fuel feed. Observe operation and adjust fuel rate and air as required until boiler steam pressure is at normal operating pressure.

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

6-1.2 Operation of auxiliary fuel burners may be required when starting up and firing high moisture fuel.

6-1.3 If a boiler is equipped with auxiliary gas or oil burners, it is possible to put the boiler on line using this auxiliary fuel and then feed the solid fuel upon the grate, which will ignite from radiant heat of the auxiliary burners. Care should be taken to protect the grate from overheating.

6-1.4 Start-up procedure 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.

6-2 Normal Operation.

6-2.1 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.

6-2.2 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 9.8).

6-2.3 Manual adjustments to the individual rows of overfire turbulence air nozzles for maximum furnace efficiency and minimum emission discharge may be required.

6-2.4 Fuel should be fed to maintain an even depth of ash discharge. As the present ash in the fuel changes, it may be necessary to make adjustments for changes in ash quantity percentages in the fuel. It is necessary to observe this condition from the depth of ash coming off the discharge end of the grates.

6-3 Normal Shutdown.

6-3.1 Normal shutdown procedure is as follows:

(a) Manually reduce the boiler load to minimum normal load.
(b) Fuel shut-off 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) When the fire is burned out, after fuel feed ceases, the overfire air and forced draft fan can be shut off or left running depending on the desired rate of boiler cool-down.
(f) If the forced draft fan is shut off, ensure that a natural draft flow of air through the grates is provided.
(g) 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.
(h) 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.

6-4 Normal Hot Start.
6-8.1 When it is desired to restart the unit after it has been shut down, and grate burning has stopped, follow cold start procedure - Section 6-1(d) through (g) and 6-1.1(a) to (i). If grate fire is continuing, follow the Cold Start Procedure - Section 6-1.1(a) through (i).

6-5 Emergency Shutdown.

6-5.1 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 a normal shutdown.

6-5.2 Loss of the induced draft fan would require that the uptake damper go into the full open position, the fuel feed immediately shut off, and the induced draft fan shutdown. 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 will be required.

7 Maintenance

7-1 Maintenance Objective.

7-1.1 The objective of a maintenance program is to identify and correct conditions relating to the safety, reliability, and efficiency of the 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.

7-2.1 An effective maintenance program should include the areas listed below:

(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 make-shift repairs.

7-3 Equipment Inspections.

7-3.1 In-Service Inspections.

7-3.1.1 In-service inspection of equipment should be done on a continual basis to evaluate operation and abnormal conditions that need corrective action.

7-3.2 Shutdown Inspection.

7-3.2.1 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.

7-4.1 Several areas of stoker-fired boilers routinely require maintenance attention. These are listed below:
7-4.1.1 Under Grate 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 grate 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 bypassing around the fuel bed and to distribute air properly between zones.

7-4.1.2 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.

7-4.1.3 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.

7-4.1.4 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 hangup. 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.

7-4.1.5 Tuyeres. Air tuyeres must be checked for plugging and burnout. These are necessary for proper air sealing and feeder cooling.

7-4.1.6 Overfire air and cinder return nozzles must be checked for plugging and burnout.

7-4.1.7 Air Dampers. Air dampers should be checked for proper stroke and position.

7-4.1.8 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 and 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 and videotapes, programmed instruction, testing, field training, 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, or contaminants, or oxygen-deficient atmosphere, internal pressures, and limited access or confined space requirements should be included.

8-2.3 Procedure 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.

9-1.1 Protective clothing including but not limited to hard hats and safety glasses shall 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 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 shall be developed and used for personnel entering confined spaces which shall:

(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 shall be made.

(f) Provide 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) Provide for use of proper safety belts or harnesses, which shall 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 shall 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 shall 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 shall 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 shall review with the safety attendant and the workmen the scope of the job and safety procedures to be followed.

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

9-3.5 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 prohibited until the atmosphere returns to safe limits. Sufficient retests shall be made during the course of the work to ensure a safe atmosphere; and if it is not maintained, the bunker shall be evacuated.

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

9-3.7 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 life line. The life line shall be secured to an adequate support above the person and shall have only sufficient slack to permit limited movement necessary to performance on the job. The life line shall be manila rope at least 1/2 in. (12.7 mm) in diameter, or equivalent, in good condition.

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

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

9-3.10 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.

9-3.11 Full-face respirators or respirators and goggles shall be worn when dust conditions require them, as directed by the responsible supervisor or the safety attendant.

9-4 Housekeeping.

9-4.1 Good housekeeping is essential for safe operations. This includes 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.

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

9-5 Welding and Flame Cutting.

(See also NFPA 51, "Oxygen-Fuel Gas Systems for Cutting and Welding," and NFPA 51B, "Fire Prevention in Use of Cutting and Welding Processes").

9-5.1 Fire-resistant blankets or other approved methods shall 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, shall 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 dusts or dust clouds are present, sparking electrical tools shall not be used. All lamps shall be suitable for Class II, Division 1 locations as defined in NFPA 70-1978 (ANSI), National Electrical Code.

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

9-7 Furnace Inspection.

9-7.1 Prevent personnel from entering the furnace until slag deposits have been removed. Care must be exercised to protect personnel from falling objects.

9-7.2 On overfeed mass burning stokers, the feed gate should be blocked open to prevent accidental dropping of the gate.

9-8 On-Line Maintenance.

9-8.1 Extreme care must 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.

9-9 Access Doors.

9-9.1 Proper protective clothing and face shield should be used while viewing the furnace through access doors and while manipulating the fuel/ash bed.

9-9.2 The furnace draft should be increased before access doors are opened to prevent any potential blowback.

9-10 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.

9-10.1 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.

9-10.2 Care should be taken when opening ash hopper access doors after shutdown. Hot or smoldering fly ash which 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 Ash Handling.

9-11.1 Hazards associated with ash handling include high temperature materials and dust. Appropriate protective equipment should be utilized.

9-12 Finely Divided Solid Fuels.

9-12.1 Characteristics of finely divided solid fuel approach those of pulverized fuel. Care must be taken in the handling of these to prevent accumulations that could ignite spontaneously.

9-12.2 These fuels must 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 document 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. These references are listed separately to facilitate updating to the latest edition by the user.


NFPA 70-1987, National Electrical Code

NFPA 85A-1987, Standard for Explosion Prevention - Single Burner Boiler Furnaces Oil or Gas Fired or Simultaneous Firing of Oil and Gas.


NFPA 85G-1987, Standard for Prevention of Furnace Implosions in Multiple Burner Boiler-Furnaces

10-1.2 Other Publications. The following publication is available from the American Boiler Manufacturers Association, 950 N. Glebe Road, Arlington, VA 22203.

ABMA Recommended Design Guidelines for Stokers Firing Bituminous Coal