NFPA 85

Boiler and Combustion Systems Hazards Code

2001 Edition

NFPA, 1 Batterymarch Park, PO Box 9101, Quincy, MA 02269-9101
An International Codes and Standards Organization

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NFPA 85

Boiler and Combustion Systems Hazards Code

2001 Edition

This edition of NFPA 85, *Boiler and Combustion Systems Hazards Code*, was prepared by the Technical Committees on Fluidized Bed Boilers, Fundamentals of Combustion System Hazards, Heat Recovery Steam Generators, Multiple Burner Boilers, Pulverized Fuel Systems, Single Burner Boilers, and Stoker Operations, released by the Technical Correlating Committee on Boiler Combustion System Hazards, and acted on by the National Fire Protection Association, Inc., at its November Meeting held November 12–15, 2000, in Orlando, FL. It was issued by the Standards Council on January 13, 2001, with an effective date of February 9, 2001, and supersedes all previous editions.

This edition of NFPA 85 was approved as an American National Standard on February 9, 2001.

Origin and Development of NFPA 85

This document originated as a compilation of the following six standards:

NFPA 8501, *Standard for Single Burner Boiler Operation*

NFPA 8502, *Standard for the Prevention of Furnace Exposions/Implosions in Multiple Burner Boilers*

NFPA 8503, *Standard for Pulverized Fuel Systems*

NFPA 8504, *Standard on Atmospheric Fluidized-Bed Boiler Operation*

NFPA 8505, *Standard for Stoker Operation*

NFPA 8506, *Standard on Heat Recovery Steam Generator Systems*

This document has been organized to provide common requirements in the first chapter, Fundamentals of Boiler Combustion System. Subsequent chapters cover the specific requirements for each of the boiler and combustion systems covered by this document.

Technical Correlating Committee on Boiler Combustion System Hazards (BOI–AAC)

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

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Committee Scope: This Committee shall have primary responsibility for documents on the operation and reduction of combustion system hazards and the prevention of boiler furnace explosions of fluidized-bed boilers. This includes all fuels at any heat input rate.

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Committee Scope: This Committee shall have primary responsibility for documents or portions of documents on fundamentals, maintenance, inspection, training, and safety for the reduction of combustion system hazards. Fundamentals shall specifically include definitions, furnace explosion/implosion prevention, manufacture, design and engineering, installation, coordination of design, construction and operation, basic operating objectives, equipment requirements, and commissioning.

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Committee Scope: This Committee shall have primary responsibility for documents covering the operation of heat recovery steam generators and the related reduction of combustion system hazards and prevention of boiler furnace explosions. This includes all fuels at any heat input rate.

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Committee Scope: This Committee shall have primary responsibility for documents covering the reduction of combustion system hazards and the prevention of boiler furnace explosions and implosions in multiple burner boilers with a heat input rate of 12,500,000 Btu/hr and above. This includes all fuels.

Technical Committee on Pulverized Fuel Systems (BOI–PFS)

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Robert Christianson, Stone & Webster Engr Corp., CO [SE]
David A. Cowdrick, Tampa Electric Co., FL [U]
John C. deRuyter, DuPont Co., DE [U]
Michael B. Doherty, American Electric Power Service Corp., OH [U]
Rory G. Eastman, ABB Alstom Power, CT [M]
Kenneth L. Gardner, Svedala Industries, Inc., PA [M]
Walter E. Keiser, GA Power Co., GA [U]
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Committee Scope: This Committee shall have primary responsibility for documents on the operation and design requirements of pulverized fuel systems and reduction of hazards associated with those systems. This includes all carbonaceous solid fuels at any heat input rate.

Technical Committee on Single Burner Boilers (BOI–SBB)

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Courtney D. Alvey, Baltimore, MD [SE]
Thaddeus Bukowski, Underwriters Laboratories Inc., IL [RT]
John M. DeLacy, Coen Co., CA [M]
Lee J. Doran, Nat'l Board of Boiler & Pressure Vessel Inspectors, OH [E]
Robert M. Herdman, ABB Combustion Engr Services, Inc., CT [M]
Thomas L. Oakey, Procter & Gamble Co., OH [U]
Glenn A. Raney, Premier Consulting & Engr, TX [SE]
Gary J. Shrider, Babcock & Wilcox, OH [M]
Jacques van Heijningen, Siemens Building Technologies, Inc., IL [M]
J. A. "Red" Wagner, Fireye, NJ [M]
Jeff C. Williams, Jr., American Risk Consultants Corp., GA [I]
Peter J. Gore Willse, Industrial Risk Insurers, CT [I]
Steven J. Young, Honeywell, Inc., MN [M]

Alternates

Raymond J. Heitland, Solutia Inc., FL [U]
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Committee Scope: This Committee shall have primary responsibility for documents on the reduction of combustion system hazards and the prevention of boiler furnace explosions in single burner boilers with a heat input rate of 12,500,000 Btu/hr and above. This includes all fuels.

Technical Committee on Stoker Operations (BOI–STO)

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Andrew K. Dant, Cogentrix Energy, Inc., NC [U]
John C. deRuyter, DuPont Co., DE [U]
Thomas B. Hamilton, Hamilton Consulting Services, NC [SE]
John Hoh, Nat'l Board of Boiler and Pressure Vessel Inspectors, OH [E]
Gerald E. McCullion, Honeywell, Inc., GA [M]

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

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Boiler and Combustion Systems Hazards Code

2001 Edition

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

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

Chapter 1 Fundamentals of Boiler Combustion Systems

1.1* Scope.

1.1.1 This code shall apply to the design, installation, operation, training, and maintenance as they relate to the safety of combustion systems as defined in 1.1.1 through 1.1.7.

1.1.2 This code shall apply to single burner boilers, multiple burner boilers, stokers, and atmospheric fluidized bed boilers with a fuel input rating of 12.500 MBtu/hr (3.663 MW) or greater, to pulverized fuel systems, and to fired or unfired steam generators used to recover heat from combustion turbines [heat recovery steam generators (HRSGs)].

1.1.3 This code shall cover strength of the structure, operation and maintenance procedures, combustion and draft control equipment, safety interlocks, alarms, trips, and other related controls that are essential to safe equipment operation.

1.1.4 Process heaters used in chemical and petroleum manufacture, wherein steam generation is incidental to the operation of a processing system, shall not be covered by this code.

1.1.5 This code shall apply to new installations and to major alterations or extensions that are contracted for subsequent to the effective date of this code.

1.1.6* This code shall not be retroactive.

1.1.7 Coordination of the design and operating procedures of the boiler furnace or HRSG system and any flue gas cleanup systems downstream of the post-combustion gas passes shall be required. Such coordination shall include requirements for ensuring a continuous flow path from the combustion air inlet through the stack.

1.2 Purpose.

1.2.1* The purpose of this document shall be to contribute to operating safety and to prevent uncontrolled fires, explosions, and implosions in equipment described in 1.1.2.

1.2.2 This code shall establish minimum requirements for the design, installation, operation, training, and maintenance of pulverized fuel systems, boilers, HRSGs, and their systems for fuel-burning, air supply, and combustion products removal.

1.2.3 The code shall require the coordination of operating procedures, control systems, interlocks, and structural design.

1.2.4 This code shall not be used as a design handbook. A designer capable of applying more complete and rigorous analysis to special or unusual problems shall have latitude in the development of such designs. In such cases, the designer shall be responsible for demonstrating and documenting the validity of the proposed design.

1.3 Definitions. The definitions contained in Section 1.3 shall apply to the terms used in this document. Where terms are not defined in Section 1.3, common usage of the term shall apply.

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

1.3.2 Air.

1.3.2.1 Auxiliary Air. Air that is supplied from an auxiliary source to maintain a minimum fuel mixture velocity in burner piping.

1.3.2.2 Combustion Air. Air used to react with the fuel in the combustion process. For duct burners, this generally is combustion turbine exhaust.

1.3.2.3* Excess Air. Air supplied for combustion in excess of theoretical air.

1.3.2.4 Overfire Air. Air supplied for combustion that is admitted into the furnace at a point above the burners or fuel bed.

1.3.2.5 Primary Air. Air supplied for combustion that is admitted into the furnace through a burner pre-mixed with the fuel.

1.3.2.5.1 Primary Air (in Bubbling Fluidized Bed). That portion of total air used to transport or inject fuel or sorbent and to recycle material to the bed.

1.3.2.5.2 Primary Air (in Circulating Fluidized Bed). That portion of total air introduced at the base of the combustor through the air distributor.

1.3.2.5.3 Primary Air (in an HRSG). The air that is contained in the combustion turbine exhaust.

1.3.2.5.4 Primary Air (in Pulverized Fuel System). In a pulverized fuel system, may be either air or a flue gas/air mixture, and may simultaneously also be pulverizer air and/or transport air.

1.3.2.6 Pulverizer Air. Air or inert gas that is introduced into the pulverizer to dry the fuel, aid in pulverization and classification, and convey the pulverized fuel from the pulverizer.

1.3.2.7 Seal Air. Air or inert gas supplied to any device at sufficient pressure for the specific purpose of minimizing contamination.

1.3.2.8 Secondary Air. Air for combustion supplied to the burners or fuel bed in addition to the primary air.

1.3.2.8.1 Secondary Air (in a Bubbling Fluidized Bed). That portion of the air introduced through the air distributor.

1.3.2.8.2 Secondary Air (in a Circulating Fluidized Bed). That air that enters the combustor at levels above the air distributor.

1.3.2.8.3 Secondary Air (in a Single or Multiple Burner Boiler). That portion of the air entering through the air registers.

1.3.2.9 Tempering Air. Cool air added to the hot primary air or gas to modify its temperature.

1.3.2.10 Theoretical Air. The chemically correct quantity of air needed for complete combustion of a given quantity of a specific fuel.

1.3.2.11 Transport Air. Air or inert gas that is used to convey pulverized fuel.

1.3.2.11.1 Transport Air (in a Fluidized Bed). The air used to convey or inject solid fuel or sorbent or to recycle material.

1.3.2.12 Undergrate Air. Combustion air introduced below the grate.

1.3.3 Air Change. A quantity of air, provided through the burner, that is equal to the volume of furnace and boiler gas passes.

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

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

1.3.6 Alteration. A change or modification that results in a deviation from the original design specifications or criteria.

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

1.3.8* Approved. Acceptable to the authority having jurisdiction.

1.3.9 Atmospheric Fluidized-Bed Combustion. A fuel-firing technique using a fluidized bed operating at near-atmospheric pressure on the fire side.

1.3.10 Atomizer. The device in a burner that breaks down liquid fuel into a finely divided state.

1.3.10.1 Mechanical Atomizer. The device in a burner that breaks down liquid fuel into a finely divided state without using an atomizing medium.

1.3.11 Atomizing Medium. A supplementary fluid, such as steam or air, that assists in breaking down liquid fuel into a finely divided state.

1.3.12 Augmented Air Firing. In an HRSG, supplementary firing with the addition of air at the duct burners to support and stabilize combustion or to reduce emissions.

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

1.3.14* Autoignition Temperature. The minimum temperature required to initiate or cause self-sustained combustion of a solid, liquid, or gas independently of the heating or heated element.

1.3.15 Bed Compartment. Segments of a fluidized bed, which might be individually controlled with respect to combustion airflow and fuel feed.

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

1.3.17 Bed Material. Granular particles that compose a fluidized bed.

1.3.18 Bed Temperature. The average temperature of a fluidized bed.

1.3.19 Bin. An enclosure to store pulverized fuel.

1.3.20 Bin System (Storage System). A system in which the fuel is pulverized and stored in bins from which it is withdrawn through feeders, as needed, for burning.

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

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

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

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

1.3.25 Bunker. An enclosure to store raw fuel.

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

1.3.26.1 Auxiliary Load-Carrying Burner. In a fluidized bed boiler, a burner whose primary purpose is load carrying, located over the bed and having its own air supply.

1.3.26.2 Duct Burner. A burner, mounted in a duct, used to heat air or combustion turbine exhaust gas.

1.3.26.3 Over Bed Burner. In a fluidized bed boiler, a warm-up burner located above the bed and firing over or into the bed.

1.3.26.4 Warm-Up Burner (Warm-Up Gun). A burner, usually smaller than the main burner, that is ignited by another ignition source and is used to warm up the boiler. In cases where it is used as an igniter, its classification shall be verified by test.

1.3.26.4.1 Warm-Up Burner (in a Fluidized Bed Boiler). A burner having its own air supply used to warm up the bed to the ignition temperature of the main fuel. The warm-up burner also can be used for limited load carrying.

1.3.27* Burner Management System. The control system dedicated to combustion safety and operator assistance in the starting and stopping of fuel preparation and burning equipment and for preventing misoperation of and damage to fuel preparation and burning equipment.

1.3.27.1 Automatic Burner Management System — Nonrecycling. A burner management system by which a furnace is purged and a burner is started, ignited, and stopped automatically but does not recycle automatically.

1.3.27.2 Automatic Burner Management System — Recycling. A burner management system by which a furnace is purged and a burner is started, ignited, and stopped automatically and recycles on a preset pressure range.

1.3.27.3 Manual Burner Management System. A burner management system by which a furnace is purged and a burner is started, ignited, and stopped manually.

1.3.27.4 Manual, Supervised, Burner Management System. A burner management system by which a furnace is purged and a burner is started, ignited, and stopped manually. Interlocks are included to ensure that the operation follows established, proper procedures.

1.3.28 Bypass Stack. A stack applied in addition to and separate from the normal HRSG exhaust stack that allows combustion turbine exhaust gas to flow independently to the atmosphere.

1.3.29 Calcination. The endothermic chemical reaction that takes place when converting calcium carbonate or calcium hydroxide to calcium oxide.

1.3.30 Calcium to Sulfur Molar Ratio (Ca/S). The ratio of the total moles of calcium in the sorbent fed to the boiler to the total moles of sulfur in the fuel fed to the boiler.

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

1.3.32 Cinder Return. In a stoker-fired boiler, an apparatus for the return of collected cinders to the furnace, either directly or with the fuel.

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

1.3.34 Classifier. A device to control pulverized fuel particle size distribution.

1.3.35 Coal. See 1.3.72.2, Coal Fuel.

1.3.36* Code. A standard that is an extensive compilation of provisions covering broad subject matter or that is suitable for adoption into law independently of other codes and standards.

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

1.3.38 Combustion Chamber. The portion of the boiler or HRSG enclosure into which the fuel is fed, ignited, and burned.

1.3.39 Combustion Turbine. A turbine in which the rotating element is actuated by the pressure of combustion gases on curved vanes.

1.3.40 Commercial Operation. The date that the full plant capacity is formally added to the power grid.

1.3.41 Commissioning. The time period of plant testing and operation between initial operation and commercial operation.

1.3.42 Confined Space. Any work location or enclosure in which either of the following exists: (a) the dimensions are such that a person who is 6 ft (1.8 m) tall cannot stand up in the middle of the space or extend his or her arms in all directions without hitting the enclosure, (b) access to or from the enclosure is by manhole, hatch, port, or other relatively small opening that limits ingress and egress to one person at a time. Confined spaces include but are not limited to the following: pulverizers, ducts, heaters, windboxes, cyclones, coal dust collectors, furnaces, bunkers, bins and HRSGs.

1.3.43 Continuous Trend Display. A dedicated visual display of an operating trend(s) by any instrument such as a cathode ray tube (CRT), chart recorder, or other device to quantify changes in the measured variable(s).

1.3.44 Control System.

1.3.44.1 Boiler Control System. The group of control systems that regulates the boiler process, including the combustion control system but not the burner management system.

1.3.44.2 Combustion Control System. The control system that regulates the furnace fuel and air inputs to maintain the air/fuel ratio within the limits that are required for continuous combustion and stable flame throughout the operating range of the boiler in accordance with demand. In a fluidized bed, the control system that regulates the furnace fuel input, furnace air input, bed inventory, and other bed heat transfer mechanisms to maintain the bed temperature and the air/fuel ratio within the limits necessary for continuous combustion and stable bed operation throughout the operating range of the boiler in accordance with demand. In HRSG systems, the control system that regulates the fuel input and air, where applicable, to maintain continuous combustion and stable flame. These control systems include drum level, desuperheater spray, or furnace draft control where applicable.

1.3.44.3 HRSG Control System. The group of control systems that regulate the HRSG process, including the combustion control system but not the burner management system.

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

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

1.3.46 Damper. A mechanical device that introduces a variable resistance for regulating, blocking, or switching the volumetric flow of gas or air.

1.3.46.1 Shutoff Damper. A close-fitting damper to prevent flow and minimize leakage of air or flue gas into any system component.

1.3.47 Direct Fired System (Unit System). A system in which the fuel is pulverized and delivered in suspension directly to the burner(s).

1.3.48 Directional Blocking. An interlock that, upon detection of a significant error in furnace pressure or HRSG process variables, acts to inhibit the movement of all appropriate final control elements in the direction that would increase the error.

1.3.49 Distributor/Divider. A device that splits a single stream of pulverized coal and primary air into two or more streams.

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

1.3.51 Drip Leg. A chamber of ample volume, with suitable cleanout and drain connections, over which fuel gas is passed so that liquids and solids are trapped.

1.3.52 Dump Plate. In a stoker-fired furnace, an ash-supporting plate from which ashes may be discharged from one side of the plate by rotation of the plate.

1.3.53 Dust Collector. An auxiliary separator that is used to separate the fuel dust from the air or inert gas prior to discharge of the latter from the system.

1.3.54 Elutriation. The selective removal of fine solids from a fluidized bed by entrainment in the upward flowing products of combustion.

1.3.55 Exhauster. See 1.3.58.1, Exhauster Fan.

1.3.56 Explosive Mixture. A flammable or combustible mixture in a confined space.

1.3.57 False Start. A condition where the combustion turbine fails to complete its ignition sequence (failure to start) and can result in unburned fuels entering the HRSG enclosure.

1.3.58 Fan.

1.3.58.1 Exhauster Fan. A fan located at the pulverizer outlet used to draw the primary air through the pulverizer and to deliver the primary air/fuel mixture to the burner(s) or other apparatus.

1.3.58.2 Forced Draft Fan. A device used to pressurize and supply ambient air to the combustion chamber to support combustion. In a fluidized-bed boiler, FD fans generally include both primary air and secondary air fans.

1.3.58.3 Induced Draft Fan. A device used to remove the products of combustion from the boiler or HRSG by introducing a negative pressure differential.

1.3.58.4 Primary Air Fan. A fan used to supply coal transport air to the pulverizer or to the burner lines of a storage system.

1.3.58.5 Seal Air Fan. A fan used to supply sealing air.

1.3.59 Fan Test Block Capability. The point on the fan head versus flow characteristic curve at which the fan is selected. This is the calculated operating point associated with the maximum continuous rating of the boiler or HRSG, plus the head and flow margins.

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

1.3.61 Feed-Forward Signal. A signal used to anticipate a change in the measured variable.

1.3.62 Fixed Grate. A grate that does not have movement.

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

1.3.64 Flame Detector. A device that senses the presence or absence of flame and provides a usable signal.

1.3.64.1 Self-Checking Flame Detector. A flame detector that automatically, and at regular intervals, tests the entire sensing and signal processing system of the flame detector.

1.3.65 Flame Envelope. The confines (not necessarily visible) of an independent process that converts fuel and air into products of combustion.

1.3.66 Fluidize. To maintain a bed of finely divided solid particles in a mobile suspension by blowing air or gas through the bed at such a velocity that the particles separate and behave much like a fluid.

1.3.67 Fluidized Bed. A bed of granular particles maintained in a mobile suspension by the velocity of an upward flow of air or gas.

1.3.68 Fly Carbon Reinjection. In a stoker-fired boiler, the process of removing the coarse carbon-bearing particles from the particulate matter carried over from the furnace and returning the carbonaceous material to the furnace to be combusted.

1.3.69 Freeboard. In a fluidized bed boiler, the space or volume above the upper surface of the bubbling bed and below the entrance to the convection pass.

1.3.70 Fresh Air Mode. The operation of an HRSG with atmospheric instead of combustion turbine exhaust.

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

1.3.72 Fuel.

1.3.72.1 Auxiliary Fuel. In a fluidized bed boiler, generally a gaseous or liquid fuel used to warm the bed material sufficiently to allow ignition of the main fuel upon injection into the heated bed material.

1.3.72.2 Coal Fuel. A solid fuel classified as lignite, subbituminous, bituminous, or anthracite as defined by ASTM D 388, *Standard Classification of Coals by Rank.*

1.3.72.3 Pulverized Coal Fuel. Coal that is reduced to a size such that at least 50 percent can pass through a 200-mesh (74 microns) sieve.

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

1.3.72.5 JP4 Fuel. A light, volatile fuel with a boiling point between gasoline and light distillate. Its properties are defined in MIL-T-5624, *Turbine Fuel, Aviation, Grade JP4, JP5, and JP5/JP8 ST,* and are similar to ASTM D 1655, *Standard Specification for Aviation Turbine Fuels (Jet B),* and ASTM D 2880, *Standard Specification for Gas Turbine Fuel Oils.*

1.3.72.6 Kerosene Fuel. A light, highly refined fuel that is slightly more volatile than No. 2 fuel oil. Its properties are defined in ASTM D 396, *Standard Specification for Fuel Oils (No. 1);* ASTM D 1655, *Standard Specification for Aviation Turbine Fuels (Jet A);* or ASTM D 2880, *Standard Specification for Gas Turbine Fuel Oils.*

1.3.72.7 LP-Gas Fuel. A material that is composed predominantly of any of the following hydrocarbons or mixtures of them: propane, propylene, n-butane, isobutane, and butylenes.

1.3.72.8 Main Fuel. In a fluidized bed boiler, gaseous, liquid, or solid fuel introduced into the bed after the bed temperature has reached a value sufficient to support its combustion and that is used during the normal operation of the boiler. Main fuels necessitate the use of the fluidized hot bed as their ignition source.

1.3.72.9 Municipal Solid Waste (MSW). Untreated solid waste material as collected from households and commercial establishments; it is highly variable in appearance, density, and heating value.

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

1.3.72.11 Oil Fuel. Liquid fuels defined as Grades 2, 4, 5, and 6 in ASTM D 396, *Standard Specification for Fuel Oils,* or as Grade 2GT in ASTM D 2880, *Standard Specification for Gas Turbine Fuel Oils.*

1.3.72.12 Pulverized Fuel. Solid fuel that is reduced to a size such that at least 50 percent will pass through a 200-mesh (74 microns) sieve.

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

1.3.72.14 Supplementary Fuel. Fuel burned to supply additional heat to the steam generator or to support combustion.

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

1.3.74 Fuel Trip. The automatic shutoff of a specific fuel as the result of an interlock or operator action.

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

1.3.76 Gas. See 1.3.72.7, LP-Gas Fuel, and 1.3.72.10, Natural Gas Fuel.

1.3.77 Gate.

1.3.77.1 Raw Fuel Gate (Silo Gate; Bunker Gate). A shutoff gate between the raw-fuel bunker and the raw-fuel feeder.

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

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

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

1.3.79 Grindability. The characteristic of solid fuel that indicates its relative ease of pulverization (as defined by ASTM D 409, *Standard Test Method for Grindability of Coal by the Hardgrove-Machine Method*).

1.3.80 Header. A pipe or duct through which liquid or gas is conveyed and supplied to or received from multiple branches.

1.3.81 Heat Recovery Steam Generator (HRSG). A heat exchanger that uses a series of heat transfer sections (e.g., superheater, evaporator, and economizer) positioned in the exhaust gas flow of a combustion turbine to recover heat and supply a rated steam flow at a required temperature and pressure.

1.3.81.1 HRSG Enclosure. All ductwork from the combustion turbine exhaust through the steam generator to the stack, including any bypass duct connection.

1.3.81.2 HRSG Purge. See 1.3.119.1, Combustion Turbine Purge; 1.3.119.2, Duct Burner (HRSG) Purge; and 1.3.120, Purge Rate.

1.3.81.3 HRSG System. The unit assembly from the combustion turbine inlet to the flue gas outlet to the atmosphere.

1.3.82 Hogged Fuel. See 1.3.72.4.

1.3.83 Igniter. A permanently installed device that provides proven ignition energy to light off the main burner.

1.3.83.1 Class 1 Igniter. An igniter that is applied to ignite the fuel input through the burner and to support ignition under any burner light-off or operating conditions. Its location and capacity are such that it will provide sufficient ignition energy, generally in excess of 10 percent of full load burner input, at its associated burner to raise any credible combination of burner inputs of both fuel and air above the minimum ignition temperature.

1.3.83.2 Class 2 Igniter. An igniter that is applied to ignite the fuel input through the burner under prescribed light-off conditions. It is also used to support ignition under low load or certain adverse operating conditions. The range of capacity of such igniters is generally 4 percent to 10 percent of full load burner fuel input.

1.3.83.3 Class 3 Igniter. A small igniter applied particularly to gas and oil burners to ignite the fuel input to the burner under prescribed light-off conditions. The capacity of such igniters generally does not exceed 4 percent of the full-load burner fuel input.

1.3.83.4 Class 3 Special Igniter. A special Class 3 high energy electrical igniter capable of directly igniting the main burner fuel.

1.3.84 Inert Gas. A gas that is noncombustible, nonreactive, and incapable of supporting combustion with the contents of the system being protected.

1.3.85 Initial Operation. The first coordinated operation of the unit.

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

1.3.87 JP4. See 1.3.72.5, JP4 Fuel.

1.3.88 Kerosene. See 1.3.72.6, Kerosene Fuel.

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

1.3.90 Lance. A device, without its own air supply, that provides fuel input directly into a fluidized bed.

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

1.3.92 Light-Off Time Limit Timer. A device that is used on supervised manual burner management systems and limits the allowable time between completion of purge and light-off.

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

1.3.94 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 the pressure existing in the solid's storage area. Also, a letdown device that incorporates a double pressure seal, thus enabling solids to be withdrawn from a system with a higher pressure than that existing downstream of the lock hopper.

1.3.95 Logic System. The decision-making and translation elements of the burner management system. A logic system provides outputs in a particular sequence in response to external inputs and internal logic. Logic systems are comprised of the following: (a) hardwired systems — individual devices and interconnecting wiring — and (b) microprocessor-based systems — (1) Computer hardware, power supplies, I/O devices, and the interconnections among them; and (2) Operating system and logic software.

1.3.96 Low Fire. The minimum fire rate that results in stable combustion.

1.3.97 LP-Gas. See 1.3.72.7, LP-Gas Fuel.

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

1.3.99* Master Fuel Trip. An event resulting in the rapid shutoff of all fuel, including igniters; for HRSGs, an event resulting in the rapid shutoff of all fuel to the duct burners, including igniters.

1.3.100 Master Fuel Trip Relay. An electromechanical relay(s) utilized to trip all required equipment simultaneously when a master fuel trip is initiated.

1.3.101 Minimum Fluidization Velocity. In a fluidized bed, the lowest velocity sufficient to cause incipient fluidization.

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

1.3.103 Natural Gas. See 1.3.72.10, Natural Gas Fuel.

1.3.104 Oil. See 1.3.72.11, Oil fuel.

1.3.105 Open Flow Path. A continuous path for movement of an airstream from the forced draft fan inlet to the stack; in an HRSG, a continuous path for movement of an airstream through the HRSG system.

1.3.106 Open Register Light-Off Procedure. A procedure for purging and lighting off a boiler under specified, controlled conditions.

1.3.107 Operating Range. The range between the maximum fuel input and minimum fuel input within which the burner flame can be maintained in a continuous and stable manner.

1.3.108 Overfire Air Port. An opening in a furnace wall to enable the introduction of an overfire airstream.

1.3.109 Override Action, Fan. A control that, upon detection of significant error in combustion chamber pressure, acts to reposition the induced draft fan control device(s) in a direction to reduce the error.

1.3.110 Partial Loss of Flame. Loss of flame at any of the separate flame envelopes or burners while flame is maintained at any of the other flame envelopes or burners.

1.3.111 Positive Means. The physical methods of satisfying a requirement.

1.3.112 Postpurge. A purge performed after the burner(s) is shut down.

1.3.113 Pressure/Air Lock. A device for transferring pulverized fuel between zones of different pressure without permitting appreciable flow of air or gas in either direction.

1.3.114 Primary Air Fan (Pulverizer Air Fan). See 1.3.58.4, Primary Air Fan.

1.3.115 Prove. To establish by measurement or test the existence of a specified condition such as flame, level, flow, pressure, or position.

1.3.116 Pulverized Fuel. See 1.3.72.12.

1.3.117 Pulverized Fuel Pump. A device or system for transporting fuel mechanically or pneumatically by utilizing minimum airflow.

1.3.118 Pulverizer. A machine for reducing the particle size of a solid fuel so that it burns in suspension.

1.3.119 Purge. A flow of air or an inert medium at a rate that will effectively remove any gaseous or suspended combustibles and replace them with air.

1.3.119.1 Combustion Turbine Purge. A flow of air at purge rate through the combustion turbine and the appropriate portion of the HRSG enclosure for a sufficient number of volume changes that effectively removes any gaseous or suspended combustibles and replaces them with the purging medium.

1.3.119.2 Duct Burner (HRSG) Purge. A flow of combustion turbine exhaust gas or air at purge rate through the HRSG enclosure for a sufficient number of volume changes that effectively removes any gaseous or suspended combustibles and replaces them with the purging medium.

1.3.120 Purge Rate. A constant flow of purging medium at sufficient velocity to achieve a purge.

1.3.121 Reburn. The process of admitting fuel downstream of the main burners to create a fuel-rich zone where chemical reactions reduce NO_x to molecular nitrogen.

1.3.122 Reburn Injector. A device that introduces fuel without combustion air into a furnace for the purpose of reducing NO_x emissions from the furnace.

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

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

1.3.125 Recycle. A single burner boiler start-up that is initiated by steam pressure or water temperature following a normal shutdown.

1.3.126 Recycle Rate. In a fluidized bed, the rate at which a mass of material is reinjected into the bed. This value is often expressed as the ratio of the amount being reinjected to the total amount being elutriated from the fluidized bed.

1.3.127 Recycle Ratio. In a fluidized bed, the mass of material being reinjected into the bed divided by the mass of fuel being fed into the bed.

1.3.128 Refuse-Derived Fuel (RDF). See 1.3.72.13.

1.3.129 Register (Burner Air). A set of dampers for a burner or air supply system to a particular burner used to distribute the combustion air admitted to the combustion chamber. Frequently controls the direction and velocity of the airstream for efficient mixing with the incoming fuel.

1.3.130 Reinjection. In a fluidized bed boiler, the return or recycling of material removed or carried from the furnace back to the furnace. Also refers to fly ash collected and returned to the furnace or combustion chamber, sometimes expressed as a percent of the total collected.

1.3.131 Remote Operation. Control from a location removed from the combustion area.

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

1.3.133 Repeatability. The ability of a device to maintain a constant set point characteristic.

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

1.3.135 Restart. A manually initiated start-up.

1.3.136 Runback, Combustion Turbine. The controlled unloading of a combustion turbine to a level required by HRSG or other equipment control demands.

1.3.137 Safety Shutdown Trip Relay. See 1.3.100, Master Fuel Trip Relay.

1.3.138 Safety Shutoff Valve (Safety Trip Valve). A fast-closing valve that automatically and completely shuts off the gaseous or liquid fuel supply to the main burner(s) or to the igniter(s) in response to a normal or a safety shutdown signal.

1.3.139 Scavenging. The procedure by which liquid fuel left in a burner or igniter after a shutdown is cleared by admitting steam or air through the burner passages, typically through a dedicated scavenging medium valve.

1.3.140 Selective Catalytic Reduction (SCR). A method of reducing NO_x in flue gas.

1.3.141 Semifluidized. In a fluidized bed boiler, the state in which a uniform flow of air that is less than that necessary to fluidize the bed is admitted and is found to be sufficient to adequately remove gaseous combustibles.

1.3.142 Service Connection. A point at which fuel, an atomizing medium, or power is connected to the firing equipment or controlled devices.

1.3.143 Set Point. A predetermined value to which a device or system is adjusted and at which it performs its intended function.

1.3.144 Shall. Indicates a mandatory requirement.

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

1.3.146 Shutdown.

1.3.146.1 Emergency Shutdown (HRSG). An event resulting in the rapid shutoff of all fuel to the combustion turbine along with a master fuel trip.

1.3.146.2 Normal Shutdown. Stopping burner operation by shutting off all fuel and ignition energy to the combustion equipment.

1.3.146.3 Safety Shutdown (Single Burner Boiler). Stopping burner operation by shutting off all fuel and ignition energy to the furnace.

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

1.3.148 Sorbent. In a fluidized bed boiler, a constituent that reacts with and captures a pollutant or, more generally, a constituent that reacts with and captures another constituent.

1.3.149 Soot Blower. A mechanical device for introducing steam, air, or water to clean heat-absorbing surfaces.

1.3.150 Spent Bed Material. In a fluidized bed boiler, material removed from the bed generally comprised of reacted sorbent, calcined limestone, ash, and solid, unburned combustibles. For some applications, the spent bed material might also contain some inert material, such as sand.

1.3.151 Stable Bed. In a fluidized bed boiler, a bed of granular material that maintains sustained combustion at a desired temperature.

1.3.152 Stable Flame. A flame envelope that retains its continuity throughout the maximum rate of change within the operating range of the boiler, burner, or HRSG.

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

1.3.154 Steam Generator. A pressure vessel in which water is converted to steam or steam is superheated, or in which any combination thereof takes place.

1.3.155 Steam Generator Capacity. The manufacturer's stated steam output rate over a period of time for which the steam generator is designed to operate.

1.3.156 Steam Generator Enclosure. The physical boundary for all steam generator pressure parts and the combustion process.

1.3.157 Stoker.

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

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

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

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

1.3.157.5 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.

1.3.157.6 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.

1.3.157.7 Overfeed Stoker. A stoker in which fuel is fed onto grates above the point of air admission to the fuel bed. Overfeed stoker grates include the following: (a) *Front Feed, Inclined Grate* — Fuel is fed from the front onto a grate inclined downward toward the rear of the stoker; (b) *Chain or Traveling Grate* — A moving endless grate that conveys fuel into and through the furnace where it is burned, after which it discharges the refuse; (c) *Vibrating Grate* — An inclined vibrating grate in which fuel is conveyed into and through the furnace where it is burned, after which it discharges the refuse.

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

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

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

1.3.157.11 Single Retort Stoker. An underfeed stoker using one retort only in the assembly of a complete stoker.

1.3.157.12 Spreader Stoker. A stoker that distributes fuel into the furnace from a location above the fuel bed with a portion of the fuel burned in suspension and a portion on the grates. Spreader stoker grates include the following: (a) *Stationary Grate* — A grate in which fuel is fed onto a fixed position grate; (b) *Dump Grate* — A grate in which fuel is fed onto a nonmoving grate that is arranged to allow intermittent discharge of refuse through tilting action of the grate bars; (c) *Continuous Discharge or Traveling Grate* — A grate that continuously discharges the refuse from the end after burning the fuel.

1.3.157.13 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.

1.3.157.14 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.

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

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

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

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

1.3.158 Stoker Gate. 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 is controlled. It is generally used in connection with chain or traveling grate stokers and has the form of a guillotine.

1.3.159 Sulfation. The exothermic chemical reaction that takes place when calcium oxide unites with oxygen and sulfur dioxide to form calcium sulfate.

1.3.160 Sulfur Capture. The molar fraction of sulfur in the fuel input that is "captured" by calcium oxide to form calcium sulfate.

1.3.161 Sulfur Reacted. In a fluidized bed, the fraction of the total sulfur in the fuel fed to the bed that is converted to sulfur dioxide or calcium sulfate.

1.3.162 Sulfur Retention. The molar ratio of the total sulfur in the fuel minus the sulfur leaving the unit as sulfur dioxide to the total sulfur in the fuel.

1.3.163 Supervise. To sense and indicate a condition requiring attention and to automatically initiate corrective action.

1.3.164 Supplementary Firing. The provision of duct burners in an HRSG to increase the temperature of the combustion turbine exhaust gases.

1.3.165 Switch.

1.3.165.1 Normal Shutdown, High Steam Pressure, Switch. A pressure-actuated device that is arranged to effect a normal burner shutdown when the steam pressure exceeds a preset pressure.

1.3.165.2 Normal Shutdown, High Steam Temperature, Switch. A temperature-actuated device that is arranged to effect a normal burner shutdown when the water temperature exceeds a preset temperature.

1.3.165.3 Process Monitoring, High Oil Temperature, Switch. A temperature-actuated device that initiates a signal when oil temperature rises above the limits that are required to maintain the viscosity range recommended by the burner manufacturer.

1.3.165.4 Process Monitoring, Low Oil Temperature, Switch. A temperature-actuated device that initiates a signal when the oil temperature falls below the limits that are required to maintain the viscosity range recommended by the burner manufacturer.

1.3.165.5 Safety Shutdown, Excessive Steam Pressure, Switch. A pressure-actuated device that is arranged to effect a safety shutdown of the burner when the steam pressure exceeds a preset pressure.

1.3.165.6 Safety Shutdown, Excessive Water Temperature, Switch. A temperature-actuated device that is arranged to effect a safety shutdown of the burner when the water temperature exceeds a preset temperature.

1.3.165.7 Safety Shutdown, High Gas Pressure, Switch. A pressure-actuated device that is arranged to effect a safety shutdown or to prevent starting when the gas pressure exceeds the preset value.

1.3.165.8 Safety Shutdown, Low Gas Pressure, Switch. A pressure-actuated device that is arranged to effect a safety shutdown or to prevent starting when the gas pressure falls below the preset value.

1.3.165.9 Safety Shutdown, Low Oil Pressure, Switch. A pressure-actuated device that is arranged to effect a safety shutdown or to prevent starting when the oil pressure falls below the preset value.

1.3.165.10 Safety Shutdown, Low Water Cutout, Switch. A device that is arranged to effect a safety shutdown or master fuel trip when the water level in the boiler or HRSG falls to a predetermined low level.

1.3.165.11 Safety Shutdown, Low Water Cutout, Auxiliary Switch. On single burner boilers, a device that is arranged to effect a safety shutdown of the burner when the water level in the boiler falls to a predetermined low level.

1.3.166 Trial-for-Ignition Period (Igniter). The interval of time during light-off in which a safety control circuit permits the igniter fuel safety shutoff valve(s) to be opened before the flame detection system is required to supervise the igniter flame.

1.3.167 Trial-for-Ignition Period (Main Burner). The interval of time during light-off in which a safety control circuit permits the main burner fuel safety shutoff valve(s) to be opened before the flame detection system is required to supervise the main burner flame only.

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

1.3.169 Unattended Operation. A means of operation where the operator is not in view of operating instrumentation (local or remote), nor in a position to operate control systems.

1.3.170 Unit. The combined spaces of the furnace and the associated boiler passes, ducts, and fans that convey the gases of combustion to the stack; for HRSGs, the combined spaces of the combustion turbine, the HRSG, and the associated ducts that convey the air and combustion gases from the air intake to the stack.

1.3.171 Valve.

1.3.171.1 Barrier Valve. A valve, not necessarily dusttight, used to inhibit hot gases from traveling back into any system component open for inspection or maintenance.

1.3.171.2 Burner Shutoff Valve. In a pulverized fuel system, a valve that is installed in the fuel line between the pulverizer and the burner.

1.3.171.3 Charging Valve. In a gaseous or liquid fuel system, a small valve bypassing the main safety shutoff valve used for purging and charging the fuel headers and piping and for testing for leaks.

1.3.171.4 Check Valve. A self-operating valve that is used to prevent reverse flow through any portion of the system.

1.3.171.5 Dusttight Valve. In a pulverized fuel system, a tight-seating valve installed in the fuel supply pipe to the burner to allow or stop flow.

1.3.171.6 Flow Control Valve. A valve capable of regulating quantity of through-put to a controlled range.

1.3.171.7 Safety Shutoff Valve (Fuel Trip Valve). In a gaseous or liquid fuel system, a fast-closing valve that automatically and completely shuts off the fuel supply to main burners or igniters in response to a fuel trip.

1.3.171.8 Supervisory Shutoff Valve. In a gaseous or liquid fuel system, a manually operated shutoff valve with a means to provide a "valve closed" position signal.

1.3.171.9 Vent Valve. A valve used to allow venting of air or gas from the system to the atmosphere.

1.3.171.10 Vent Control Valve. A controllable valve for regulating the flow of vented air or gas from the system.

1.3.172 Valve-Proving System. In a gaseous or liquid fuel system, a system that proves the leak tightness of all safety shutoff valves and prevents main burner or igniter light-off if the test is not satisfied.

1.3.173 Vent, Explosion. An outlet through which air or gas can be discharged from the system to relieve explosion pressures.

1.3.174 Volatile Matter. The portion of mass, except water vapor, that is driven off in a gaseous form when solid fuels are heated.

1.3.175 Watch-Dog Timer, External. A timer external to a microprocessor based control that is used to compare the microprocessor cycle timing against itself and that fails safely if the microprocessor timing stops or exceeds the watch-dog time interval.

1.4* Manufacture, Design, and Engineering.

1.4.1 The owner or the owner's representative shall, in cooperation with the manufacturer, ensure that the unit is not deficient in apparatus that is necessary for operation with respect to pressure parts, fuel-burning equipment, air and fuel metering, light-off and maintenance of stable flame.

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

1.4.3* An evaluation shall be made to determine the optimum integration of manual and automatic safety features.

1.4.4 Although this code requires a minimum degree of automation, more complex plants, plants with increased automation, or plants designed for remote operation shall require additional provisions for the following:

(1) Information regarding significant operating events that allow the operator to make a rapid evaluation of the operating situation
(2) Continuous and usable displays of variables that allow the operator to avoid hazardous conditions
(3) In-service maintenance and checking of system functions without impairment of the reliability of the overall control system
(4) An environment conducive to timely and correct decisions and actions

1.4.5 The burner or fuel feed piping and equipment shall be designed and constructed to prevent the formation of hazardous concentrations of combustible gases that exist under normal operating conditions.

1.5 Installation.

1.5.1 The party responsible for the erection and installation of the equipment shall ensure that all apparatus is installed and connected in accordance with the system design.

1.5.2 The owner or owner's representative, the engineering consultant, the equipment manufacturer, and the operating company shall not operate the system until the safeguards have been tested and operated as a system.

Exception: If temporary interlocks and instrumentation are necessary to meet these requirements, any such temporary system shall be reviewed by the owner or owner's representative, the engineering consultant, the equipment manufacturer, and the operating company, and agreement shall be reached on its suitability in advance of start-up.

1.5.3 The safety interlock system and protective devices shall be tested jointly by the organization responsible for the system design and those who operate and maintain such a system and devices during the operating life of the plant. These tests shall be completed before initial operation.

1.5.4 Documentation of the plant equipment, the system, and maintenance activities shall be accurately updated to reflect changes in the status of equipment and operating procedures.

1.6 Coordination of Design, Construction, and Operation.

1.6.1* During the planning and engineering phases of plant construction, the design shall be coordinated with operating personnel.

1.6.2* The integration of the various components, including boiler or HRSG, burner, fuel and air supply equipment, controls, interlocks and safety devices, operator and maintenance functions, and communication and training, shall be the responsibility of the owner and the operating company.

1.7 Maintenance, Inspection, Training, and Safety.

1.7.1* Maintenance and Equipment Inspection.

1.7.1.1* A program shall be provided for inspection and maintenance of equipment at intervals consistent with the type of equipment used, service requirements, and manufacturers' recommendations.

1.7.1.2 As a minimum, the maintenance program shall include the following:

(1) In-service inspections to identify conditions that need corrective action
(2) Well-defined planning for making repairs or modifications using qualified personnel and tools and instruments designed for the work
(3) An equipment history and record of date of service, conditions found, maintenance performed, and changes made
(4) Written comprehensive maintenance procedures incorporating the manufacturer's instructions to define the tasks and skills required
(5) Nondestructive examination requirements; tasks needing special tools; special environmental factors such as temperature limitations, dusts, contaminated or oxygen-deficient atmospheres, and limited access or confined space restrictions
(6) Equipment condition assessment before and after maintenance
(7) A supply of well-maintained spare parts to perform required maintenance
(8) Housekeeping essential for safe operation and prevention of fires or explosions.
    a. Provision shall be made for cleaning of horizontal ledges or surfaces of buildings and equipment to prevent the accumulation of dust deposits greater than the minimum required to create an explosion hazard.
    b. Water washing or vacuum cleaning methods shall be used to reduce the possibility of creating dust clouds. Compressed air shall not be used for cleaning.

1.7.1.3 Operation, set points, and adjustments shall be verified by testing at specified intervals, and the results shall be documented.

1.7.1.4 Defects shall be reported and corrected, and the changes or repairs documented.

1.7.1.5 System configuration, including logic, set points, and sensing hardware, shall not be changed without a detailed engineering review and documentation.

1.7.1.6 System operation shall be verified for compliance with this code whenever a controller is replaced, repaired, or updated.

1.7.1.7 When a unit that fires liquid fuel is out of service and available for inspection, personnel shall check for any accumulation of unburned fuel in the boiler or HRSG enclosure, especially in the fin-tube area of an HRSG.

1.7.2 Training.

1.7.2.1 Operator Training.

1.7.2.1.1* The owner or the owner's representative shall be responsible for establishing a formal training program to prepare personnel to operate equipment. The training program shall be consistent with the type of equipment and hazards involved.

1.7.2.1.2 Operating procedures shall be established that cover normal and emergency conditions. Start-up, shutdown, and lockout procedures shall all be covered in detail. Where different modes of operation are possible, procedures shall be prepared for each operating mode. Procedures also shall be prepared for switching from one mode to another.

1.7.2.1.3 The owner or owner's representative shall verify that operators are trained and competent to operate the equipment under all conditions prior to their operation of such equipment.

1.7.2.1.4 The owner or owner's representative shall be responsible for retraining operators, including reviewing their competence, at intervals determined by the owner.

1.7.2.1.5 The training program and operating manuals shall be kept current with changes in equipment and operating procedures. The training program and manuals covering operation and maintenance procedures shall be available for reference and use at all times.

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

1.7.2.2 Maintenance Training.

1.7.2.2.1* The owner or owner's representative shall be responsible for establishing a formal and ongoing program for training maintenance personnel to perform all required maintenance tasks. The training program shall be consistent with the equipment and hazards involved.

1.7.2.2.2 Maintenance procedures and their associated training programs shall be established to cover routine and special techniques. Environmental factors such as temperature, dusts, contaminated or oxygen-deficient atmospheres, internal pressures, and limited access or confined space requirements shall be included.

1.7.2.2.3 Maintenance procedures shall be consistent with safety requirements and the manufacturer's recommendations and shall be kept current with changes in equipment and personnel.

1.8 Basic Operating Requirements.

1.8.1 Operating procedures with a minimum number of manual operations shall be established.

1.8.2 Standard operating procedures that result in well-defined and controlled operations shall be established.

1.8.3 Interlocks shall be provided to ensure correct operating sequences and to interrupt sequences when conditions are not correct for continuation.

1.8.4 No interlocks shall be bypassed during start-up or operation of the unit unless the bypass is tagged and is governed by operating procedures.

1.8.5* Purge and start-up procedures with necessary interlocks shall be established.

1.8.6 Written operating procedures and detailed checklists for operator guidance shall be provided for achieving all automatic and manual operating functions.

1.9 Equipment Requirements.

1.9.1* Structural Design. The furnace shall be capable of withstanding a transient design pressure without permanent deformation due to yield or buckling of any support member.

1.9.1.1* For all boilers other than fluidized bed boilers, the positive transient design pressure shall be at least, but shall not be required to exceed, +35 in. of water (+8.7 kPa). For fluidized bed boilers the requirements of 4.4.1.1 shall apply.

Exception: For all boilers other than fluidized bed boilers, if the test block capability of the forced draft fan at ambient temperature is less positive than +35 in. of water (+8.7 kPa), the positive transient design pressure shall be at least, but shall not be required to exceed, the test block capability of the forced draft fan.

1.9.1.2* The negative transient design pressure shall be at least as negative as, but shall not be required to be more negative than, −35 in. (−8.7 kPa) of water.

Exception: If the test block capability of the induced draft fan at ambient temperature is less negative than −35 in. of water (−8.7 kPa), for example, −27 in. of water (−6.72 kPa), the negative transient design pressure shall be at least as negative as, but shall not be required to be more negative than, the test block capability of the induced draft fan.

1.9.2* Functional Requirements of Fuel-Burning System.

1.9.2.1 Function. The fuel-burning system shall function to convert continuously any ignitable input into unreactive products of combustion at the same rate that the fuel(s) and air reactants enter the combustion chamber.

1.9.2.2 Compatibility. The fuel-burning system shall be sized to meet the operating requirements of the unit, compatible with other component systems, and capable of being controlled for the full operating range of the unit.

1.9.2.3 System Requirements.

1.9.2.3.1 The fuel-burning system shall provide means for start-up, operation, and shutdown of the combustion process. This shall include openings and configurations in the component assemblies to allow observation, measurement, and control of the combustion process.

1.9.2.3.2 The fuel-burning system consists of the boiler or HRSG enclosure and the following subsystems, as applicable: air supplies, fuel supplies, main fuel burning, ignition, and combustion products removal and reinjection. Each shall be sized and interconnected to meet the following requirements:

(a) Boiler enclosure or HRSG enclosure

(1) The enclosure shall be sized and arranged with respect to the main fuel-burning subsystem so that stable flame is maintained.
(2) The enclosure shall be free from "dead pockets" when prescribed purge procedures are followed.
(3) Observation ports shall be provided to allow visual inspection of the combustion chamber, igniter and burner flames (including the ignition zone), overfire air ports, reburn injectors, and stoker grates.

(b) Air supply subsystem

(1) The air supply equipment shall be sized and arranged to ensure a continuous airflow for all operating conditions on the unit.
(2) The arrangement of air inlets, ductwork, and air preheaters shall be designed to minimize contamination of the air supply by such materials as flue gas, water, and fuel(s). Drain and access openings shall be provided and shall be accessible.
(3) The air supply equipment shall be capable of continuing the required airflow during anticipated combustion chamber pressure pulsations.

(c) Fuel supplies and main fuel-burning subsystems *(Refer to applicable Chapter(s) 2 through 7 for specific systems.)*

(d)*Ignition subsystem

(1) The ignition subsystem shall be sized and arranged to ignite the main burner input within the limitation of the igniter classification. It shall be tested to verify that the igniters furnished meet the requirements of the class specified in the design. Igniters shall be designated as Class 1, Class 2, or Class 3 as defined in 1.3.83.1, 1.3.83.2, and 1.3.83.3 and as verified by test.
(2) Class 1 igniters shall be permitted to be used as Class 2 or Class 3 igniters. Class 2 igniters shall be permitted to be used as Class 3 igniters.
(3) Where Class 2 igniters are used, the burner shall be operated under controlled conditions to limit the potential for abnormal operation, as well as to limit the charge of fuel in the event that ignition does not occur during light-off. They shall not be used to ignite the main fuel under uncontrolled or abnormal conditions.
(4) Where Class 3 igniters are used, the igniter shall be turned off as a part of the burner light-off procedure when the time trial for ignition of the main burner has expired in order to ensure that the main flame is not dependent on ignition support from the igniter.
(5) Class 2 igniters shall not be used to extend the turndown range but shall be permitted to be used to support ignition under low-load or adverse operating conditions.
(6) Class 3 igniters shall not be used to support ignition or to extend the burner turndown range.
(7) Class 3 special igniters shall not be used unless supervision of the individual main burner flame is provided.

Exception: Class 3 special igniters shall be permitted to be used without supervision of the individual main burner flame while scavenging the main burner.

(8) Where Class 1 and Class 2 igniters are used, the tests described in 3.6.3.2.2, 3.7.3.2.2, and 3.8.3.3.2 shall also be performed with the ignition subsystem in service to verify that the igniters furnished meet the requirements of the class specified in the design. This results in extended turndown range when Class 1 igniters are in service and flame is proved.
(9) Tests shall be performed to determine transient limits in the ignition air and fuel supplies or in the main air and fuel supplies that do not extinguish the igniter flame or reduce the igniter's ability to perform its intended function or adversely affect other burners and igniters in operation.
(10) Igniters shall be permanently installed. They shall be supervised to verify that the requirements of 1.9.2.3.2(d)(1) and 1.9.2.3.2(d)(2) are met. This supervision shall include igniter capacity and individual igniter flame monitoring. The capacity shall be measured by igniter header pressure as a minimum.

Exception: On single burner boilers, igniters do not require supervision of igniter capacity.

(11) The ignition equipment shall be located in an environment free of excessive heat and accessible for maintenance.

(12) All igniter safety shutoff valves shall be located to minimize the volume of fuel that is downstream of the valve in the individual igniter fuel lines or that could flow by gravity into the combustion chamber after an emergency shutdown or burner shutdown.

(e) Combustion products removal subsystem

(1) The flue gas ducts, fans, and stack shall be sized and arranged to remove the products of combustion at the same rate at which they are generated by the fuel-burning process during operation of the unit.
(2) Drain and access openings shall be provided and shall be accessible.
(3) The flue gas ducts shall be designed so that they do not contribute to combustion chamber pulsations.
(4) Components common to more than one boiler or HRSG shall not limit the rate of removal of products of combustion generated during the operation of all boilers or HRSGs.
(5) Boilers that share a common component between the furnace outlet and the stack shall have provisions to bypass the common component for unit purge.

Exception: Where the common component does not contain a possible ignition source, a bypass shall not be required.

1.9.2.3.3 Where multiple boilers are supplied from the same fuel supply source, there shall be a means of manual isolation for each boiler. Dedicated safety shutoff valving, with related alarm, interlock, and control instrumentation, shall also be provided for each boiler.

1.9.2.4 Gaseous Vent System Requirements.

1.9.2.4.1* The discharge from atmospheric vents shall be located so that there is no possibility of the discharged gas being drawn into a combustion air intake, ventilating system, or windows of the boiler or HRSG room or adjacent buildings and shall be extended above the boiler or HRSG and adjacent structures so that gaseous discharge does not present a hazard. Vent sizes shall not be less than the values shown in Table 1.9.2.4.1.

Table 1.9.2.4.1 Vent Line Sizes

Fuel Line Size (NPS)	Minimum Vent Line Size (NPS)
≤1$^1/_2$	$^3/_4$
2	1
2$^1/_2$ to 3	1$^1/_4$
3$^1/_2$	1$^1/_2$
4 to 5	2
5$^1/_2$ to 6	2$^1/_2$
6$^1/_2$ to 7$^1/_2$	3
8	3$^1/_2$
>8	15% of the cross-sectional area of the pipe

1.9.2.4.2 The vent lines from individual burners shall be permitted to be manifolded together. The vent lines from individual igniters shall be permitted to be manifolded together.

Exception No. 1: Burner vents shall not be manifolded with igniter vents or lance vents in any combination.

Exception No. 2: Header vents shall be permitted to be manifolded with other header vents only where they are operated and tripped in parallel.

Exception No. 3: Vents of headers served from different pressure-reducing stations shall not be manifolded.

Exception No. 4: Vent systems of different boilers or HRSGs shall not be manifolded.

Exception No. 5: Vents of systems operating at different pressure levels shall not be manifolded.

Exception No. 6: Vents of systems using different fuel sources shall not be manifolded.

1.9.2.4.3 The cross-sectional area of the manifold line shall not be less than the greater of (1) or (2):

(1) The cross-sectional area of the largest vent plus 50 percent of the sum of the cross-sectional areas of the additional vent lines
(2) The sum of the cross-sectional areas of the two largest vent lines

Exception: Manifold lines for multiple burner boilers shall be permitted to be in accordance with 3.6.3.1.9.

1.9.3 Burner Management System Logic.

1.9.3.1 General Requirements. A logic system provides outputs in a particular sequence in response to external inputs and internal logic. The logic system for burner management shall be designed specifically so that a single failure in that system does not prevent an appropriate shutdown.

1.9.3.2* Specific Requirements. As a minimum, the requirements of 1.9.3.2.1 through 1.9.3.2.7 shall be included in the design to ensure that a logic system for burner management meets the intent of these standards. Alarms shall be generated to indicate equipment malfunction, hazardous conditions, and misoperation. The primary concern is to alarm conditions that pose a threat of impending or immediate hazards.

1.9.3.2.1 Failure Effects. The logic system designer shall evaluate the failure modes of components. As a minimum, the following failures shall be evaluated and addressed:

(1) Interruptions, excursions, dips, recoveries, transients, and partial losses of power
(2) Memory corruption and losses
(3) Information transfer corruption and losses
(4) Inputs and outputs (fail-on, fail-off)
(5) Signals that are unreadable or not being read
(6) Failure to address errors
(7) Processor faults
(8) Relay coil failure
(9) Relay contact failure (fail-on, fail-off)
(10) Timer failure

1.9.3.2.2 Design. The design of the logic system for burner management shall include and accommodate the following requirements:

(1) Diagnostics shall be included in the design to monitor processor logic function.
(2) Logic system failure shall not preclude proper operator intervention.

(3) Logic shall be protected from unauthorized changes.
(4) Logic shall not be changed while the associated equipment is in operation.
(5) System response time (throughput) shall be short to prevent negative effects on the application.
(6) Protection from the effects of noise shall prevent false operation.
(7) No single component failure within the logic system shall prevent a mandatory master fuel trip.
(8) The operator shall be provided with a dedicated manual switch(es) that shall actuate the master fuel trip relay independently and directly. At least one identified manual switch shall be located remotely where it can be reached in case of emergency.

1.9.3.2.3 Requirement for Independence.

(a) The burner management system shall be provided with independent logic, independent input/output systems, and independent power supplies and shall be a functionally and physically separate device from other logic systems, such as the boiler or HRSG control system.

Exception: For single burner boilers, boiler control systems shall be permitted to be combined with the burner management system only if the fuel/air ratio is controlled externally from the boiler control system (e.g., locked fuel/air ratio with mechanical positioning type system).

(b) The burner management safety functions shall include, but shall not be limited to, purge interlocks and timing, mandatory safety shutdowns, trial timing for ignition, and flame monitoring.

(c) The logic system shall be limited to one steam generator only.

(d) The same hardware type used for burner management systems shall be permitted to be used for other logic systems.

(e) Data highway communications between the burner management system and other systems shall be permitted. Signals that initiate mandatory master fuel trips shall be hardwired.

1.9.3.2.4 Momentary Closing of Fuel Values. Logic sequences or devices intended to cause a safety shutdown, once initiated, shall cause a burner or master fuel trip, as applicable, and shall require operator action prior to resuming operation of the affected burner(s). No logic sequence or device shall be permitted that allows momentary closing and subsequent inadvertent reopening of the main or ignition fuel valves.

1.9.3.2.5 Circuit Devices. No momentary contact or automatic resetting device, control, or switch that can cause chattering or cycling of the safety shutoff valves shall be installed in the wiring between the load side (terminal) of the primary or programming control and the main or ignition fuel valves.

1.9.3.2.6 Documentation. Documentation shall be provided to the owner and operator, indicating that all safety devices and logic meet the requirements of the application.

1.9.3.2.7 Programmable Logic Controllers. Programmable logic controllers, if used, shall be monitored by external watchdog timers. If a watchdog timer trips, a master fuel trip for boilers or a duct burner trip for HRSGs shall then occur.

1.9.4 Flame Monitoring and Tripping Systems. Additional requirements concerning flame detection associated with each type of steam generator covered by this code are given in their respective chapters.

1.9.4.1 Functional Requirements. The basic requirements of any flame monitoring and tripping system shall be as follows:

(1) Combustion instability situations shall be brought to the attention of the operator for remedial action.
(2) An emergency shutdown of the involved equipment shall be automatically initiated upon detection of serious combustion problems that will lead to the accumulation of unburned fuel.

1.9.4.2 Flame Detection.

1.9.4.2.1 Flame Detector Sighting. Flame detector sighting shall be a factor in the initial design. Field tests shall be required to establish optimum sighting angles of burners or nozzles and also to check the effective angular range of flame detectors in relation to burners or nozzles.

1.9.4.2.2 Clean Air Supply. Clean air, where necessary, shall be supplied in order to minimize problems with dirty detector lenses.

1.9.4.2.3 Self-Checking of Flame Detectors. Where flame-sensing detectors can fail in the flame-proven mode, self-checking features shall be provided to ensure that the failure of any single component cannot result in a false indication of flame.

1.9.4.2.4* Reduced Emissions Control Effects.

1.9.4.2.4.1 Flame detector selection, sighting, and location shall be reevaluated in accordance with 1.9.4.2 following implementation of methods or installation of equipment to reduce the emission of air pollutants.

1.9.4.2.4.2 When changes made to reduce the emission of air pollutants affect flame characteristics, main burners shall be tested for the limits of stable flame.

1.9.4.3 System Objectives. System objectives shall be developed that include those requirements that are specifically related to the combustion conditions typical for particular combustion chamber configurations, burner or firing systems, and fuel characteristics. Such objectives shall be consistent with the individual manufacturer's design philosophy.

1.9.5* Combustion Control System.

1.9.5.1 Functional Requirements.

1.9.5.1.1 The combustion control system shall regulate the inputs into the combustion chamber to ensure continuous combustion and stable flame under all operating conditions.

1.9.5.1.2 Draft control, where applicable, shall be coordinated with the combustion control system.

1.9.5.1.3 On multiple burner boilers, equipment shall be provided and procedures shall be established to maintain the air/fuel ratio within design limits at each burner. The equipment and procedures shall not be required to be a part of the combustion control system.

1.9.5.1.4 Boiler or HRSG control systems shall be permitted to be combined for more than one boiler or HRSG where separated from the burner management system.

1.9.5.2 System Requirements.

1.9.5.2.1 Under no circumstances shall the airflow demand be less than the purge rate.

Exception: For single burner boilers, airflow demand shall not be reduced below the low limit of the fuel-burning system as determined by the burner manufacturer and verified by operating test.

1.9.5.2.2 The fuel demand shall not increase the fuel input(s) above the available airflow.

1.9.5.2.3 Airflow demand shall not reduce airflow below that required by the actual fuel input(s).

1.9.5.2.4 The fuel demand shall not exceed the capability of the operating draft fans. If the loss or shutdown of a draft fan causes the fuel demand to be greater than the capacity of the fans in service, the fuel(s) shall be rapidly reduced to a value that can be accommodated.

1.9.5.2.5 Measurements used in the combustion control system shall be accurate and reproducible to maintain stable firing conditions. Pressure, temperature, density and/or viscosity corrections shall be employed, as applicable to meet this requirement.

1.9.5.2.6 When multiple fuels are fired, the fuel inputs shall be totalized on the basis of their relative heat values.

1.9.5.2.7 The total heat input to a given burner or combustion zone shall not exceed the maximum limits specified by the boiler or HRSG manufacturer.

1.9.5.2.8* Means shall be provided to enable the operator to adjust the air/fuel ratio for all boilers. The span of the adjustment shall be consistent with the fuel(s) being fired.

1.9.5.2.9 The equipment selection and the design of the combustion control system shall facilitate the on-line calibration, testing, and maintenance requirements described in 1.7.1.

1.9.5.2.10 The rate of increase of reburn fuel injection shall not exceed the response capability of the main combustion control system.

1.9.5.3 Permissives.

1.9.5.3.1 Any logic commands from the burner management system shall take precedence over the combustion control system.

1.9.5.3.2 Where applicable, automatic control of airflow shall not be permitted unless the draft control is maintained in automatic control.

1.9.5.3.3* Automatic control of the fuel input(s) shall not be permitted unless the airflow is maintained in automatic control.

Exception: For HRSGs designed and operated in accordance with Chapter 5, automatic control of fuel inputs is permitted without automatic control of airflow.

1.9.5.3.4 The combustion control system shall neither automatically increase nor decrease a fuel input beyond the fuel-burning system's operating range as determined by the manufacturer and verified by operating test.

1.9.5.3.5 The combustion control system shall not reduce the fuel feed to a pulverizer below the minimum feed rate established by the pulverizer manufacturer for the manufacturer's specified design fuel.

For fuels with ignition characteristics different from the manufacturer's design fuel, the combustion control system shall not reduce the fuel feed rate below the value that ensures stable and self-sustaining combustion at the burners served by the pulverizer. The minimum feed rate shall be determined by operational tests for fuels not conforming to the fuel specifications used by the manufacturer in the design of the pulverizer system.

1.9.6 Power Supplies. Precautions shall be taken to ensure the availability of a failure-free power supply (electric or pneumatic) to all control and safety devices.

1.9.7 Operating Information. As a minimum, continuous trend display of steam flow, feed water flow rate, total fuel flow rate, and total airflow rate as a percentage of the maximum unit load, drum level, final steam temperature, main steam pressure, and furnace or combustion chamber draft shall be simultaneously available at the operating location.

Exception: For single burner package boilers, minimum continuous trend display shall include steam flow, airflow, drum level, steam pressure, and, where applicable, the furnace draft.

1.9.7.1 Alarms and indicators shall be grouped operationally and shall be visible to the operator to allow access to operational devices.

1.9.7.2 All emergency alarm indicators, push buttons, and selector switches shall be visible to the operator and shall be labeled clearly. They shall be protected to avoid inadvertent actuation.

1.9.7.3 All control functions shall be grouped for accessibility and in proximity to their associated alarm and indication devices.

1.9.7.4* Where video display units (VDUs) are used, data shall be displayed on monitor screens in a logical, operational grouping to minimize the number of keystroke operations needed to respond to system upsets. Alarm functions shall be prioritized to appear on the monitor screen upon being sensed, regardless of any information already displayed.

1.10 Commissioning.

1.10.1 The boiler, HRSG, or pulverized fuel system shall not be released for operation before the installation and checkout of the required safeguards and instrumentation system has been successfully completed.

1.10.2 The party responsible for the erection and installation of the equipment shall ensure that all pertinent apparatus is installed and connected in accordance with the system design.

1.10.3 The owner or owner's representative, the engineering consultant, the equipment manufacturer, and the operating company shall prohibit operation until the safeguards have been tested for correct operation as a system.

Exception: If temporary interlocks and instrumentation are necessary to meet these requirements, any such temporary system shall be reviewed by the purchaser, the engineering consultant, the equipment manufacturer, and the operating company, and agreement shall be reached on its ability to protect equipment and personnel in advance of start-up. All temporary modifications shall be documented and permanent resolutions shall be accomplished prior to commercial operation.

1.10.4 The safety interlock system and protective devices shall be tested jointly by the organization responsible for the system design and those who operate and maintain such a system and devices. After installation but before initial operation, coordinated tests of all systems shall be accomplished.

1.10.5 Documentation of the plant equipment, the system, and maintenance activities shall be updated to reflect changes in the status of equipment and operating procedures.

Chapter 2 Single Burner Boilers

2.1 Scope.

2.1.1 This chapter shall apply to single burner boilers with a fuel input rating of 12.500 MBtu/hr (3.663 MW) or greater. This chapter shall apply only to boilers using a single burner that fires the following fuels:

(1) Natural gas as defined in 1.3.72.10.
(2) Other gas having a calorific value and characteristics similar to natural gas
(3) Fuel oil of No. 2, 4, 5, or 6 grade
(4) Gas and oil that are fired simultaneously for fuel transfer
(5) Gas and oil that are fired simultaneously and continuously

2.1.2 This chapter shall be used in conjunction with Chapter 1 and requires the coordination of operation procedures, control systems, interlocks, and structural design. Where conflicts exist, the requirements of Chapter 2 shall apply.

2.2 Purpose. The purpose of this chapter is to establish minimum requirements for the design, installation, operation, and maintenance of single burner boilers, their fuel-burning systems, and related systems to contribute to safe operation and, in particular, to the prevention of furnace explosions.

2.3 Equipment Requirements.

2.3.1 Fuel Supply — Oil.

2.3.1.1 Fuel shall be stored, prepared, and delivered to the oil service connection under anticipated operating conditions in accordance with the applicable portions of NFPA 31, *Standard for the Installation of Oil-Burning Equipment.*

2.3.1.2 Operation of the burner shall not be attempted until a continuous fuel supply is assured.

2.3.1.3 Fuel shall be delivered continuously to the combustion chamber in a finely atomized form that can be ignited readily and consumed.

2.3.1.4 All equipment that is associated with pumping, heating, and straining the fuel from storage to the service connection shall be designed, sized, and interconnected so as to provide a suitable fuel supply over a full range of conditions. Relief valves shall be installed after the pump to prevent overpressure in the system.

2.3.1.5 Fuel being burned shall be delivered to the burner at the temperature and pressure specified by the burner manufacturer.

2.3.1.6 Where the fuel must be heated, the interlocks and instruments shall reflect the correct values of the variable being measured, particularly in dead-end lines where heavy oil will tend to solidify.

2.3.1.7 The operation of a burner system that has the capability to burn heated and unheated oils shall include a procedure to ensure that the specified grade of oil, compatible with the selected mode of operation, is being supplied to the burner. Precautions shall include the intended routing of recirculated oil.

2.3.1.8* Two safety shutoff valves in series, each with proof of closure, shall be provided in the oil line to the main burner. Where pressure can develop in excess of the valve or piping rated pressure(s), the piping design shall include a means to prevent or relieve excess pressure between these valves.

2.3.1.9 Oil piping materials and system design shall be in accordance with NFPA 31, *Standard for the Installation of Oil-Burning Equipment* (for oil piping inside industrial or institutional buildings), or ASME B 31.1, *Power Piping* (for oil piping in power applications), or ASME B 31.3, *Process Piping* (for oil piping in process applications).

2.3.2* Fuel Supply — Gas.

2.3.2.1 The gas supply at the gas service connection shall be controlled at the pressure for which the fuel-burning system had been designed.

2.3.2.2 Gas piping shall be sized to maintain the desired constant pressure for maximum burner flow.

2.3.2.3* Two safety shutoff valves in series, each with proof of closure, shall be provided in the gas line to the main burner. An automatic vent valve shall be provided between the two valves. Where the automatic vent valve is prohibited by the authority having jurisdiction, two safety shutoff valves in series, each with proof of closure switches, supervised by a listed automatic valve-proving system, shall be provided in the gas line to the main burner. Valve proving shall be performed either after every burner shutdown or prior to every burner light-off.

Exception: Elimination of the automatic vent valve from between the two main gas safety shutoff valves shall be permitted when heavier-than-air fuel gases are used.

2.3.2.4 Foreign matter such as welding beads, chips, scale, dust, and debris shall be removed from the gas piping.

2.3.2.5 A drip leg shall be provided in the gas piping. *(Refer to A.2.3.2.3 and A.2.3.4.1.)*

2.3.2.6 Gas piping material and system design shall be in accordance with NFPA 54, *National Fuel Gas Code* (for gas piping inside industrial and institutional buildings), or ASME B 31.1, *Power Piping* (for gas piping in power applications), or ASME B 31.3, *Process Piping* (for gas piping in process applications).

2.3.2.7 Permanent means shall be provided for making leakage-tightness tests of the main burner gas safety shutoff valves. Leakage-tightness tests of the main safety shutoff valves shall be conducted at least annually.

2.3.3 Alternate Fuel Firing.

2.3.3.1 Manual Fuel Selection. Where oil and gas are to be burned alternately, a manually positioned fuel selector switch shall be provided to permit operation of the necessary interlocks, fuel safety shutoff valves, and controls for the fuel to be fired.

2.3.3.2 Automatic Fuel Selection. Where oil and gas are to be burned alternately, an automatic change from one fuel to the other shall be accomplished only after a shutdown. Provisions for manual changeover of the system shall be provided in accordance with 2.3.3.1 and Section 2.7. For simultaneous firing of oil and gas fuels, see Section 2.6.

2.3.4 Fuel-Burning Equipment.

2.3.4.1* Ignition.

2.3.4.1.1 The main burner shall be equipped with a permanently installed igniter.

2.3.4.1.1.1 Where a Class 1 igniter is used, the main burner flame shall be proven by a flame detector. Either the main flame or the igniter flame shall be proven.

2.3.4.1.1.2 Where a Class 2 igniter is used, it shall not be used to ignite main fuel under uncontrolled or abnormal conditions. The burner shall be operated under controlled conditions to limit the potential for abnormal operation as well as to limit the charge of fuel to the furnace in the event that ignition does not occur during light-off. If the Class 2 igniter is not shut down once the main flame sequence is successfully completed, then the main burner flame shall be proven by a flame scanner independently of the igniter.

2.3.4.1.1.3 Where a Class 3 igniter is used, the igniter shall be shut down as a part of the burner light-off procedure when the time trial for ignition of the main burner has expired. The purpose of this requirement is to ensure that the main flame is self-supporting, is stable, and is not dependent upon ignition support from the igniter. The use of such igniters to support ignition or to extend the burner control range shall be prohibited. The main flame shall be proven by a flame scanner.

2.3.4.1.1.4 Where a Class 3 special igniter is used, the main burner flame shall be proven by a flame scanner.

2.3.4.1.2 The igniter flame or arc shall impinge on the main burner air/fuel mixture and shall supply sufficient ignition energy to provide immediate ignition of all fuel discharge from the main burner under light-off conditions.

2.3.4.1.3* Two safety shutoff valves in series shall be provided in the line to the gas igniter. An automatic vent valve shall be provided between the two valves for gas igniters. One safety shutoff valve shall be provided in the line to the oil igniter. Where the automatic vent valve is prohibited by the authority having jurisdiction, two safety shutoff valves in series, supervised by a listed automatic valve-proving system, shall be provided in the gas line to the igniter burner. Valve proving shall be performed either after every burner shutdown or prior to every burner light-off. *(Also refer to Figure A.2.3.4.1, Typical ignition systems for gas/oil-fired burner.)*

Exception: Elimination of the automatic vent valve from between the two igniter gas safety shutoff valves shall be permitted when heavier-than-air fuel gases are used.

2.3.4.1.4 The igniter shall be designed for periodic removal, cleaning, and maintenance.

2.3.4.2 Main Burner.

2.3.4.2.1 The main burner shall direct the fuel and air into the furnace so as to provide a stable flame and efficient combustion over its entire operating range.

2.3.4.2.2 The limits of stable flame for the burner shall be determined by tests. These tests shall be performed without the igniter in service and shall include the intended range and grade of fuel(s).

The tests shall verify that transients that are generated in the fuel and air systems do not adversely affect burner operation. Such transients are generated by burner control valves, dampers, and other equipment that operate at speeds faster than the speed of response of other components in the system.

2.3.4.2.3 Each manual adjustment feature on the burner shall be provided with means for securing it in its intended position.

2.3.4.2.4 The atomizing equipment for oil burners shall be designed for periodic removal, cleaning, and maintenance.

2.3.4.2.5 Any procedure for clearing the atomizer and piping into the furnace prior to shutdown shall be accomplished while the fan is operating and the igniter is reestablished or the main flame is proven continuously during this operation.

2.3.4.2.6 Clearing of the oil passages of the atomizer into the furnace immediately after a shutdown shall be prohibited.

2.3.4.3 Atomizing Medium for Oil Burners.

2.3.4.3.1 Where the fuel is to be atomized with the assistance of another medium, this atomizing medium shall be supplied free of contaminants that could cause an interruption of service.

2.3.4.3.2 The atomizing medium shall be provided at the pressure and temperature specified by the burner manufacturer.

2.3.4.3.3 Provisions shall be made to ensure that fuel cannot enter the atomizing medium line during or after operation.

2.3.4.4 Combustion Air Supply.

2.3.4.4.1 The combustion air supply equipment shall be capable of supplying combustion air for the optimum air/fuel ratio over the entire operating range of the burner.

2.3.4.4.2 Provisions shall be made for periodic cleaning of the combustion air supply equipment.

2.3.4.4.3 The requirements for the availability of combustion air shall be determined from NFPA 31, *Standard for the Installation of Oil-Burning Equipment*, and NFPA 54, *National Fuel Gas Code*.

2.3.4.4.3.1 Louvers and grilles shall be fixed in the open position or interlocked with the equipment so that they are opened automatically or manually during equipment operation. The interlock shall be placed on the driven member.

2.3.4.4.3.2 Fans supplying air to the boiler room for combustion shall be interlocked with the burner so that airflow is proven during equipment operation.

2.3.4.5 Furnace. The furnace shall be designed to promote main burner stability while minimizing zones that cannot be purged.

2.3.4.6 Combustion Products Removal.

2.3.4.6.1* The outlet draft equipment shall be capable of removing combustion products without adversely affecting stable flame conditions.

2.3.4.6.2 Where two or more boilers are connected to a common stack, each connection shall be equipped with a damper system. All boiler outlet dampers shall be equipped with accessible operating and locking devices. This equipment shall be compatible with the combustion control system of the boiler. Interlocks shall be provided to prevent firing against a closed damper. Provisions shall be made to prevent rendering the interlock nonfunctional if the linkage becomes disconnected. This shall be accomplished by one of the following means:

(1) Placing the interlock on the driven member
(2) Utilizing a furnace pressure switch
(3) Other approved means

Exception: Dampers shall not be required on the outlet of boilers of a type in which maintenance operations are performed from outside the boiler.

2.3.5* Combustion Control System.

2.3.5.1 The combustion control system shall be installed in accordance with the requirements of 1.9.5.1.

2.3.5.2 The combustion control system shall maintain air/fuel mixtures at preestablished ratios throughout the operating range of the burner and during changes in the firing rate.

2.3.5.3* The system shall provide limits on fuel and air to prevent reducing furnace input below the point of stable burner operation. The minimum and maximum points of stable burner operation shall be defined by the burner manufacturer and verified by operational tests.

2.3.6 Interlock System.

2.3.6.1 The system shall be equipped with a method of determining the operating state of each interlock without disassembling any of the interlock devices.

2.3.6.2 Each interlock shall be provided with a method of establishing the set point. The set point shall be repeatable within prescribed limits.

2.3.6.3 Interlock devices shall be designed for anticipated environmental conditions, such as temperature, humidity, vibration, and corrosive agents.

2.3.6.4 The interlocks on the low water cutouts shall be permitted to be bypassed for blowdown purposes only. This bypass shall be of a type that is temporarily held during blowdown.

2.3.6.5 Interlocks shall not be manually bypassed at any time during normal operation.

Exception: Interlocks shall be permitted to be bypassed as allowed by 2.3.6.4, 2.4.3.2.1(4), and 2.4.3.3.1(4).

2.3.6.6* Each safety control ac circuit shall be two wire, one side grounded, and shall be protected with a suitable fuse or circuit breaker in the hot side only.

2.3.6.7 Safety control dc circuits shall be arranged as called for in 2.3.6.6 where grounding is possible. Where grounding is not possible and the circuit voltage exceeds 50 volts, the circuit shall have switching contacts in one side of the line and shall be provided with ground-fault circuit interrupters.

2.3.7 Flame Safety Shutdown System.

2.3.7.1 The response time from flame failure to de-energization of the safety shutoff valves shall not exceed 4 seconds.

2.3.7.2 The response time from de-energization of the safety shutoff valves to full closure shall not exceed 1 second.

2.3.7.3 Where flame-sensing detectors can fail in the flame-proven mode, self-checking features shall be provided unless the burner is operated for periods less than 24 hours and the burner management system includes a safe-start component check feature. A safe-start component checking feature shall include a circuit incorporated in the burner management system that prevents light-off if the flame-sensing relay is in the flame-present position due to component failure or due to the presence of actual or simulated flame.

2.3.8 Electrical Equipment.

2.3.8.1* All electrical equipment and wiring shall conform to NFPA 70, *National Electrical Code.*

2.3.8.2 Special fuels or applications could require components for hazardous location and shall be reviewed during the design of the system.

2.3.9 Gas and Oil Firing: Special Problems.

2.3.9.1* (Low NO_x Operations). Systems installed or designed to reduce NO_x emissions shall be evaluated to ensure that the performance of flame safety and combustion control systems are not impaired.

2.4 Starting a Cold Boiler.

2.4.1 General.

2.4.1.1 Starting of a cold boiler shall be accomplished in conformance with the manufacturer's recommendations. In no case shall a boiler that has been taken out of service for maintenance, repair, or extended shutdown be started from a cold condition without a trained operator present.

2.4.1.2 Applicable start-up procedures for the provided boiler shall be followed. The firing rate shall be limited in accordance with the boiler manufacturer's instructions.

2.4.2 Gas-Fired Boilers. The procedures of Section 2.5 shall be followed for starting a cold gas-fired boiler.

2.4.3 Oil-Fired Burners. When steam is not available for heating oil, as an atomizing medium, or for driving auxiliary equipment, one of the starting methods described in 2.4.3.1, 2.4.3.2, or 2.4.3.3 shall be used.

2.4.3.1 Auxiliary Air Atomizing of Oil. When auxiliary air atomizing of oil is used for a cold start-up, all the equipment, facilities, and procedures listed in 2.4.3.1.1, 2.4.3.1.2, and 2.4.3.1.3 shall be required.

2.4.3.1.1 Required Equipment. The following equipment shall be required:

(1) Forced draft (FD) fan
(2) Approved auxiliary oil heater for start-up fuel flow with a capacity not less than that required for minimum fire with stable flame (only for fuel oils that require heating)
(3) Check valves in steam and air lines to the atomizer

2.4.3.1.2* Required Facility. An alternate atomizing air supply shall be required.

2.4.3.1.3 Starting Procedure. The following procedural steps shall be followed:

(1) Circulate and heat oil, using auxiliary heater and recirculating system, to satisfy all interlocks, where included.
(2) Follow the pre-firing and light-off cycles as described in Section 2.5, using air as the atomizing medium.
(3) Set combustion control at the light-off firing rate.
(4) When steam pressure has reached the point required for heating and atomizing the oil, shut down in accordance with the normal shutdown procedure described in Section 2.5.
(5) Close the atomizing air supply and open the atomizing steam supply, making certain that dry steam is available.
(6) Change over from auxiliary oil heater to steam oil heater.
(7) Continue the boiler start-up sequence.

2.4.3.2 Auxiliary Mechanical Atomizing of Heavy Oil. When auxiliary mechanical atomizing of heavy oil is used for a cold start-up, all the following equipment, facilities and procedures shall be required.

2.4.3.2.1 Required Equipment. The following equipment and facilities shall be required:

(1) FD fan
(2) Approved auxiliary oil heater for start-up fuel flow with a capacity not less than that required for minimum fire with stable flame
(3) Mechanical atomizer
(4) Means to bypass atomizing medium interlocks. The bypassed interlocks shall be made evident to the operator with warning devices.

2.4.3.2.2 Starting Procedure. The following procedural steps shall be followed:

(1) Circulate and heat oil using auxiliary heater and recirculating systems to satisfy oil interlocks, where included.
(2) Bypass atomizing medium interlocks. *[Refer to 2.4.3.2.1(4).]*
(3) Insert mechanical atomizer.
(4) Follow the pre-firing and light-off cycles as described in Section 2.5.
(5) Set combustion control at the light-off firing rate.
(6) When steam pressure has reached the point required for heating and atomizing the oil, shut down in accordance with the normal shutdown procedure as described in Section 2.5.
(7) Remove the mechanical atomizer.
(8) Insert the steam atomizer.
(9) Make the atomizing medium interlocks operable and place into service.
(10) Change over from auxiliary oil heater to steam oil heater.
(11) Continue the boiler start-up sequence.

2.4.3.3 Auxiliary Mechanical Atomizing of Light (Unheated) Oil. When auxiliary mechanical atomizing of light (unheated) oil is used for a cold start-up, all the following equipment, facilities, and procedures shall be required.

2.4.3.3.1 Required Equipment. The following equipment shall be required:

(1) FD fan
(2) Mechanical atomizer
(3) Check valves in the heavy and light oil lines
(4) Means to bypass atomizing medium interlocks. The bypassed interlocks shall be made evident to the operator with warning devices.

2.4.3.3.2 Required Facility. A light oil supply shall be required.

2.4.3.3.3 Starting Procedure. The following procedural steps shall be followed:

(1) Shut off heavy oil to the system.
(2) Insert the mechanical atomizer.
(3) Bypass oil and atomizing medium interlocks. *[Refer to 2.4.3.3.1(4).]*
(4) Open the light oil supply into the system.
(5) Follow pre-firing and light-off cycles described in Section 2.5.
(6) Set combustion control at the light-off rate.
(7) When steam pressure has reached the point required for heating and atomizing the oil, shut down in accordance with the normal shutdown procedure as described in Section 2.5.
(8) Shut off the light oil supply to the system.
(9) Remove the mechanical atomizer.
(10) Insert the steam atomizer.
(11) Make the oil and atomizing medium interlocks operable by removing bypasses.
(12) Open the heavy oil supply to the system.
(13) Continue the boiler start-up sequence.

2.5 Operating Systems.

2.5.1* General. This section shall be used to define requirements for automatic recycling and automatic nonrecycling operating systems. Manual systems shall not be installed for new installations or major alterations. Different arrangements shall be permitted if they provide protection and meet the intent of this standard. *(Refer to Figures A.2.3.1.8, A.2.3.2.3, and A.2.3.4.1 for typical arrangements.)*

2.5.2 Automatic (Recycling) Systems for Watertube Boilers.

2.5.2.1 An automatic (i.e., recycling) unit shall not be started from a cold condition unless a trained operator is present. This section is based on the premise that the unit is hot and that steam pressure and operating water level shall have been established.

2.5.2.2 The fuel to be fired shall have been manually selected. The alternate fuel system shall be placed in a nonfiring condition, and the manual burner valve(s) shall be closed.

2.5.2.3 An igniter as specified in 2.3.4.1.1 shall be provided.

2.5.2.4 An automatic (i.e., recycling) unit shall recycle on a preset pressure and perform four major functions as follows:

(1) Prefiring cycle
(2) Light-off cycle
(3) Modulation, where provided
(4) Shutdown cycle

2.5.2.4.1 Prefiring Cycle. The prefiring cycle shall accomplish the following in the listed order. The order of items (5), (6), and (7) in the sequence shall be permitted to vary.

(1) Prove the main fuel safety shutoff valves are closed.
(2) Prove no flame is present at the burner.
(3) Start the fan.
(4) Satisfy the fan interlock.
(5) Where an atomizing medium is used and if not already on, admit medium to main burner.
(6) Where an atomizing medium is used, satisfy the atomizing medium interlocks.
(7) Satisfy fuel interlocks.
(8) Prove the purge airflow by satisfying one of the following two items:
    a. Air pressure and "open damper" interlocks for all dampers in the flow path
    b. Airflow interlock

    Purge airflow shall reach no less than 70 percent of the airflow required at maximum continuous capacity of the unit.
(9) The purge shall be for at least eight air changes. Airflow during the period of opening the damper and returning it to light-off position shall be permitted to be included in computing the time for eight air changes.
(10) Set controls to light-off position.
(11) Prove the dampers and fuel control valve are in light-off position.

2.5.2.4.2 Light-Off Cycle — Class 3 Igniter. The light-off cycle for a burner with a Class 3 igniter shall accomplish the following in the listed order:

(1) Energize the ignition transformer and igniter fuel valves.
(2)* Prove igniter flame within 10 seconds of the energization of the igniter fuel valves. For a Class 3 special igniter, proof of igniter operation shall not be required.
    a. If proven, admit fuel to main burner. For an oil burner other than a return flow type, simultaneously shut off oil-recirculating flow.
    b. If not proven, establish safety shutdown.
(3) After a maximum of 10 seconds for gas and Nos. 2 and 4 oils or 15 seconds for Nos. 5 and 6 oils, shut off igniter.
(4) Prove main flame (refer to 2.3.4.1.1.3 and 2.3.4.1.1.4).
    a. If proven, release to modulating control where provided.
    b. If not proven, establish safety shutdown.

2.5.2.4.3 Light-Off Cycle — Class 2 Igniter. The light-off cycle for a burner with a Class 2 igniter shall accomplish the following in the listed order:

(1) Energize the ignition transformer and igniter fuel valves.
(2)* Prove igniter flame within 10 seconds of the energization of the igniter fuel valves.

a. If proven, admit fuel to the main burner. For an oil burner other than a return flow type, simultaneously shut off the recirculating flow.
b. If not proven, establish safety shutdown.

(3) After a maximum of 10 seconds for gas and Nos. 2 and 4 oils or 15 seconds for Nos. 5 and 6 oils, prove the main flame (refer to 2.3.4.1.1.2).

a. If proven, release to combustion control for modulation, where provided.
b. If not proven, establish safety shutdown.

2.5.2.4.4 Light-Off Cycle — Class 1 Igniter. The light-off cycle for a burner with a Class 1 igniter shall accomplish the following in the listed order:

(1) Energize the ignition transformer and igniter fuel valves.
(2)* Prove igniter flame within 10 seconds of the energization of the igniter fuel valves.

a. If proven, admit fuel to the main burner. For an oil burner other than a return flow type, simultaneously shut off recirculating flow.
b. If not proven, establish safety shutdown.

(3) After a maximum of 10 seconds for gas and Nos. 2 and 4 oils or 15 seconds for Nos. 5 and 6 oils, prove the main flame (refer to 2.3.4.1.1.1).

a. If proven, release to combustion control for modulation, where provided.
b. If not proven, establish safety shutdown.

2.5.2.4.5 Modulation. Modulation, where provided, shall be accomplished by a combustion control system.

2.5.2.4.6 Normal Shutdown Cycle. The normal shutdown cycle shall accomplish the following in the listed order:

(1) Shut off the fuel supply to the main burner.
(2) For oil:

a. If a Class 1 igniter is used, the manufacturer's instructions shall be used to purge the main burner oil gun prior to continuing the normal shutdown.
b. Where used, open the recirculating valve.
c. Shut off atomizing medium, if desired.

(3) Shut off the fuel supply to the igniter if in operation.
(4) Perform a postpurge of the furnace and boiler gas passes. The duration of the postpurge shall be no less than 15 seconds at an airflow rate not exceeding that at which the unit was shut down.
(5) Shut down the fan, if desired.

2.5.2.4.7 Normal Shutdown. For automatic (i.e., recycling) boilers, high steam pressure, high water temperature, or low water level (not determined by the auxiliary low water cutout) shall accomplish a normal shutdown; and the burner shall be allowed to recycle when steam pressure, water temperature, or water level has returned to within the preset operating range.

2.5.2.4.8 Safety Shutdown Cycle. The safety shutdown cycle shall accomplish the following in the listed order and shall activate an alarm:

(1) Shut off the fuel supply to the main burner.
(2) Shut off the fuel supply and interrupt spark to the igniter if in operation.
(3) For oil:

a. Where used, open the recirculating valve.
b. Where used, shut off the atomizing medium, if desired.

(4) Where the inerting system is used, it shall be energized simultaneously with 2.5.2.4.8(a).
(5) Perform a postpurge of the furnace and boiler gas passes. The duration of the postpurge shall be no less than 15 seconds at an airflow rate not exceeding that at which the unit was shut down.
(6) After postpurge, shut down the fan, if desired.
(7) Require manual reset.

2.5.2.4.9* Safety Shutdown. Any of the following conditions shall accomplish a safety shutdown, and the burner shall not be allowed to recycle until a trained operator determines the cause of the shutdown and takes the necessary corrective action to assure that conditions are within specified operating limits prior to restarting.

(a) For oil

(1) Low fuel pressure
(2) Low temperature of heated oils
(3) Loss of combustion air supply
(4) Loss of or failure to establish flame
(5) Loss of control system actuating energy
(6) Power failure
(7) Low water level as determined by the auxiliary low water cutout
(8) Loss of atomizing medium, where used, as interlocked by flow or two pressure switches (one located at the service connection and the other at the burner, either one of which shall initiate a safety shutdown on low pressure)
(9) Excessive steam pressure or water temperature
(10) High temperature of heated oil

(b) For gas

(1) High gas pressure
(2) Low gas pressure
(3) Loss of combustion air supply
(4) Loss of or failure to establish flame
(5) Loss of control system actuating energy
(6) Power failure
(7) Low water level as determined by the auxiliary low water cutout
(8) Excessive steam pressure or water temperature

2.5.3 Automatic (Nonrecycling) Systems for Watertube Boilers.

2.5.3.1 The provisions of 2.5.2.1, 2.5.2.2, 2.5.2.3, and 2.5.2.4 shall apply.

Exception: Section 2.5.2.4.7 shall not apply.

2.5.3.2 When high steam pressure, high water temperature, or low water level establishes a normal shutdown, the burner shall not be allowed to recycle. A trained operator shall initiate the restart.

2.5.4 Automatic (Recycling) Systems for Firetube Boilers.

2.5.4.1 This section is based on the premise that the equipment shall be in accordance with Section 2.3, that the boiler shall have been placed in service in accordance with Section 2.5, and that the operating water level shall have been established.

2.5.4.2 An automatic recycling unit shall recycle on a preset pressure or temperature and perform four major functions as follows:

(1) Prefiring cycle
(2) Light-off cycle
(3) Modulation, where provided
(4) Shutdown cycle

2.5.4.2.1 Prefiring Cycle. The prefiring cycle shall accomplish the following in the listed order. The order of items (5), (6), and (7) in the sequence shall be permitted to vary.

(1) Prove the fuel safety shutoff valves are closed.
(2) Prove no flame is present at burner.
(3) Start the fan.
(4) Satisfy the fan interlock.
(5) Where an atomizing medium is used, and if not already on, admit the medium to the main burner.
(6) Where an atomizing medium is used, satisfy the atomizing medium interlocks.
(7) Satisfy the fuel interlocks.
(8) Prove purge airflow by satisfying one of the following two items:

  a. Air pressure and "open damper" interlocks for all dampers in the flow path
  b. Airflow interlock

  Purge airflow shall reach no less than 70 percent of the airflow required at maximum continuous capacity of the unit.

(9) The purge of the furnace and boiler gas passes shall be for at least four air changes. During the purge, the air damper shall be driven to the full open position. Airflow during the time to open the damper and return it to light-off position shall be permitted to be included in computing the time for four air changes.
(10) Prove the control system is in light-off position.

2.5.4.2.2 Light-Off Cycle. The light-off cycle shall accomplish the following in the listed order:

(1) Energize the ignition transformer and igniter fuel valves.
(2)* Prove the igniter flame within 10 seconds of the energization of the igniter fuel valves. For a Class 3 special igniter, proof of igniter operation shall not be required.

  a. If proven, admit fuel to main burner.
  b. If not proven, establish safety shutdown.

(3) After a maximum of 10 seconds for gas and Nos. 2 and 4 oils or 15 seconds for Nos. 5 and 6 oils, shut off the igniter.
(4) Prove the main flame.

  a. If proven, release to modulating control where provided.
  b. If not proven, establish safety shutdown.

2.5.4.2.3 Modulation. Modulation, where provided, shall be accomplished by a combustion control system.

2.5.4.2.4 Normal Shutdown. High steam pressure, high water temperature, or low water (not determined by the auxiliary low water cutoff) shall accomplish a normal shutdown, and the burner shall be allowed to recycle when steam pressure, water temperature, or water level has returned to within the preset operating range.

2.5.4.2.5 Normal Shutdown Cycle. The normal shutdown cycle shall accomplish the following in the listed order:

(1) Shut off the fuel supply to the main burner.
(2) For oil:

  a. Where used, open the recirculating valve.
  b. Where the manufacturer's instructions permit, purging the main burner oil gun in conjunction with the operation of its igniter shall be permitted.
  c. Where used, shut off the atomizing medium, if desired.

(3) Perform a postpurge of the furnace and boiler gas passes. The duration of the postpurge shall be no less than 15 seconds at an airflow rate not exceeding that at which the unit was shut down.
(4) After postpurge, shut down the fan, if desired.

2.5.4.2.6 Safety Shutdown Cycle. The safety shutdown cycle shall accomplish the following in the listed order:

(1) Shut off the fuel supply to the main burner.
(2) Shut off the fuel supply and interrupt the spark to the igniter if in operation.
(3) For oil:

  a. Where used, open the recirculating valve.
  b. Where used, shut off the atomizing medium, if desired.

(4) Where the inerting system is used, it shall be energized simultaneously with 2.5.4.2.6(a).
(5) Perform a postpurge of the furnace and boiler gas passes. The duration of the postpurge shall be no less than 15 seconds at an airflow rate not exceeding that at which the unit was shut down.
(6) After postpurge, shut down the fan, if desired.
(7) Require manual reset.

2.5.4.2.7* Safety Shutdown. Any of the following conditions shall accomplish a safety shutdown, and the burner shall not be allowed to recycle until a trained operator determines the cause of the shutdown and takes the necessary corrective action to assure that conditions are within specified operating limits prior to restarting.

(a) For oil

(1) Low oil pressure
(2) Low temperature of heated oils
(3) Loss of combustion air supply
(4) Loss of or failure to establish flame
(5) Loss of control system actuating energy
(6) Low water level as determined by the auxiliary low water cutout
(7) Loss of atomizing medium where used
(8) Excessive steam pressure or water temperature
(9) Power failure
(10) High temperature of heated oil

(b) For gas

(1) High gas pressure
(2) Low gas pressure
(3) Loss of combustion air supply
(4) Loss of or failure to establish flame
(5) Loss of control system actuating energy
(6) Low water level as determined by the auxiliary low water cutout
(7) Excessive steam pressure or water temperature
(8) Power failure

2.5.5 Automatic (Nonrecycling) Systems for Firetube Boilers.

2.5.5.1 The provisions of 2.5.4.1 and 2.5.4.2 shall apply.

Exception: Section 2.5.4.2.4 shall not apply.

2.5.5.2 When high steam pressure, high water temperature, or low water level establishes a normal shutdown, the burner shall not be allowed to recycle. A trained operator shall initiate the restart.

2.5.6 Supervised Manual Systems for Oil-Fired Watertube Boilers.

2.5.6.1* The steps listed in Tables 2.5.6.1(a), 2.5.6.1(b), 2.5.6.1(c), and 2.5.6.1(d) shall be taken by a trained operator when starting a supervised manual unit, and the indicated interlocks shall be satisfied at each step. Fuel pressure and temperature, atomizing medium, control system energy, power, and water level shall have been established. When interlocks have been satisfied, this fact shall be indicated to the operator.

Table 2.5.6.1(a) Prefiring Cycle (in listed order).

Operator Functions	Interlock Functions
1. Check that manual fuel shutoff valve(s) is closed.	1. Manual fuel shutoff valve(s) is closed.
2. Start fan.	2. Fan is on.
3. Where used, open atomizing medium valve.	3. Atomizing medium supply is available.
4. Open damper(s) to purge position.	4. (a) Air pressure and open damper(s), or (b) airflow. *[Refer to 2.5.2.4.1(h) and (i).]*
5. Start purge timer.	5. Purge is complete.
6. Place damper and fuel control valve in light-off position.	6. Damper and fuel control valve are in light-off position. If light-off airflow is less than purge airflow rate, start light-off time limit timer.
7. None.	7. Spark and igniter and main safety shutoff valves are ready for operation.

Table 2.5.6.1(b) Light-Off Cycle (in listed order).

Operator Functions	Interlock Functions
1. Energize ignition transformer and igniter fuel valves.	1. Prove igniter flame within 10 seconds of the energization of the igniter fuel valves. (For Class 3 special igniter, proof of igniter operation is not required.)
2. Open fuel safety shutoff valve to main burner.	2. None.
3. Close recirculating valve, where used.	3. None.
4. Open manual fuel shutoff valve.	4. Prove main flame within 10 seconds for Nos. 2 and 4 oils or 15 seconds for Nos. 5 and 6 oils. Close igniter safety shutoff valve(s).
5. Bring unit to present operating pressure at a rate specified by the manufacturer, maintaining air/fuel ratios as established by tests.	5. None.
6. On reaching preset pressure range, change to automatic combustion control.	6. None.

Table 2.5.6.1(c) Normal Shutdown Cycle (in listed order).

Operator Functions	Interlock Functions
1. Shut off fuel supply to the main burner.	1. Fuel safety shutoff valve(s) to main burner is closed.
2. Open fuel recirculating valve, where used.	2. None.
3. Where used, shut off atomizing medium.	3. None.
4. Remove fuel atomizer.	4. None.
5. Perform a postpurge of the furnace and boiler gas passes. The duration of the postpurge shall be no less than 15 seconds at an airflow rate not exceeding that at which the unit was shut down.	5. None.
6. After postpurge, fan shall be permitted to be shut down.	6. None.

Table 2.5.6.1(d) Safety Shutdown Cycle (in listed order).

Operator Functions	Interlock Functions
1. None.	1. Shut off fuel supply to the main burner; shut off fuel supply and interrupt spark to the igniter if in operation.
2. Perform a postpurge of the furnace and boiler gas passes. The duration of the postpurge shall be no less than 15 seconds at an airflow rate not exceeding that at which the unit was shut down.	2. None.
3. After postpurge, fan shall be permitted to be shut down.	3. None.

2.5.6.2 The fuel to be fired shall be selected. The alternate fuel system shall be placed in a nonfiring condition, and the manual burner valve(s) shall be closed.

2.5.6.3 An igniter as specified in 2.3.4.1.1 shall be provided.

2.5.6.4* Any of the following conditions shall accomplish a safety shutdown, and the burner shall not be restarted until a trained operator determines the cause of the shutdown and takes the necessary corrective action to ensure that conditions are within specified operating limits prior to restarting:

(1) Low pressure in the fuel supply
(2) Loss of combustion air supply
(3) Loss or failure to establish flame
(4) Loss of control system actuating energy
(5) Power failure
(6) Low water level as determined by the auxiliary low water cutout
(7) Loss of atomizing medium
(8) Excessive steam pressure or water temperature

2.5.6.5 Either of the following conditions, where oil heating is provided, shall sound alarms:

(1) Low oil temperature
(2) High oil temperature

2.5.7 Supervised Manual Systems for Gas-Fired Watertube Boilers.

2.5.7.1* The steps listed in Tables 2.5.7.1(a), 2.5.7.1(b), 2.5.7.1(c), and 2.5.7.1(d) shall be taken by a trained operator when starting a supervised manual unit, and the indicated interlocks shall be satisfied at each step. Control system energy, power, and water level shall have been established. When interlocks have been satisfied, this fact shall be indicated to the operator.

Table 2.5.7.1(a) Prefiring Cycle (in listed order).

Operator Functions	Interlock Functions
1. Check that gas safety shutoff valves are closed.	1. Gas safety shutoff valves are closed.
2. Start fan.	2. Fan motor is on.
3. Open damper(s) to purge position.	3. (a) Air pressure and open damper(s), or (b) airflow. *[Refer to 2.5.2.4.1(h) and (i).]*
4. Start purge timer.	4. Purge is complete.
5. Place damper and gas control valve in light-off position.	5. Damper and fuel control valve are in light-off position. If light-off airflow is less than purge airflow rate, start light-off time limit timer.
6. None.	6. Spark and igniter and main safety shutoff valves are ready for operation.

Table 2.5.7.1(b) Light-Off Cycle (in listed order).

Operator Functions	Interlock Functions
1. Energize ignition transformer and igniter fuel valves.	1. Prove igniter flame within 10 seconds of the energization of the igniter fuel valves. (For Class 3 special igniter, proof of igniter operation is not required.)
2. Open gas safety shutoff valves to main burner.	2. Prove main flame is within 10 seconds. Close igniter safety shutoff valve(s).
3. Bring unit to preset operating pressure at a rate specified by the manufacturer, maintaining air/fuel ratios as established by tests.	3. None.
4. On reaching preset range, change to automatic combustion control.	4. None.

Table 2.5.7.1(c) Normal Shutdown Cycle (in listed order).

Operator Functions	Interlock Functions
1. Shut off gas supply to the main burner and to the igniter, if in operation, and interrupt spark.	1. None.
2. Perform a postpurge of the furnace and boiler gas passes. The duration of the postpurge shall be no less than 15 seconds at an airflow rate not exceeding that at which the unit was shut down.	2. None.
3. After postpurge, fan shall be permitted to be shut down.	3. None.

Table 2.5.7.1(d) Safety Shutdown Cycle (in listed order).

Operator Functions	Interlock Functions
1. None.	1. Shut off gas supply to the main burner, shut off fuel supply, and interrupt spark to the igniter if in operation. Where used, simultaneously energize inerting system.
2. Perform a postpurge of the furnace and boiler gas passes. The duration of the postpurge shall be no less than 15 seconds at an airflow rate not exceeding that at which the unit was shut down.	2. None.
3. After postpurge, fan shall be permitted to be shut down.	3. None.

2.5.7.2 The fuel to be fired shall be selected. The alternate fuel system shall be placed in a nonfiring condition, and the manual burner valve(s) shall be closed.

2.5.7.3 An igniter as specified in 2.3.4.1.1 shall be provided.

2.5.7.4 Any of the following conditions shall accomplish a safety shutdown, and the burner shall not be restarted until a trained operator determines the cause of the shutdown and takes the necessary corrective action to assure that conditions are within specified operating limits prior to restarting:

(1) High gas pressure
(2) Low gas pressure
(3) Loss of combustion air supply
(4) Loss of or failure to establish flame
(5) Loss of control systems actuating energy
(6) Power failure
(7) Low water level as determined by the auxiliary low water cutout
(8) Excessive steam pressure or water temperature

2.5.8 Soot Blowing. Where soot blowers are used, the following shall apply:

(1) Soot blowing at non-optimum air/fuel ratios has been known to lead to explosive formations of air–soot clouds within the boiler and shall be avoided.
(2) Soot blowers shall be operated only while burners are firing at rates that avoid extinguishing the burner flame.
(3) Boilers that are equipped with automatic soot-blowing equipment shall have their controls interlocked to prevent operation when the burner is shut down or in the prefiring or light-off cycles.

2.6 Simultaneous Firing of Oil and Gas Fuels.

2.6.1* General. The equipment and procedures required in 2.6.1.1 through 2.6.1.3 shall be used to avoid a hazardous furnace condition when firing oil and gas simultaneously in a single burner boiler on a continuous basis.

2.6.1.1 Class 1 or Class 2 igniters shall be used during the light-off of the second fuel as required by the manufacturer or established by test.

2.6.1.2 Each boiler shall be tested during initial start-up to determine whether any modifications to the procedures specified in Section 2.5 are required in order to establish ignition or to satisfy other design limitations during light-off, warm-up, or normal operation.

2.6.1.3 The initial prefiring cycle, light-off cycle, and normal shutdown cycles for the initial fuel to be fired and for single fuel operation shall be completed in accordance with Section 2.5, Operating Systems.

2.6.2 Equipment Requirements. The following equipment shall be provided for continuous firing of both oil and gas:

(a) A burner that is capable of burning either oil or gas fuel individually or both fuels simultaneously

(b) A combustion control system that is capable of performing the following functions:

(1) Metering and totalizing the inputs from both gas and oil fuels alone or in any combination
(2) Proportioning total fuel input, each fuel individually or in any combination, to total airflow in order to maintain the air/fuel ratio within design limits
(3) Limiting fuel demand to be less than measured airflow and limiting air demand to be greater than measured fuel flow

Exception: For items 2.6.2(b)(1), (2), and (3), a control system that is designed to accommodate a fixed amount of secondary fuel without metering and totaling all fuels shall be permitted, provided the system maintains air/fuel ratios within design limits throughout the entire operating range of the burner.

(4) Limiting total fuel input to the maximum capacity of the boiler
(5) Controlling and maintaining a minimum airflow rate
(6) Controlling and maintaining minimum input rates of each fuel
(7) Requiring a stable return to design air/fuel ratio after the trip or shutdown of either fuel

(c) A safety interlock system with the following capabilities:

(1) Meets the requirements of 2.3.6 for each fuel being fired
(2) Requires, on an interlock action specific to only one of the fuels being fired, that this particular fuel shall automatically shut down with operation continuing on the unaffected fuel in a stable manner

Exception: Shutdown of both fuels shall be permitted.

(3) Requires that both the first and second fuels be introduced with their flow control valves in light-off positions
(4) Provides for the introduction of the second fuel without requiring a boiler purge
(5) Requires a manual reset following any interlock shutdown
(6) Prohibits the simultaneous light-off of both fuels
(7) Requires flame detector(s) in accordance with 2.3.4 to supervise any of the following conditions:

   a. Igniter flame as permitted by igniter class
   b. Gas firing
   c. Oil firing
   d. Combined gas and oil firing

Exception: Burner flame detectors shall be permitted to supervise multiple fuels.

2.6.3 Simultaneous Firing of Oil and Gas Fuels (Automated Second Fuel Start). This section describes the requirements and procedures for an automated light-off and subsequent operation on a continuous basis of a second fuel.

2.6.3.1 Equipment Requirements. Equipment requirements shall be in accordance with 2.6.2 with the following additional requirements.

A fuel transfer mode with the following functions shall be provided:

(1) A gas-firing mode in which oil cannot be fired
(2) An oil-firing mode in which gas cannot be fired
(3) A gas/oil-firing mode that permits simultaneous firing of both fuels
(4) The capability to signal the combustion control system to bias up the airflow, to position the control valve for the second fuel to light-off, and to open the safety shutoff valve(s) of the fuel being introduced
(5) The capability to bias up the airflow by a preset value in response to a fuel transfer signal while the airflow remains in automatic mode

2.6.3.2 Subsequent Fuel Light-Off — Oil. When oil is introduced as the second fuel, the light-off cycle for the oil shall accomplish the following in the listed order:

(1) Place fuel gas flow and airflow control loops in automatic mode.
(2) Satisfy oil fuel system interlocks.
(3) Install oil atomizer.
(4) Open atomizing medium shutoff valve.
(5) Select dual fuel firing.
(6) Set oil control valve in light-off position.
(7) Prove fuel oil control valve in light-off position.
(8) With airflow in automatic mode, gradually bias up airflow by a preset amount corresponding to fuel input of fuel oil in light-off.
(9) Establish ignition energy in accordance with manufacturer's instructions. When an igniter is required, refer to 2.5.2.4.2, 2.5.2.4.3, or 2.5.2.4.4 for operating requirements.
(10) Open oil safety shutoff valves and establish oil flow through the burner.
(11) Gradually remove airflow bias.
(12) Verify stable flame and that the air/fuel ratio is within design limits.
(13) Place the combustion control system into the desired mode for controlling input rate of each fuel.
(14) Shut down igniter as required.

2.6.3.3 Subsequent Fuel Light-Off — Gas. When gas is introduced as the second fuel, the light-off cycle for the gas shall accomplish the following in the listed order:

(1) Place fuel oil flow and airflow control loops in automatic mode.
(2) Satisfy gas fuel system interlocks.
(3) Select dual fuel firing.
(4) Set gas control valve in light-off position.
(5) Prove fuel gas control valve in light-off position.
(6) With airflow in automatic mode, gradually bias up airflow by a preset amount corresponding to fuel input of fuel gas in light-off.
(7) Establish ignition energy in accordance with manufacturer's instructions. When an igniter is required, refer to 2.5.2.4.2, 2.5.2.4.3, or 2.5.2.4.4 for operating requirements.
(8) Close the vent valve (where used), open the gas safety shutoff valves, and establish gas flow to the burner.
(9) Gradually remove airflow bias.
(10) Verify stable flame and that the air/fuel ratio is within design limits.
(11) Place the combustion control system into the desired mode for controlling input rate of each fuel.
(12) Shut down igniter as required.

2.6.4 Simultaneous Firing of Oil and Gas Fuels (Manual Second Fuel Start). This section describes the requirements and procedures required for the manual light-off and subsequent operation on a continuous basis of a second fuel.

2.6.4.1 Equipment Requirements. Equipment requirements shall be in accordance with 2.6.2 with the following additional requirements.

The combustion control system shall the have capability to manually bias up the airflow while the airflow remains in automatic mode. (Either the oxygen trim or airflow control station shall be permitted to be used.)

2.6.4.2 Subsequent Fuel Light-Off — Oil. When oil is introduced as the second fuel, the light-off cycle for the oil shall accomplish the following in the order:

(1) Verify that fuel gas flow and airflow control loops are in automatic mode.
(2) Satisfy oil fuel system interlocks.
(3) Install oil atomizer.
(4) Open atomizing medium shutoff valve.
(5) Place oil control valve in light-off position.
(6) With airflow in automatic mode, gradually bias up airflow by a preset amount corresponding to fuel input of fuel oil in light-off.
(7) Establish ignition energy in accordance with manufacturer's instructions. When an igniter is required, refer to 2.5.2.4.2, 2.5.2.4.3, or 2.5.2.4.4 for operating requirements.
(8) Open oil safety shutoff valves and establish oil flow through the burner.
(9) Gradually remove airflow bias.
(10) Verify stable flame and that the air/fuel ratio is within design limits.
(11) Place the combustion control system into the desired mode for controlling the input rate of each fuel.
(12) Shut down igniter as required.

2.6.4.3 Subsequent Fuel Light-Off — Gas. When gas is introduced as the second fuel, the procedure shall be in the following order:

(1) Verify that fuel oil flow and airflow control are in the automatic mode.
(2) Satisfy gas fuel system interlocks.
(3) Place the gas control valve in light-off position.
(4) With airflow in automatic mode, gradually bias up airflow by a preset amount corresponding to fuel input of fuel oil in light-off.
(5) Establish ignition energy in accordance with manufacturers' instructions. When an igniter is required, refer to 2.5.2.4.2, 2.5.2.4.3, or 2.5.2.4.4 for operating requirements.
(6) Close the vent valve (where used), open the gas safety shutoff valves, and establish gas flow to the burner.
(7) Gradually remove airflow bias.
(8) Verify stable flame and that the air/fuel ratio is within design limits.
(9) Place the combustion control system into the desired mode for controlling input rate of each fuel.
(10) Shut down igniter as required.

2.6.5 Shutdown Cycle.

2.6.5.1 Normal Oil Shutdown Cycle. The normal shutdown procedure for oil while continuing to fire gas shall be in the following order:

(1) Reduce the oil flow to the light-off rate.
(2) Shut off the oil supply to the burner and open the oil recirculating valve, where used.
(3) Verify stable flame and adjust air/fuel ratio in preparation for purging oil atomizer.
(4) Purge oil passages of oil atomizer.
(5) Shut off the atomizing medium if required.
(6) Remove the oil atomizer from burner if required.
(7) Verify stable flame and that the air/fuel ratio of the gas fire is within design limits.

2.6.5.2 Normal Gas Shutdown Cycle. The normal shutdown procedure for gas while continuing to fire oil shall be in the following order:

(1) Reduce the gas flow to the light-off rate.
(2) Shut off the gas supply to the burner.
(3) Verify stable flame and that the air/fuel ratio of the oil fire is within design limits.

2.6.5.3* Oil Safety Shutdowns. Any of the following operating conditions shall accomplish a safety shutdown of the oil supply to the burner (i.e., fuel trip). A complete boiler safety shutdown shall occur if oil is the only fuel being fired.

(1) Low fuel pressure
(2) Low temperature of heated oils
(3) Loss of atomizing medium, where used, as interlocked by flow or two pressure switches, one located at the service connection and the other at the burner, either one of which shall initiate a safety shutdown on low pressure
(4) High temperature of heated oil

2.6.5.4 Gas Safety Shutdowns. Either of the following conditions shall accomplish a safety shutdown of the gas supply to the burner (i.e., fuel trip):

(1) High gas pressure
(2) Low gas pressure

A complete boiler safety shutdown shall occur if gas is the only fuel being fired.

2.6.5.5 Boiler Safety Shutdowns. Any of the following conditions shall accomplish a complete safety shutdown of the boiler:

(1) Loss of combustion air supply
(2) Loss of or failure to establish flame
(3) Loss of control system actuating energy
(4) Power failure
(5) Excessive steam pressure or water temperature
(6) Low water level as determined by the auxiliary low water cutout
(7) The occurrence of either an oil or a gas fuel trip when only that fuel is being fired

2.7 Simultaneous Firing of Oil and Gas for Fuel Transfer Only.

2.7.1* General. The following equipment and procedures shall be used to avoid a hazardous furnace condition when transferring operation of the boiler from fuel oil to fuel gas or from fuel gas to fuel oil without requiring a shutdown of the boiler.

2.7.1.1 Simultaneous Firing for Fuel Transfer on a Continuous Basis. When the combustion control and burner management system are both designed for fuel transfer and simultaneous firing of oil and gas fuels on a continuous basis, the requirements of Section 2.6 shall apply.

2.7.1.2 Class 1 or Class 2 igniters shall be used during the fuel transfer as required by the manufacturer or established by test.

2.7.1.3 Each boiler shall be tested during initial start-up to determine whether any modifications to the procedures specified in Section 2.5 are required in order to establish ignition or to satisfy other design limitations during light-off, warm-up, or normal operation.

2.7.1.4 The initial prefiring cycle, light-off cycle, and normal shutdown cycles for the initial fuel to be fired and for single fuel operation shall be completed in accordance with Section 2.5, Operating Systems.

2.7.2 Required Equipment. The following equipment shall be required:

(a) A burner that is capable of firing the two fuels simultaneously during the transfer period

(b) A combustion control system that is capable of performing the following functions:

(1) Proportioning fuel flow for each fuel individually
(2) Limiting total fuel input to the maximum capacity of the boiler
(3) Controlling a minimum airflow rate
(4) Controlling minimum input rates of each fuel
(5) Providing a stable return to design air/fuel ratio after the trip or shutdown of either fuel

(c) A fuel transfer mode that includes the following:

(1) A gas-firing mode in which oil cannot be fired
(2) An oil-firing mode in which gas cannot be fired
(3) A gas/oil-firing mode that permits simultaneous firing of both fuels, provided all interlocks for both fuels are satisfied, including light-off position for both fuel valves
(4) A control device, transfer timer, and an alarm for 2.7.2(c)(3), to limit continuous operation in this mode

(d) A safety interlock system with the following capabilities:

(1) Meets the requirements of 2.3.6 for each fuel being fired
(2) Provides, on an interlock action peculiar to only one of the fuels being fired, that this particular fuel shall automatically shut down with operation continuing on the unaffected fuel in a stable manner

Exception: Shutdown of both fuels shall be permitted.

(3) Provides that both the first and second fuels be introduced with their flow control valves in light-off positions
(4) Provides an interlock action that will trip either fuel should its respective flow control valve leave a predetermined setting during fuel transfer
(5) Provides for the introduction of the second fuel without requiring a boiler purge
(6) Requires a manual reset following any interlock shutdown
(7) Prohibits the simultaneous light-off of both fuels
(8) Provides detector(s) to supervise any of the following conditions:
    a. Igniter flame as permitted by igniter class
    b. Gas firing
    c. Oil firing
    d. Combined gas and oil firing

Exception: Burner flame detectors shall be permitted to supervise multiple fuels.

2.7.3 Simultaneous Firing of Oil and Gas for Fuel Transfer Only (Automated Transfer). This section describes the requirements and procedures that shall be used for an automated transfer of operation from one fuel to a second fuel without requiring a shutdown of the burner.

2.7.3.1 Required Equipment. Equipment requirements shall be in accordance with 2.7.2 with the following additional requirements:

(1) The combustion control system shall have the capability to automatically increase the airflow by a preset value in response to a fuel transfer signal. The airflow shall be held in a fixed position for the transfer period.
(2) The fuel transfer mode shall have the capability to signal the combustion control system to increase airflow and open the safety shutoff valve(s) of the fuel being introduced.

2.7.3.2 Subsequent Fuel Light-Off — Oil. When oil is introduced as the second fuel, the transfer cycle from gas to oil shall be in the following order:

(1) Satisfy oil fuel system interlocks.
(2) Install an oil atomizer.
(3) Open the atomizing medium shutoff valve.
(4) Select dual fuel firing.
(5) Set the gas-firing rate to light-off flow.
(6) Set the oil control valve in the light-off position.
(7) Prove fuel gas and fuel oil control valves are in light-off position.
(8) Gradually increase airflow by a preset amount corresponding to fuel input of fuel oil in light-off.
(9) Establish ignition energy in accordance with the manufacturer's instructions. When an igniter is required, refer to 2.5.2.4.2, 2.5.2.4.3, or 2.5.2.4.4 for operating requirements.
(10) Open the oil safety shutoff valves and establish oil flow to the burner.
(11) Verify stable flame and that the air/fuel ratio is within design limits.
(12) Select the oil firing mode, which automatically trips the gas safety shutoff valves.
(13) Gradually remove airflow increase.
(14) Return the combustion control system and burner firing rate to automatic operation.
(15) Shut down igniter as required.

2.7.3.3 Subsequent Fuel Light-Off — Gas. When gas is introduced as the second fuel, the transfer cycle from oil to gas shall be in the following order:

(1) Establish the gas fuel system to satisfy interlocks.
(2) Select the dual fuel firing mode.
(3) Set the oil-firing rate to light-off flow.
(4) Set the gas control valve to the light-off position.
(5) Prove fuel gas and fuel oil control valves are in light-off position.
(6) Increase airflow by a preset amount corresponding to fuel input of fuel gas in light-off.
(7) Establish ignition energy in accordance with the manufacturer's instructions. When an igniter is required, refer to 2.5.2.4.2, 2.5.2.4.3, or 2.5.2.4.4 for operating requirements.
(8) Close the vent valve (where used), open the gas safety shutoff valves, and establish gas flow to the burner.
(9) Verify stable flame and that the air/fuel ratio is within design limits.
(10) Select the gas-firing mode, which automatically trips the oil safety shutoff valves.
(11) Gradually remove airflow increase.
(12) Return the combustion control system and burner-firing rate to automatic operation.
(13) Purge the oil gun into furnace, if required.
(14) Close atomizing medium shutoff valve, if required.
(15) Remove oil atomizer, if required.
(16) Shut down igniter as required.

2.7.4 Simultaneous Firing of Oil and Gas for Fuel Transfer Only (Manual Transfer). This section describes the requirements and procedures that shall be used for a manual transfer of operation from one fuel to a second fuel without requiring a shutdown of the burner.

2.7.4.1 Required Equipment. Equipment requirements shall be in accordance with 2.7.2 with the following additional requirements:

(1) The combustion control system shall have the capability to manually adjust the airflow.
(2) Manual shutoff valves shall be provided at the burner, downstream of the safety shutoff valves for each fuel.
(3) A pressure gauge shall be provided in each fuel line downstream of the manual shutoff valve.

2.7.4.2 Subsequent Fuel Light-Off — Oil. When oil is introduced as the second fuel, the procedure to transfer from gas to oil shall be as follows:

(a) Where a Class 1 or Class 2 igniter is available, place it in service in accordance with the manufacturer's instructions as required.

(b) Confirm that the manual oil valve at the burner is closed.

(c) Satisfy oil fuel system interlocks.

(d) Install an oil atomizer.

(e) Open the atomizing medium shutoff valve.

(f) Place the combustion control system in manual mode.

(g) Reduce the gas-firing rate to light-off flow.

(h) Place the oil control valve in the light-off position.

(i) Place the fuel transfer into oil/gas mode.

When the oil safety interlocks are satisfied, the oil safety shutoff valves shall open. Fuel oil pressure now will be upstream of the manual oil valve at the burner.

(j) Slowly close the manual gas shutoff valve while observing the gas pressure downstream of the valve until the gas pressure starts to drop. At this point the gas flow rate is controlled by the manual valve instead of by the control valve.

(k) Slowly close the manual gas valve while simultaneously opening the manual oil valve to light the oil flame from the gas flame. Continue to increase the oil firing rate while cutting back on the gas-firing rate to maintain a constant heat input of the combined fuels to the burner, until the manual gas valve is closed and the manual oil valve is fully open. Excess air shall be maintained at all times by continuously observing the burner flame or by observing the air/fuel ratio, oxygen indicator, or opacity indicator, if provided. During this period, airflow shall be maintained at a constant rate with only the manual fuel valves operated.

(l) Place the fuel transfer mode in the oil position.

(m) Return the combustion control system and burner-firing rate to automatic operation.

(n) Shut down igniter as required.

2.7.4.3 Subsequent Fuel Light-Off — Gas. When gas is introduced as the second fuel, the procedure to transfer from oil to gas shall be as follows:

(a) Where a Class 1 or Class 2 igniter is available, place it in service in accordance with the manufacturer's instructions as required.

(b) Confirm that the manual gas valve at the burner is closed.

(c) Satisfy gas fuel system interlocks.

(d) Place the combustion control system in manual mode.

(e) Reduce the oil-firing rate to light-off flow.

(f) Place the gas control valve in the light-off position.

(g) Place fuel transfer in the gas/oil mode. When the gas safety interlocks are satisfied, the gas safety shutoff valves shall open. Gas pressure now will be upstream of manual gas valve at the burner.

(h) Slowly close the manual oil valve while observing the oil pressure downstream of the valve until the oil pressure starts to drop. At this point the oil flow is controlled by the manual valve instead of by the control valve.

(i) Slowly close the manual oil valve while simultaneously opening the manual gas valve to light the gas flame from the oil flame. Continue to increase the gas-firing rate while cutting back on the oil-firing rate to maintain a constant heat input of the combined fuels to the burner until the manual oil valve is closed and the manual gas valve is fully open. Excess air shall be maintained at all times by continuously observing the burner flame or by observing the air/fuel ratio, oxygen indicator, or opacity indicator, if provided. During this period, airflow shall be maintained at a constant rate with only the manual fuel valves operated.

(j) Place the fuel transfer mode in the gas position. The oil safety shutoff valves shall close.

(k) Return the combustion control system and burner-firing rate to automatic operation.

(l) Purge the oil gun into the furnace, if required.

(m) Shut off the atomizing medium, if required.

(n) Remove the oil atomizer from burner, if required.

(o) Shut down the igniter as required.

2.7.5 Safety Shutdowns. Safety shutdowns shall be initiated in accordance with 2.6.5.3, 2.6.5.4, and 2.6.5.5.

2.8 Dual Oil Atomizers in a Single Burner.

2.8.1* General. Where a burner is equipped with main and auxiliary oil atomizers for the purpose of changing atomizers for maintenance without affecting the boiler load, the changeover of atomizers shall be carried out manually under stable firing conditions by a trained operator.

2.8.1.1 Class 1 or Class 2 igniters shall be used during the fuel transfer as required by the manufacturer or established by test.

2.8.1.2 Each boiler shall be tested during initial start-up to determine whether any modifications to the procedures specified in Section 2.5 are required in order to establish ignition or to satisfy other design limitations during light-off, warm-up, or normal operation.

2.8.1.3 The initial prefiring cycle, light-off cycle, and normal shutdown cycles for the initial fuel to be fired and for single fuel operation shall be completed in accordance with Section 2.5, Operating Systems.

2.8.2 Required Equipment. The following equipment shall be required:

(1) A burner that is capable of firing two oil atomizers simultaneously during the transfer period
(2) A combustion control system that is capable of limiting the total fuel input to the maximum capacity of the boiler and that has the capability to manually adjust the airflow
(3) A safety interlock system in accordance with 2.3.6 that also prohibits the simultaneous light-off of both atomizers
(4) Manual oil shutoff valves at the burner, downstream of the safety shutoff valves for each atomizer
(5) A pressure gauge in the fuel line downstream of each manual shutoff valve
(6) Manual atomizing media shutoff valves for each atomizer

Exception: Atomizing media shutoff valves shall not be required on mechanically atomized systems.

2.8.3 Oil Atomizer Changeover Procedure. This section describes the requirements and procedures that shall be used for a manual transfer of operation from one oil atomizer (main or auxiliary) to a second oil atomizer (auxiliary or main) without requiring a shutdown of the burner.

(a) Where a Class 1 or Class 2 igniter is available, place it in service in accordance with the manufacturer's instructions as required.

(b) Confirm that the manual oil valve at the burner for the atomizer to be started is closed.

(c) Install the second oil atomizer.

(d) Place the combustion control system in manual mode.

(e) Slowly close the manual shutoff valve while observing the oil pressure downstream of the valve until the oil pressure starts to drop. At this point, the oil flow rate is controlled by the manual valve instead of by the control valve.

(f) For nonmechanically atomized oil atomizers, slowly open the second atomizing medium shutoff valve until it is fully open.

(g) Slowly close the manual oil valve for the atomizer in service while simultaneously opening the manual oil valve of the second atomizer to light the second atomizer from the first. Continue to slowly increase the oil firing rate on the second atomizer while cutting back on the firing rate of the first atomizer in order to maintain a constant heat input of the combined atomizers until the manual valve of the first atomizer is closed and the manual oil valve of the second atomizer is fully open. Excess air shall be maintained at all times by continuously observing the burner flame or by observing the air/fuel ratio, oxygen indicator, or opacity indicator, if provided. During this period, airflow shall be maintained at a constant rate with only the manual fuel valves operated.

(h) Close the atomizing media shutoff valve on the first atomizer if present.

(i) Return the combustion control system and burner-firing rate to automatic operation.

(j) Shut down the igniter as required.

Chapter 3 Multiple Burner Boilers

3.1 Scope.

3.1.1 This chapter of the code shall apply to multiple burner boilers firing one or more of the following:

(1) Gas fuel, as defined in 1.3.72.7 and 1.3.72.10
(2) Oil fuel, as defined in 1.3.72.11
(3) Pulverized coal fuel, as defined in 1.3.72.12

3.1.2 This chapter shall apply to simultaneous firing of more than one fuel.

3.1.3 This chapter shall be used in conjunction with Chapter 1 and requires the coordination of operation procedures, control systems, interlocks, and structural design. Where conflicts exist, the requirements of this chapter shall apply.

3.1.4 The sections of this code that are common to all fuels to be burned in a multiple burner boiler shall be used in conjunction with those sections that are applicable to a specific fuel being utilized.

3.1.5 Section 3.5 shall apply to minimizing the risk of negative furnace draft in excess of furnace structural capability.

3.1.6 Section 3.6 shall apply to burner management, combustion control systems, and operating procedures for multiple burner boilers utilizing gas fuel as defined in 1.3.72.7 and 1.3.72.10.

3.1.7 Section 3.7 shall apply to burner management, combustion control systems, and operating procedures for multiple burner boilers utilizing oil fuel as defined in 1.3.72.11.

3.1.8 Section 3.8 shall apply to burner management, combustion control systems, and operating procedures for multiple burner boilers utilizing pulverized coal fuel as defined in Section 1.3.

3.2 Purpose.

3.2.1 The purpose of this chapter shall be to contribute to operating safety and to prevent furnace explosions and implosions in multiple burner boilers. It establishes minimum requirements that shall be followed for the design, installation, operation, and maintenance of multiple burner boilers and their fuel-burning, air supply, and combustion products removal systems.

3.2.2* The user of this chapter shall recognize the complexity of firing fuel with regard to the type of equipment and the characteristics of the fuel. This chapter shall not eliminate the need for competent engineering judgment.

3.3 Mechanical Equipment Requirements.

3.3.1 Mechanical Equipment. General requirements for mechanical equipment shall be in accordance with Section 1.9.

3.3.2 Furnace Structural Design.

3.3.2.1* The furnace shall be capable of withstanding a transient design pressure without permanent deformation due to yield or buckling of any support member. *(See 3.5.1.)*

3.3.2.1.1 The positive transient design pressure shall be at least, but shall not be required to exceed, +35 in. of water (+8.7 kPa).

Exception: If the test block capability of the forced draft fan at ambient temperature is less positive than +35 in. of water (+8.7 kPa), the positive transient design pressure shall be at least, but shall not be required to exceed, the test block capability of the forced draft fan.

3.3.2.1.2* The negative transient design pressure shall be at least as negative as, but shall not be required to be more negative than, −35 in. of water (−8.7 kPa).

Exception: If the test block capability of the induced draft fan at ambient temperature is less negative than −35 in. of water (−8.7 kPa) [e.g., −27 in. of water (−6.72 kPa)], the negative transient design pressure shall be at least as negative as, but shall not be required to be more negative than, the test block capability of the induced draft fan.

3.4 Burner Management and Combustion Control Requirements.

3.4.1 Burner management and combustion control general requirements shall be in accordance with 1.9.3 through 1.9.7.

3.4.2* Unattended and Off-Site Operation. Unattended operation, no operator at the operating location(s), or operation of the plant from an off-site operating location shall require a higher level of automation, safety interlocks, and reliability, which are not addressed in this code. In addition to operational and safety analysis, designs for off-site and unattended operations shall include risk analysis and hazard studies and be approved by the authority having jurisdiction. Jurisdictional requirements regarding operator attendance shall be met.

3.4.3 Interlock System.

3.4.3.1 General. The basic requirement of an interlock system for a unit is that it shall protect personnel from injury and also protect the equipment from damage. The interlock system shall function to protect boiler operation by limiting actions to a prescribed operating sequence or by initiating trip devices when approaching out-of-range or unstable operating condition. The interlock system shall comply with 1.9.3.

3.4.3.1.1* The mandatory automatic trips specified in 3.4.3.3 shall be provided. Fuel specific interlocks shall be provided for each design basis fuel. The use of additional automatic trips shall be permitted. *(Refer to 1.4.3 for trip function evaluation requirements.)*

3.4.3.1.2 Since all conditions conducive to a furnace explosion or implosion are not detected by any of the mandatory automatic trip devices, even though they are adjusted and maintained in accordance with the manufacturer's instructions and as required by this code, operating personnel shall be made aware of the limitations of the interlock system.

3.4.3.2 Functional Requirements.

3.4.3.2.1 The operation of any interlock that causes a trip shall be annunciated.

3.4.3.2.2 The interlock system shall be installed, adjusted, and tested to confirm design function and timing. Testing and maintenance shall be performed to keep the interlock system functioning as designed.

3.4.3.2.3 If a reburn system is employed, the reburn interlocks shall be integrated with the interlock system. Interlocks associated exclusively with the reburn system shall trip the reburn system only and not generate a master fuel trip.

3.4.3.2.4 The design of an interlock system shall be predicated on the following fundamentals:

(1) The starting procedure and operation shall be supervised to ensure that design operating parameters and sequences are used.
(2) The minimum amount of equipment shall be tripped in the correct sequence when the safety of personnel or equipment is jeopardized.
(3) The initiating cause of the trip shall be indicated, and no portion of the process shall be started until stable operating conditions within design parameters are established.
(4) The necessary trip devices shall be coordinated into an integrated system.
(5) Where automatic equipment is not installed or in service to accomplish the intended function, instrumentation or alternative means to enable the operator to complete the operating sequence shall be provided.
(6) The design shall retain as much flexibility with respect to alternative modes of operation as is consistent with operating procedures and parameters.
(7) The capability for preventive maintenance shall be provided.
(8) The design shall not require any deliberate "defeating" of an interlock in order to start or operate equipment. Whenever a required interlock device is removed temporarily from service, it shall be noted in the log and annunciated. Other means shall be substituted to supervise this interlock function.
(9) The mandatory master fuel trip sensing elements and circuits shall be independent of all other control elements and circuits.

Exception No. 1: Individual burner flame detectors also shall be permitted to be used for initiating master fuel trip systems.

Exception No. 2: Airflow measurement and auctioneered furnace draft signals from the boiler control system shall be permitted to be used for a master fuel trip, provided all the following conditions are met:

(a) These interlocks are hardwired into the burner management system.

(b) Tripping set points are protected from unauthorized changes.

(c) Any single component failure of these sensing elements and circuits does not prevent a mandatory master fuel trip.

(10) Misoperation of the interlock system due to an interruption or restoration of the interlock energy supply shall be prevented.

3.4.3.2.5 The actuation values and time of action of the initiation 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 verify these adjustments.

3.4.3.3 Required Interlocks.

3.4.3.3.1 Interlock System. Figure 3.4.3.3.1 shows the minimum required system of interlocks that shall be provided for basic furnace protection for a multiple burner boiler operated in accordance with this code.

Block 1: Loss of an individual igniter flame shall cause the following actions:

(1) Close the individual igniter safety shutoff valve(s) and deenergize the spark(s).
(2) Open the vent valve (gas ignition only).
(3) Signal the main flame protection system that the igniter flame has been lost.

Block 2a1: High or low igniter fuel gas header pressure shall be interlocked to initiate the tripping of the igniter header and individual igniter safety shutoff valves and deenergize sparks.

Block 2a2: Low igniter fuel oil header pressure shall be interlocked to initiate the tripping of the igniter header and individual igniter safety shutoff valves and deenergize sparks.

Block 2b: Where oil is used for ignition fuel with air or steam atomization, atomizing air or steam pressure out of range shall trip the igniter and individual igniter safety shutoff valves and deenergize sparks.

Where direct electric igniters are used, blocks 1 and 2 shall not apply. However, the master fuel trip system shall deenergize sparks and prevent reenergizing until all conditions for light-off have been reestablished.

Blocks 3 through 12: These blocks represent conditions that initiate the tripping of all main and ignition fuel supplies through a master fuel trip relay(s). The master fuel trip relay(s) shall be of the type that stays tripped until the furnace purge system interlock permits it to be reset, as shown at the bottom of Figure 3.4.3.3.1. Whenever the master fuel trip relay(s) is operated, it trips all fuel safety shutoff valves and de-energizes sparks and all ignition devices within the unit and flue gas path.

The master fuel trip relay(s) shall also trip the oil system circulating and recirculating valves. If the design of the oil supply system is such that backflow of oil through the recirculating valve is inherently impossible or positively prevented, this valve shall be permitted to be manually operated and shall not be required to be interlocked to close automatically on a master fuel trip.

The master fuel trip relay(s) shall also trip the coal burner line shutoff valves or take equivalent functional action to stop coal delivery to burners, primary air fans, or exhausters and coal feeders.

Block 3: The loss of all induced draft fans shall activate the master fuel trip relay.

Block 4: The loss of all forced draft fans shall activate the master fuel trip relay.

Block 5: Low combustion airflow below the permitted limits shall activate the master fuel trip relay.

Block 6: High furnace pressure, such as that resulting from a tube rupture or damper failure, shall activate the master fuel trip relay.

Block 7: Loss of all flame in the furnace shall activate the master fuel trip relay.

Block 8:* A partial loss of flame that results in a hazardous condition shall activate the master fuel trip relay.

Block 9: When all fuel inputs to the furnace are shut off following a shutdown of the boiler for any reason, the master fuel trip relay shall be activated. This necessitates the use of the purge sequence before the fuel supply is permitted to be established. This is a trip function in addition to the permissive function for verification that all individual burner safety shutoff valves are closed as shown in the Furnace Purge System near the bottom of Figure 3.4.3.3.1.

Block 10: A manual switch that actuates the master fuel trip relay directly shall be provided for use by the operator in an emergency.

Block 11: The igniter fuel trip shall activate the master fuel trip relay if igniter fuel is the only fuel in service or if it is being used to stabilize a main fuel.

Block 12a: When the gas burner header fuel pressure is above the maximum or below the minimum for a stable flame, that fuel shall be tripped. If gas was the only fuel in service, the master fuel trip relay shall be actuated.

Block 12b: When the oil burner header fuel pressure is below the minimum for a stable flame, that fuel shall be tripped. If oil was the only fuel in service the master fuel trip relay shall be actuated.

Block 12c: This block represents operation of the oil fuel trip to prevent operation when atomizing air or steam pressure is out of range. If oil was the only fuel in service the master fuel trip relay shall be actuated.

Block 12d: This block represents the tripping/shutdown of coal-firing equipment that will cause a coal fuel trip. If coal was the only fuel in service the master fuel trip relay shall be actuated.

Block 13a: Loss of flame at an individual gas or oil burner with one or more additional burners operating with stable flames that does not introduce a serious enough condition to warrant a master fuel trip as called for in block 8 shall close the individual burner safety shutoff valve(s) and associated igniter safety shutoff valve(s) and deenergize the associated igniter spark. For gang-operated burner valves, the requirements of 3.6.5.2.1.3(s) and 3.7.5.2.1.3(s) shall be met.

Block 13b: On loss of main coal burner flame, the tripping strategies of 3.8.4 shall be followed. *(Refer to Figure 3.4.3.3.1.)*

3.4.3.3.2 Each source of operation of the master fuel trip relay shall actuate a cause of trip indication, which informs the operator of the initiating cause of the tripping impulse.

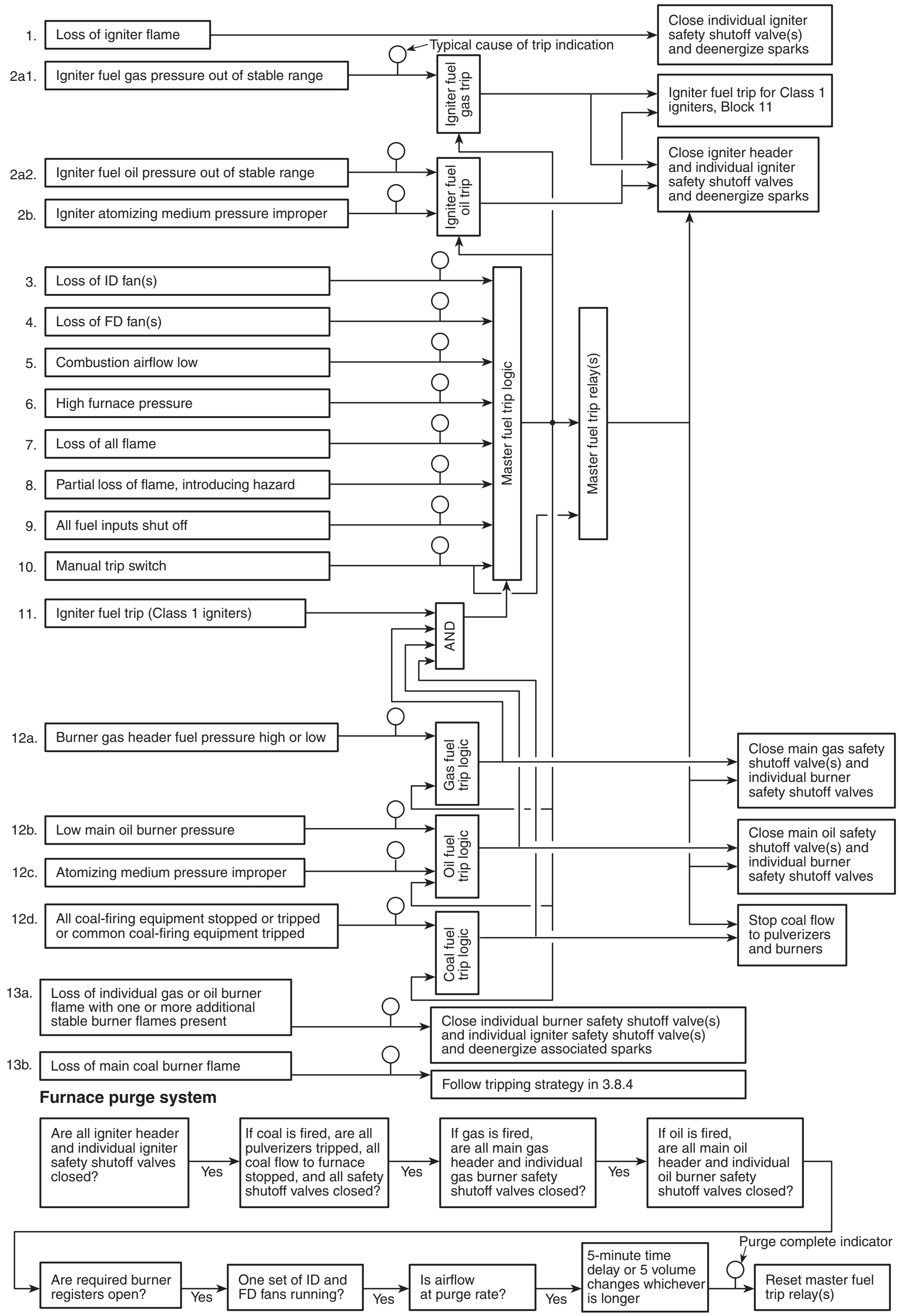
3.4.3.3.3 Main fuel oil recirculating valves shall be permitted to be reset separately and opened following a trip of the master fuel trip relay only after all burner safety shutoff valves have been proven closed.

3.4.3.3.4 The starting sequence shall be supervised by a series of permissive interlocks shown in Figure 3.4.3.3.1 as the furnace purge system. All requirements of the furnace purge system shall be satisfied before permitting resetting of the master fuel trip relay. Unit purge shall be completed with all required burner registers in purge position and all burner header, igniter header, individual burner, and individual igniter safety shutoff valves proven closed by valve position. Purge rate shall not be less than 25 percent of full load mass airflow. Purge rate shall not be greater than 40 percent of full load mass airflow for coal-fired units. Completion of the purge shall be indicated.

Exception: Where the igniter capacity is 5.0 MBtu/hr or less, proof of closure of individual igniter safety shutoff valves by means other than valve position shall be permitted.

3.4.3.3.5 Components (e.g., precipitators, fired reheaters) containing sources of ignition energy shall be purged for either (1) a period of not less than 5 minutes or (2) five volume changes of that component, prior to being placed in operation, whichever is longer. Completion of the purge shall be indicated.

FIGURE 3.4.3.3.1 Interlock system for multiple burner boiler.



3.4.3.3.6* Loss of Induced Draft Fan Interlocks.

(a)*An interlock to prove each induced draft fan is running and capable of providing the required flow shall be provided. Loss of such proofs shall initiate loss of induced draft fan interlocks.

(b) Associated damper(s) shall be closed on loss of an individual induced draft fan, unless it is the last induced draft fan in service.

(c) Where an interlock system is provided to start, stop, and trip induced draft fans and forced draft fans in pairs, the associated forced draft fan shall be tripped on loss of an individual induced draft fan, and the dampers associated with both fans shall be closed, provided they are not the last fans in service. If they are the last fans in service, the dampers associated with both fans shall remain open.

(d) On loss of all induced draft fans, all forced draft fans shall be tripped. All induced draft fan dampers shall be opened after a time delay to minimize high draft during fan coast-down. Dampers shall remain open and fans shall be started in accordance with 3.5.3.2 through 3.5.3.4. Gas recirculation fan system dampers shall be closed.

(e) The master fuel trip (not necessarily automatic) shall be activated when the furnace negative pressure exceeds the value recommended by the manufacturer. If fans are operating after the trip, they shall be continued in service. The airflow shall not be increased by deliberate manual or automatic control actions.

(f) Before the main fuel firing and following a master fuel trip, all induced draft fans shall be tripped if furnace negative pressure exceeds the value recommended by the manufacturer. A short time delay shall be permitted to allow for the negative pressure transients due to loss of the main flame. The value of the negative pressure at which this trip is activated shall be greater than that specified in 3.4.3.3.6(e).

3.4.3.3.7* Loss of Forced Draft Fan Interlocks.

(a)*An interlock to prove each forced draft fan is running and capable of providing the required flow shall be provided. Loss of such proofs shall initiate loss of forced draft fan interlocks.

(b) Associated damper(s) shall be closed on loss of an individual forced draft fan, unless it is the last forced draft fan in service.

(c) Where an interlock system is provided to start, stop, and trip induced draft fans and forced draft fans in pairs, the associated induced draft fan shall be tripped on loss of an individual forced draft fan, and the dampers associated with both fans shall be closed, provided they are not the last fans in service. If they are the last fans in service, the induced draft fan shall remain in controlled operation, and the dampers associated with the forced draft fan shall remain open.

(d) On loss of all forced draft fans, all forced draft fan dampers shall be opened after a time delay to minimize high duct pressure during fan coast-down. Dampers shall remain open. Gas recirculation fan system dampers shall be closed.

(e) The master fuel trip shall be activated when the furnace pressure exceeds the maximum pressure value recommended by the manufacturer. If fans are operating after the trip, they shall be continued in service. The airflow shall not be increased by deliberate manual or automatic control actions.

(f) Before main fuel firing and following a 5-minute period after a master fuel trip (furnace postpurge), forced draft fans shall be tripped if the furnace pressure exceeds the maximum pressure value recommended by the manufacturer.

3.4.3.3.8 Multiple and Variable-Speed Fan Interlocks. On start of the second fan and subsequent fan(s), whether the forced draft or induced draft type, the fan shall be capable of delivering airflow before opening its damper(s).

3.4.3.3.9 Trips and Interlocks for Individual Pulverizer Subsystem on Direct-Fired Furnaces.

3.4.3.3.9.1 Mandatory Automatic Pulverizer Subsystem Trips. A direct-fired pulverized coal system shall be interlocked so that trips are initiated as follows:

(a) Failure of the primary air fan or exhauster shall trip the coal burner shutoff valve, or equivalent, and feeder. The manufacturer's requirements regarding pulverizer tripping shall apply.

(b) Failure of the pulverizer shall trip the feeder and primary airflow.

(c) Failure of the feeder shall initiate an alarm, and restarting shall be blocked until feeder start-up conditions are reestablished.

3.4.3.3.9.2 Mandatory Pulverizer Subsystem Trips — Not Necessarily Automatically Initiated.

(a) Loss of igniters or ignition energy less than required to safely ignite the associated coal burners during the start-up of a pulverizer shall trip that pulverizer subsystem.

(b) Loss of individual coal burner flame shall trip that burner or its pulverizer subsystem. *(Refer to 3.8.5.2.2.8.)*

(c)*Loss of coal feed to the burners of a pulverizer subsystem shall trip the feeder. Feeder tripping shall not be required if the associated Class 1 igniters are in operation.

3.4.3.3.9.3 Mandatory Sequential Starting Interlocks. Permissive sequential interlocking shall be arranged so that the pulverizer subsystem is started only in the following sequence:

(1) Igniters for all burners served by the pulverizer are in service and proven.
(2) The primary air fan or exhauster is started.
(3) The pulverizer is started.
(4) The raw coal feeder is started.

3.4.3.3.10 Interlocks and Trips for Reburn Fuel. The following interlocks shall initiate a reburn fuel trip:

(1) Master fuel trip
(2) Operator-actuated manual trip switch
(3) Reburn gas header pressure high or low
(4) Reburn fuel oil header pressure low
(5) Reburn fuel oil atomizing medium pressure outside of specified limits
(6) Reburn fuel (coal) transport equipment failure or low flow

Exception: If multiple transport systems are used on one boiler, only the failed system shall be tripped.

(7) Reburn fuel (coal) feed or preparation equipment failure

Exception: If multiple reburn fuel preparation systems are used on one boiler, only the failed system shall be tripped.

(8)* Boiler load less than minimum for reburn operation
(9) Overfire airflow, where used, less than minimum for reburn operation as specified by the reburn system manufacturer
(10) Loss of temperature or loss of flame as specified in 3.6.3.4.2 and 3.6.3.4.3.

3.4.4 Alarm System.

3.4.4.1 Functional Requirements.

3.4.4.1.1 The functional requirement of any alarm system is to bring a specific condition to the attention of the operator. Alarms shall be used to indicate equipment malfunction, hazardous conditions, and misoperation. For the purpose of this standard, the primary concern is alarms that indicate conditions that pose a threat of impending or immediate hazards.

3.4.4.1.2 Alarm systems shall be designed so that, for the required alarms in 3.4.4.2, the operator receives audible and visual indication of the out-of-limits condition. Means shall be permitted to silence the audible alarm after actuation, but the visual indication shall continue until the condition is within acceptable limits.

3.4.4.1.3 Where equipment malfunction makes it necessary to manually defeat an alarm, it shall be performed by authorized personnel and the alarm shall be tagged as inoperative.

3.4.4.2* Required Alarms. Fuel-specific alarms shall be provided for all design basis fuels. In addition to the trip alarms in the interlock system shown in Figure 3.4.3.3.1, the following separately annunciated alarms shall be provided.

(a) *Ignition fuel gas header pressure (high and low).* The ignition fuel gas header pressure shall be monitored as close to the burners as practicable.

(b) *Ignition fuel oil header pressure (low).* The ignition fuel oil header pressure shall be monitored as close to the burners as practicable.

(c) *Igniter atomizing steam or air pressure (low).* For steam or air-assisted igniters, an alarm shall be provided to warn that steam or air pressure is outside of operating range and that poor oil atomization is possible.

(d) *Fuel gas supply pressure (high and low).* The gas pressure supplied to the plant shall be monitored at a point as far upstream of the final constant fuel pressure regulator, main fuel control, and main safety shutoff valves as practicable. These alarms shall warn the operator of pressure conditions that might result in damage to equipment or indicate a complete loss of gas supply.

(e) *Fuel gas meter pressure (high and low).* The fuel gas meter pressure shall be monitored at the upstream tap if the fuel gas flowmeter is part of the combustion control system and is not pressure compensated. These alarms shall warn the operator that significant error is present in the flow signal to the control system.

(f) *Fuel gas burner header pressure (high and low).* The burner header gas pressure shall be monitored as close to the burners as practicable.

(g) *Main oil supply pressure (low).* The oil supply pressure shall be monitored at a point as far upstream of the main fuel control and safety shutoff valves as practicable. This alarm shall warn the operator of pressure conditions that might indicate a complete loss of oil supply.

(h) *Main oil viscosity (high).* The main oil temperature shall be monitored to warn that the fuel oil temperature is dropping and that poor atomization of the oil is possible. *[Refer to A.3.4.4.2A, item (h).]*

(i) *Fuel oil burner header pressure (low).* The burner header oil pressure shall be monitored as close to the burners as practicable.

(j) *Atomizing steam or air pressure (low).* For steam or air-assisted burners, an alarm shall be provided to warn that the steam or air pressure and oil pressure is outside of operating range and that poor oil atomization is possible.

(k) *Pulverizer tripped.* An alarm shall indicate when the pulverizer is automatically tripped (not intentionally shut down).

(l) *Primary air fan tripped.* An alarm shall indicate when the primary air fan is automatically tripped (not intentionally shut down).

(m) *Coal stoppage to pulverizer.* An alarm shall indicate when the feeder is running and the coal detecting device indicates no coal is flowing or when the feeder is automatically tripped (not intentionally shut down).

(n) *Coal-air high temperature.* An alarm shall indicate when coal-air temperature within or at the pulverizer outlet exceeds design operating limits. (*Refer to Chapter 6, Pulverized Fuel Systems.*)

(o) *Furnace pressure (high).* This pressure shall be measured as close to the furnace pressure tap used for control as practicable.

(p) *Furnace draft (high).* This applies to balanced draft furnace operation. It shall be measured as close to the furnace draft tap used for control as practicable.

(q) *Loss of operating FD fan.* This shall be sensed and alarmed only when the fan is not operating when expected.

(r) *Loss of operating ID fan.* This applies to balanced draft furnace operation. It shall be sensed and alarmed only when the fan is not operating when expected.

(s) *Furnace airflow (low).* This shall be sensed and alarmed when total airflow falls below purge rate.

(t) *Loss of interlock power.* This shall be sensed and alarmed and shall include all sources of power necessary to complete interlock functions. If more than one source of energy, such as electric power, compressed air, or hydraulics, is needed for an interlock scheme, loss of each source of energy shall be annunciated separately.

(u) *Loss of control power.* This shall be sensed and alarmed to include any sources of power for the control systems.

(v) *Loss of flame.* A partial or total loss of flame envelope still receiving fuel shall be monitored and alarmed.

(w) *Burner valves not closed.* The closed position of individual burner safety shutoff valves shall be monitored, and failure of any valve to close following a trip shall be alarmed.

(x) *Drum water level (low).* The average water level in the boiler drum shall be monitored and shall alarm when the level in the drum drops to the lowest operating point, as recommended by the manufacturer.

(y) *Initiation of directional blocking or override action.* Initiation of directional blocking or override action within the furnace pressure control system shall be monitored and alarmed.

(z) *Redundant transmitter malfunctions.* Redundant transmitter malfunctions within the furnace pressure control system shall be monitored and alarmed.

(aa) *Axial flow fan nearing stall line.*

(bb) *Reburn fuel gas pressure (high and low).* This applies to units with a reburn system. The reburn fuel header pressure shall be monitored as close to the burners/injectors as practicable in order to warn the operator of abnormal fuel pressures in advance of trip conditions.

(cc) *Failure of reburn safety shutoff valve to close.* This applies to units with a reburn system. The closed position of reburn safety shutoff valves shall be monitored, and failure of any valve to close following a trip shall be alarmed.

(dd) *Reburn fuel oil supply pressure low.*

(ee) *Reburn fuel oil temperature low.* A low fuel oil temperature shall be provided if the reburn fuel needs to be heated to maintain viscosity for correct atomization.

(ff) *Reburn atomizing steam or air pressure low.* A low differential pressure alarm between the fuel oil and the atomizing medium or a low atomizing pressure alarm shall be provided, depending on the requirements.

(gg) *Reburn fuel (coal) transport flow (low).* This applies to units with a reburn system.

(hh) *Reburn fuel (coal) transport temperature (high).* This applies to units with a reburn system.

(ii) *Reburn fuel (coal) preparation system fault.* This applies to units with a reburn system. Any failure of the fuel preparation equipment that results in reburn fuel preparation outside of design specifications shall be alarmed.

(jj) *Flue gas combustibles (high).* This applies to units with a reburn system. This alarm shall occur when combustible mixtures measured by the analyzer exceed 1 percent by volume of the flue gas.

(kk) *Furnace temperature (low).* This applies to units with a reburn system and shall be set as defined in 3.6.3.4.2, 3.7.3.5.2, and 3.8.3.5.2. *(Refer to A.3.4.4.2 for additional recommended alarms and monitors.)*

3.5 Furnace Implosion Protection.

3.5.1* General. The requirements of Section 3.5 shall be applied to minimize the risks of negative furnace draft in excess of furnace structural capability. One or both of the following methods shall be used:

(a) The furnace and flue gas removal system shall be designed so that the maximum head capability of the induced draft fan system with ambient air does not exceed the design pressure of furnace, ducts, and associated equipment. This design pressure shall be defined the same as the wind and seismic stresses of the *American Institute of Steel Construction Manual of Steel Construction*, Section A5.2.

(b) A furnace pressure control system shall be provided in accordance with 3.5.2, and furnace design shall be in accordance with 3.3.2.

3.5.2 Furnace Pressure Control Systems (Implosion Protection).

3.5.2.1 Functional Requirements. The furnace pressure control system shall control the furnace pressure at the desired set point in the combustion chamber.

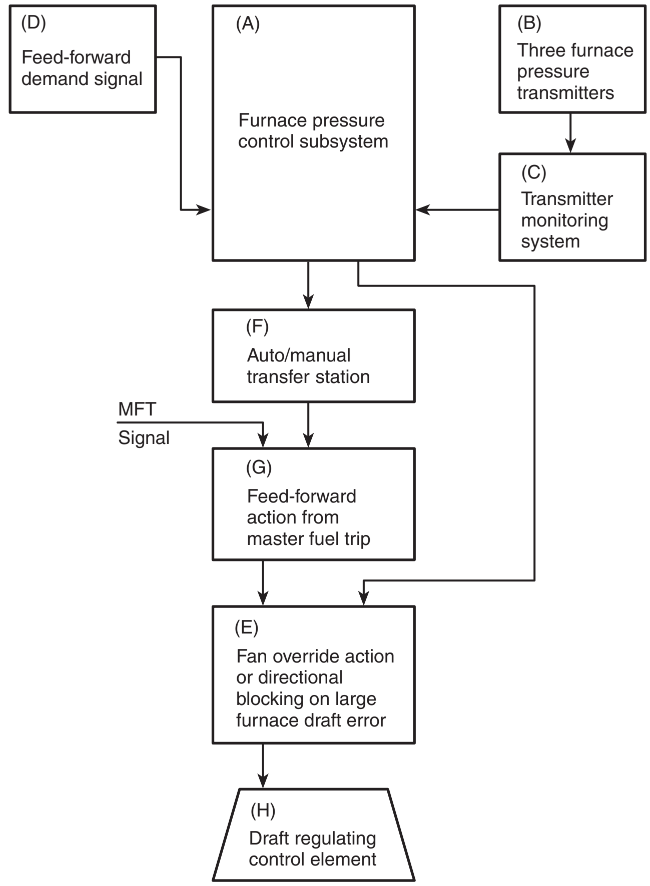
3.5.2.2 System Requirements.

3.5.2.2.1 The furnace pressure control subsystem (A), as shown in Figure 3.5.2.2.1, shall position the draft-regulating equipment so as to maintain furnace pressure at the desired set point.

3.5.2.2.2 The control system, as shown in Figure 3.5.2.2.1, shall include the following features and functions:

(1) Three furnace pressure transmitters (B) in an auctioneered median-select system, each on a separate pressure-sensing tap and suitably monitored (C) to minimize the possibility of operating with a faulty furnace pressure measurement.
(2) A feed-forward signal (D), representative of boiler airflow demand. This shall be permitted to be a fuel flow signal, a boiler-master signal, or other index of demand but shall not be a measured airflow signal.
(3) An override action or directional blocking (E) on large furnace draft errors introduced after the auto/manual transfer station (F).
(4) A feed-forward action (G) initiated by a master fuel trip to minimize the pressure excursions, introduced after the auto/manual transfer station (F).
(5) Axial fans, where used, shall be operated in their stable range to prevent a stall condition in order to prevent uncontrolled changes in airflow or flue gas flow.

FIGURE 3.5.2.2.1 Systems requirements.



3.5.2.3 Component Requirements. The furnace pressure control element(s) (block H in Figure 3.5.2.2.1) (draft fan inlet damper drive, blade pitch control, speed control) shall meet the following criteria:

(1)* The operating speed shall not exceed the control system's sensing and positioning capabilities.
(2) The operating speed of the draft control equipment shall not be less than that of the airflow control equipment.

3.5.3 Sequence of Operations Requirements.

3.5.3.1 The purpose of sequencing shall be to ensure that the operating events occur in the order required. Fan start-up and shutdown procedures as defined by manufacturers, engineering consultants, and operating companies shall be coordinated with the operating procedures specified in this section and in the related sections applicable to the fuel being fired as follows:

(1) Gas-fired systems, Section 3.6
(2) Oil-fired systems, Section 3.7
(3) Pulverized coal-fired systems, Section 3.8

3.5.3.2 An open-flow path from the inlet of the forced draft fans through the stack shall be ensured under all operating conditions. Where the system design does not permit the use of fully open air paths, the minimum open area air paths shall be not less than that required for purge airflow requirements with fans in operation.

(a) The following requirements shall apply:

(1)* On installations with multiple induced draft or forced draft fans, all fan flow control devices and shutoff dampers shall be opened in preparation for starting the first induced draft fan. In addition, isolating dampers, windbox dampers, air registers, and other control dampers shall be opened as required to ensure an open-flow path from the forced draft fan inlet through the furnace, the induced draft fans, and the stack. Unless an open-flow path is provided by other means, provision of the open path shall be ensured while starting the first induced draft and forced draft fan.

(2) On installations with a single induced draft fan or forced draft fan, the induced draft fan's associated control devices and shutoff dampers shall be permitted to be closed as required during the fan's start-up. The forced draft fan's associated flow control devices and shutoff dampers shall be brought to the position that limits starting current for the fan's start-up and then shall be brought to the position for purge airflow during fan operation.

(b)*Within the limitations of the fan manufacturer's recommendations, all flow control devices and shutoff dampers on idle fans shall remain open until the first induced draft fan and first forced draft fans are in operation while maintaining furnace pressure conditions and indication of an open flow path.

(c) The practice of operating with excess induced draft fan capability in relation to either forced draft fan capability or boiler load shall be prohibited.

3.5.3.3 The sequence for starting and stopping fans under all conditions shall be as follows:

(1) An induced draft fan is started and followed by the start of a forced draft fan. Succeeding induced draft and forced draft fans shall be started in accordance with 3.5.3.4.

(2) Shutdown procedures shall be the reverse of those specified in 3.5.3.3(1).

3.5.3.4 Where starting and stopping fans, the methods employed and the manipulation of the associated control elements shall minimize furnace pressure and airflow excursions. The furnace pressure control subsystem shall be placed and maintained on automatic control as soon as practicable.

3.5.3.5 Following shutdown of the last fan due to any cause, the opening of fan dampers shall be delayed or controlled to prevent positive or negative furnace pressure transients in excess of design limits during fan coast-down.

3.5.4 Interlock System Functional Requirements.

3.5.4.1 The functional requirements for interlock systems shall be as specified in 3.4.3.

3.5.4.2 Not all conditions conducive to a furnace implosion are detected by any of the mandatory automatic-trip devices, even though such devices are adjusted and maintained in accordance with the manufacturer's instructions and as required by this standard; therefore, operating personnel shall be made aware of the limitations of the automatic protection system.

3.6 Fuel Gas Systems.

3.6.1 General. The requirements of Section 3.6 shall apply to installations where fuel gas is supplied.

3.6.2 Gas Firing — Special Problems. In addition to the common hazards involved in the combustion of solid, liquid, and gaseous fuels, the following special hazards related to the physical characteristic of gas shall be addressed in the design of the firing systems:

(a) Gas is colorless; therefore, a leak is not visually detectable. In addition, detection of a gas leak by means of odor is unreliable.

(b) Leakage within buildings creates hazardous conditions, particularly where the gas piping is routed through confined areas. In the latter situation, adequate ventilation shall be provided. Outdoor boilers tend to minimize confined area problems.

(c) The nature of fuel gas makes it possible to experience severe departures from design air/fuel ratios without any visible evidence at the burners, furnace, or stack that could escalate into a progressively worsening condition. Therefore, combustion control systems that respond to reduced boiler steam pressure or steam flow with an impulse for more fuel unless protected or interlocked to prevent a fuel-rich mixture are potentially hazardous. This also shall apply to firing with fuel or air on manual without the previously mentioned interlocks or alarms. *(Refer to subsections 3.6.3, 3.6.4, 3.6.5, and 3.4.3, which provide requirements; refer to Appendix D.)*

(d) Special requirements as defined in NFPA 54, *National Fuel Gas Code*, shall be taken with wet gas systems.

(e) Widely different characteristics of gas from either a single source or multiple sources could result in significant change in the heat input rate to the burners without a corresponding change in airflow.

(f) Relief valves and atmospheric vents shall discharge into areas away from building ventilation systems, sources of ignition, or other areas where the discharge gases create a hazard.

(g) Gas piping shall be purged prior to and after maintenance and repair, as defined in NFPA 54, *National Fuel Gas Code*.

3.6.3 System Requirements.

3.6.3.1 Fuel Supply Subsystem — Fuel Gas. The requirements in this section shall apply to fuel gas supply piping. All installed piping arrangements shall meet the functional requirements of this code. *[Refer to Figures A.3.6.5.1.2(a) and (b), which show the typical fuel gas piping arrangements on which the text in this code is based.]*

3.6.3.1.1 The fuel supply equipment shall be sized to satisfy the design requirements and arranged to ensure a continuous, steady fuel flow over all operating requirements of the unit. This shall include coordination of the main fuel control valve, burner safety shutoff valves, and associated piping volume to ensure against fuel pressure transients that exceed burner limits for stable flame as a result of placing burners in service or taking them out of service.

3.6.3.1.2 The portion of the fuel supply system outside the boiler room shall be arranged to prevent excessive fuel gas pressure in the fuel-burning system, even in the event of failure of the main supply constant fuel pressure regulator(s). This shall be accomplished by providing full relieving capacity that is vented to a safe location or by providing a high gas pressure trip when full relieving capacity is not installed. *[Refer to Figure A.3.6.5.1.2(b), which shows a typical gas supply system outside the boiler room.]*

3.6.3.1.3 The fuel supply equipment shall be designed to inhibit fuel contamination. Access to important fuel system components shall be provided. Drains shall be provided at low points in the piping.

3.6.3.1.4 The fuel supply equipment shall be capable of continuing uninterrupted fuel flow during anticipated furnace pressure pulsation.

3.6.3.1.5 The fuel supply equipment shall be designed based on the operating environment and ambient conditions. The piping shall be designed to be resistant to severe external conditions such as fire or mechanical damage.

3.6.3.1.6* Positive means to prevent leakage of gas into an idle furnace shall be provided. Any line to a burner or igniter shall include provisions to vent the piping upstream of the last shutoff valve.

3.6.3.1.7 Tightness tests of the main safety shutoff valves, individual burner safety shutoff valves, and associated vent valves shall be performed. Permanent provisions shall be made in the gas piping to allow for making leak tests and subsequent repairs. Valves added in vent lines for leak testing shall be either continuously monitored and alarmed when in the incorrect position or be locked in the open position except when leak testing is being performed.

3.6.3.1.8 The discharge from atmospheric vents and relief valves shall be located so that there is no possibility of the discharged gas being drawn into the air intake, ventilating system, or windows of the boiler room or adjacent buildings and shall be extended above the boiler and adjacent structures so that gaseous discharge does not present a fire hazard.

3.6.3.1.9* Manifolding of all vents shall be permitted.

Exception No. 1: Burner vents shall not be manifolded with igniter vents.

Exception No. 2: Header vents shall be manifolded only with other header vents.

Exception No. 3: Vents of headers being served from different pressure reducing stations shall not be manifolded.

Exception No. 4: Vent systems of different boilers shall not be manifolded.

Exception No. 5: Vents of systems operating at different pressures shall not be manifolded.

Exception No. 6: Vents of systems using different fuel sources shall not be manifolded.

3.6.3.1.10 Gas piping material and system design shall be in accordance with NFPA 54, *National Fuel Gas Code* (for gas piping inside industrial and institutional buildings), or ASME B 31.1, *Power Piping* (for gas piping in power applications), or ASME B 31.3, *Process Piping* (for gas piping in process applications).

3.6.3.2 Main Burner Subsystem.

3.6.3.2.1* The main burner subsystem shall be designed so that the burner inputs are supplied to the furnace continuously and within their stable flame limits. Class 1 or Class 2 igniters, as demonstrated by test in accordance with 1.9.2.3.2(d) and 3.6.3.2.2, shall be permitted to be used to maintain stable flame.

3.6.3.2.2* The limits of stable flame for each burner subsystem producing a separate flame envelope shall be determined by tests without the ignition subsystem in service. These tests shall verify that transients generated in the fuel and air subsystems do not affect the burners adversely during operation. These tests shall include the expected range of fuels. These tests shall be repeated after any combustion process modification, such as the addition of overfire air, low NO_x burners, reburn, and after switching to any fuel not previously tested.

3.6.3.2.3 Each main burner or burners in combination shall provide enough system resistance or damping to the fuel and airflow to override furnace pulsations and maintain stable combustion.

3.6.3.2.4 Provisions shall be made for visual observation of conditions at the burner ignition zone. Additional provisions shall be made for flame detection equipment.

3.6.3.2.5* The burner equipment shall be in a location that allows access for maintenance. The requirements of housekeeping in 1.7.1.2(8) shall be followed.

3.6.3.2.6 All burner safety shutoff valves shall be located close to the burner to minimize the volume of fuel left downstream of the burner valves in the burner lines.

3.6.3.3 Flue Gas Recirculation to Burners. When flue gas or other inert gases are introduced to the secondary air or combustion air being supplied to burners, testing shall be used to demonstrate that the methods and devices used provide uniform distribution and mixing. The oxygen content of the mixture being supplied to the burners shall not be permitted to go below the limit specified by the burner manufacturer or as proven by tests to provide stable combustion. Means shall be provided to monitor either the ratio of flue gas to air or the oxygen content of the mixture.

3.6.3.4 Reburn Fuel Supply Subsystem — Fuel Gas.

3.6.3.4.1 Positive means to prevent leakage of gas into an idle furnace shall be provided. This shall include a double block and vent valve arrangement on the reburn fuel gas supply, separate from any other double block and vent valve arrangements for other systems, that is, igniters or main burners. Provisions shall be made to vent the piping between individual reburn shutoff valves and the last main reburn safety shutoff valve.

3.6.3.4.2 Furnace temperature at the location of reburn fuel injection shall be at least 300°F (167°C) above the autoignition temperature of the reburn fuel and shall be verified by test. The tests shall be performed for a variety of boiler loads, burner firing configurations, furnace cleanliness conditions, and excess air levels to determine the conditions under which reburn operation shall be permitted.

3.6.3.4.3* Fuel reburn systems shall include either temperature monitoring or reburn flame sensors.

3.6.3.4.4 Fuel reburn systems shall utilize a flue gas combustibles analyzer to detect combustibles.

3.6.4 Flame Monitoring and Tripping System.

3.6.4.1 Each burner shall be supervised individually. Upon detection of loss of a burner flame, that individual burner safety shutoff valve shall be automatically closed.

3.6.4.1.1 Where Class 1 igniters are provided, the main burner flame shall be proven either by the flame scanner or by the igniter being proven. At least one flame detector shall be provided for each burner to detect the burner flame or igniter flame where a Class 1 igniter is provided.

3.6.4.1.2 Burners with Class 2 igniters shall have at least two flame detectors. One detector shall be positioned to detect the main burner flame and shall not detect the igniter flame. The second detector shall be positioned to detect the igniter flame during prescribed light-off conditions.

3.6.4.1.3 Burners with Class 3 igniters shall have at least one flame detector. The detector shall be positioned to detect the igniter flame. It also shall detect the main burner flame after the igniter is removed from service at the completion of the main burner trial for ignition.

3.6.4.2 Upon detection of loss of all flame in the furnace or partial loss of flame to the extent that hazardous conditions develop as defined in 3.4.3.3.1, block 8, a master fuel trip shall be automatically initiated.

3.6.4.3 Any fuel input that does not ignite and burn on a continuous basis shall be classified as a hazard. Regardless of the number or pattern of flame loss indications used for tripping, loss of flame indication on an operating burner or "flame envelope" shall initiate an alarm that warns the operator of a potential hazard.

3.6.4.4* The flame tripping concept used on the unit shall have been validated by the boiler manufacturer for the specific furnace configuration being used. This validation shall not be used to replace unit acceptance tests relating to proof of design, function, and components.

3.6.4.5 The reburn system shall be shut down in accordance with the reburn system manufacturer's requirements if the temperature falls below the limit specified in 3.6.3.4.2. The reburn system shall be tripped if the temperature drops to 100°F (56°C) below the limit specified in 3.6.3.4.2. Loss of flame shall trip the operation of the reburn system, or portions of the reburn system, in accordance with the reburn system manufacturer's requirements.

3.6.5 Sequence of Operations.

3.6.5.1 General.

3.6.5.1.1 Sequencing shall be required to ensure that operating events occur in the order established by proven operating procedures. Sequencing shall follow procedures that allow fuel that falls within design specifications to be admitted to the burners only when there is ignition energy and airflow within minimum design requirements needed to ignite the fuel as it enters the furnace. Sequencing also shall be utilized where removing burners from operation.

3.6.5.1.2* The sequences of operation in 3.6.5 shall be followed whether the unit is operated manually or certain functions are accomplished by interlocks or automatic controls. *[Refer to Figures A.3.6.5.1.2(a) and (b), which show the typical piping arrangements on which the text in 3.6.5 is based.]*

3.6.5.1.3 The starting and shutdown sequence outlined in this chapter shall be followed. It shall provide the required practice of maintaining a continuous airflow through the unit at the rate that is used during the purge operation. This rate shall be maintained throughout the start-up and initial load-carrying period of operation until such time as more fuel and air are needed. This means that the same number of burner registers or burner dampers needed for purging the boiler shall be left open throughout the starting sequence as described in the following subparagraphs. The objective of this practice shall be to ensure an air-rich furnace atmosphere during start-up and establish minimum velocities through the furnace to prevent hazardous accumulations of unburned fuel.

3.6.5.1.4 Burners shall not be placed in service or removed in a random pattern but in a sequence defined by operating instructions and verified by actual experience with the unit in order to minimize laning or stratification of fuel or combustion products. Burners shall be placed in service as necessary, with fuel flows and individual register or damper settings positioned for light-off according to an established operating procedure.

3.6.5.1.4.1 The fuel pressure at the burner header shall be permitted to be used as a guide in maintaining the necessary fuel flow for each burner and shall be maintained automatically within prescribed limits as additional burners are placed in service. The total number of burners placed in service shall be that number necessary to accomplish the following:

(1) Raise the boiler pressure or temperature.
(2) Carry the initial load on the unit.

3.6.5.1.4.2 If some registers have been maintained in the closed position, the registers shall not be opened without either readjusting the total airflow to maintain the same burner airflow or closing an equal number of registers on idle burners to obtain the same effect. The total furnace air throughput shall not be reduced below the purge flow rate.

3.6.5.1.5* The open register light-off and purge procedure shall be used to maintain airflow at or above the purge rate during all operations of the boiler. The open register–purge procedure shall include the following:

(1) Use of minimum number of required equipment manipulations, thereby minimizing exposure to operating errors or equipment malfunction
(2) Creation of a fuel-rich condition at individual burners during their light-off
(3) Creation of an air-rich furnace atmosphere during light-off and warm-up by maintaining total furnace airflow at the same rate as that needed for the unit purge

3.6.5.1.5.1 This procedure shall incorporate the following conditions:

(1) All of the registers necessary to establish airflow at or above purge rate and uniform flow distribution throughout the furnace placed in a predetermined open position
(2) Overfire air port dampers placed in a predetermined position providing a purge of the overfire air system
(3) A unit purge completed with the burner air registers and overfire air ports in the position specified in 3.6.5.1.5.1(1) and (2)
(4) Components (e.g., precipitators, fired reheaters) containing sources of ignition energy purged for either (1) a period of not less than 5 minutes or (2) five volume changes of that component, prior to being placed into service, whichever is longer
(5) Common component(s) between the furnace outlet and the stack shared with other operating boilers bypassed for unit purge
(6) The first burner or group of burners lighted without any change in the airflow setting, overfire air control damper position, or burner air register position, except as permitted in 3.6.5.2.1.3(h)

3.6.5.1.5.2 Each boiler shall be tested during initial start-up to determine whether any modifications to the procedure specified in 3.6.5.1.5 are required in order to establish ignition or to satisfy other design limitations during light-off and warm-up. For boilers that are purged with the registers in their normal operating position, it shall be allowed to momentarily close the registers of the burner being lighted, if proven necessary to establish ignition. Modifications in the basic procedure shall be allowed only if they have been proven to be necessary to obtain light-off. However, 3.6.5.1.5(1) shall always be followed, thereby satisfying the basic objectives in 3.6.5.1.5.1.

3.6.5.1.6 Modification to the mode of operation due to water, steam, and flue gas temperatures being outside the established limits in the economizers and superheaters shall be made only after it has been determined to be necessary by operating experience.

3.6.5.2 Functional Requirements.

3.6.5.2.1 Cold Start. This section covers the requirements for placing gas in service as the initial fuel being fired. Subparagraph 3.6.5.2.6 covers the requirements for placing gas in service as a subsequent fuel.

3.6.5.2.1.1 Preparation for starting shall include a thorough inspection that shall verify the following:

(1) The furnace and gas passages are free of foreign material and not in need of repair.
(2)* The bottom of the furnace is free of accumulations of solid or liquid fuel, gases, or vapors prior to each start-up.
(3) All personnel are evacuated from the unit and associated equipment, and all access and inspection doors are closed.
(4) All airflow and flue gas flow control dampers have been operated through their full range to check the operating mechanism and then are set at a position that allows the fans to be started at a minimum airflow and without overpressuring any part of the unit.
(5) All individual burner dampers or registers that are subject to adjustment during operations have been operated through their full range to check the operating mechanism.
(6) The drum water level is established in drum-type boilers and circulating flow is established in forced circulation boilers, or minimum water flow is established in once-through boilers.
(7) The oxygen and combustibles analyzer(s), if provided, are operating as designed and a sample has been obtained. Combustible indication is at zero and oxygen indication is at maximum.
(8) All safety shutoff valves are closed. All sparks are de-energized.
(9) Oil ignition systems meet the requirements of Section 3.7.
(10) The fuel system vents are open and venting to atmosphere outside the boiler room. Lines are drained and cleared of materials such as condensate.
(11) The burner elements and igniters are positioned in accordance with the manufacturer's specification.
(12) Energy is supplied to control systems and to interlocks.
(13) The meters or gauges indicate fuel header pressure to the unit.
(14) A complete functional check of the interlocks has been made after an overhaul or modification of the interlock system.
(15)*An operational test of each igniter has been made. The test shall be integrated into the starting sequence and shall follow the unit purge and precede the admission of any main fuel.
(16) Individual igniters or groups of igniters also shall be permitted to be tested while the unit is in service. Such tests shall be made with no main fuel present in the igniter's associated burner, and the burner air register shall be in its start-up or light-off position as described in the established operating procedure.
(17)*Units with a history of igniter unreliability shall require additional test routines to verify the continuing operating ability of igniters and ignition system components.

3.6.5.2.1.2 Where provided, regenerative air heaters and gas recirculation fans shall be operated during all operations of the unit in a manner recommended by the boiler manufacturer.

3.6.5.2.1.3 Starting Sequence. Operation of regenerative-type air heaters, precipitators, and gas recirculation fans shall be included in the start-up sequence in accordance with the manufacturer's recommendations. The starting sequence shall be performed in the following order:

(a) An open flow path from the inlets of the forced draft fans through the stack shall be verified.

(b) An induced draft fan, if provided, shall be started; a forced draft fan then shall be started. Additional induced draft fans or forced draft fans shall be started in accordance with 3.5.3, as necessary, to achieve purge flow rate.

(c) Dampers and burner registers shall be opened to the purge position in accordance with the open register purge method objectives outlined in 3.6.5.1.5.

(d) The airflow shall be adjusted to purge airflow rate, and a unit purge shall be performed. Special provisions shall be utilized as necessary to prevent the hazardous accumulation of volatile vapors that are heavier than air or to detect and purge accumulations in the furnace bottom.

(e) The main fuel control valve shall be closed and the main safety shutoff valve(s) shall be opened, but only after the requirements of 3.6.5.4.6 for leak test requirements and 3.4.3.3.4 for permissive conditions in the furnace purge system have been satisfied.

(f) It shall be determined that the main fuel control valve is closed, and the main fuel bypass control valve, if provided, then shall be set to maintain the necessary burner header fuel pressure for light-off. The burner headers shall be vented in order to be filled with gas and to provide a flow (if necessary) so that the main fuel and bypass fuel control valves function to regulate and maintain the correct pressure for burner light-off. The main fuel control valve shall be opened when necessary. The time needed to vent for control of header pressure after header charging shall be evaluated and minimized.

(g) The igniter safety shutoff valve shall be opened, and it shall be determined that the igniter fuel control valve is holding the manufacturer's recommended fuel pressure necessary to allow the igniter to operate at design capacity. The igniter headers shall be vented in order to be filled with gas and to provide a flow (if necessary) so that the igniter fuel control valve functions to regulate and maintain the pressure within design limits specified by the manufacturer for lighting the igniters. The time needed to vent for control of header pressure after header charging shall be evaluated and minimized.

(h) The air register or damper on the burner selected for light-off shall be adjusted to the position recommended by the manufacturer or the established operating procedure, in accordance with the requirements of 3.6.5.1.5.2.

(i) The spark or other source of ignition for the igniter(s) on the burner(s) to be lit shall be initiated. The individual igniter safety shutoff valve(s) shall be opened, and all igniter system atmospheric vent valves shall be closed. If flame on the first igniter(s) is not established within 10 seconds, the individual igniter safety shutoff valve(s) shall be closed and the cause of failure to ignite shall be determined and corrected. With airflow maintained at purge rate, repurge shall not be required, but at least 1 minute shall elapse before attempting a retrial of this or any other igniter. Repeated retrials of igniters without investigating and correcting the cause of the malfunction shall be prohibited.

(j) Where Class 3 special electric igniters are used, the procedures described in 3.6.5.2.1.3(a) through (f), (h), and (k) through (n) shall be used, recognizing the requirements for individual main burner flame supervision.

(k) After making certain that the igniter(s) is established and is providing the required level of ignition energy for the main burner(s), the individual burner safety shutoff valve(s) shall be opened and the individual burner atmospheric vent valves shall be closed. The master fuel trip shall be initiated when the flame detection system(s) indicates that ignition has not been obtained within 5 seconds of the time the fuel actually begins to enter the furnace. Purging shall be repeated, and the conditions that caused the failure to ignite shall be corrected before another light-off attempt is made. For the following burner and all subsequent burners placed in operation, failure to ignite or loss of ignition for any reason on any burner(s) shall cause fuel flow to that burner(s) to stop. All conditions required by the manufacturer or by established operating procedures for light-off shall exist before restarting the burner(s).

(l) After stable flame is established, the air register(s) or damper(s) shall be adjusted slowly to its operating position, making certain that ignition is not lost in the process. With automatic burner management systems, the air register shall be permitted to be opened simultaneously with the burner safety shutoff valve.

(m) Class 3 igniters shall be shut off at the end of the time trial for proving the main flame. It shall be verified that the stable flame continues on the main burners after the igniters are shut off. Systems that allow the igniters to remain in service on either an intermittent or a continuous basis shall have been tested to meet all the requirements of Class 1 igniters or Class 2 igniters with associated interlocks in service.

(n) After the main burner flame is established, the burner header atmospheric vent valve shall be closed. If the charging valve is used, the burner header atmospheric vent valve will have been closed in accordance with 3.6.5.4.7. The main fuel bypass control valve will automatically control the burner header gas pressure.

(o)*The procedures in 3.6.5.2.1.3(h) through (m) shall be followed for placing additional burners with open registers in service, as necessary, to raise steam pressure or to carry additional load. If used, automatic control of burner fuel flow and burner airflow during the lighting and start-up sequence shall be in accordance with the requirements of 3.6.5.2.1.3(q). The fuel flow to each burner (as measured by the burner fuel header pressure) shall be maintained at a controlled value that is compatible with the established airflow through the corresponding burner. The established airflow through each open register shall be permitted to be maintained by controlling the windbox-to-furnace differential.

Total furnace airflow shall not be reduced below purge rate airflow and shall be at least that which is necessary for complete combustion in the furnace. If it is necessary to vary fuel header pressure to eliminate a problem of having excessive lighting off and shutting down of burners, such variations shall be limited to a predetermined range. This range shall be a function of the incremental fuel input that is added by the lighting of a single burner or gang of burners.

(p) The maximum number of burners shall be placed in service consistent with the anticipated continuous load and the operating range of fuel header pressures.

(q) The on-line metering combustion control (unless designed specifically for start-up procedures) shall not be placed into service until the following have occurred:

(1) A predetermined minimum main fuel input has been attained.
(2) All registers on nonoperating burners are closed unless compensation is provided for by the control system.
(3) The burner fuel and airflow are adjusted as necessary.
(4) Stable flame and specified furnace conditions have been established.

(r) It shall be permitted to place a multiple number of igniters in service that are served simultaneously from a single igniter safety shutoff valve, provided that the igniters are reliably supervised, so that failure of one of the group to light causes the fuel to all igniters in the group to shut off.

(s) It also shall be permitted to place in service simultaneously a multiple number of burners served by their corresponding multiple igniters from a single burner safety shutoff valve, provided that the burners are reliably supervised, so that failure of one of the group to light causes the fuel to all burners in the group to shut off.

(t) On units with an overfire air system, the overfire air control damper positions shall be permitted to be changed only when repositioning of all burner air registers or burner air dampers is permitted.

(u) On units with an overfire air system, the boiler shall be operating in a stable manner before the overfire air is introduced. The introduction of the overfire air shall not adversely affect boiler operation.

(v) On units with an overfire air system and a reburn system, the overfire air shall be placed in operation before starting the reburn fuel sequence.

(w) A reburn system shall only be placed in service after the boiler is operating at such a load as to ensure that the introduction of the reburn fuel will not adversely affect continued boiler operation. This shall include a load that maintains the required reburn zone temperatures in accordance with 3.6.3.4.2. The boiler shall be operating in a stable manner before the reburn start-up sequence is initiated.

3.6.5.2.2 Normal Operation.

3.6.5.2.2.1* The firing rate shall be regulated by increasing or decreasing the fuel and air supply simultaneously to all operating burners, maintaining air/fuel ratio within predetermined operating limits continuously at all firing rates. This requirement shall not eliminate the requirements for air lead and lag during changes in the fuel firing rate.

Exception: This requirement shall not apply to systems provided with metering of air and fuel to each burner and designed specifically for individual burner modulating control.

3.6.5.2.2.2 The reburn injection rate shall be regulated within the design limits of the reburn equipment. Air flow lead and lag shall be used during changes in the reburn fuel injection rate. Reburn safety shutoff valves shall be fully open or completely closed. Intermediate settings shall not be used.

3.6.5.2.2.3 The firing rate shall not be regulated by varying the fuel to individual burners by means of the individual burner safety shutoff valve(s). The individual burner safety shutoff valve(s) shall be fully open or completely closed. Intermediate settings shall not be used.

3.6.5.2.2.4 Air registers shall be set at the firing positions as determined by tests.

Exception: This requirement shall not apply to systems provided with metering of air and fuel to each burner and designed specifically for individual burner modulating control.

3.6.5.2.2.5 The burner fuel and airflow shall be maintained within a range between the maximum and minimum limits as determined by trial or, if trial results do not exist, as specified by the combustion equipment manufacturer(s). These trials shall test for minimum and maximum limits and stable flame under each of the following conditions:

(1) With all gas burners in service and combustion controls on automatic
(2) With different combinations of gas burners in service and combustion controls on automatic
(3) With different combinations of gas, oil, and coal burners in service and combustion controls on automatic
(4) With minimum and maximum reburn flow rates
(5) With each reburn fuel injection pattern
(6) With overfire air operating at its minimum and maximum limits

Where changes occur to any of the minimum and maximum limits because of equipment modifications, operating practices, or fuel conditions, retesting shall be required.

3.6.5.2.2.6 On loss of an individual burner flame, that individual burner's safety shutoff valve shall be automatically closed and the vent shall be opened immediately. The burner register shall be closed if it interferes with the air/fuel ratio supplied to any other individual burner flame.

3.6.5.2.2.7 Total airflow shall not be reduced below the purge rate.

3.6.5.2.3 Normal Shutdown. The requirements in 3.6.5.2.3 shall apply to the removal of gas from service as the only main burner fuel being fired. The requirements in 3.6.5.2.7 shall apply to the removal of gas from service with other fuel remaining in service.

3.6.5.2.3.1 When taking the unit out of service, the boiler load shall be reduced to that necessitating a purge rate airflow, while maintaining operation within the tested limits determined in 3.6.5.2.2.5. Prior to removing gas from service and prior to loss of reburn permissives, reburn fuel shall be shut down as defined in 3.6.5.2.9, 3.7.5.2.9, or 3.8.5.2.9.

3.6.5.2.3.2 The metering combustion control shall be taken out of service, and the start-up fuel supply pressure, register settings, and airflows shall be established in accordance with written start-up procedures.

Exception: Where designed for start-up and shutdown procedures, the metering combustion control shall not be required to be taken out of service.

3.6.5.2.3.3 As the fuel is reduced, a sequential shutdown of the burners shall be accomplished by closing the individual burner safety shutoff valves and opening the vent valves. Registers shall be placed in the position prescribed by the established operating procedure(s).

3.6.5.2.3.4 When the last individual burner safety shutoff valves are closed, the main safety shutoff valve shall be closed.

3.6.5.2.3.5 All atmospheric vent valves shall be opened to minimize the possibility of gas leaking into the boiler enclosure.

3.6.5.2.3.6 When all burners, igniters, and the reburn system have been removed from service, the purge rate airflow shall be verified and a unit purge shall be performed.

3.6.5.2.3.7 After completion of the unit purge, closing the burner air registers and shutting down the forced draft fans and induced draft fans shall be permitted to be optional; however, maintaining airflow through the unit to prevent accumulation of combustible gases is a prudent procedural step due to the potential of fuel leak-by. Leakage of main or igniter fuel into the furnace or windbox shall be prevented.

3.6.5.2.4 Normal Hot Restart.

3.6.5.2.4.1 When restarting a hot unit, the requirements of 3.6.5.2.1.1(6) through (13) for a cold start shall be met.

3.6.5.2.4.2 The starting sequence in 3.6.5.2.1.3 shall be followed.

3.6.5.2.5 Emergency Shutdown — Master Fuel Trip.

3.6.5.2.5.1 An emergency shutdown shall initiate a master fuel trip.

3.6.5.2.5.2 A master fuel trip that results from any of the emergency conditions tabulated in Tables 3.6.5.2.5.2(a) and (b) shall stop all fuel flow to the furnace from all burners and the reburn system by tripping the main and individual burner safety shutoff valves and the main and individual reburn safety shutoff valves. All vent valves shall be opened. The igniter safety shutoff valve and individual igniter safety shutoff valves shall be tripped, and the igniter sparks shall be deenergized. If a furnace inerting system is installed, the inerting system shall be operated simultaneously with the master fuel trip. Master fuel trips shall operate to stop all fuel flow into the furnace within a period that does not allow a dangerous accumulation of fuel in the furnace. A master fuel trip shall not initiate a forced draft fan or induced draft fan trip. Electrostatic precipitators, fired reheaters, or other ignition sources shall be tripped.

3.6.5.2.5.3* Procedure for Purging after an Emergency Shutdown. Fans that are operating after the master fuel trip shall be continued in service. The airflow shall not be increased by deliberate manual or automatic control action. If the airflow is greater than the purge rate, it shall be permitted to be decreased gradually to the purge rate for a unit purge. If the airflow is less than the purge rate at the time of the trip, it shall be continued at the existing rate for 5 minutes and then increased gradually to the purge rate airflow and held at this value for a unit purge.

3.6.5.2.5.4 During a master fuel trip event, the overfire air system shall remain at the same setting as when the event occurred for such time as the main combustion airflow is held. Following this hold period, the overfire air shall be permitted to be gradually adjusted to overfire air purge settings or cooling flows either manually or automatically.

3.6.5.2.5.5 If the emergency trip was caused by loss of draft fans or if draft fans also have tripped, all dampers in the air and flue gas passages of the unit shall be opened slowly to the fully open position in order to create as much natural draft as possible to ventilate the unit. Opening fan dampers shall be timed or controlled to ensure positive or negative furnace pressure transients beyond design limits do not occur during fan coast-down. This condition shall be maintained for at least 15 minutes. At the end of this period, the fan(s) shall be started in accordance with Section 3.5. The airflow shall be increased gradually to the purge rate, and a unit purge shall be completed.

Table 3.6.5.2.5.2(a) Mandatory Automatic Master Fuel Trips (Install interlocks in accordance with 3.5.4 and 3.4.3)

A master fuel trip shall result from any of the following conditions:
(1) Fuel pressure at the burner below the minimum established by the manufacturer or by trial and no other fuel proven in service. Where fuel pressure at the burner is not measurable, a low gas pressure trip shall be provided upstream of the control valve. If another fuel is proven in service, this shall cause a gas fuel trip, but not a master fuel trip.
(2) Total airflow decrease below the purge rate by 5 percent full-load airflow.
(3) Loss of either all induced draft fans or all forced draft fans.
(4) Loss of all flame.
(5) Partial loss of flame predetermined to be likely to introduce a hazardous accumulation of unburned fuel in accordance with the guidelines given in 3.4.3.3.1, block 8.
(6) Furnace pressure in excess of the prescribed operating pressure by a value specified by the manufacturer.
(7) All fuel inputs shut off.
(8) High fuel gas pressure and no other fuel proven in service. If another fuel is proven in service, this shall cause a gas fuel trip, but not a master fuel trip.

Table 3.6.5.2.5.2(b) Mandatory Master Fuel Trips with Alarms — Not Necessarily Automatically Initiated

A master fuel trip shall result from any of the following conditions:
(1) Loss of energy supply for boiler control, burner management, or interlock systems.
(2) Furnace negative pressure in excess of the value specified by the manufacturer. *[Refer to 3.4.3.3.6(e)].*

3.6.5.2.5.6 Action following the purge after an emergency shutdown (3.6.5.2.5.4 and 3.6.5.2.5.5 describe purging following an emergency shutdown) shall be in accordance with either of the following:

(1) The unit shall be shut down in accordance with 3.6.5.2.3.7.
(2) If a unit purge was successfully completed following an emergency shutdown and the conditions of 3.6.5.2.1.1(6) through (13) and 3.6.5.2.1.3(c) are satisfied, a relight in accordance with 3.6.5.2.1.3(e) through (s) shall be permitted.

3.6.5.2.6 Starting Sequence — Second Fuel.

3.6.5.2.6.1 When starting gas as a second fuel, the requirements of 3.6.5.2.1.1(8) through 3.6.5.2.1.1(13) shall have been satisfied. Also, the total heat input shall be limited as described in 3.6.5.4.9.

3.6.5.2.6.2 The starting sequence of the first fuel (oil or coal) shall be completed. The starting sequence of second fuel (gas) shall be performed in the following order.

(a) The main gas control valve shall be closed and the main safety shutoff valve(s) shall be opened, but only after 3.6.5.4.6 leak test requirements have been met.

(b) The starting sequence in 3.6.5.2.1.3(f) through 3.6.5.2.1.3(j) shall be followed.

(c) After making certain that the igniter(s) is established and is providing the predetermined, required level of ignition energy for the main burner(s), the individual burner safety shutoff valve(s) shall be opened and the individual burner atmospheric vent valves shall be closed. Failure to ignite or loss of ignition for any reason on any burner(s) shall cause fuel flow to that burner(s) to stop. All conditions required by the established light-off procedure shall exist before restarting the burner(s).

(d) The starting sequence in 3.6.5.2.1.3(k) through 3.6.5.2.1.3(q) shall be followed.

Exception: For sequence 3.6.5.2.1.3(k), where gas is the second fuel to be placed in service, a gas fuel trip shall be initiated when the flame detection system(s) indicates that ignition has not been obtained within 5 seconds of the time the fuel gas actually begins to enter the furnace. A master fuel trip shall not be required.

3.6.5.2.7 Shutdown Sequence — Second Fuel. The requirements in 3.6.5.2.7 shall apply to the removal of gas from service with other main burner fuel remaining in service. The requirements in 3.6.5.2.3 shall apply to the removal of gas from service as the only main burner fuel being fired.

3.6.5.2.7.1 When shutting off gas with oil or coal remaining in service, a sequential shutdown of the gas burners shall be accomplished by closing the individual burner safety shutoff valves and opening the vent valves.

3.6.5.2.7.2 The remaining burners shall be shut down sequentially as previously described, leaving the registers in the position prescribed by the established operating procedure.

3.6.5.2.7.3 When the last individual burner safety shutoff valves are closed, the main safety shutoff valve shall be closed.

3.6.5.2.7.4 All atmospheric vent valves shall be opened to minimize the possibility of gas leaking into the boiler enclosure.

3.6.5.2.8 Reburn System Start.

3.6.5.2.8.1* The reburn system shall not be started until the requirements of 3.6.3.4.2 have been met and shall follow the prerequisites of 3.6.5.2.1.3(w). In addition, the furnace temperature characteristics as a function of heat input, steam flow, or other reliable control signal shall be utilized as a permissive to initiate the reburn fuel injection.

3.6.5.2.8.2 If the reburn system admits reburn fuel through burners, the starting sequence shall also follow that specified for burners in 3.6.5.2.1.3(f) through (n).

3.6.5.2.8.3 If the reburn system admits reburn fuel by means other than through burners, the starting sequence shall incorporate the following:

(1) Include all reburn operation permissives required by this chapter
(2) Follow the procedure specified by the manufacturer of the reburn system

3.6.5.2.9 Shutdown Sequence — Reburn Fuel.

3.6.5.2.9.1 If the reburn system admits reburn fuel through burners, the shutdown sequence shall follow that specified for burners in 3.6.5.2.3.

3.6.5.2.9.2 If the reburn system admits reburn fuel by means other than through burners, the shutdown sequence shall be as follows:

(1) Reduce the reburn fuel flow to minimum.
(2) Close individual reburn shutoff valves.

(3) Close the main reburn safety shutoff valve(s).

(4) Open the reburn header atmospheric vent valves.

3.6.5.3 Emergency Conditions Not Requiring Shutdown or Trip.

3.6.5.3.1 In the event of a loss of a fan or fans, for units with multiple induced draft fans, or forced draft fans, or both, the control system shall be capable of reducing the fuel flow to match the remaining airflow; otherwise, tripping of the unit shall be mandatory.

3.6.5.3.2* If an air deficiency develops while flame is maintained at the burners, the fuel shall be reduced until the air/fuel ratio has been restored to within predetermined acceptable limits; or, if fuel flow cannot be reduced, the airflow shall be increased slowly until the air/fuel ratio has been restored to within those limits.

3.6.5.4 General Operating Requirements — All Conditions.

3.6.5.4.1 Prior to starting a unit, action shall be taken to prevent fuel from entering the furnace.

3.6.5.4.2 A unit purge shall be completed prior to starting a fire in the furnace.

3.6.5.4.3 The purge rate shall be not less than 25 percent of the full load mass airflow.

3.6.5.4.4 The igniter for the burner shall always be used. Burners shall not be lighted using a previously lighted burner or from hot refractory.

3.6.5.4.5 Where operating at low capacity, the burner fuel pressure shall be maintained above minimum by reducing the number of burners in service as necessary.

3.6.5.4.6 Sootblowers shall be operated only where heat input to the furnace is at a rate high enough to prevent a flameout during the sootblower operation. Sootblowers shall not be operated at low-load and high excess air conditions. This requirement shall not preclude the use of wall sootblowers and high-temperature superheater and reheater sootblowers for cleaning during periods of power outage if a unit purge has been completed and purge rate airflow is maintained, nor does it preclude the use of air heater sootblowers during start-up.

3.6.5.4.7 An operational leak test of the fuel header piping system shall be performed in accordance with established procedures while maintaining, at a minimum, purge rate airflow. Successful completion of the leak test shall be done before placing the main gas system into operation. *[Refer to Figure A.3.6.5.1.2(b), which shows a typical main burner fuel supply system that includes the piping that should be checked.]*

3.6.5.4.8 Before maintenance is performed on the gas header, the header shall be purged in accordance with the requirements of 3.6.2(g).

3.6.5.4.9 The total heat input within a burner or furnace zone, or both, shall not exceed the maximum limits specified for the equipment by the manufacturer. Multiple fuels' total heat inputs shall be accounted for where a burner or furnace zone, or both, simultaneously fires more than one fuel.

3.6.6 Boiler Front Control (Supervised Manual). Supervised manual operation shall not apply to new construction. Appendix C describes procedures for this mode of operation.

3.6.7 Two-Burner Systems — Single Fuel Flow Control.

3.6.7.1 Fundamental Principles.

3.6.7.1.1* Two-burner boilers that are served by a single fuel flow control valve and a single airflow control damper and provided with fuel safety shutoff valves for each burner shall meet the special design and operating requirements of this section.

3.6.7.1.2 This section shall not apply to two-burner boilers with separate air/fuel ratio controls that consist of a fuel flow control valve and an airflow control damper for each burner and that provide independent burner operation.

3.6.7.1.3 This section shall not apply to two burners that are lighted off, operated, and shut down in unison as a single burner, with common fuel and airflow controls and fuel safety shutoff valves. Such systems shall be in accordance with Chapter 2, 3.6.5.2.1.3(r), and 3.6.5.2.1.3(s).

3.6.7.2 System Requirements.

3.6.7.2.1 The following control system design options shall be provided in order to maintain the air/fuel ratio within manufacturer's suggested limits on one burner in the event of an automatic trip of the other burner.

3.6.7.2.1.1 A flame failure signal at one of the two burners shall initiate one of the following immediately and automatically:

(a) A master fuel trip.

(b)*A trip of the individual fuel safety shutoff valve(s) for the failed burner and a reduction of total boiler fuel flow by 50 percent of the flow prior to trip without reducing total boiler airflow or individual burner airflow. This action shall be accomplished by correcting the burner header fuel pressure to the value at which it had been operating prior to the trip of the first burner.

(c) A trip of the individual fuel safety shutoff valve(s) for the failed burner and simultaneous shutoff of the air supply to that burner. The fuel input to the operating burner shall not exceed the established maximum firing rate or the manufacturer's suggested air/fuel ratio limits of the burner.

3.6.7.2.1.2 The automatic recycling mode of operation shall be prohibited.

3.6.7.2.2 Burner Light-Off Procedures. The following operating procedures shall be followed to prevent air/fuel ratio upsets during burner light-off:

(a) Prior to light-off of the first burner, the furnace shall be purged with airflow through both burner registers at purge rate.

(b) When lighting the first burner, the registers in the second burner shall be left open to the purge position.

(c) The operator shall observe main flame stability while making any register or burner damper adjustments.

(d) During and after the light-off of the second burner, the operator shall observe the flame stability on the first burner.

(e) If a boiler is operating on one burner with the air supply closed off to the other burner and it becomes necessary to light the second burner, established operating procedures shall be used to prevent creating a hazardous air/fuel ratio at the first operating burner. The following general procedures shall be followed to prevent air starvation of the operating burner when air is introduced to the idle burner in preparation for its light-off:

(1) Before admitting any air to the idle burner, the excess air on the operating burner shall be increased by either

increasing airflow while holding fuel flow constant or reducing fuel flow while holding airflow constant.

(2) The register or damper at the idle burner shall be opened slowly while continuously observing the effect on the operating burner and making any adjustments to fuel flow or total boiler airflow necessary to maintain a stable flame.

(3) After lighting the second burner, flame stability shall be confirmed at both burners before transferring the control to the combustion control system.

(f) Where the two burners are not equipped with individual burner air registers or dampers, 3.6.7.2.2(e) shall not apply. Total boiler airflow shall be maintained so that the operating burner's air/fuel ratio stays within the manufacturer's suggested limits.

3.6.7.3 Fuel Transfer Procedure. An operating procedure, either manual or automatic, that prevents a hazardous air/fuel ratio at either burner when making a fuel transfer shall be followed. The following procedure shall be followed.

Total fuel and airflow shall be reduced to within the design capacity of one burner. Both fuel and air to the burner on which fuels are to be transferred shall be shut off simultaneously. The burner shall be restarted on the new fuel in accordance with the procedures in 3.6.7.2.2(e).

3.7 Fuel Oil Systems.

3.7.1* General. The requirements of Section 3.7 shall apply to installations where fuel oil is supplied.

3.7.2* Oil Firing — Special Problems. In addition to the common hazards involved in the combustion of solid, liquid, and gaseous fuels, the following special hazards related to the physical characteristics of oil shall be addressed in the design of the firing systems:

(a) Piping systems shall be designed to prevent leakage.

(b) Limits to maintain atomization shall be in accordance with design parameters.

(c) Fuel oil piping systems shall be designed to prevent water or sludge from plugging strainers or burner tips.

(d)*Combustion airflow shall follow changes in calorific content of fuel.

(e) On installations designed to fire both heated and unheated fuel oils, the burner control system shall be designed to ensure that interlocks are activated for the selected fuel oil. The fuel oil piping supply to the burner as well as the oil recirculating piping to the fuel storage tanks shall be provided with interlocks, depending on the arrangement of the equipment provided.

(f) Oil guns shall not be inserted without a tip or sprayer plate and new gasket.

(g) Pumping and atomization of fuel oils are dependent on control of viscosity. Changes in viscosity in relation to temperature vary for different oils and blends of oils. Viscosity control systems shall be designed for each fuel where the source or properties are variable.

(h)*Because clear distillate fuels have low conductivities and generate static electrical charges in the fuel stream, flowing velocities shall be limited.

(i)* Piping systems shall prevent flow transients caused by operation of system valves.

(j)* Operation of air heater sootblowers shall be in accordance with the requirements of the air heater manufacturer.

3.7.3 System Requirements.

3.7.3.1 Fuel Supply Subsystem — Fuel Oil. The requirements in this section shall apply to fuel oil supply piping. All installed piping arrangements shall meet the functional requirements of this code. *[Refer to Figures A.3.7.5.1.2(a) through (d), which show the typical fuel gas piping arrangements on which the text in this code is based.]*

3.7.3.1.1 The fuel supply equipment shall be sized to satisfy the design requirements and arranged to ensure a continuous, steady fuel flow over all operating requirements of the unit. This shall include coordination of the main fuel control valve, burner safety shutoff valves, and associated piping volume to ensure against fuel pressure transients that exceed burner limits for stable flame as a result of placing burners in or taking them out of service.

3.7.3.1.2 Unloading, storage, pumping, heating, and piping facilities shall be designed and arranged to inhibit contamination of the fuel. Where necessary, cleaning devices shall be provided to ensure a clean fuel to valves and burners. Convenient access to important fuel system components and drains shall be provided.

3.7.3.1.3* Fill and recirculation lines to storage tanks shall discharge below the liquid level.

3.7.3.1.4* Strainers, filters, traps, sumps, and other such items shall be provided to remove harmful contaminants; compensation for those materials not removed shall be provided by special operating and maintenance procedures.

3.7.3.1.5* The fuel supply equipment shall be designed based on the operating environment and ambient conditions. The piping shall be designed to be resistant to severe external conditions such as fire or mechanical damage.

3.7.3.1.6 All of the fuel supply subsystem components not shown on Figures A.3.7.5.1.2(a) through (d) shall be located outside of the boiler house. A manual emergency shutoff valve located outside of the boiler house shall be provided that is accessible in the event of fire in the boiler area.

3.7.3.1.7* Means shall be provided to prevent or relieve excess pressure from expansion of entrapped oil in the fuel system.

3.7.3.1.8* Relief valve discharge passages, vents, and telltales shall be provided with suitable piping to allow safe discharge of oil, vapors, or toxic fumes.

3.7.3.1.9 Oil piping materials and system design shall be in accordance with NFPA 31, *Standard for the Installation of Oil-Burning Equipment* (for oil piping inside industrial or institutional buildings), ASME B 31.1, *Power Piping* (for oil piping in power applications), or ASME B 31.3, *Process Piping* (for oil piping in process applications).

3.7.3.1.10* All instrument and control piping and other small lines containing oil shall be rugged, capable of withstanding the expected range of external temperatures, suitably protected against damage, and maintained at the temperature specified in established operating procedures.

3.7.3.1.11 Positive means to prevent leakage of oil into an idle furnace shall be provided.

3.7.3.1.12 Provisions shall be made in the oil supply system to allow testing for leakage and subsequent repair. This shall include a permanent means for making accurate tightness tests of the main safety shutoff valves and individual burner safety shutoff valves.

3.7.3.1.13 Fuel oil shall be delivered to the burners at the temperature and pressure as recommended by the burner manufacturer to ensure that the oil is at the viscosity necessary for atomization.

3.7.3.1.14 If heating of oil is necessary, it shall be accomplished without contamination or coking.

3.7.3.1.15 Recirculation provisions shall be incorporated for controlling the viscosity of the oil to the burners for initial light-off and for subsequent operation. These systems shall be designed and operated to prevent excessively hot oil from entering fuel oil pumps that could cause them to vapor-bind with subsequent interruption to the fuel oil supply.

3.7.3.1.16 Positive means shall be provided to prevent fuel oil from entering the burner header system through recirculating valves, particularly from the fuel supply system of another boiler. This shall include the requirements of 3.4.3.3.1, blocks 3 through 12. Check valves have not proven dependable in heavy oil service and shall not be used for this function.

3.7.3.1.17 Provisions shall be included for clearing (scavenging) the passages of an atomizer that leads into the furnace. This shall be performed in accordance with the requirements of 3.7.5.2.3.3, 3.7.5.2.5.7, and 3.7.5.4.5.

3.7.3.2 Main Burner Subsystem.

3.7.3.2.1* The main burner subsystem shall be designed so that the burner inputs are supplied to the furnace continuously and within their stable flame limits. Class 1 or Class 2 igniters, as demonstrated by tests as specified in 3.7.3.2.2 and 3.7.3.2.3, shall be permitted to be used to maintain stable flame at the lower operating limits of the main fuel subsystem in any given furnace design.

3.7.3.2.2* The limits of stable flame for each burner subsystem producing a separate flame envelope shall be determined by tests without the ignition subsystem in service. These tests shall verify that transients generated in the fuel and air subsystems do not affect the burners adversely during operation. These tests shall include the expected range of fuels to be fired in the unit. These tests shall be repeated after any combustion process modification, such as the addition of overfire air, low NO_x burners, and reburning, and after switching to any fuel not previously tested.

3.7.3.2.3 Where Class 1 and Class 2 igniters are used, the tests described in 1.9.2.3.2(d) and 3.7.3.2.2 shall be performed with the ignition subsystem in service to verify that the igniters furnished meet the requirements of the class specified in the design. The resulting extended turndown range shall be permitted when Class 1 igniters are in service and flames are proved.

3.7.3.2.4 Provisions shall be made for visual observation of conditions at the burner ignition zone. Additional provisions shall be made for flame detection equipment.

3.7.3.2.5 Provisions shall be made for cleaning of the burner nozzle and tip.

3.7.3.2.6* The burner equipment shall be in a location that allows access for maintenance. The requirements of housekeeping in 1.7.1.2(8) shall be followed.

3.7.3.2.7 All burner safety shutoff valves shall be located close to the burner to minimize the volume of oil that is left downstream of the burner valves in the burner lines or that flows by gravity into the furnace on an emergency trip or burner shutdown.

3.7.3.3 Atomizing Subsystem.

3.7.3.3.1 Where the fuel is to be atomized with the assistance of another medium, the atomizing medium shall be supplied free of contaminants that could cause an interruption of service. For steam atomizing, insulation and traps shall be included to ensure dry atomizing steam to the burners.

3.7.3.3.2 The atomizing medium shall be provided and maintained at the specified pressure necessary for operation.

3.7.3.3.3 Provisions shall be made to ensure that fuel does not enter the atomizing medium line during or after operation.

3.7.3.3.4 The atomizing subsystem shall be designed for convenient cleaning and maintenance.

3.7.3.4 Flue Gas Recirculation to Burners. When flue gas or other inert gases are introduced to the secondary air or combustion air being supplied to burners, testing shall be used to demonstrate that the methods and devices used provide uniform distribution and mixing. The oxygen content of the mixture being supplied to the burners shall not be permitted to go below the limit specified by the burner manufacturer or as proven by tests to provide stable combustion. Means shall be provided to monitor either the ratio of flue gas to air or the oxygen content of the mixture.

3.7.3.5 Reburn Fuel Supply Subsystem — Fuel Oil.

3.7.3.5.1 Positive means to prevent leakage of oil into an idle furnace shall be provided. This shall include a double block valve arrangement on the reburn fuel oil supply, separate from any other double block valve arrangements for other systems, that is, igniters or main burners.

3.7.3.5.2 Furnace temperature at the location of the reburn fuel injection shall be at least 300°F (167°C) above the autoignition temperature of the reburn fuel and shall be verified by test. The tests shall be performed for a variety of boiler loads, burner firing configurations, furnace cleanliness conditions, and excess air levels to determine the conditions under which reburn operation shall be permitted.

3.7.3.5.3* Fuel reburn systems shall include either temperature monitoring or reburn flame sensors.

3.7.3.5.4 Fuel reburn systems shall utilize a flue gas combustibles analyzer to detect combustibles.

3.7.4 Flame Monitoring and Tripping System.

3.7.4.1 Each burner shall be supervised individually. Upon detection of loss of a burner flame, that individual burner safety shutoff valve shall be automatically closed.

3.7.4.1.1 Where Class 1 igniters are provided, the main burner flame shall be proven either by the flame scanner or by the igniter being proven. At least one flame detector shall be provided for each burner to detect the burner flame or igniter flame where a Class 1 igniter is provided.

3.7.4.1.2 Burners with Class 2 igniters shall have at least two flame detectors. One detector shall be positioned to detect the main burner flame and shall not detect the igniter flame. The second detector shall be positioned to detect the igniter flame during prescribed light-off conditions.

3.7.4.1.3 Burners with Class 3 igniters shall have at least one flame detector. The detector shall be positioned to detect the igniter flame. It also shall detect the main burner flame after the igniter is removed from service at the completion of the main burner trial for ignition.

3.7.4.2 Upon detection of loss of all flame in the furnace or partial loss of flame to the extent that hazardous conditions develop as defined in 3.4.3.3.1, block 8, a master fuel trip shall be automatically initiated.

3.7.4.3 Any fuel input that does not ignite and burn on a continuous basis shall be classified as a hazard. Regardless of the number or pattern of flame loss indications used for tripping, loss of flame indication on an operating burner or "flame envelope" shall initiate an alarm that warns the operator of a potential hazard.

3.7.4.4* The flame tripping concept used on the unit shall have been validated by the boiler manufacturer for the specific furnace configuration being used. This validation shall not be used to replace unit acceptance tests relating to proof of design, function, and components.

3.7.4.5 The reburn system shall be shut down in accordance with the reburn system manufacturer's requirements if the temperature falls below the limit specified in 3.7.3.5.2. The reburn system shall be tripped if the temperature drops to 100°F (56°C) below the limit specified in 3.7.3.5.2. Loss of flame shall trip the operation of the reburn system, or portions of the reburn system, in accordance with the reburn system manufacturer's requirements.

3.7.5 Sequence of Operations.

3.7.5.1 General.

3.7.5.1.1 Sequencing shall be required to ensure that operating events occur in the order established by proven operating procedures. Sequencing shall follow procedures that allow fuel that falls within design specifications to be admitted to the burners only when there is ignition energy and airflow within design minimum requirements needed to ignite the fuel as it enters the furnace. Sequencing also shall be utilized when removing burners from operation.

3.7.5.1.2* The sequences of operation in 3.7.5 shall be followed whether the unit is operated manually or certain functions are accomplished by interlocks or automatic controls. *[Refer to Figures A.3.7.5.1.2(a) through (d), which show the typical piping arrangements on which the text in 3.7.5 is based.]*

3.7.5.1.3 The starting and shutdown sequence outlined in this chapter shall be followed. It shall provide the required practice of maintaining a continuous airflow through the unit at the rate that is used during the purge operation. This rate shall be maintained throughout the start-up and initial load-carrying period of operation until such time as more fuel and air are needed. This means that the same number of burner registers or burner dampers needed for purging the boiler shall be left open throughout the starting sequence as described in the following subparagraphs. The objective of this practice shall be to ensure an air-rich furnace atmosphere during start-up and establish minimum velocities through the furnace to prevent hazardous accumulations of unburned fuel.

3.7.5.1.4 Burners shall not be placed in service or removed in a random pattern but in a sequence defined by operating instructions and verified by actual experience with the unit in order to minimize laning or stratification of fuel or combustion products. Burners shall be placed in service as necessary, with fuel flows and individual register or damper settings positioned for light-off according to an established operating procedure.

3.7.5.1.4.1 The fuel pressure at the burner header shall be permitted to be used as a guide in maintaining the necessary fuel flow for each burner and shall be maintained automatically within prescribed limits as additional burners are placed in service. The total number of burners placed in service shall be that number necessary to accomplish the following:

(1) Raise the boiler pressure and temperature.
(2) Carry the initial load on the unit.

3.7.5.1.4.2 If some registers have been maintained in the closed position, these registers shall not be opened without either readjusting the total airflow to maintain the same burner airflow or closing an equal number of registers on idle burners to obtain the same effect. The total furnace air throughput shall not be reduced below the purge flow rate.

3.7.5.1.5 The open register light-off and purge procedure shall be used to maintain airflow at or above the purge rate during all operations of the boiler. The open register-purge procedure shall include the following:

(1) Use of a minimum number of required equipment manipulations, thereby minimizing exposure to operating errors or equipment malfunction
(2) Creation of a fuel-rich condition at individual burners during their light-off
(3) Creation of an air-rich furnace atmosphere during light-off and warm-up by maintaining total furnace airflow at the same rate as that needed for the unit purge

3.7.5.1.5.1 This procedure shall incorporate the following:

(1) All of the registers necessary to establish airflow at or above purge rate and uniform flow distribution throughout the furnace placed in a predetermined open position
(2) Overfire air port dampers placed in a predetermined position and providing a purge of the overfire air system
(3) A unit purge completed with the burner air registers and overfire air ports in the position specified in 3.7.5.1.5.1(1) and (2)
(4) Components (e.g., precipitators, fired reheaters) containing sources of ignition energy purged for either (a) a period of not less than 5 minutes or (b) five volume changes of that component, prior to being placed into service, whichever is longer
(5) Common component(s) between the furnace outlet and the stack shared with other operating boilers bypassed for unit purge
(6) The first burner or group of burners lighted without any change in the airflow setting, overfire air control damper position, or burner air register position [except as permitted in 3.7.5.2.1.3(i)]

3.7.5.1.5.2 Each boiler shall be tested during initial start-up to determine whether any modifications to the procedure specified in 3.7.5.1.5 are required in order to establish ignition or to satisfy other design limitations during light-off and warm-up. For boilers that are purged with the registers in their normal operating position, it shall be allowed to momentarily close the registers of the burner being lighted, if proven necessary to establish ignition. Modifications in the basic procedure shall be allowed only if they have been proven to be necessary to obtain light-off. However, 3.7.5.1.5(1) shall always be followed, thereby satisfying the basic objectives in 3.7.5.1.5.1.

3.7.5.1.6 Modification to the mode of operation due to water, steam, and flue gas temperatures being outside the established limits in the economizers and superheaters shall be made only after it has been determined to be necessary by operating experience.

3.7.5.2 Functional Requirements.

3.7.5.2.1 Cold Start. This section covers the requirements for placing oil in service as the initial fuel being fired. Subparagraph 3.7.5.2.6 covers the requirements for placing oil in service as a subsequent fuel.

3.7.5.2.1.1 Preparation for starting shall include a thorough inspection that shall verify the following:

(1) The furnace and gas passages are free of foreign material and not in need of repair.
(2)* The bottom of the furnace, including the ash hopper, is free of accumulations of liquid fuel, gases, or vapors prior to each start-up.
(3) All personnel are evacuated from the unit, and associated equipment and all access and inspection doors are closed.
(4) All airflow and flue gas flow control dampers have been operated through their full range to check the operating mechanism and then are set at a position that allows the fans to be started at a minimum airflow and without overpressuring any part of the unit.
(5) All individual burner dampers or registers that are subject to adjustment during operations have been operated through their full range to check the operating mechanism.
(6) The drum water level is established in drum-type boilers, and circulating flow is established in forced circulation boilers or minimum water flow is established in once-through boilers.
(7) The oxygen analyzer(s) and combustibles analyzer(s), if provided, are operating as designed and a sample has been obtained. The combustibles indication is at zero, and the oxygen indication is at maximum.
(8) All safety shutoff valves are closed. All sparks are de-energized.
(9) Gas ignition systems meet the requirements of Section 3.6.
(10) The circulating valves are open to provide and maintain hot oil in the burner headers.
(11) The burner guns are checked to ensure the correct burner tips or sprayer plates and gaskets are in place to ensure a safe operating condition.
(12) The burner elements and igniters are positioned in accordance with the manufacturer's specification.
(13) Energy is supplied to control system and to interlocks.
(14) The meters or gauges indicate fuel header pressure to the unit.
(15) A complete functional check of the interlocks has been made after an overhaul or modification of the interlock system.
(16)*An operational test of each igniter has been made. The test shall be integrated into the starting sequence and shall follow the unit purge and precede the admission of any main fuel.
(17) Individual igniters or groups of igniters also shall be permitted to be tested while the unit is in service. Such tests shall be made with no main fuel present in the igniter's associated burner, and the burner air register shall be in its start-up or light-off position as described in the established operating procedure.
(18)*Units with a history of igniter unreliability shall require additional test routines to verify the continuing operating ability of igniters and ignition system components.

3.7.5.2.1.2 Where provided, regenerative air heaters and gas recirculation fans shall be operated during all operations of the unit in a manner recommended by the boiler manufacturer.

3.7.5.2.1.3* Starting Sequence. Operation of regenerative-type air heaters, precipitators, and gas recirculation fans shall be included in the start-up sequence in accordance with the manufacturer's recommendations. The starting sequence shall be performed in the following order:

(a) An open flow path from the inlets of the forced draft fans through the stack shall be verified.

(b) An induced draft fan, if provided, shall be started; a forced draft fan then shall be started. Additional induced draft fans or forced draft fans shall be started in accordance with 3.5.3, as necessary, to achieve purge flow rate.

(c) Dampers and burner registers shall be opened to purge position in accordance with the open register purge method objectives outlined in 3.7.5.1.5.

(d) The airflow shall be adjusted to purge airflow rate and a unit purge shall be performed. Special provisions shall be utilized as necessary to prevent the hazardous accumulation of volatile vapors that are heavier than air or to detect and purge accumulations in the furnace ash pit.

(e) It shall be determined that the oil temperature or viscosity is within predetermined limits to ensure atomization will occur. The circulating valve and throttle recirculating valve, if necessary, shall be closed to allow establishment of burner header pressure within manufacturer's limits as specified in 3.7.5.2.1.3(g).

(f) The main fuel control valve shall be closed and the main safety shutoff valve(s) shall be open but, only after the requirements of 3.7.5.4.8 for leak test requirements and 3.4.3.3.4 for permissive conditions in the furnace purge system have been satisfied.

(g) It shall be determined that the main fuel control valve is closed, and the main fuel bypass control valve, if provided, then shall be set to maintain the necessary burner header pressure for light-off. The main fuel control valve shall be opened when necessary.

(h) For gas- or oil-fired igniters, the igniter safety shutoff valve(s) shall be opened, and it shall be confirmed that the igniter fuel control valve is holding the manufacturer's recommended fuel pressure necessary for the igniter to operate at design capacity. Gas igniter headers shall be vented in order to be filled with gas and to provide a flow (if necessary) so that the igniter fuel control valve functions to regulate and maintain the pressure within design limits specified by the manufacturer for lighting the igniters.

(i) The air register or damper on the burner selected for light-off shall be adjusted to the position recommended by the manufacturer or the established operating procedure, in accordance with the guidelines stated in 3.7.5.1.5.2.

(j) The spark or other source of ignition for the igniter(s) on the burner(s) to be lit shall be initiated. The individual igniter safety shutoff valve(s) shall be opened and all igniter system atmospheric vent valves (gas igniters only) shall be closed. If flame on the first igniter(s) is not established within 10 seconds, the individual igniter safety shutoff valve(s) shall be closed and the cause of failure to ignite shall be determined and corrected. With airflow maintained at purge rate, repurge shall not be required, but at least 1 minute shall elapse before attempting a retrial of this or any other igniter. Repeated retrials of igniters without investigating and correcting the cause of the malfunction shall be prohibited.

(k) Where Class 3 special electric igniters are used, the procedures described in 3.7.5.2.1.3(a) through (g), (i), and (l) through (n) shall be used, recognizing the requirements for individual main burner flame supervision.

(l) After making certain that the igniter(s) is established and is providing the required level of ignition energy for the main burner(s), the individual burner safety shutoff valve(s) shall be opened. The master fuel trip shall be initiated when the flame detection system(s) indicates that ignition has not been obtained within 5 seconds of the time the fuel actually begins to enter the furnace. Purging shall be repeated, and the conditions that caused the failure to ignite shall be corrected before another light-off attempt is made. For the following burner and all subsequent burners placed in operation, failure to ignite or loss of ignition for any reason on any burner(s) shall cause fuel flow to that burner(s) to stop. All conditions required by the manufacturer and established operating procedures for light-off shall exist before restarting the burner(s).

(m) After stable flame is established, the air register(s) or damper(s) shall be adjusted slowly to its operating position, making certain that ignition is not lost in the process. With automatic burner management systems, the air register shall be permitted to be opened simultaneously with the burner safety shutoff valve.

(n) Class 3 igniters shall be shut off at the end of the time trial for proving the main flame. It shall be verified that the stable flame continues on the main burners after the igniters are shut off. Some systems that allow the igniters to remain in service on either an intermittent or a continuous basis shall have been tested to meet all the requirements of Class 1 igniters or Class 2 igniters with associated interlocks in service.

(o) The same procedures of 3.7.5.2.1.3(i) through (n) shall be followed for placing additional burners with open registers in service, as necessary, to raise steam pressure or to carry additional load. If used, automatic control of burner fuel flow and burner airflow during the lighting and start-up sequence shall be in accordance with the requirements of 3.7.5.2.1.3(r). The fuel flow to each burner (as measured by burner fuel header pressure) shall be maintained at a controlled value that is compatible with the established airflow through the corresponding burner. The established airflow through each open register shall be permitted to be maintained by controlling the windbox-to-furnace differential.

Total furnace airflow shall not be reduced below purge rate airflow and shall be at least that which is necessary for complete combustion in the furnace. If it is necessary to vary fuel header pressure to eliminate a problem of having excessive lighting-off and shutting down of burners, such variations shall be limited to a predetermined range. This range shall be a function of the incremental fuel input that is added by the lighting of a single burner or gang of burners.

(p) After a predetermined number of burners that allow control of header fuel flow and temperature have been placed in service, the recirculating valve shall be closed unless the system is designed for continuous recirculation.

(q) The maximum number of burners shall be placed in service consistent with the anticipated continuous load and the operating range of fuel header pressures.

(r) The on-line metering combustion control (unless designed specifically for start-up procedures) shall not be placed into service until the following have occurred:

(1) A predetermined minimum main fuel input has been attained.
(2) All registers on nonoperating burners are closed, unless compensation is provided by the control system.
(3) The burner fuel and airflow are adjusted as necessary.
(4) Stable flame and specified furnace conditions have been established.

(s) It shall be permitted to place a multiple number of igniters in service that are served simultaneously from a single igniter safety shutoff valve, provided that the igniters are reliably supervised, so that failure of one of the group to light causes the fuel to all igniters in the group to shut off.

(t) It also shall be permitted to place a multiple number of burners served by their corresponding multiple igniters from a single burner safety shutoff valve, in service simultaneously, provided that the burners are reliably supervised, so that failure of one of the group to light causes the fuel to all burners in the group to shut off.

(u) On units with an overfire air system, the overfire air control damper position shall be permitted to be changed only when repositioning of all burner air registers or burner air dampers is permitted.

(v) On units with an overfire air system, the boiler shall be operating in a stable manner before the overfire air is introduced.

(w) On units with an overfire air system, the boiler shall be operating in a stable manner before the overfire air is introduced. The introduction of the overfire air shall not adversely affect boiler operation.

(x) A reburn system shall be placed in service only after the boiler is operating at such a load as to ensure that the introduction of the reburn fuel will not adversely affect continued boiler operation. This shall include a load that maintains the required reburn zone temperatures in accordance with 3.7.3.5.2. The boiler shall be operating in a stable manner before the reburn start-up sequence is initiated.

3.7.5.2.2 Normal Operation.

3.7.5.2.2.1 The firing rate shall be regulated by increasing or decreasing the fuel and air supply simultaneously to all operating burners, maintaining air/fuel ratio within predetermined operating limits continuously at all firing rates. This shall not eliminate requirements for air lead and lag during changes in the fuel firing rate.

Exception: This requirement shall not apply to systems provided with metering of air and fuel to each burner and designed specifically for individual burner-modulating control.

3.7.5.2.2.2 The reburn injection rate shall be regulated within the design limits of the reburn equipment. Air flow lead and lag shall be used during changes in the reburn fuel injection rate. Reburn safety shutoff valves shall be fully open or completely closed. Intermediate settings shall not be used.

3.7.5.2.2.3 The firing rate shall not be regulated by varying the fuel to individual burners by means of the individual burner safety shutoff valve(s). The individual burner safety shutoff valve(s) shall be fully open or completely closed. Intermediate settings shall not be used.

3.7.5.2.2.4 Air registers shall be set at the firing positions as determined by tests.

Exception: This requirement shall not apply to systems provided with metering of air and fuel to each burner and designed specifically for individual burner modulating control.

3.7.5.2.2.5 The burner fuel and airflow shall be maintained within a range between the maximum and minimum limits as determined by trial or, if trial results do not exist, as specified by the combustion equipment manufacturer(s). These trials shall test for minimum and maximum limits and stable flame under each of the following conditions:

(1) With all oil burners in service and combustion control on automatic
(2) With different combinations of oil burners in service and combustion control on automatic
(3) With different combinations of gas, oil, and coal burners in service and combustion controls on automatic
(4) With minimum and maximum reburn flow rates
(5) With each reburn fuel injection pattern
(6) With overfire air operating at its minimum and maximum limits

Where changes occur to any of the minimum and maximum limits because of equipment modifications, operating practices, or fuel conditions, retesting shall be required.

3.7.5.2.2.6 On loss of an individual burner flame, that individual burner's safety shutoff valve shall be automatically closed. The burner register shall be closed if it interferes with the air/fuel ratio supplied to any other individual burner flame.

3.7.5.2.2.7 Total airflow shall not be reduced below the purge rate.

3.7.5.2.3 Normal Shutdown. The requirements in 3.7.5.2.3 shall apply to the removal of oil from service as the only main burner fuel being fired. The requirements in 3.7.5.2.7 shall apply to removal of oil from service with other fuel remaining in service.

3.7.5.2.3.1 When taking the unit out of service, the boiler load shall be reduced to that necessitating a purge rate airflow, while maintaining operation within the tested limits determined in 3.7.5.2.2.5. Prior to removing oil from service and prior to the loss of reburn permissives, reburn fuel shall be shut down as defined in 3.6.5.2.9, 3.7.5.2.9, or 3.8.5.2.9.

3.7.5.2.3.2 The metering combustion control shall be taken out of service, and the start-up fuel supply pressure, register settings, and airflows shall be established in accordance with written start-up procedures.

Exception: Where designed for start-up and shutdown procedures, the metering combustion control shall not be required to be taken out of service.

3.7.5.2.3.3 As the fuel is reduced, a sequential shutdown of the burners shall be accomplished by closing the individual burner safety shutoff valves. Each burner shall be shut down in the following sequence:

(1) The igniter shall be placed into service on the particular burner to be shut down.
(2) With the igniter in service, the burner safety shutoff valve shall be closed and the steam (or air) clearing valves shall be opened.
(3) The clearing steam (or clearing air) shall be left in service a predetermined length of time that has been proven adequate to remove all oil so as to ensure there will be no carbonization and plugging of the burner tip.
(4) The igniter shall be removed from service, and the oil gun shall be removed or retracted unless cooling is provided.
(5) If the oil passages of the igniter are to be cleared into the furnace, the spark or other ignition source for the igniter shall be initiated before opening the steam (or air) clearing valve.
(6) Registers shall be placed in the position prescribed by the established operating procedure(s).

3.7.5.2.3.4 As the fuel is reduced, the remaining burners shall be shut down sequentially as described in 3.7.5.2.3.3. The last burner shall not be scavenged.

Exception: Where associated Class 1 igniters are in use, the last burner shall be permitted to be scavenged.

3.7.5.2.3.5 When the last individual burner safety shutoff valve is closed, the main safety shutoff valve shall be checked to confirm that it has closed.

3.7.5.2.3.6 When all burners, igniters, and the reburn system have been removed from service, the purge rate airflow shall be verified and a unit purge shall be performed.

3.7.5.2.3.7 After completion of the unit purge, closing the burner air registers and shutting down the forced draft fans and induced draft fans shall be permitted to be optional; however, maintaining airflow through the unit to prevent accumulation of combustible gases is a prudent procedural step due to the potential of fuel leak-by. Leakage of main or igniter fuel into the furnace or windbox shall be prevented.

3.7.5.2.3.8 If fuel recirculation in the burner header is to be established, the following shall be completed:

(1) Confirmation that individual burner safety shutoff valves are closed and that flame is out on each burner
(2) Confirmation that main safety shutoff valve is closed
(3) Opening of circulating valve and recirculating valve

3.7.5.2.4 Normal Hot Restart.

3.7.5.2.4.1 When restarting a hot unit, the requirements of 3.7.5.2.1.1(6) through (14) for a cold start shall be met.

3.7.5.2.4.2 The starting sequence in 3.7.5.2.1.3 shall be followed.

3.7.5.2.5 Emergency Shutdown — Master Fuel Trip.

3.7.5.2.5.1 An emergency shutdown shall initiate a master fuel trip.

3.7.5.2.5.2 A master fuel trip that results from any of the emergency conditions tabulated in Tables 3.7.5.2.5.2(a) and (b) shall stop all fuel flow to the furnace from all burners and the reburn system by tripping the main and individual burner safety shutoff valves and the main and individual reburn safety shutoff valves. The igniter safety shutoff valve and individual igniter safety shutoff valves shall be tripped, and the igniter sparks shall be deenergized. If a furnace inerting system is installed, the inerting system shall be operated simultaneously with the master fuel trip. Master fuel trips shall operate in a manner to stop all fuel flow into the furnace within a period that does not allow a dangerous accumulation of fuel in the furnace. A master fuel trip shall not initiate a forced draft or induced draft fan trip. Electrostatic precipitators, fired reheaters, or other ignition sources shall be tripped.

Table 3.7.5.2.5.2(a) Mandatory Automatic Master Fuel Trips (Install interlocks in accordance with 3.4.3 and 3.5.4.)

A master fuel trip shall result from any of the following conditions:
(1) Fuel and atomizing medium (if provided) to the burners outside operating limits necessary to accomplish atomization as established by trial or by the burner manufacturer and no other fuel proven in service. If another fuel is proven in service, this shall cause an oil fuel trip, but not a master fuel trip.
(2) Total airflow decrease below the purge rate by 5 percent full-load airflow.
(3) Loss of either all induced draft fans or all forced draft fans.
(4) Loss of all flame.
(5) Partial loss of flame predetermined to be likely to introduce a hazardous accumulation of unburned fuel in accordance with the guidelines given in 3.4.3.3.1, block 8.
(6) Furnace pressure in excess of the prescribed operating pressure by a value specified by the manufacturer.
(7) All fuel inputs shut off.

Table 3.7.5.2.5.2(b) Mandatory Master Fuel Trips with Alarms — Not Necessarily Automatically Initiated

A master fuel trip shall result from any of the following conditions:
(1) Loss of energy supply for boiler control, burner management, or interlock systems.
(2) Furnace negative pressure in excess of the value specified by the manufacturer. *[Refer to 3.4.3.3.6(e)]*

3.7.5.2.5.3 During a master fuel trip event, the overfire air system shall remain at the same setting as when the event occurred for such time as the main combustion airflow is held. Following this hold period, the overfire air shall be permitted to be gradually adjusted, either manually or automatically, to overfire air purge settings or cooling flows.

3.7.5.2.5.4 Clearing of oil passages into the furnace immediately following an emergency trip shall not be permitted.

3.7.5.2.5.5* Procedure for Purging After an Emergency Shutdown. Fans that are operating after the master fuel trip shall be continued in service. The airflow shall not be increased by deliberate manual or automatic control action. If the airflow is above the purge rate, it shall be permitted to be decreased gradually to the purge rate for a unit purge. If the airflow is below the purge rate at the time of the trip, it shall be continued at the existing rate for 5 minutes and then increased gradually to the purge rate airflow and held at this value for a unit purge.

3.7.5.2.5.6 If the emergency trip was caused by loss of draft fans, or draft fans also have tripped, all dampers in the air and flue gas passages of the unit shall be opened slowly to the fully open position in order to create as much natural draft as possible to ventilate the unit. The opening of fan dampers shall be timed or controlled to ensure that positive or negative furnace pressure transients beyond design limits do not occur during fan coast-down. This condition shall be maintained for at least 15 minutes. At the end of this period, the fan(s) shall be started in accordance with Section 3.5. The airflow shall be increased gradually to the purge rate, and a unit purge shall be completed.

3.7.5.2.5.7 Action following the purge after an emergency shutdown *(Refer to 3.7.5.2.5.5 and 3.7.5.2.5.6, which describe purging following an emergency shutdown)* shall be in accordance with either of the following:

(1) The unit shall be shut down in accordance with 3.7.5.2.3.7, 3.7.5.2.3.8, and 3.7.5.2.5.6.
(2) If a unit purge was successfully completed following an emergency shutdown and the conditions of 3.7.5.2.1.1(6) through (14) and 3.7.5.2.1.3(c) and (e) are satisfied, a relight in accordance with 3.7.5.2.1.3(f) through (s) shall be permitted.

3.7.5.2.5.8 One burner (or group of burners) at a time shall be placed in service in a manner specified in 3.7.5.2.1.3. Oil passages then shall be cleared into the furnace from each burner when the igniter has been established for that burner. After each burner is cleared, its igniter shall be shut down.

3.7.5.2.6 Starting Sequence — Second Fuel.

3.7.5.2.6.1 When starting oil as a second fuel, the requirements of 3.7.5.2.1.1(8) through 3.7.5.2.1.1(14) shall be satisfied. Also, the total heat input shall be limited as described in 3.7.5.4.9.

3.7.5.2.6.2 The starting sequence of the first fuel (gas or coal) shall be complete. The starting sequence of the second fuel (oil) shall be performed in the following order:

(1) The main oil control valve shall be closed and the main safety shutoff valve(s) shall be opened, but only after 3.7.5.4.8 leak test requirements have been met.
(2) The starting sequence in 3.7.5.2.1.3(g) through (t) shall be followed.

Exception: For sequence 3.7.5.2.1.3(l), where oil is the second fuel to be placed in service, an oil fuel trip shall be initiated when the flame detection system(s) indicates that ignition has not been obtained within 5 seconds of the time the fuel oil actually begins to enter the furnace. A master fuel trip shall not be required.

3.7.5.2.7 Shutdown Sequence — Second Fuel. The requirements in 3.7.5.2.7 shall apply to the removing of oil from service with other main burner fuel remaining in service. The requirements in 3.7.5.2.3 shall apply to the removal of oil from service as the only main burner fuel being fired.

3.7.5.2.7.1 When shutting off oil with gas or coal remaining in service, a sequential shutdown of the oil burners shall be accomplished by the following sequence:

(1) The igniter shall be placed into service on the particular burner to be shut down.
(2) With the igniter in service, the burner safety shutoff valve shall be closed and the steam (or air) clearing valves shall be opened.
(3) The clearing steam (or clearing air) shall be left in service a predetermined length of time that has been proven adequate to remove all oil so as to ensure there will be no carbonization or plugging of the burner tip.
(4) The igniter shall be removed from service, and the oil gun shall be removed or retracted unless cooling is provided.

3.7.5.2.7.2 The remaining burners shall be shut down sequentially as previously described leaving the registers in the position prescribed by the established operating procedure.

3.7.5.2.7.3 When the last individual burner safety shutoff valve is closed, the main safety shutoff valve shall be closed.

3.7.5.2.8 Reburn System Start.

3.7.5.2.8.1* The reburn system shall not be started until the requirements of 3.7.3.5.2 have been met and shall follow the prerequisites of 3.7.5.2.1.3(x). In addition, the furnace temperature characteristics as a function of heat input, steam flow, or other reliable control signal shall be utilized as a permissive to initiate the reburn fuel injection.

3.7.5.2.8.2 If the reburn system admits reburn fuel through burners, then the starting sequence shall also follow that specified for burners in 3.7.5.2.1.3(f) through (n).

3.7.5.2.8.3 If the reburn system admits reburn fuel by means other than through burners, then the starting sequence shall incorporate the following:

(1) Include all reburn operation permissives required by this chapter
(2) Follow the procedure specified by the manufacturer of the reburn system

3.7.5.2.9 Shutdown Sequence — Reburn Fuel.

3.7.5.2.9.1 If the reburn system admits reburn fuel through burners, the shutdown sequence shall follow that specified for burners in 3.7.5.2.3.

3.7.5.2.9.2 If the reburn system admits reburn fuel by means other than through burners, the shutdown sequence shall be as follows:

(1) Reduce the reburn fuel flow to minimum.
(2) Close individual reburn shutoff valves.
(3) Open the reburn steam (or air) clearing valves. Leave the clearing valves open until all fuel oil has been removed from the reburn atomizer tip.
(4) Close the main reburn safety shutoff valve(s).
(5) Retract the reburn system from service, or place reburn cooling in service, if equipped.

3.7.5.3 Emergency Conditions Not Requiring Shutdown or Trip.

3.7.5.3.1 In the event of a loss of a fan or fans for unit installations with multiple induced draft fans or forced draft fans or both, the control system shall be capable of reducing the fuel flow to match the remaining airflow; otherwise, tripping of the unit shall be mandatory.

3.7.5.3.2* If an air deficiency develops while flame is maintained at the burners, the fuel shall be reduced until the air/fuel ratio has been restored to within predetermined, acceptable limits; or, if fuel flow cannot be reduced, the airflow shall be increased slowly until the air/fuel ratio has been restored to within those limits.

3.7.5.3.3 Burners with poor atomization shall be shut down. If a predetermined number, as outlined in an established operating procedure, are so affected as to introduce a hazardous condition, all fuel shall be tripped.

3.7.5.4 General Operating Requirements — All Conditions.

3.7.5.4.1 Prior to starting a unit, action shall be taken to prevent fuel from entering the furnace.

3.7.5.4.2 A unit purge shall be completed prior to starting a fire in the furnace.

3.7.5.4.3 The purge rate shall be not less than 25 percent of the full load mass airflow.

3.7.5.4.4 The igniter for the burner shall always be used. Burners shall not be lighted using a previously lighted burner or from hot refractory.

3.7.5.4.5 Where operating at low capacity, the burner fuel pressure shall be maintained above minimum by reducing the number of burners in service as necessary.

3.7.5.4.6 Where clearing oil passages into the furnace, igniters shall be in service, with ignition established.

3.7.5.4.7* Sootblowers shall be operated only where heat input to the furnace is at a rate high enough to prevent a flameout during the sootblower operation. Sootblowers shall not be operated at low load and high excess air conditions. This requirement shall not preclude the use of wall sootblowers and high-temperature superheater and reheater sootblowers for cleaning during periods of power outage if a unit purge has been completed and purge rate airflow is maintained, nor does it preclude the use of air heater sootblowers during startup. Operation of air heater sootblowers shall be in accordance with the requirements of the air heater manufacturer.

3.7.5.4.8* The following leak test shall be performed before the oil header is placed in service.

A nominal pressure on the oil header shall be established with the main and individual burner safety shutoff valves, and the recirculating valves closed. If this oil pressure remains within predetermined limits for a predetermined amount of time, the individual burner safety valves are properly sealing off their burners.

3.7.5.4.9 The total heat input within a burner or furnace zone, or both, shall not exceed the maximum limits specified for the equipment by the manufacturer. Multiple fuels' total heat inputs shall be accounted for where a burner or furnace zone, or both, simultaneously fires more than one fuel.

3.7.6 Boiler Front Control (Supervised Manual). Supervised manual operation shall not apply to new construction. Appendix C describes procedures for this mode of operation.

3.7.7 Two-Burner Systems — Single Fuel Flow Control.

3.7.7.1 Fundamental Principles.

3.7.7.1.1* Two-burner boilers that are served by a single fuel flow control valve and a single airflow control damper and provided with fuel safety shutoff valves for each burner shall meet the special design and operating requirements of this section.

3.7.7.1.2 This section shall not apply to two-burner boilers with separate air/fuel ratio controls that consist of a fuel flow control valve and an airflow control damper for each burner and that provide independent burner operation.

3.7.7.1.3 This section shall not apply to two burners that are lighted off, operated, and shut down in unison as a single burner, with common fuel and airflow controls and fuel safety shutoff valves. Such systems shall be in accordance with Chapter 2, 3.7.5.2.1.3(s), and 3.7.5.2.1.3(t).

3.7.7.2 System Requirements.

3.7.7.2.1 The following control system design options shall be provided in order to maintain the air/fuel ratio within the manufacturer's suggested limits on one burner in the event of an automatic trip of the other burner.

3.7.7.2.1.1 A flame failure signal at one of the two burners shall initiate one of the following immediately and automatically:

(a) A master fuel trip.

(b)*A trip of the individual fuel safety shutoff valve(s) for the failed burner and a reduction of total boiler fuel flow by 50 percent of the flow prior to trip without reducing total boiler airflow or individual burner airflow. This action shall be accomplished by correcting the burner header fuel pressure to the value at which it had been operating prior to the trip of the first burner.

(c) A trip of the individual fuel safety shutoff valve(s) for the failed burner and simultaneous shutoff of the air supply to that burner. The fuel input to the operating burner shall not exceed the established maximum firing rate or the manufacturer's suggested air/fuel ratio limits of the burner.

3.7.7.2.1.2 The automatic recycling mode of operation shall be prohibited.

3.7.7.2.2 Burner Light-Off Procedures. The following operating procedures shall be followed to prevent air/fuel ratio upsets during burner light-off:

(a) Prior to light-off of the first burner, the furnace shall be purged with airflow through both burner registers at purge rate.

(b) When lighting the first burner, the registers in the second burner shall be left open to the purge position.

(c) The operator shall observe main flame stability while making any register or burner damper adjustments.

(d) During and after the light-off of the second burner, the operator shall observe the flame stability on the first burner.

(e) If a boiler is operating on one burner with the air supply closed off to the other burner and it becomes necessary to light the second burner, established operating procedures shall be used to prevent creating a hazardous air/fuel ratio at the first operating burner. The following general procedures shall be followed to prevent air starvation of the operating burner when air is introduced to the idle burner in preparation for its light-off:

(1) Before admitting any air to the idle burner, the excess air on the operating burner shall be increased by either increasing airflow while holding fuel flow constant or reducing fuel flow while holding airflow constant.
(2) The register or damper at the idle burner shall be opened slowly while continuously observing the effect on the operating burner and making any adjustments to fuel flow or total boiler airflow necessary to maintain a stable flame.
(3) After lighting the second burner, flame stability shall be confirmed at both burners before transferring the control to the combustion control system.

(f) Where the two burners are not equipped with individual burner air registers or dampers, 3.7.7.2.2(e) shall not apply. Total boiler airflow shall be maintained so that the operating burner's air/fuel ratio stays within the manufacturer's suggested limits.

3.7.7.3 Fuel Transfer Procedure. An operating procedure, either manual or automatic, that prevents a hazardous air/fuel ratio at either burner when making a fuel transfer shall be followed. The following procedure shall be followed:

Total fuel and airflow shall be reduced to within the design capacity of one burner. Both fuel and air to the burner on which fuels are to be transferred shall be shut off simultaneously. The burner shall be restarted on the new fuel in accordance with the procedures in 3.7.7.2.2(e).

3.8 Pulverized Coal Systems.

3.8.1 General.

3.8.1.1 The requirements of Section 3.8 shall apply to installations where pulverized coal is supplied.

3.8.1.2 Pulverized coal systems shall be in accordance with Chapter 6.

3.8.1.3 Although the pulverized coal section of this code emphasizes direct-fired systems, it shall also apply to bin systems.

3.8.2* Coal Firing — Special Problems.

3.8.2.1 In addition to the common hazards involved in the combustion of solid, liquid, and gaseous fuels, the following special hazards related to the physical characteristic of pulverized coal shall be addressed in the design of the firing systems:

(a) It takes as little as 3 lb (1.36 kg) of pulverized coal in 1000 ft^3 (0.05 oz/ft^3) (0.05 kg/m^3) of air to form an explosive mixture. Because a larger boiler burns 100 lb (45.4 kg) or more of coal per second, the safe burning of pulverized coal necessitates strict adherence to planned operating sequences. *(Refer to 3.8.5, which defines sequences of operation.)*

(b)*Each coal processing subsystem shall be operated within design parameters.

(c)*Methane gas shall not be allowed to accumulate.

(d)*Foreign materials shall not be allowed to interrupt coal flow.

(e)*Coal burners shall be removed from service in a predetermined manner.

(f)* Pulverized coal dust shall be prevented from accumulating in pulverizer air ducts.

(g) The burning of pulverized coal shall be accomplished by integration of the pulverizer system. The pulverizer and the burner systems function as a unit so that start-up of the pulverizer is integrated with the light-off of all its associated burners. Ignition of the pulverized coal in the burner pipe shall be prevented. The velocity of the transport air shall be prevented from falling below a predetermined value during operation (transport air shall not be maintained during an emergency trip condition) and by purging the pipes with this minimum airflow during the shutdown procedure. In addition, by operating above these minimum velocities, settling of the fuel in the burner pipe is prevented. The danger associated with this settling is that the accumulated coal is discharged to the furnace as the flow in the pipe is increased. Means shall be provided to prevent the reverse flow of furnace gases into idle burners or pulverizers.

(h) The difficulty in equalizing transport air velocities in multiple coal/air pipes from the same pulverizer also introduces the need to maintain minimum transport air velocity, as described in 3.8.2.1(g). Positive means shall be provided to ensure that all pipe velocities are equal to or above the minimum velocity necessary for fuel transport. Testing during initial start-up and retesting shall be performed to verify that individual pipe velocities are above the minimum for fuel transport.

(i)* The coal–air mixture temperature leaving the pulverizer shall be maintained within limits. The pulverizer outlet temperature shall be adjusted for the type of coal being burned.

(j) To minimize explosions in the pulverizer or burner pipes, provision shall be made for cooling down and emptying the pulverizers as part of the process of shutting down the associated burners. If the pulverizer is tripped under load, the clearing procedure outlined in 3.8.5.3 shall be followed to prevent spontaneous combustion and a possible explosion in the pulverizer or burner pipes.

(k) Caution shall be exercised in the interpretation of combustibles meter indications. Many meters and associated sampling systems measure only gaseous combustibles. Therefore, the lack of meter indication of combustibles shall not be proof that unburned coal particles or other combustibles are not present.

3.8.2.2 Coal Burner Turndown Ratio.

3.8.2.2.1 The additional requirements in 3.8.2.2.2 and 3.8.2.2.3 shall be addressed within the burner design parameters in 3.8.3.3.2 that determine the range of burner operation for stable flame.

3.8.2.2.2* Minimum firing rates shall be established for the range of volatility and fineness expected.

3.8.2.2.3* The turndown ratio for extended reduced load operation shall be determined for the full range of coals to be fired.

Caution: Where operating with pulverized coal for an extended time at reduced loads, incomplete combustion causes large quantities of unburned combustible dust to settle in hoppers and on horizontal surfaces. Do not disturb this dust by rapidly increasing airflow or by sootblowing.

3.8.2.3 Effect of Turndown Ratio on Open Register Light-Off.

3.8.2.3.1* Coal burners shall light off at their predetermined minimum stable load.

3.8.2.3.2* The burner and pulverizer turndown ratio shall be tested to determine the impact of burner throat size, number of spare pulverizers, and coal quality.

3.8.2.3.3* The windbox-to-furnace differential shall be maintained at levels required for fuel/air turbulence through the use of burner registers. Registers shall be opened to the predetermined firing position.

3.8.2.3.4 The basic objectives of an open register light-off as set forth in 3.8.5.1.5 shall be met. Variations in light-off procedures shall be permitted in accordance with the low turndown ratio and other restrictions described in 3.8.2.3.1 through 3.8.2.3.3.

3.8.3 System Requirements.

3.8.3.1 Raw Coal Supply Subsystem.

3.8.3.1.1 The raw coal supply subsystem shall be sized to satisfy the design requirements and arranged to ensure a continuous, steady fuel flow over all operating requirements of the unit.

3.8.3.1.2 The unloading, storage, transfer, and preparation facilities for raw coal shall be designed and arranged to size the coal, to remove foreign material, and to minimize interruption of the coal supply to the coal feeders. This shall include, where necessary, the installation of breakers, cleaning screens, and magnetic separators.

3.8.3.1.3 Raw coal 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. Raw coal piping to and from feeders shall be designed for free flow within the design range of coal size and moisture content. Means shall be provided for observation and detection of the coal flow. Access shall be provided for clearing of obstructions and sampling of coal.

3.8.3.2 Pulverizer Subsystems. Coal pulverizing equipment shall be designed to provide a range of capacity that minimizes starting and stopping of pulverizers during boiler load changes. It shall produce specified coal fineness over the specified design range of coal analyses and characteristics. Pulverizer systems shall be designed and operated in accordance with Chapter 6.

3.8.3.3 Main Burner Subsystem.

3.8.3.3.1* The main burner subsystem shall be designed so that the burner inputs are supplied to the furnace continuously and within their stable flame limits. Class 1 or Class 2 igniters, as demonstrated by test, shall be permitted to be used to maintain stable flame when operating at the lower operating limits determined in 3.8.3.3.2 and 3.8.3.3.3 for the main fuel subsystem in any given furnace design.

3.8.3.3.2* The limits of stable flame for each burner subsystem producing a separate flame envelope shall be determined by tests without the ignition subsystem in service. These tests shall verify that transients generated in the fuel and air subsystems do not affect the burners adversely during operation. These tests shall include the expected range of fuels to be fired in the unit. These tests shall be repeated after any combustion process modification, such as the addition of overfire air, low NO_x burners, reburn, and after switching to any fuel not previously tested.

3.8.3.3.3 Where Class 1 and Class 2 igniters are used, the tests described in 1.9.2.3.2(d)(1), 1.9.2.3.2(d)(2), and 3.8.3.3.2 shall be performed to determine the limits of stable flame with the igniters in service. Operation using any extended turndown range from that established in 3.8.3.3.2 shall be permitted only when Class 1 igniters are in service and flame is proved.

3.8.3.3.4 Provisions shall be made for visual observation of conditions at the burner ignition zone. Additional provisions shall be made for flame detection equipment.

3.8.3.3.5 Provisions shall be made for the cleaning of the burner nozzle and tip.

3.8.3.3.6* The burner equipment shall be in a location that allows access for maintenance. The requirements of housekeeping in 1.7.1.2(8) shall be followed to prevent the accumulation of unburned coal.

3.8.3.4 Flue Gas Recirculation to Burners. When flue gas or other inert gases are introduced to the secondary air or combustion air being supplied to burners, testing shall be used to demonstrate that the methods and devices used provide uniform distribution and mixing. The oxygen content of the mixture being supplied to the burners shall not be permitted to go below the limit specified by the burner manufacturer or as proven by tests to provide stable combustion. Means shall be provided to monitor either the ratio of flue gas to air or the oxygen content of the mixture.

3.8.3.5 Reburn Fuel Supply Subsystem — Coal.

3.8.3.5.1 The reburn fuel supply equipment shall be designed in accordance with Chapter 6, Section 6.4.

3.8.3.5.2 Furnace temperature at the location of reburn fuel injection shall be at least 300°F (167°C) above the auto ignition temperature of the reburn fuel and shall be verified by test. The tests shall be performed for a variety of boiler loads, burner firing configurations, furnace cleanliness conditions, and excess air levels to determine the conditions under which reburn operation shall be permitted.

3.8.3.5.3* Fuel reburn systems shall include either temperature monitoring or reburn flame sensors.

3.8.3.5.4 Fuel reburn systems shall utilize a flue gas combustibles analyzer to detect combustibles.

3.8.4 Flame Monitoring and Tripping System.

3.8.4.1* The flame monitoring philosophy for coal firing shall not require that a consistently detectable flame be maintained at each burner of the flame envelope.

3.8.4.2 Regardless of the number or pattern of flame loss indications used for tripping, loss of flame indication on an operating burner or flame envelope shall initiate an alarm that warns the operator of potential hazard.

3.8.4.3* The flame tripping concepts as described in 3.8.4.4.1, 3.8.4.4.2, and 3.8.4.4.3 shall be used on units only when the boiler manufacturer has validated that concept for the specific furnace configuration being used. This validation shall not be used to replace unit acceptance tests relating to proof of design, function, and components.

3.8.4.4 Upon detection of loss of flame on a burner, a pulverizer/burner group, or the furnace as a whole, an automatic trip of the associated equipment shall be initiated as required in 3.8.4.4.1 through 3.8.4.4.3.

3.8.4.4.1* Monitoring with Automatic Tripping of Individual Burners or Burner Groups. Where automatic selective tripping of individual burner nozzles or groups is provided, the related feeder, or the pulverizer and feeder, shall be tripped when a predetermined number or arrangement of burners served by that pulverizer have tripped.

3.8.4.4.2 Monitoring with Automatic Tripping of Individual Feeder or Pulverizer and Feeder. Upon detection of loss of flame on a predetermined number or arrangement of burners served by a pulverizer, that feeder or pulverizer and feeder shall be automatically tripped. In addition, an alarm shall sound upon detection of loss of flame on each burner involved, and the operator shall inspect flame conditions visually to determine whether burner or pulverizer operation should be continued. The number and arrangement of burners for each pulverizer showing loss of flame that are necessary to automatically initiate a feeder or pulverizer and feeder trip shall be determined by the boiler manufacturer as a function of the spatial arrangement of burners and unit load. Under circumstances of operation where support between the operating burners does not exist, either from proven igniters or from proven adjacent burners, loss of flame on an individual burner shall automatically initiate a trip of the feeder or pulverizer and feeder.

3.8.4.4.3 Furnace Tripping. The following conditions shall apply in furnace configurations where individual pulverizer/burner sets are not selectively tripped:

(1) Detectors shall be located and adjusted to monitor specific zones within the furnace.
(2) Under all reasonable operating conditions, main fuel combustion in one zone shall provide sustaining energy to adjacent zones if each zone is not self-sustaining.
(3) Under circumstances of operation where support between each zone receiving fuel does not exist, ignition support shall be provided *[refer to 3.8.5.2.1.3(q)]*, or, upon loss of flame in a zone or in the entire furnace, the master fuel trip shall be automatically initiated.

3.8.4.5 The reburn system shall be shut down in accordance with the reburn system manufacturer's requirements if the temperature falls below the limit specified in 3.8.3.5.2. The reburn system shall be tripped if the temperature drops to 100°F (56°C) below the limit specified in 3.8.3.5.2. Loss of flame shall trip the operation of the reburn system, or portions of the reburn system, in accordance with the reburn system manufacturer's requirements.

3.8.5 Sequence of Operations.

3.8.5.1 General.

3.8.5.1.1 Sequencing shall be required to ensure that operating events occur in the order established by proven operating procedures. Sequencing shall follow procedures that allow fuel that falls within design specifications to be admitted to the burners only when there is ignition energy and airflow within design minimum requirements needed to ignite the fuel as it enters the furnace. Sequencing also shall be utilized when removing burners from operation.

3.8.5.1.2* The sequences of operation in 3.8.5 shall be followed whether the unit is operated manually or certain functions are accomplished by interlocks or automatic controls. *[Refer to Figures A.3.8.5.1.2(a) through (c), which show the typical fuel supply systems on which the text in 3.8.5 is based.]*

3.8.5.1.3 The starting and shutdown sequence outlined in this chapter shall be followed. It provides the required practice of maintaining a continuous airflow through the unit at the rate that is used during the purge operation. This rate shall be maintained throughout the start-up and initial load-carrying period of operation until such time as more fuel and air are needed. This means that the same number of burner registers or burner dampers needed for purging the boiler shall be left open throughout the starting sequence, as described in the following paragraphs. The objective of this practice shall be to ensure an air-rich furnace atmosphere during start-up and to establish minimum velocities through the furnace to prevent hazardous accumulations of unburned fuel.

3.8.5.1.4 Burners shall not be placed in service or removed in a random pattern but in a sequence defined by operating instructions and verified by actual experience with the unit in order to minimize laning or stratification of fuel or combustion products. Pulverizers and burners shall be placed in service as necessary, with fuel flows and individual register or damper settings positioned for light-off according to an established operating procedure.

3.8.5.1.4.1 The pulverizer loading and primary airflow shall be permitted to be used as a guide in maintaining the necessary fuel flow for each burner and shall be maintained within prescribed limits.

(a) A minimum limit of either a mechanical stop or a control setting shall be provided so that the primary air through the pulverizer and burner lines cannot be reduced below a minimum flow that is found by test to prevent settling in the burner lines. This minimum setting shall not prevent isolation of the pulverizing equipment.

(b) Because of the relatively high fuel input at the minimum permitted pulverizer load, it is a practice in some plants to fire intermittently. This practice is not recommended. Every effort shall be made to establish a start-up procedure that permits continuous firing.

(c) Although light-off of all burners associated with a pulverizer is recommended, it is sometimes necessary to operate or light-off with less than the total number of burners served by the pulverizer. In this event, positive means shall be provided to prevent fuel leakage into idle pulverized fuel piping and through idle burners into the furnace.

(d) The associated igniter shall be placed in service prior to admitting coal to any burner.

(e) When the burner(s) and furnace fuel input is within the predetermined prescribed limits necessary to maintain stable flame without the aid of igniters (as determined by test), the igniters shall be permitted to be removed from service.

3.8.5.1.4.2 If some registers have been maintained in the closed position, these registers shall not be opened without either readjusting the total airflow to maintain the same burner airflow or closing an equal number of registers on idle burners to obtain the same effect. The total furnace air throughput shall not be reduced below the purge flow rate.

3.8.5.1.5 The open register light-off and purge procedure shall be used to maintain airflow at or above the purge rate during all operations of the boiler. The open register–purge procedure shall include the following:

(1) Use of a minimum number of required equipment manipulations, thereby minimizing exposure to operating errors or equipment malfunction
(2) Creation of fuel-rich condition at individual burners during their light-off
(3) Creation of an air-rich furnace atmosphere during the light-off and warm-up by maintaining total furnace airflow at the same rate as that needed for the unit purge
(4) Minimization of the hazard of dead pockets in the gas passes and the accumulation of combustibles by continuously diluting the furnace with large quantities of air

3.8.5.1.5.1 This procedure shall incorporate the following operating objectives:

(1) All the registers necessary to establish airflow at or above purge rate and uniform flow distribution throughout the furnace placed in a predetermined open position.
(2) All overfire air port dampers placed in a predetermined position providing a flow of air into the furnace through each overfire air port.
(3) A unit purge completed with the burner air registers and overfire air ports in the position specified in 3.8.5.1.5.1(1) and (2). The purge flow rate shall not be so high as to cause an explosive condition due to stirring up of combustibles smoldering in the hoppers.
(4) Components (e.g., precipitators, fired reheaters) containing sources of ignition energy purged for either (1) a period of not less than 5 minutes or (2) five volume changes of that component, prior to being placed into service, whichever is longer.
(5) Common component(s) between the furnace outlet and the stack shared with other operating boilers bypassed for unit purge.
(6) The first burner or group of burners lighted without any change in the airflow setting, burner air register position except as permitted in 3.8.5.2.1.3(f), or overfire air control damper position.

3.8.5.1.5.2 Each boiler shall be tested during initial start-up to determine whether any modifications to the procedures specified in 3.8.5.1.5 are required in order to obtain desired ignition or to satisfy other design limitations during light-off and warm-up. For boilers that are purged with the registers in their normal operating position, it shall be allowed to momentarily close the registers of the burner being lighted if proven necessary to establish ignition. Modifications in the basic procedure shall be allowed only if they have been proven to be necessary to obtain light-off. However, 3.8.5.1.5(1) shall always be followed, thereby satisfying the basic objectives in 3.8.5.1.5.1.

3.8.5.1.6 Modification to the mode of operation resulting due to water, steam, and flue gas temperatures being outside the established limits in the economizers and superheaters shall be made only after it has been determined to be necessary by operating experience.

3.8.5.2 Functional Requirements.

3.8.5.2.1 Cold Start. This section covers the requirements for placing coal in service as the initial fuel being fired. Subsection 3.8.5.2.6 covers the requirements for placing coal in service as a subsequent fuel.

3.8.5.2.1.1 Preparation for starting shall include a thorough inspection that shall verify the following:

(a) The furnace and gas passages are free of foreign material and not in need of repair.

(b)*The bottom of the furnace, including ash hopper, is free of accumulations of solid or liquid fuel, gases, or vapors prior to each start-up.

(c) All personnel are evacuated from the unit and associated equipment, and all access and inspection doors are closed.

(d) All airflow and flue gas flow control dampers have been operated through their full range to check the operating mechanism and then are set at a position that allows the fans to be started at a minimum airflow and without overpressuring any part of the unit.

(e) All individual burner dampers or registers that are subject to adjustment during operations have been operated through their full range to check the operating mechanism.

(f) The drum water level is established in drum-type boilers, and circulating flow is established in forced circulation boilers, or minimum water flow is established in once-through boilers.

(g) The oxygen analyzer(s) and combustibles analyzer(s), if provided, are operating as designed, and a sample has been obtained. Combustibles indication is at zero, and oxygen indication is at maximum.

(h) The igniter safety shutoff valves are closed, and sparks are deenergized. Gas ignition systems shall comply with the requirements of Section 3.6. Oil ignition systems shall comply with the requirements of Section 3.7.

(i) The pulverizing equipment is isolated effectively to prevent inadvertent or uncontrolled leakage of coal into the furnace.

(j) The pulverizers, feeders, and associated equipment are operable, not in need of repair, and adjusted to the requirements of established operating procedures that ensure their standby start-up status. All pulverizer and feeder sensor lines are clean prior to starting.

(k) Energy is supplied to control system and to interlocks.

(l) A complete functional check of the interlocks has been made after an overhaul or modification of the interlock system.

(m)*An operational test of each igniter has been made. The test shall be integrated into the starting sequence and shall follow the unit purge and precede the admission of any main fuel.

(n) Individual igniters or groups of igniters also shall be permitted to be tested while the unit is in service. Such tests shall be made with no main fuel present in the igniter's associated burner, and the burner air register shall be in its start-up or light-off position as described in the established operating procedure.

(o)*Units with a history of igniter unreliability shall require additional test routines to verify the continuing operating ability of igniters and ignition system components.

3.8.5.2.1.2 Where provided, regenerative air heaters and gas recirculation fans shall be operated during all operations of the unit in a manner recommended by the boiler manufacturer.

3.8.5.2.1.3 Starting Sequence. Operation of regenerative-type air heaters, precipitators, and gas recirculation fans shall be included in the start-up sequence in accordance with the manufacturer's recommendations. The starting sequence shall be performed in the following order:

(a) An open flow path from the inlets of the forced draft fans through the stack shall be verified.

(b) An induced draft fan, if provided, shall be started; a forced draft fan then shall be started. Additional induced draft fans or forced draft fans shall be started in accordance with Section 3.5, as necessary, to achieve purge flow rate.

(c) Dampers and burner registers shall be opened to purge position in accordance with the open register purge method objectives outlined in 3.8.5.1.5.

(d) The airflow shall be adjusted to purge airflow rate and a unit purge shall be performed. Special provisions shall be utilized as necessary to prevent the hazardous accumulation of volatile vapors that are heavier than air or to detect and purge accumulations in the furnace ash pit.

(e) For gas- or oil-fired igniters, the igniter safety shutoff valve(s) shall be opened, and it shall be confirmed that the igniter fuel control valve is holding the manufacturer's recommended fuel pressure necessary to allow the igniter to operate at design capacity. Gas igniter headers shall be vented in order to be filled with gas and to provide a flow (if necessary) so that the igniter fuel control valve can function to regulate and maintain the pressure within design limits specified by the manufacturer for lighting the igniters.

(f) The air register or damper on the burners selected for light-off shall be adjusted to the position recommended by the manufacturer or the established operating procedure, in accordance with the guidelines stated in 3.8.5.1.5.2.

(g) The spark or other source of ignition for the igniter(s) on the burner(s) to be lit shall be initiated. The individual igniter safety shutoff valve(s) shall be opened. If flame on the first igniter(s) is not established within 10 seconds, the individual igniter safety shutoff valve(s) shall be closed and the cause of failure to ignite shall be determined and corrected. With airflow maintained at purge rate, repurge shall not be required, but at least 1 minute shall elapse before attempting a retrial of this or any other igniter. Repeated retrials of igniters without investigating and correcting the cause of the malfunction shall be prohibited.

(h) With the coal feeder off, all gates between the coal bunker and pulverizer feeder shall be opened, and it shall be confirmed that coal is available to the feeder.

(i) The igniters shall be checked to ensure they are established and are providing the required level of ignition energy for the main burners. The pulverizing equipment shall be started in accordance with the equipment manufacturer's instruction.

(j) The furnace airflow shall be readjusted after conditions stabilize, as necessary. Airflow shall not be reduced below the purge rate.

(k) The feeder shall be started at a predetermined setting with the feeder delivering coal to the pulverizer. Pulverized coal shall be delivered to the burners after the specific time delay necessary to build up storage in the pulverizer and transport the fuel to the burner. This time delay, which is determined by test, may be as short as a few seconds with some types of equipment or as long as several minutes with others.

(l) Ignition of the main burner fuel admitted to the furnace shall be confirmed. Required ignition shall be obtained within 10 seconds following the specific time delay described in 3.8.5.2.1.3(k). The master fuel trip shall be initiated on failure to ignite or loss of ignition on burners served by the first pulverizer placed in operation.

Exception: Where the cause of failure to ignite or loss of ignition is known to be due to loss of coal in the pulverizer subsystem, initiation of the master fuel trip shall not be required, but all required conditions for light-off shall exist before restoring coal feed.

(m) For the following pulverizer and all subsequent pulverizers placed in operation, failure to ignite or loss of ignition for any reason on any burner shall cause the fuel flow to that burner to stop in accordance with the manufacturer's recommendations. All conditions required by established operating procedures for light-off shall exist before restarting the burner.

(n) After stable flame is established, the air register(s) or damper(s) shall be adjusted slowly to its operating position, making certain that ignition is not lost in the process.

(o) The load for the operating pulverizer shall be at a level that prevents its load from being reduced below operating limits when an additional pulverizer is placed in operation.

(p) If an operating pulverizer does not have all of its burners in service, the idle burners shall not be restarted. Instead, another pulverizer with all burners in service shall be started, and the pulverizer with idle burners shall be shut down and emptied.

Exception: In accordance with the guidelines in 3.8.5.5.5, idle burners shall be permitted to be started on the first pulverizer without shutting it down if precautions are taken to prevent all the following conditions:

(a) Accumulation of coal in idle burner lines

(b) Hot burner nozzles and diffusers that have the potential to cause coking and fires when coal is introduced

(c) Excessive disturbance of the air/fuel ratio of the operating burners

(q)*The procedures of 3.8.5.2.1.3(f) through (p) shall be followed for placing an additional pulverizer into service. When fuel is being admitted to the furnace, igniters shall never be placed into service for any burner without proof that there is a stable fire in the furnace.

(r) Igniters shall be permitted to be shut off after exceeding a predetermined minimum main fuel input that has been determined in accordance with the guidelines in 3.8.3.3.2. The burners then are supposed to be providing sustaining ignition energy for the incoming fuel. Verification shall be made that the stable flame continues on the main burners after the igniters are removed from service. Some systems allow the igniters to remain in service on either an intermittent or a continuous basis. Furnace explosions have been attributed to reignition of an accumulation of a fuel by igniters after an undetected flameout of main burners.

(s) The on-line metering combustion control (unless designed specifically for start-up procedures) shall not be placed into service until the following have occurred:

(1) A predetermined minimum main fuel input has been attained.
(2) All registers on nonoperating burners are closed, unless compensation is provided by the control system.
(3) The burner fuel and airflow are adjusted as necessary.
(4) Stable flame and specified furnace conditions have been established.

(t) Additional pulverizers shall be placed into service as needed by the boiler load in accordance with the procedures of 3.8.5.2.1.3(f) through (p).

(u) On units with an overfire air system, the overfire air control damper positions shall be permitted to be changed only when repositioning of all burner air registers or burner air dampers is permitted.

(v) On units with an overfire air system, the boiler shall be operating in a stable manner before the overfire air is introduced. The introduction of the overfire air shall not adversely affect boiler operation.

(w) On units with an overfire air system and a reburn system, the overfire air shall be placed in operation before starting the reburn fuel sequence.

(x) A reburn system shall be placed in service only after the boiler is operating at such a load as to ensure that the introduction of the reburn fuel will not adversely affect continued boiler operation. This shall include a load that maintains the required reburn zone temperatures in accordance with 3.8.3.5.2. The boiler shall be operating in a stable manner before the reburn start-up sequence is initiated.

3.8.5.2.2 Normal Operation.

3.8.5.2.2.1 The firing rate shall be regulated by increasing or decreasing the fuel and air supply simultaneously to all operating burners, maintaining the air/fuel ratio within predetermined operating limits continuously at all firing rates. This shall not eliminate requirements for air lead and lag during changes in the fuel firing rate.

3.8.5.2.2.2 The reburn injection rate shall be regulated within the design limits of the reburn equipment. Airflow lead and lag shall be used during changes in the reburn fuel injection rate. Reburn safety shutoff valves shall be fully open or completely closed. Intermediate settings shall not be used.

3.8.5.2.2.3 The firing rate shall not be regulated by varying the fuel to individual burners by means of the individual burner safety shutoff valve(s). The individual burner safety shutoff valve(s) shall be fully open or completely closed. Intermediate settings shall not be used.

3.8.5.2.2.4 Air registers shall be set at the firing positions as determined by tests.

Exception: This requirement shall not apply to systems provided with metering of air and fuel to each burner and designed specifically for individual burner modulating control.

3.8.5.2.2.5 The burner fuel and airflow shall be maintained within a range between the maximum and minimum limits as determined by trial or, if trial results do not exist, as specified by the combustion equipment manufacturer(s). These trials shall test for minimum and maximum limits and stable flame under the following conditions:

(1) With all coal burners in service and combustion control on automatic
(2) With different combinations of coal burners in service and combustion control on automatic
(3) With different combinations of gas, oil, and coal burners in service and combustion controls on automatic
(4) With minimum and maximum reburn flowrates
(5) With each reburn fuel injection pattern
(6) With overfire air operation at its minimum and maximum limits

Where changes occur to any of the maximum and minimum limits because of equipment modifications, operating practices, or fuel conditions, retesting shall be required.

3.8.5.2.2.6 If lower minimum loads are required, the pulverizer(s) and associated burners shall be removed from service and the remaining pulverizers shall be operated at a fuel rate above the minimum rate needed for stable operation of the connected burners. The minimum fuel rate shall be determined by tests with various combinations of burners in service and with various amounts of excess air and shall reflect the most restrictive condition. These tests also shall ensure the transient stability factors described in 3.8.3.3.2 are taken into account.

3.8.5.2.2.7 The ignition system shall be tested for stable operation at the various conditions described in 3.8.5.2.2.5.

3.8.5.2.2.8 On loss of an individual burner flame, the flow of fuel to all burners of the pulverizer subsystem shall be stopped unless furnace configuration and tests have determined that one of the three automatic tripping philosophies described in 3.8.4.4.3 is applicable. Registers of shutdown burners shall be closed if interference with the air/fuel ratio at other burner flame envelopes occurs. (Hazards in these types of situations shall be reduced by following the guidelines listed in 3.8.5.3 and Chapter 6, which contain procedures for clearing pulverizers tripped while full of coal.)

3.8.5.2.2.9 Total airflow shall not be reduced below the purge rate.

3.8.5.2.3 Normal Shutdown. The requirements in 3.8.5.2.3 shall apply to the removal of coal from service as the only main burner fuel being fired. The requirements in 3.8.5.2.7 shall apply to the removal of coal from service with other fuel remaining in service.

3.8.5.2.3.1 When taking the unit out of service, the boiler load shall be reduced to that necessitating a purge rate airflow using the procedures outlined in 3.8.5.2.3.2 and 3.8.5.2.3.3, while maintaining operation within the tested limits determined in 3.8.5.2.2.5. Prior to removing coal from service and prior to loss of reburn permissives, reburn fuel shall be shut down as defined in 3.6.5.2.9, 3.7.5.2.9, or 3.8.5.2.9.

3.8.5.2.3.2 A pulverized fuel system shall be shut down in the following sequence:

(1) The pulverizer's fuel input, airflow, and register positions shall be adjusted to values established for start-up.
(2) Igniters shall be placed into service at these burners, when required to maintain flame stability.
(3) The hot primary air shall be shut off and the cold primary air shall be opened to cool down the pulverizer in accordance with Chapter 6.
(4) The feeder shall be stopped in accordance with the manufacturer's recommendation. Operation of the pulverizer shall be continued with a predetermined airflow prescribed in an established operating procedure that

has been proven to be sufficient to empty out the pulverizer and associated burner lines.
(5) The inerting medium shall be introduced into the pulverizer as dictated by the coal characteristics.
(6) The pulverizer subsystem shall be shut down when burner fires are out and the pulverizer is empty and cool.
(7) All individual burner line shutoff valves shall be closed unless otherwise directed by the manufacturer's instructions.
(8) Igniters shall be removed from service.

3.8.5.2.3.3 As the fuel is reduced, the following procedures shall be followed:

(1) The remaining pulverizers shall be shut down consecutively following the procedures of 3.8.5.2.3.2(1) through (8).
(2) In cases where the next pulverizer being removed has the potential to result in flame instability, igniters shall be placed into service on burners that are still being fired.

3.8.5.2.3.4 When all pulverizers, igniters, and the reburn system have been removed from service, the purge rate airflow shall be verified and a unit purge shall be performed.

3.8.5.2.3.5 After completion of the unit purge, closing the burner air registers and shutting down the forced draft fans and induced draft fans shall be permitted to be optional; however, maintaining airflow through the unit to prevent accumulation of combustible gases is a prudent procedural step due to the potential of fuel leak-by. Leakage of main or igniter fuels into the unit shall be prevented.

3.8.5.2.4 Normal Hot Restart.

3.8.5.2.4.1 When restarting a hot unit, the requirements of 3.8.5.2.1.1(f) through (k) for a cold start shall be met.

3.8.5.2.4.2 The starting sequence in 3.8.5.2.1.3(a) through (q) shall be followed.

3.8.5.2.5 Emergency Shutdown — Master Fuel Trip.

3.8.5.2.5.1 An emergency shutdown shall initiate a master fuel trip.

3.8.5.2.5.2 A master fuel trip that results from any of the emergency conditions tabulated in Tables 3.8.5.2.5.2(a) and (b) shall stop all coal flow to the furnace from all pulverizer subsystems by tripping the burner and reburn safety shutoff valves or other devices designed for emergency shutoff of all coal flow. The igniter safety shutoff valve, individual igniter safety shutoff valves, primary air fans or exhausters, recirculating fans, coal feeders, and pulverizers shall be tripped, and the igniter sparks shall be deenergized. If a furnace inerting system is installed, the inerting system shall be operated simultaneously with the master fuel trip. Master fuel trips shall operate in a manner to stop all fuel flow into the furnace within a period that does not allow a dangerous accumulation of fuel in the furnace. A master fuel trip shall not initiate a forced draft or induced draft fan trip. Electrostatic precipitators, fired reheaters, or other ignition sources shall be tripped.

3.8.5.2.5.3* Procedure for Purging After an Emergency Shutdown. Fans that are operating after the master fuel trip shall be continued in service. The airflow shall not be increased by deliberate manual or automatic control action. If the airflow is above the purge rate, it shall be permitted to be decreased gradually to the purge rate for a unit purge. If the airflow is below the purge rate at the time of the trip, it shall be continued at the existing rate for 5 minutes and then increased gradually to the purge rate airflow and held at this value for a unit purge.

Table 3.8.5.2.5.2(a) Mandatory Automatic Master Fuel Trips (Install interlocks in accordance with 3.4.3 and 3.5.4)

A master fuel trip shall result from any of the following conditions:
(1) Loss of either all forced draft fans or all induced draft fans.
(2) Total airflow decrease below the purge rate by 5 percent of full-load airflow.
(3) Furnace pressure in excess of the prescribed operating pressure by a value recommended by the manufacturer.
(4) All fuel inputs shut off in accordance with the guidelines given in paragraph 3.4.3.3.1, block 9. Subparagraph 3.4.3.3.9 contains a list of the required interlocks and trips for individual pulverizer subsystems.
(5) Loss of all flame.
(6) Partial loss of flame predetermined to be likely to introduce a hazardous accumulation of unburned fuel in accordance with the guidelines given in 3.4.3.3.1, block 8.

Table 3.8.5.2.5.2(b) Mandatory Master Fuel Trips with Alarms — Not Necessarily Automatically Initiated

A master fuel trip shall result from any of the following conditions:
(1) Failure of the first pulverizer subsystem to operate successfully under the conditions specified in 3.8.5.2.1.3(l) and 3.4.3.3.1, block 12d.
(2) Loss of energy supply for combustion control, burner control, or interlock systems.
(3) Furnace negative pressure in excess of the value specified by the manufacturer. *(Refer to 3.4.3.3.6, item 5.)*

3.8.5.2.5.4 During a master fuel trip event, the overfire air system shall remain at the same setting as when the event occurred for such time as the main combustion airflow is held. Following this hold period, the overfire air shall be permitted to be gradually adjusted to overfire air purge settings or cooling flows, either manually or automatically.

3.8.5.2.5.5 Where the emergency trip was caused by loss of draft fans, or draft fans also have tripped, all dampers in the air and flue gas passages of the unit shall be opened slowly to the fully open position in order to create as much natural draft as possible to ventilate the unit. Opening fan dampers shall be timed or controlled to ensure that positive or negative furnace pressure transients beyond design limits do not occur during fan coast-down. This condition shall be maintained for at least 15 minutes. At the end of this period, the fan(s) shall be started in accordance with Section 3.5. The airflow shall be increased gradually to the purge rate, and a unit purge shall be completed.

3.8.5.2.5.6 Action following the purge after an emergency shutdown *(Refer to 3.8.5.2.5.3 through 3.8.5.2.5.5, which describe purging following an emergency shutdown)* shall be in accordance with either of the following:

(1) The unit shall be shut down in accordance with 3.8.5.2.3.5.
(2) If a unit purge was successfully completed following an emergency shutdown and the conditions of 3.8.5.2.1.1(f) through (k) and 3.8.5.2.1.3(d), (e), and (f) are satisfied, a relight in accordance with 3.8.5.2.1.3(g) through (t) shall be permitted.

3.8.5.2.5.7 If it is impossible to restart for an extended time, a flow of air through the unit shall be maintained to prevent accumulations of combustible gases.

3.8.5.2.6 Starting Sequence — Second Fuel.

3.8.5.2.6.1 When starting coal as a second fuel, the requirements of 3.8.5.2.1.1(h) through (k) shall be satisfied. Also, the total heat input shall be limited as described in 3.8.5.5.9.

3.8.5.2.6.2 The starting sequence of the first fuel (gas or oil) shall be complete. The starting sequence of second fuel (coal) shall be performed in the starting sequence in 3.8.5.2.1.3(e) through (t).

Exception: For sequence 3.8.5.2.1.3(l), where coal is the second fuel to be placed in service, a coal fuel trip shall be initiated on failure to ignite or loss of ignition on burners served by the first pulverizer placed in operation. A master fuel trip shall not be required.

3.8.5.2.7 Shutdown Sequence — Second Fuel.

3.8.5.2.7.1 The requirements in 3.8.5.2.7 shall apply to the removal of coal from service with other main burner fuel remaining in service. The requirements in 3.8.5.2.3 shall apply to the removal of coal from service as the only main burner fuel being fired.

3.8.5.2.7.2 When shutting off coal with gas or oil remaining in service, a sequential shutdown of coal shall be accomplished in accordance with 3.8.5.2.3.2 and 3.8.5.2.3.3.

3.8.5.2.8 Reburn System Start.

3.8.5.2.8.1* The reburn system shall not be started until the requirements of 3.8.3.5.2 have been met and shall follow the prerequisites of 3.8.5.2.1.3(x). In addition, the furnace temperature characteristics as a function of heat input, steam flow, or other reliable control signal shall be utilized as a permissive to initiate the reburn fuel injection.

3.8.5.2.8.2 The reburn fuel preparation and transport equipment shall be started in accordance with 6.5.2 of Chapter 6 for direct-fired systems, or 6.5.3 for storage systems, and all system purging or warm-up shall be completed before starting any reburn fuel feeders.

3.8.5.2.8.3 If the reburn system admits reburn fuel through burners, then the starting sequence shall also follow that specified for burners in 3.8.5.2.1.3(f) through (n).

3.8.5.2.8.4 If the reburn system admits fuel by means other than through burners, then the starting sequence shall:

(1) Include all reburn operation permissives required by this chapter
(2) Follow the procedure specified by the manufacturer of the reburn system

3.8.5.2.9 Shutdown Sequence — Reburn Fuel.

3.8.5.2.9.1 If the reburn system admits reburn fuel through burners, the shutdown sequence shall follow that specified for burners in 3.8.5.2.3.

3.8.5.2.9.2 If the reburn system admits reburn fuel by means other than through burners, the shutdown sequence for dedicated and direct fired pulverizers shall be as follows:

(1) Transfer combustion controls from automatic to manual control unless controls are designed and tuned to bring system down to shutdown conditions.
(2) Reduce the reburn fuel flow to minimum.
(3) Shut down the reburn fuel supply system in accordance with Chapter 6.
(4) Close individual reburn shutoff valves.

3.8.5.3 Hazards of Residual Coal Charges in Pulverizers and Clearing After Shutdown.

3.8.5.3.1* The start-up procedure in Chapter 6, Pulverized Fuel Systems, shall be followed unless it is positively known that the pulverizer is not charged with coal.

3.8.5.3.2 If the boiler is to be restarted and brought up to load without delay, the pulverizers with a charge and their feeders shall be started in sequence as dictated by the load in accordance with the procedure described in Chapter 6, Pulverized Fuel Systems.

3.8.5.3.3 If a delay in load demand is expected or undetermined but boiler conditions, including completion of purge, allow firing, the pulverizers shall be started and cleared in sequence in accordance with Chapter 6, Pulverized Fuel Systems. If during this sequence it becomes possible to fire at a rate greater than the capacity of one pulverizer operating within its range of operation for stable flame, one of the pulverizers and its feeder shall be placed into service to help burn the coal being injected from the remaining pulverizers that are being cleared.

3.8.5.3.4 If there is a significant delay before firing is initiated for the purpose of clearing pulverizers, the pulverizer subsystem shall be inerted. The time delay before inerting depends on the coal characteristics, pulverizer temperature, and size and arrangement of the pulverizer equipment. The inerting procedure shall be prescribed by the pulverizer equipment manufacturer in accordance with Chapter 6, Pulverized Fuel Systems.

3.8.5.3.5 If firing is not to be initiated for an extended time, the pulverizer shall be cleaned manually or mechanically after having been cooled to ambient temperature and inerted before opening. To avoid the danger of an explosion when opening and cleaning any pulverizer, caution shall be used. The guidelines in Chapter 6, Pulverized Fuel Systems, shall be followed.

3.8.5.4 Emergency Conditions Not Requiring Shutdown or Trip.

3.8.5.4.1 In the event of a loss of a fan or fans for unit installations with multiple induced draft fans or forced draft fans, or both, the control system shall be capable of reducing the fuel flow to match the remaining airflow; otherwise, tripping of the unit shall be mandatory.

3.8.5.4.2* If an air deficiency develops while flame is maintained at the burners, the fuel shall be reduced until the air/fuel ratio has been restored within predetermined acceptable limits; or, if fuel flow cannot be reduced, the airflow shall be increased slowly until the air/fuel ratio has been restored to within those limits.

3.8.5.4.3* Where raw coal hangs up ahead of the feeder, or where wet coal or changing coal quality is encountered, the igniters shall be placed into service on all operating burners. If the malfunction is corrected or required ignition energy is resupplied before the burner flame is lost, the pulverizer subsystem shall be permitted to operate, provided there is a stable flame. If the flame becomes unstable or is extinguished, the burner and subsystem shall be shut down. Start-up conditions shall be established before coal feed is restored. *(Refer to 3.8.4.4, which describes loss of flame trip requirements.)*

3.8.5.5 General Operating Requirements — All Conditions.

3.8.5.5.1 Prior to starting a unit, action shall be taken to prevent fuel from entering the furnace.

3.8.5.5.2 A unit purge shall be completed prior to starting a fire in the furnace.

3.8.5.5.3 Purge rate shall be not less than 25 percent or more than 40 percent of the full load mass airflow.

3.8.5.5.4 The igniter for the burner shall always be used. Burners shall not be lighted using a previously lighted burner or from the hot refractory.

3.8.5.5.5 Where operating at low capacity, a reduced number of pulverizers shall be operated. Operation with less than the full complement of burners associated with a pulverizer is not recommended unless the pulverizer-burner subsystem is designed specifically for such operation. Idle burners are subject to accumulations of unburned pulverized coal in burner lines, leakage of coal into furnace or windboxes, and overheated burner nozzles or diffusers. With high volatile coals, there is a high probability that coking or serious fires will result from operation under such conditions.

3.8.5.5.6 Sootblowers shall be operated only where heat input to the furnace is at a rate high enough to prevent a flameout during the sootblower operation. Sootblowers shall not be operated at low-load and high excess air conditions. This requirement shall not preclude the use of wall sootblowers and high-temperature superheater and reheater sootblowers for cleaning during periods of power outage if a unit purge has been completed and purge rate airflow is maintained, nor does it preclude the use of air heater sootblowers during start-up.

3.8.5.5.7 When pulverizer or burner line maintenance is being performed with the boiler in service, positive means to isolate the pulverizer or burner line from the furnace shall be used.

3.8.5.5.8 Where the pulverizer and burner piping is being cleared into a furnace, the procedures of 3.8.5.3 shall apply.

3.8.5.5.9 The procedures of Chapter 6 shall apply where dealing with pulverizer equipment fires.

3.8.5.5.10 The total heat input within a burner or furnace zone, or both, shall not exceed the maximum limits specified for the equipment by the manufacturer. Multiple fuels' total heat inputs shall be accounted for where a burner or furnace zone, or both, simultaneously fires more than one fuel.

Chapter 4 Atmospheric Fluidized-Bed Boilers

4.1 Scope.

4.1.1 The material in this chapter shall apply to the design, installation, operation, training, and maintenance as they relate to safety of atmospheric fluidized-bed boilers.

4.1.2 This chapter shall be used in conjunction with Chapter 1 and requires the coordination of operation procedures, control systems, interlocks, and structural design. Where conflicts exist, the requirements of Chapter 4 shall apply.

4.1.3 Differences between fluidized-bed combustion and other combustion technologies, covered elsewhere in this code, means that material contained in this chapter shall not be construed to apply to these other technologies. However, Chapter 1 of this code shall apply to atmospheric fluidized-bed combustion.

4.2 Purpose. The purpose of this chapter is to establish minimum standards for the design, installation, operation, and maintenance of atmospheric fluidized-bed boilers, their fuel-burning systems, and related systems to contribute to safe operation and, in particular, to the prevention of furnace explosions.

4.3 General.

4.3.1 Combustion Explosions.

4.3.1.1* To prevent explosions in fluidized-bed systems, the following conditions shall be avoided:

(1) An interruption of the fuel or air supply or ignition energy to warm-up burners, sufficient to result in causing momentary loss of flames, followed by restoration and delayed reignition of accumulated combustibles
(2)* The accumulation of an explosive mixture of fuel and air as a result of the 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
(3) Insufficient air to all or some bed compartments, causing incomplete combustion and accumulation of combustible material

4.3.2* Furnace Implosions.

4.3.3 Manufacture, Design, and Engineering. The manufacture, design, and engineering shall be in accordance with 1.4.3.

4.3.4 Installation. The installation shall be in accordance with Sections 1.5 and 1.10.

4.3.5 Coordination of Design, Construction, and Operation. The coordination of design, construction, and operation shall be in accordance with Section 1.6.

4.3.6 Maintenance, Inspection, Training, and Safety. The maintenance, inspection, training, and safety shall be in accordance with Section 1.7.

4.3.7 Fluidized-Bed Combustion — Special Problems.

4.3.7.1 Heating the Bed. The bed material shall be heated to a temperature above the autoignition temperature of the main fuel prior to admitting the main fuel to the bed. Warm-up burners shall be sized to permit warming the bed without the need to use fuel lances.

4.3.7.2* Char Carryover. Because char carryover is a characteristic of fluidized-bed combustion, the system design shall include provisions to minimize char accumulations in the flue gas ductwork and dust collection equipment.

4.3.7.3 Coal Firing. In addition to the common hazards involved in the combustion of solid, liquid, and gaseous fuels, the following shall be included in the design of the coal firing systems:

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

(b) Methane gas released from freshly crushed coal can accumulate in enclosed spaces.

(c) The raw coal delivered to the plant can contain foreign substances (e.g., scrap iron, wood shoring, rags, excelsior, rock). 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 can constitute a hazard by interrupting coal flow. Wet coal can cause a coal hang-up in the raw coal supply system. Wide variations in the size of raw coal can cause erratic or uncontrolled coal feeding or combustion.

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

(e) Caution shall be exercised where interpreting the meter indication for combustibles. Most meters and associated sampling systems measure only gaseous combustibles. Therefore, the lack of a 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. Changes in the percentage of volatile matter and moisture affects the ignition characteristics of the coal and will affect the minimum required bed temperature prior to admission of coal into the bed. The amount of fines in the coal also affects its ignition and burning characteristics.

4.3.7.4 Waste Fuel Firing. Common hazards involved in the combustion of waste fuels shall be recognized as follows:

(a) The considerations described in 4.3.7.3 also apply to waste fuels.

(b) Many waste fuels contain volatile solvents or liquids; therefore, precautions shall be taken in the design of the fuel-handling and storage system.

(c) Waste fuels are more variable in analysis and burning characteristics than conventional fuels, and, therefore, an evaluation of special fuel-handling and burning safeguards shall be carried out. Operators shall conduct tests when a new waste fuel is to be used. *(See Appendix H.)*

4.3.7.5 Bed Ignition Temperature. The minimum bed temperature necessary to allow the admission of fuel into the bed shall not be less than that required for the highest ignition temperature for the range of fuels.

4.3.7.6 Hot Bed Material. Hot bed material, removed from the fluidized-bed combustion system, shall be cooled prior to disposal.

4.3.7.7* Personnel Hazards.

4.3.7.7.1 A number of personnel hazards are peculiar to fluidized-bed combustion. Safety precautions for dealing with such hazards shall be required for personnel safety. These hazards include the following:

(1) Hot solids
(2) Lime
(3) Hydrogen sulfide
(4) Calcium sulfide

4.3.7.7.2 Procedures shall be provided to assure that, before personnel enter the furnace or connected space, hot solids are not present and that hot solids in a connected space cannot flow into the space to be occupied. The procedure shall include inspections that start from the upper elevations of the hot cyclone(s) and other equipment and proceed to each space or chute below. In addition, soundings shall be made to confirm the absence of accumulated solids.

4.3.7.8 Additional Special Problems in Fluidized-Bed Combustion Systems. The following additional problems shall be addressed by system designers and operators:

(1)* Thermal inertia of the bed, causing steam generation to continue after fuel trip
(2) Requirements for continuity of the feed water supply for extended periods following a fuel trip or the loss of all power supply to the plant
(3) Potential for unintended accumulations of unburned fuel in the bed
(4) Potential for generation of explosive gases if the air supply to a bed is terminated before the fuel in the bed is burned out
(5) Potential risk of explosion when reestablishing the air supply to a hot bed
(6) Bed solidification as a result of a tube leak
(7) Structural load requirements for abnormal accumulations of ash or bed material within the boiler furnace enclosure and the solids return path
(8)* Structural or fire hazards associated with backsifting of bed material

4.4 Equipment Requirements.

4.4.1 Structural Design.

4.4.1.1 Boiler Enclosure. *(See 1.9.1.)*

4.4.1.1.1* The boiler enclosure shall be capable of withstanding a transient pressure without permanent deformation due to yield or buckling of any support member. The minimum design pressure *(see 4.5.1)* shall meet both of the following:

(1) Whichever is greater, 1.67 times the predicted operating pressure of the component or +35 in. of water (+8.7 kPa), but shall not be in excess of the maximum head capability of the air supply fan at ambient temperature
(2)* The maximum head capability of the induced draft fan at ambient temperature, but not more negative than −35 in. of water (−8.7 kPa)

4.4.1.2 Solid Material Feed Systems.

4.4.1.2.1 All components of the solid material feed system shall be designed to withstand, in addition to loads caused by the solid fuel, an internal gauge pressure without permanent deformation due to yield or buckling of any component. The minimum design pressure shall be the greater of the following:

(1) 1.67 times the predicted operating pressure of the component
(2) +35 in. (+8.7 kPa) of water

Exception: The design pressure defined in 4.4.1.2.1(1) need not be in excess of the maximum head capability of the pressure source under worst-case operating conditions.

4.4.1.2.2 Equipment design strength shall incorporate the combined stresses from mechanical loading, operationally induced loading, and internal design pressures plus an allowance for wear, which shall be determined by agreement between the manufacturer and the purchaser.

4.4.1.2.3 The components falling within the requirements of 4.4.1.2.1 shall begin at a point that is 2 ft (0.61 m) above the inlet of the solid material feeder. They shall end at the discharge of the solid material feed system, seal air connection if provided, and at the connection of any other air or flue gas source. These components shall include, but are not limited to, the following:

(1) Solid material feeding devices, discharge hoppers, and feed pipes to the feed system
(2) All parts of the solid material feed system that are required for containment of internal pressure

(3) Connecting piping from the feeder
(4) Foreign material-collecting hoppers that are connected to the feed system
(5) All valves in the fuel feed lines

Exception: Not included in the scope of these requirements are the raw fuel bunker or mechanical components, such as seals, gear, bearings, shafts, drives, and so forth.

4.4.2 Fuel-Burning System.

4.4.2.1 System Requirements.

4.4.2.1.1 The fuel-burning system shall provide means for start-up, operation, and shutdown of the combustion process. This shall include appropriate openings and configurations in the component assemblies to allow observation, measurement, and control of the combustion process.

4.4.2.1.2 The fuel-burning system consists of the boiler enclosure and the following subsystems: air supply; coal, other solid fuel supply, or both; crusher (where utilized); bed feed; liquid or gaseous fuel lances; burners; ash removal; ash re-injection; and combustion products removal. Each subsystem shall be sized and interconnected to satisfy the following requirements:

(a) Boiler Enclosure

(1) The boiler enclosure shall be sized and arranged so that stable bed operations and stable combustion are maintained.
(2) The boiler enclosure shall be free of dead pockets where prescribed purge procedures are followed.
(3) Observation ports shall be provided to allow inspection of the duct and warm-up burners.
(4) Means shall be provided for monitoring of conditions at the bed and its ignition zone. Accessibility for maintenance shall be provided.

(b) Air Supply Subsystem *[See 1.9.2.3.2(b).]*

(1) The air supply equipment shall be sized and arranged to ensure a continuous airflow, sufficient for ensuring complete combustion of all fuel input, across all operating conditions of the unit.
(2) The arrangement of air inlets, ductwork, and air preheaters shall minimize contamination of the air supply by such materials as flue gas, water, fuel, and bed material. Appropriate drain and access openings shall be provided.

(c) Bed Warm-Up Burner Subsystem. *(See 4.4.3.)*

(d)*Solid Fuel Supply.

(1) The solid fuel supply subsystem shall be designed 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 shall include the installation of breakers, cleaning screens, and magnetic separators where necessary. Means for detection of flow interruption and correction shall 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 fuel 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, quality, and moisture content. Means shall be provided for proving solid fuel flow. Means shall be provided for clearing obstructions.
(4) A bed feed that operates at a lower pressure than the boiler enclosure to which it is connected shall have a lock hopper or other means to prevent backflow of combustion products.
(5) If transport air is required, a means shall be provided to ensure a supply that continuously transports the required fuel input.

(e) Crusher Subsystem (where utilized in the fuel feed system).

(1) Fuel crushing equipment shall produce fuel sizing over a specified range of fuel analyses 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. *(For further information, see Chapter 6, Pulverized Fuel Systems.)*
(2) The transport system shall be sized and arranged to transport the material throughout the crusher's operating range.

(f) Fuel Oil or Fuel Gas Lances. *(See 4.4.3.)*

(g) Solids Removal Subsystems.

(1) The bed drain subsystem and flue gas cleaning subsystem shall be sized and arranged to remove the bed material, fly ash, and spent sorbent at a rate that is at least equal to the rate at which they are 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 material cooling before discharging material into ash-handling and storage equipment. Safety interlocks equipped with a device to monitor cooling medium flow and material discharge temperature shall be provided to prevent fires or equipment damage.

(h) Combustion Products Removal Subsystem. *[See 1.9.2.3.2(e).]*

(i) Ignition Subsystem. *[See 1.9.2.3.2(d).]*

4.4.3 Warm-Up Burners and Lances.

4.4.3.1 Fuel Supply Subsystem — Gas.

4.4.3.1.1 The fuel supply equipment shall be sized and arranged to ensure a continuous fuel flow for all operating requirements of the unit. These include coordination of the fuel control valve, burner safety shutoff valves, and associated piping volume to prevent fuel pressure transients that result in exceeding burner limits for stable flame caused by placing burners in service or taking them out of service.

4.4.3.1.2 The portion of the fuel supply system located outside the boiler room shall be arranged to prevent excessive fuel gas pressure in the fuel-burning system, even in the event of a failure of the gas supply constant fuel pressure regulator(s). The design shall be accomplished by a full relieving capacity vent or a high gas supply pressure trip. *(Refer to 4.7.5.3.)*

4.4.3.1.3 The fuel supply equipment shall be designed to inhibit contamination of the fuel. Convenient access to important fuel system components shall be provided. Drains shall be provided at low points in the piping.

4.4.3.1.4 The fuel supply equipment shall be capable of continuing fuel flow at the set point (demand) rate during anticipated furnace pressure pulsations.

4.4.3.1.5 The fuel supply equipment shall be designed to minimize system exposure to severe external conditions such as fire, ash spills, or mechanical damage. Piping routes and valve locations shall minimize exposure to explosion hazard or high-temperature sources.

4.4.3.1.6 As much of the fuel subsystem as is practicable shall be located outside the boiler house. A manual emergency shutoff valve that is accessible in the event of fire in the boiler area shall be provided.

4.4.3.1.7 For each burner or lance, the minimum requirement for safety shutoff valves shall be two (2) block valves with an intermediate vent valve (double block and vent) or equivalent valve arrangement. For units with multiple burners or lances, a header safety shutoff valve and provisions to automatically vent the piping volume between the header safety shutoff valve and any individual burner or lance safety shutoff valves shall also be provided.

Exception: Multiple burners or lances supplied from a common set of safety shutoff valves shall be treated as a single (individual) burner or lance [see 4.4.3.4.2.2, 4.7.5.2.1.2(o), 4.8.5.2.1.2(p)].

4.4.3.1.8 Proof of closure shall be provided for all safety shutoff and supervisory shutoff valves. Proof of closure shall be provided for all vent valves.

4.4.3.1.9 For each igniter, the minimum requirement for safety shutoff valves shall be two (2) block valves with an intermediate vent valve or equivalent valve arrangement. For units with multiple burners, a common igniter fuel gas header safety shutoff valve and provisions to automatically vent the piping volume between the header safety shutoff valve and any igniter safety shutoff valves shall also be provided. This header safety shutoff valve and intermediate vent valve shall be dedicated to the igniter subsystem. Proof of closure in accordance with 4.4.3.1.8 shall be provided for all individual igniter safety shutoff valves where individual igniter capacity exceeds 5.0 MBtu/hr (1.465 MW).

Exception: Multiple igniters supplied from a common set of safety shutoff valves shall be treated as a single (individual) igniter [see 4.7.5.2.1.2(n), 4.8.5.2.1.2(o)].

4.4.3.1.10 Provisions shall be made in the gas piping to allow testing for leakage and subsequent repair. Such provisions shall include a permanent means for making accurate tightness tests of the header safety shutoff valves and individual safety shutoff valves.

4.4.3.1.11 Shutoff valves shall be located as close as practicable to the igniters, burners, or lances to minimize the volume of fuel downstream of the valve.

4.4.3.1.12 Gas piping materials and system design shall be in accordance with ANSI B 31.1, *Power Piping*.

4.4.3.1.13 Before maintenance is performed on any gas piping, the piping shall be isolated and purged in accordance with the requirements of NFPA 54, *National Fuel Gas Code*.

4.4.3.2 Fuel Supply Subsystem — Fuel Oil.

4.4.3.2.1 The fuel supply equipment shall be sized and arranged to ensure a continuous fuel flow for all operating requirements of the unit. The design shall include coordination of the fuel control valve, burner safety shutoff valves, and associated piping volume to prevent fuel pressure transients that result in exceeding burner limits for stable flame caused by placing burners in service or taking them out of service.

4.4.3.2.2 Unloading, storage, pumping, heating, and piping facilities shall be designed and arranged to inhibit contamination of the fuel. Where necessary, cleaning devices shall be provided to ensure a clean fuel to valves and burners. Convenient access to important fuel system components shall be provided. Drains shall be provided.

4.4.3.2.3 Fill and recirculation lines to storage tanks shall discharge below the liquid level to prevent free fall.

4.4.3.2.4 Strainers, filters, traps, sumps, and similar components shall be provided to remove harmful contaminants where practicable; materials not removed shall be accommodated by special operating and maintenance procedures. Contaminants in fuel include salt, sand, sludge, water, and other abrasive or corrosive constituents. Some fuels contain waxy materials that precipitate, clogging filters and other elements of the fuel system.

4.4.3.2.5 The fuel supply equipment shall be designed to minimize exposure to severe external conditions such as fire, ash spills, or mechanical damage. Piping routes and valve locations shall minimize exposure to explosion hazards or to high-temperature or low-temperature sources. Low temperatures increase viscosity, inhibit flow, or precipitate waxy materials and shall not be permitted. High temperatures cause carbonization or excessive pressures and leakage due to fluid expansion in "trapped" sections of the system and shall not be permitted.

4.4.3.2.6 As much of the fuel supply subsystem as is practicable shall be located outside the boiler house. A manual emergency shutoff valve shall be provided that is accessible in the event of fire in the boiler area.

4.4.3.2.7 A means shall be provided to prevent or relieve excess pressure from expansion of entrapped oil in the fuel system. This is especially important in the case of crude oil.

4.4.3.2.8 Relief valve discharge passages, vents, and telltales shall be provided with piping sized to allow the discharge of oil or vapors to prevent excessive pressure in the system. This piping shall be heat traced as required to achieve the free flow of relieved fluid.

4.4.3.2.9 Shutoff valves shall be located as close as practicable to the igniters, burners, or lances to minimize the volume of fuel downstream of the valve.

4.4.3.2.10 Oil piping materials and system design shall be in accordance with NFPA 31, *Standard for the Installation of Oil-Burning Equipment*, and ANSI B 31.1, *Power Piping*.

4.4.3.2.11 All instruments and control piping and other small lines containing oil shall be rugged, capable of withstanding the expected range of external temperatures, protected against damage, and maintained at the fluid temperature range of the specified fuel oil. The use of interface fluids or sealing diaphragms may be necessary with this instrumentation.

4.4.3.2.12 A positive means to prevent leakage of oil into a furnace or duct shall be provided.

4.4.3.2.13 Provisions shall be made in the oil supply system to allow testing for leakage and subsequent repair. Such provisions shall include a permanent means for making accurate tightness tests of all safety shutoff valves.

4.4.3.2.14 Fuel oil shall be delivered to the burners at the temperature and pressure as recommended by the burner manufacturer to ensure complete atomization.

4.4.3.2.15 Heating of oil, if necessary, shall be accomplished without contamination or coking.

4.4.3.2.16 Recirculation provisions shall be incorporated for controlling the viscosity of the oil to the burners for initial light-off and for subsequent operation. Recirculation systems shall be designed and operated to prevent excessively hot oil from entering fuel oil pumps that causes them to vapor-bind, and subsequently interrupt the fuel oil supply.

4.4.3.2.17 A positive means shall be provided to prevent fuel oil from entering the burner header system through recirculating valves, particularly from the fuel supply system of another boiler. The owner shall not rely on check valves for this function because they have not proven dependable in heavy oil service.

4.4.3.2.18 Provisions, including an ignition source, shall be provided for clearing (scavenging) the passages of an atomizer that lead into the furnace or duct.

4.4.3.3 Warm-Up Burner Subsystem.

4.4.3.3.1 General.

4.4.3.3.1.1 The warm-up burner subsystem shall function to supply the heat energy required to bring the bed to the main fuel ignition temperature.

4.4.3.3.1.2 The warm-up burner shall meet the requirements of 1.9.2.

4.4.3.3.1.3 Provision shall be made for visual observation of conditions at the burner ignition zone. Additional provisions shall be made for flame detection equipment. The burner equipment shall be located in an appropriate environment with convenient access for maintenance. Special attention shall be given to fire hazards imposed by leakage or rupture of piping near the burner. The requirements of good housekeeping shall be practiced.

4.4.3.3.1.4 Flue Gas Recirculation to Burners. When flue gas or other inert gases are introduced to the secondary air or combustion air being supplied to burners, testing shall be used to demonstrate that the methods and devices used provide uniform distribution and mixing. The oxygen content of the mixture being supplied to the burners shall not be permitted to go below the limit specified by the burner manufacturer or as proven by tests to provide stable combustion. Means shall be provided to monitor either the ratio of flue gas to air or the oxygen content of the mixture.

4.4.3.3.2 Subsystem Requirements.

4.4.3.3.2.1 Air Supply. A portion of the total air supply necessary for light-off and flame stabilization shall be supplied to the warm-up burner(s).

4.4.3.3.2.2* Ignition. The ignition subsystem shall be designed in accordance with 1.9.2.3.2(d).

4.4.3.3.2.3 Flame Monitoring and Tripping — Functional Requirements.

(a) The basic requirements of any flame monitoring and tripping system shall be as follows:

(1) The warm-up burners shall meet the requirements of 4.4.4.2.
(2) Each burner shall provide enough system resistance or dampening to the fuel and airflow to override anticipated furnace pulsations and maintain stable combustion.
(3) Each burner shall be individually supervised. Upon detection of loss of burner flame, the safety shutoff valve for the burner experiencing the loss shall automatically close.
(4)* Regardless of the number or pattern of flame loss indications used for tripping, loss of flame indication on an operating burner or flame envelope shall initiate an alarm to warn the operator of potential hazard.
(5) Field testing shall be required to validate basic flame tripping concepts. These tests shall be performed on representative units. The results of these tests shall be permitted to be applied to other units of the same size and arrangement, including burners/nozzles that are of the same capacity and use the same fuels. These tests shall not replace acceptance tests relating to proof of design, function, and components.
(6) Oil-fired warm-up burners, firing into the bed, shall be permitted to be scavenged immediately after shutdown or trip if the bed is fluidized and the bed temperature is greater than 1400°F (760°C) or if associated igniters are in service.

(b) Each burner shall be supervised individually. Upon detection of loss of a burner flame, that individual burner safety shutoff valve shall be automatically closed.

(1) Where Class 1 igniters are provided, the main burner flame shall be proven either by the flame scanner or by the igniter being proven. At least one flame detector shall be provided for each burner to detect the burner flame or igniter flame where a Class 1 igniter is provided.
(2) Burners with Class 2 igniters shall have at least two flame detectors. One detector shall be positioned to detect the main burner flame and shall not detect the igniter flame. The second detector shall be positioned to detect the igniter flame during prescribed light-off conditions.
(3) Burners with Class 3 igniters shall have at least one flame detector. The detector shall be positioned to detect the igniter flame. It also shall detect the main burner flame after the igniter is removed from service at the completion of the main burner trial for ignition.
(4) Upon detection of loss of all flame in the furnace or partial loss of flame to the extent that hazardous conditions develop, a master fuel trip shall be automatically initiated.
(5) Any fuel input that does not ignite and burn on a continuous basis shall be classified as a hazard. Regardless of the number or pattern of flame loss indications used for tripping, loss of flame indication on an operating burner or "flame envelope" shall initiate an alarm that warns the operator of a potential hazard.
(6) The flame tripping concept used on the unit shall have been validated by the boiler manufacturer for the specific furnace configuration being used. This validation shall not be used to replace unit acceptance tests relating to proof of design, function, and components.

4.4.3.3.2.4 Flame Detection. Flame detection shall be in accordance with 1.9.4.2.

4.4.3.3.2.5 Combustion Control System. *(See also 1.9.6.)*

(a) The combustion control system shall be in accordance with 4.4.4.4.

(b) Equipment shall be provided and operating procedures established to ensure a stable flame condition at each burner and to preclude the possibility of an air/fuel ratio condition that results in a fuel-rich condition within the furnace.

(c) Provision shall be made for setting minimum and maximum limits on the warm-up burner fuel and air control subsystems to prevent fuel flow and airflow beyond the stable flame limits of the burner(s). These minimum and maximum limits shall be specified by the burner manufacturer and verified by operating tests in accordance with 4.4.3.5 and 4.7.3.2.

(d) The control system shall prevent the demand for a fuel-rich mixture while in the automatic control mode.

4.4.3.4 Lance Subsystem.

4.4.3.4.1 Functional Requirements.

4.4.3.4.1.1 The lance subsystem shall function to provide alternate or supplemental fuel input to the bed.

4.4.3.4.1.2 The lances shall meet the requirements of 1.9.2.

4.4.3.4.2 Subsystem Requirements.

4.4.3.4.2.1 Fuel Supply System.

(a) 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 shall be furnished to ensure the combustion of fuel in the bed at all times.

(b) Provision shall be made for protecting the lance nozzles and tips.

(c)*The lance equipment shall be located in an appropriate environment with access for maintenance.

4.4.3.4.2.2 Multiple Lances Under Common Control.

(a) A group of lances shall be permitted to be supplied from a common header whose input is controlled by a single set of fuel safety shutoff and control valves.

(b) Flow to a group of lances that is controlled from a common source shall be treated as an individual lance.

4.4.3.5* Burner Testing. The turndown limits of stable flame for each burner subsystem producing a separate flame envelope shall be determined by tests without the ignition system in service. These tests shall verify that transients generated in the fuel and air subsystems do not adversely affect the burners in operation. These tests shall include the use of those fuels expected to be used.

4.4.4 Burner Management, Combustion Monitoring and Tripping, and Bed Temperature Monitoring.

4.4.4.1 The burner management system shall be in accordance with 1.9.3.

4.4.4.2 Combustion Monitoring and Tripping Systems — Functional Requirements. The basic requirements of the combustion monitoring and tripping system shall be as follows:

(1) Combustion instability situations shall be brought to the attention of the operator for remedial action.
(2) An emergency shutdown of the involved equipment shall be automatically initiated upon detection of serious combustion problems that would lead to the accumulation of unburned fuel or to other hazardous situations.

4.4.4.3* Bed Temperature Monitoring.

4.4.4.3.1 The bed temperature, monitored by taking a number of measurements physically located in the bed, shall provide a representative bed temperature profile under all operating conditions. If the bed is compartmented, the bed temperature of each individual compartment shall be monitored. The bed temperature(s) shall be available to the operator.

4.4.4.3.2 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.

4.4.4.3.3 Upon detection of a bed temperature that falls below the minimum value established for self-sustaining combustion of the fuel(s) being fired in the bed, that fuel supply shall be automatically shut down.

4.4.4.4 Combustion Control System.

4.4.4.4.1 Functional Requirements.

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

4.4.4.4.1.2 The combustion control system shall maintain the bed temperature within the limits required for continuous stable combustion for the full operating range of the boiler.

4.4.4.4.1.3* Furnace inputs and their relative rates of change shall be controlled to maintain the air/fuel ratio within the limits required for continuous combustion and stable bed conditions for the full operating range of the boiler.

4.4.4.4.2 System Requirements.

4.4.4.4.2.1 Equipment shall be provided and operating procedures established to heat the bed material prior to admitting fuel to the bed. For bed start-up, the temperature of the bed material shall be raised to the minimum value established for self-sustaining combustion of the fuel, and the bed shall be fluidized before fuel is admitted. *[See Appendix H.]*

4.4.4.4.2.2 Provisions shall be made for setting minimum and maximum limits on the fuel and air control subsystems to ensure stable bed operation and to prevent fuel and airflows beyond the capacity of the furnace. These minimum and maximum limits shall be defined by the boiler manufacturer and verified by operating tests.

4.4.4.4.2.3 When changing furnace heat input, the airflow and fuel flow shall be changed simultaneously to maintain an air-rich air/fuel ratio during and after the changes. This shall not eliminate the requirements for air lead and lag during changes in the fuel firing rate. Setting the fuel flow control on automatic without setting the airflow control on automatic shall be prohibited, and this function shall be interlocked. Where fluidized-bed combustion boilers burn fuels of widely varying heat value and air demand per unit of fuel, the required air/fuel ratio limits shall include provision for the calibration of the air/fuel ratio.

4.4.4.4.2.4 The control system shall prevent the demand for a fuel-rich mixture while in the automatic control mode.

4.4.4.4.2.5 Means shall be provided to limit fuel input to the air input while in the automatic control mode.

4.4.4.4.2.6 On balanced draft furnaces, furnace draft shall be maintained at the set point.

4.4.4.4.2.7 Equipment shall be designed and procedures established to allow on-line maintenance of combustion control equipment.

4.4.4.4.2.8 Provisions for calibration and testing of combustion control and associated interlock equipment shall be furnished.

4.4.4.4.2.9* Flue gas oxygen analyzers shall be provided for use as an operating guide.

4.4.4.4.2.10 Fuel gas flowmeters shall be operated at constant pressure conditions or shall be pressure compensated where pressure variations introduce a significant error.

4.4.4.4.2.11 Fuel oil flowmeters shall be compensated where variations in temperature or viscosity introduce a significant error.

4.4.4.4.2.12* Means of providing a calibrated solid fuel flow signal for each feeder shall be required as a part of the combustion control and solid fuel feed control systems.

4.4.4.4.2.13 Means shall be provided to maintain the transport/fluidizing air necessary for transporting the required fuel, sorbent, and recycled ash material, as applicable.

4.4.4.5 Operating Information. In addition to the requirements of 1.9.7, a continuous trend display of bed temperature shall be provided.

4.5* Furnace Pressure Excursion Prevention.

4.5.1* General. This section provides methods for minimizing the risks of furnace pressure excursions in excess of furnace structural capability. This shall be accomplished by one of the following methods:

(a) The boiler enclosure, the air supply system, and the flue gas removal system shall be designed so that the maximum head capability of the forced draft and induced draft fans within these systems, with ambient air, does not exceed the design pressure of the boiler enclosure, associated ducts, and equipment. This design pressure is defined the same as, and shall be in accordance with, the wind and seismic stresses of 1.5.6 of Section 5 of AISC M016, *Manual of Steel Construction Allowable Stress Design*.

(b) A furnace pressure control system shall be provided in accordance with 4.5.2 and a furnace design as specified in 4.4.1.1.

4.5.2 Furnace Pressure Control Systems.

4.5.2.1 Functional Requirements. The furnace pressure control system shall control the furnace pressure at the desired set point in the combustion chamber.

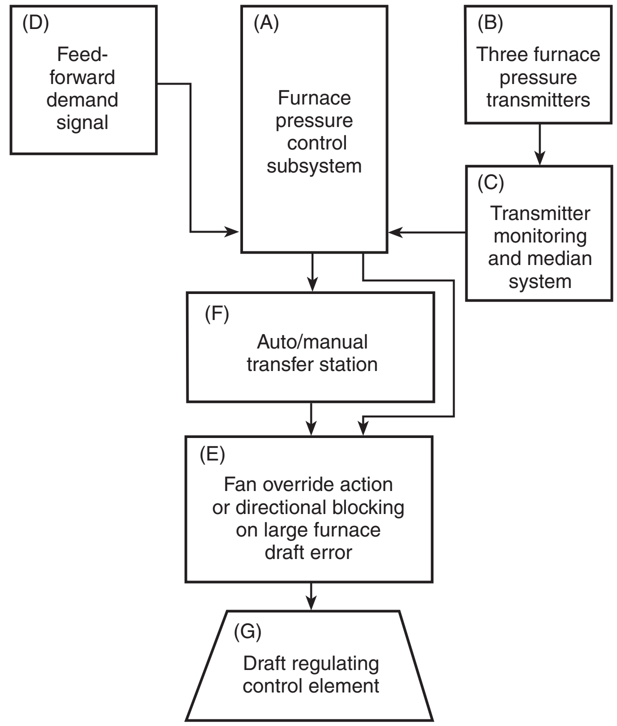
4.5.2.2 System Requirements. The technical requirements of this section shall be in accordance with the flow chart shown in Figure 4.5.2.2.

4.5.2.2.1 The furnace pressure control subsystem (A), as shown in Figure 4.5.2.2, shall position the draft regulating equipment to maintain furnace pressure at the desired set point.

4.5.2.2.2 The control system, as shown in Figure 4.5.2.2, shall include the following:

(1) Three furnace pressure transmitters (B), each on a separate pressure-sensing tap and monitored (C) to minimize the possibility of operating with a faulty furnace pressure measurement.
(2) A feed-forward signal (D) to indicate boiler airflow demand. This shall be permitted to be a fuel flow signal, a boiler master signal, or other index of demand but shall not be a measured airflow signal.
(3) Override action or directional blocking (E) for large furnace draft errors introduced after the auto/manual transfer station (F).

FIGURE 4.5.2.2 System requirements.



(4) The prevention of uncontrolled changes in air or flue gas flow caused by axial fans, where used, achieved by operating the fans in such a manner as to avoid a stall condition.
(5) Purge air as required to keep the sensing lines open.

4.5.2.3 Furnace Pressure Control Final Control Elements. The furnace pressure control element(s) [i.e., draft fan inlet damper, drive blade pitch control, speed control *(see (G) in Figure 4.5.2.2)*] shall meet the following criteria:

(1)* The operating speed shall not exceed the control system's sensing and positioning capabilities.
(2) The operating speed of the draft control equipment shall not be less than that of the airflow control equipment.

4.5.3 Sequence of Operations.

4.5.3.1 Functional Requirements.

4.5.3.1.1 The sequence for starting and stopping fans shall be in conformance with written operating procedures specified by manufacturers, engineering consultants, and operating companies. These procedures shall be integrated with the operating procedures specified in this section and in Section 4.6.

4.5.3.1.2 An open flow path from the inlet of the forced draft fans through the stack shall be ensured under all operating conditions. Where the system design does not allow the use of fully open air paths, the minimum width of open area air paths shall not be less than that required for purge airflow with fans in operation. The principles to be observed shall include the following:

(a) On installations with multiple induced draft or forced draft fans, all fan flow control devices and shutoff dampers shall be opened in preparation for starting the first induced draft fan. In addition, isolating dampers, windbox dampers, air registers, and other control dampers shall be opened as required to ensure an open flow path from the forced draft fan inlet through the furnace, the induced draft fans, and the stack. Unless an open flow path is provided by other means, the open path shall be ensured while starting the first induced draft and forced draft fan. During any individual fan's starting sequence, its associated flow control devices and shutoff dampers shall be permitted to be closed.

(b) On installations with a single induced or forced draft fan, the induced draft fan's associated control devices and shutoff dampers shall be permitted to be closed as required during the fan's start-up. Once the induced draft fan is operating and has stabilized, the forced draft fan's associated flow control devices and shutoff dampers shall be brought to the position that limits starting current for that fan's start-up and then brought to the position for purge airflow during fan operation.

(c) Within the limitations of the fan manufacturer's recommendations, all flow control devices and shutoff dampers on idle fans shall remain open until the first induced draft and first forced draft fans are in operation while maintaining furnace pressure conditions and indication of an open flow path. After the first induced draft and forced draft fans are started and are delivering air through the furnace, the shutoff damper(s) of the remaining idle fan(s) shall be permitted to be closed.

(d) The practice of operating with excess induced draft fan capability in relation to either forced draft fan capability or boiler load shall be discouraged.

4.5.3.1.3 The sequence for starting and stopping fans under all conditions shall be as follows:

(1) An induced draft fan is started, and then a forced draft fan is started. Subsequent induced draft and forced draft fans shall be started in accordance with 4.5.3.1.4.
(2) Shutdown procedures shall be the reverse of those required in 4.5.3.1.3(1).

4.5.3.1.4 Where starting and stopping fans, the method employed and the manipulation of the associated control elements shall minimize furnace pressure excursions. The furnace pressure control subsystem shall be placed on and maintained on automatic controls as soon as possible.

4.5.3.1.5 Following shutdown of the last fan due to any cause, the opening of fan dampers shall be delayed or controlled to prevent positive or negative furnace pressure transients in excess of design limits during fan coast-down.

4.5.4 Interlock System.

4.5.4.1 Functional Requirements. The functional requirements for interlock systems specified in Section 4.9 shall be followed.

4.5.4.2 System Requirements.

4.5.4.2.1 Not all conditions conducive to a furnace pressure excursion are detected by any of the mandatory automatic-trip devices, even though such devices are adjusted and maintained in accordance with the manufacturer's instructions and as required by this code; therefore, operating personnel shall be made aware of the limitations of the automatic protection system.

4.5.4.2.2 The following interlocks shall be provided. A short time delay shall be permitted to allow for rapid transients that do not present a hazard.

(a) High Furnace Pressure.

(1) A master fuel trip shall be initiated when the furnace pressure exceeds a value specified by the manufacturer. If fans are operating after the trip, they shall be continued in service. The airflow shall not be increased by deliberate manual or automatic control action.
(2) Before the main fuel firing and following a master fuel trip, forced draft fans shall be tripped if the furnace positive pressure exceeds a value specified by the manufacturer. The value of the positive pressure at which this trip is activated shall be greater than that specified in 4.5.4.2.2(a)1.

(b) High Furnace Draft (Balanced-Draft Units).

(1) A master fuel trip (not necessarily automatic) shall be initiated when the furnace negative pressure exceeds a value specified by the manufacturer. If fans are operating after the trip, they shall be continued in service. The airflow shall not be increased by deliberate manual or automatic control action.
(2) Before the main fuel firing and following a master fuel trip, all induced draft fans shall be tripped if furnace negative pressure exceeds a value specified by the manufacturer. The value of the negative pressure at which this trip is activated shall be greater than that specified in 4.5.4.2.2(b)1.

(c) Loss of Forced Draft Fans.

(1) An interlock to prove that each forced draft fan is running and capable of providing the required flow shall be provided. Loss of such proofs shall initiate "Loss of FD fan(s)" interlocks in accordance with the manufacturer's requirements and the requirements of this code.
(2) Damper(s) shall be closed on loss of an individual forced draft fan, unless it is the last forced draft fan in service.
(3) Where an interlock system is provided to start, stop, and trip induced draft fans and forced draft fans in pairs, the associated induced draft fan shall be tripped on loss of an individual forced draft fan, and the dampers associated with both fans shall be closed, provided they are not the last fans in service. If they are the last fans in service, the forced draft fan dampers shall remain open, and the induced draft fan shall remain in controlled operation.
(4) A master fuel trip shall be initiated on loss of all forced draft fans. All forced draft fan dampers shall be opened after a time delay to prevent high duct pressure during fan coast-down. Dampers shall remain open. Gas recirculation fan system dampers shall be closed.

(d) Loss of Induced Draft Fans.

(1) An interlock to prove that each induced draft fan is running and capable of providing the required flow shall be provided. Loss of such proofs shall initiate "Loss of ID fan(s)" interlocks in accordance with the manufacturer's requirements and the requirements of this code.
(2) Damper(s) shall be closed on loss of an individual induced draft fan, provided it is not the last induced draft fan in service.
(3) Where an interlock system is provided to start, stop, and trip induced draft fans and forced draft fans in pairs, the associated forced draft fan shall be tripped on loss of an individual induced draft fan. The dampers associated with both fans shall be closed, provided they are not the last fans in service.
(4) A master fuel trip shall be initiated on loss of all induced draft fans. All forced draft fans shall be tripped. All induced draft fan dampers shall be opened after a time delay to prevent high draft during fan coast-down. Dampers shall remain open, and fans shall be started in accordance with 4.5.3.1.2 through 4.5.3.1.4. Gas recirculation fan system dampers shall be closed.

(e) Multiple and Variable Speed Fans. After the start of the first induced draft and forced draft fans, any subsequent fan(s), whether of the forced draft or induced draft type, shall be capable of delivering airflow before opening its damper(s).

4.6 Sequence of Operations.

4.6.1 General.

4.6.1.1 Sequencing shall follow procedures that allow prepared fuel to be admitted to the fluidized-bed combustion zone only when hot fluidized bed mass and required combustion airflow exist 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.

4.6.1.2 The sequence of operations shall be based on the safety interlock system shown in Figure 4.9.3(b). These sequences shall be followed where the unit is operated manually or where certain functions are accomplished by interlocks or automatic controls. Different arrangements shall be permitted where equivalent protection is provided and the intent of the operating sequences specified in this section is met.

4.6.1.3* The starting and shutdown operating sequences for fluidized-bed boilers shall be permitted to be designed to preserve the temperature of the bed material and refractory. As a result, the warm-up cycle for cold start-up and hot restart, as well as the shutdown sequence, shall be permitted to be different from other coal, oil, or gas-fired boilers. Differences shall be permitted in, but not limited to, the following operating sequences:

(a) On a cold start-up, after the purge period, airflow through the bed (depending on the process design) shall be permitted to be reduced below the purge value to provide for the warm-up rate specified by the manufacturer. However, under no circumstances shall the total airflow through the unit be less than the unit purge rate.

(b) During a hot restart, if the bed material is above a predetermined minimum ignition temperature, fuel shall be permitted to be admitted to the boiler, or warm-up burners shall be permitted to be started to preserve bed temperature without a purge.

(c) Tripping the fans or diverting airflow from previously active bed sections shall be permitted after a master fuel trip without the post-purge.

4.6.1.4 Fluidized-bed boilers that have multiple beds (sometimes called zones, sections, or compartments) shall utilize a restrictive pattern of bed start-up and shutdown and shall prohibit random bed operation. In such cases, bed sequencing shall be specified by the manufacturer's operating instructions and verified by actual experience with the unit.

4.6.1.4.1 The first bed section shall have reached a predetermined ignition temperature before fuel is introduced.

4.6.1.4.2 Beds adjacent to an active bed shall have reached a predetermined ignition temperature before fuel is introduced.

4.6.1.5 Purge and light-off shall be performed under the following basic operating conditions, which significantly improve the margin of operating safety, particularly during start-up:

(1) The number of equipment manipulations necessary shall be minimized, thereby minimizing exposure to operating errors or equipment malfunction.
(2) The hazard of dead pockets in the gas passes and the accumulation of combustibles shall be minimized by continuously diluting the contents of the furnace with large quantities of air.

4.6.1.5.1 The basic start-up procedure shall incorporate the following requirements:

(a) All dampers and burner air registers shall be placed in a predetermined open position.

(b) A unit purge with the air registers and dampers in the position specified in 4.6.1.5.1(a) shall be completed. The bed shall be purged while in the fluidized or semifluidized condition.

(c) Components (e.g., precipitators, fired reheaters) containing sources of ignition energy shall be purged for not less than 5 minutes or five volume changes of that component prior to being placed into operation, whichever is greater. This purge is permitted to be done concurrently with the unit purge.

(d) The bed warm-up cycle shall start after the purge is complete. Airflow through the bed shall be permitted to be reduced below the purge requirements, depending on the process constraints. Some design of multi zone fluidized beds shall be permitted to require slumping those beds that are not being heated for start-up. Fluidized beds shall be permitted to be warmed up with the bed in a slumped or fluidized mode.

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

(f) Fuel input that necessitates ignition by the bed material shall not be fed into the bed until the average bed temperature has reached 1400°F (760°C).

Exception: A lower fuel input temperature limit shall be permitted, provided the temperature has been verified through test or actual experience as being capable of igniting the fuel. (See Appendix H.) However, in no case shall the temperature be lower than 900°F (480°C) for coal or 1100°F (590°C) for oil and natural gas.

4.6.1.5.2 Each boiler shall be tested during initial start-up to determine whether any modifications to the procedures specified in 4.6.1.5.1 are necessary in order to obtain ignition or to satisfy other design limitations during light-off and warm-up. However, modifications in the basic procedures defined in 4.6.1.5 shall not be made.

4.6.2 Operational Requirements.

4.6.2.1 Cold Start.

4.6.2.1.1 Preparation for starting shall include a thorough inspection and shall verify the following:

(1) The furnace and gas passages are in good repair and free of foreign material.
(2) All personnel are evacuated from the unit and associated equipment, all access and inspection doors are closed, and all equipment and instrumentation is ready for operation.
(3) All airflow and flue gas flow control dampers have been operated through their full range to check the operating mechanism.
(4) All adjustable individual burner dampers or registers have been operated through their full range to check the operating mechanism.
(5) All safety shutoff valves are operational and closed and ignition sparks are de-energized.
(6) The feeder equipment is effectively isolated to prevent the leakage of fuel or sorbent into the furnace and to prevent hot air or flue gas from the fluidized bed from leaking back into the feed system.
(7) The drum water level is established in drum-type boilers, circulating flow is established in forced circulation boilers, or minimum water flow is established in once-through boilers.

(8) The feeders and associated equipment are calibrated and ready for operation.
(9) Energy is supplied to the control system and to the safety interlocks.
(10) The oxygen analyzer and carbon monoxide or combustibles analyzer, if provided, are operating; the carbon monoxide or combustibles indication is at zero, and oxygen indication is at maximum.
(11) A complete functional check of the safety interlocks has been made, at minimum, after system maintenance.
(12) A complete periodic operational test of each igniter has been made; frequency of testing is dependent on the design and operating history of each individual unit and ignition system; as a minimum, a test shall be performed during every start-up following overhaul or other maintenance; a test shall be integrated into the starting sequence and shall follow the purge of and precede the admission of any warm-up burner fuel.
(13) Individual igniters or groups of igniters shall be permitted to be tested while the unit is in service. Such tests shall be made with no main fuel present in the igniter's associated burner, and the burner air register shall be in its start-up or light-off position as described in the established operating procedure.
(14) *The furnace contains the required bed inventory as defined by the manufacturer or determined by test.

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

Exception: The starting sequence order shall be permitted to be varied where specified by the boiler manufacturer.

(a) The unit shall be prepared for operation. Required cooling water flow to critical components shall be ensured. Verification that the plant air, instrument air, and service steam systems are operational shall be made.

(b) Verification of the existence of an open flow path from the inlet(s) of the forced draft fans through the furnace space and into the stack shall be made.

(c) The flue gas cleanup system, ash transportation system, and gas recirculation fans shall be started as specified by the equipment manufacturers. Where provided, regenerative-type air heaters shall be started as specified by the manufacturer. The air heater soot blower shall be operated as specified by the air heater manufacturer.

(d) An induced draft fan shall be started, then a forced draft fan(s) shall be started in accordance with the manufacturer's instructions. Subsystems associated with these fans, such as lube oil systems and cooling systems, shall be started as defined by the supplier. Additional induced draft or forced draft fans shall be started in accordance with 4.5.3.

(e) Dampers and air registers shall be opened to the purge position. For duct burners with an inlet damper or blower (if provided), the inlet damper shall be opened to the purge position and the blower shall be running to allow boiler airflow purge through the duct burner.

(f) The bed and boiler enclosure shall be purged with not less than five volumetric changes but, in any event, for a continuous period of not less than 5 minutes. A freeboard purge without air passing through the bed material shall not meet purge criteria. The purge shall include the air and flue gas ducts, air heater(s), warm-up burners(s), windbox(es), and bed(s).

(g) Gas recirculation systems present special problems with respect to ensuring a complete unit purge. The boiler manufacturer's specifications on gas recirculation fan operation during purge and light-off shall be followed.

(h) Bed height, as defined by the manufacturer, shall be established at this time. Bed height shall be adjusted by adding sorbent or inert solids or by draining excess bed material. Forced draft and induced draft fans shall remain in operation; solid fuel feeders shall remain off.

(i) The bubbling fluidized-bed starting procedure is as follows *[see 4.6.2.1.2(j) for circulating fluidized bed]*:

(1) Two different types of devices for warming the bed are utilized in the bubbling fluidized bed processes. One type is a duct burner that heats the combustion air, and the other type heats the bed or portions of the bed with in-furnace burners. The bed warm-up rate shall not exceed the manufacturer's specifications.
(2) Reduced combustion airflow through the bed is permitted for warming up the bed sections. However, in no event shall total air through the unit be reduced below purge rate.
(3) Dampers shall be permitted to be closed on bed sections that are not to be fired.
(4) Burners shall be started in accordance with Sections 4.7 and 4.8, as applicable. If the first burner fails to light within the established trial for ignition period after admission of fuel, the unit shall be repurged before a second trial.
(5) The bed shall continue to be heated at a rate specified by the manufacturer. The required bed level shall be maintained by adding sorbent or inert solids as needed.
(6) Fuel input that necessitates ignition by the bed material shall not be fed into the bed until the average bed temperature for the section being started has reached 1400°F (760°C). Warm-up burners shall remain in service until the stable ignition of this fuel has been established.

Exception: A lower fuel input temperature limit shall be permitted, provided the temperature has been verified through test or actual experience as being capable of igniting the fuel. (See Appendix H.) However, in no case shall the temperature be lower than 900°F (480°C) for coal or 1100°F (590°C) for oil and natural gas.

(7) The duct temperature shall be maintained within the manufacturer's specified limits.
(8) Verification that the fuel is igniting shall be made by watching for a steady increase in bed temperature and a decreasing oxygen level. Fuel flow shall be increased to maintain bed temperature as necessary. Airflow shall be increased as necessary to maintain the desired oxygen level. In the case of solid fuel, if the main fuel has been fed for more than 90 seconds or a period established by the manufacturer without an increase in bed temperature, solid fuel feeding shall be discontinued until the reason for ignition failure is determined.
(9) The active bed area shall be expanded by activating idle bed sections according to steam load demands by following the manufacturer's recommended sequence.

(j) The circulating fluidized-bed starting procedure is as follows:

(1) The circulating fluidized-bed process initiates its warm-up cycle with the purge complete permissive. In general, the light-off and warm-up specifications of the manufacturer shall be followed.
(2) After placing the first bed warm-up burner in service, the bed material and refractory shall be heated at the manufacturer's specified rate.
(3) Warm-up burners shall be added, if necessary, to maintain the required bed heat-up rate. Any fans and blowers

that were shut down for the warm-up cycle shall be placed back in service when the bed temperature reaches the required temperature. Preparation to admit the main fuel shall be made.

(4) Fuel input that necessitates ignition by the bed material shall not be fed into the bed until the average bed temperature has reached 1400°F (760°C). Warm-up burners shall remain in service until the stable ignition of this fuel has been established.

Exception: A lower fuel input temperature limit shall be permitted, provided the temperature has been verified through test or actual experience as being capable of igniting the fuel. (See Appendix H.) However, in no case shall the temperature be lower than 900°F (480°C) for coal or 1100°F (590°C) for oil and natural gas.

(5) Verification that the fuel is igniting shall be made by watching for a steady increase in bed temperature and a decrease in oxygen. Warm-up burners shall be removed and fuel flow shall be increased to maintain bed temperature at the recommended level. Airflow shall be increased as necessary to maintain the desired oxygen level. In the case of solid fuel, if fuel has been fed for more than 90 seconds or for a period established by the manufacturer without an increase in bed temperature, solid fuel feeding shall be discontinued until the reason for ignition failure is determined.

(k) The on-line metering combustion control (unless designed specifically for start-up procedures) shall not be placed in automatic service until the following have been accomplished:

(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 an error signal between their set point and process feedback.
(4) Airflow control is on automatic.

4.6.2.2 Normal Operation.

4.6.2.2.1 The firing rate shall be regulated by increasing or decreasing the fuel and air supply simultaneously to all fuel ports or bed sections, maintaining required air/fuel ratio continuously at all firing rates. This shall not eliminate the requirements for air lead and lag during changes in the fuel-firing rate.

4.6.2.2.2 For those applications where gas or oil is fired, the firing rate shall be regulated by flow control or pressure control valves or devices of this type and shall not be regulated by modulating the shutoff valves. Shutoff valves shall be fully open or completely closed.

4.6.2.2.3 Fuel feed rates and transport airflow 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 required combustion conditions as follows:

(1) With all feeders in service and combustion controls on automatic.
(2) With different combinations of feeders in service and combustion controls on automatic.
(3) 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 limits.

4.6.2.2.4 If a lower minimum load is required than the lowest load that can be obtained with all feeders at minimum speed, the feeder(s) (and associated bed sections if applicable) shall be removed from service. The remaining feeder(s) shall be operated 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.

4.6.2.2.5* The stable operating philosophy of a fluidized bed shall be to maintain a bed temperature greater than 1400°F (760°C) and to initiate a main fuel trip below this temperature if the required warm-up burner(s) is not in service.

Exception: A lower trip temperature for fuels other than natural gas shall be permitted [but not lower than 1200°F (650°C) for coal and fuel oil], provided the temperature has been verified through test or actual experience to maintain stable combustion of the fuel.

4.6.2.2.6 Total airflow shall not be reduced below 25 percent of full-load airflow. Airflow shall not be reduced below that required to maintain stable fluidization conditions within active beds or bed compartments.

4.6.2.3 Normal Shutdown. When taking the unit out of service, the boiler load shall be brought down to a minimum. After the boiler load is reduced, there are two options for normal shutdown as follows:

(a) If the unit is scheduled to be cooled and opened for maintenance, the main fuel shall be tripped and the forced draft and induced draft fans shall be allowed to remain in operation. Following a 5-minute post-purge, fans shall be allowed to operate until the unit is cooled for maintenance.

(b) If the unit is scheduled to be restarted soon, the fans shall be permitted to be tripped after the minimum period needed to remove volatiles and burn the fuel remaining in the bed from the furnace after the main fuel has been tripped. This is indicated by a drop in bed temperature and an increase in oxygen reading. The fans shall not be tripped until there is positive indication of fuel burnout. Fan tripping effectively reduces start-up time by conserving the temperature of the bed and the refractory.

4.6.2.4 Normal Hot Restart.

4.6.2.4.1* When restarting a unit after it has been tripped or after the furnace has been bottled up, the purge cycle outlined in 4.6.1.5.1 and the fuel header leak test as specified by 4.7.5.2.1.2 and 4.8.5.2.1.2 shall not be required prior to introduction of main fuel, provided the bed temperature is above the main fuel temperature specified in 4.6.1.5.1(f).

4.6.2.4.2* If the bed temperature has dropped below the main fuel temperature permissive during the shutdown, a unit purge shall be required as outlined in 4.6.1.5.1.

4.6.2.5* Emergency Shutdown — Master Fuel Trip.

4.6.2.5.1 An emergency shutdown shall initiate a master fuel trip.

4.6.2.5.2 Upon the occurrence of a master fuel trip as a result of any of the emergency conditions tabulated in Tables 4.6.2.5.2(a) and 4.6.2.5.2(b), all fuel shall be stopped from entering the boiler. Oil and gas safety shutoff valves shall be tripped and igniter sparks de-energized. The fuel, sorbent, and bed feed 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 does not allow 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 forced draft fan and induced draft fan trip *[see 4.6.2.3(b)]*. Where the design allows, char recirculation shall be stopped.

Table 4.6.2.5.2(a) Conditions Resulting in Mandatory Automatic Master Fuel Trips

A master fuel trip shall result from any of the following conditions:
(1) Loss of any induced draft or forced draft fan required to sustain combustion. *(See Section 4.5.)*
(2) Furnace pressure in excess of the design operating pressure by a value recommended by the manufacturer. *(See Section 4.5.)*
(3) Insufficient drum level (a short time delay as established by the manufacturer shall be permitted).
(4) Loss of boiler circulation pumps or flow, if applicable.
(5) Total airflow decrease below the purge rate by 5 percent of the full-load airflow.
(6) Bed temperature falling below the value specified in 4.6.2.2.5 when the main fuel is being admitted to bed and no warm-up burner is established.
(7) All fuel inputs zero and bed temperature not adequate once any fuel has been admitted to the unit.

Note: See Section 4.9 for more details.

Table 4.6.2.5.2(b) Conditions Resulting in Mandatory Master Fuel Trips with Alarms — Not Necessarily Automatically Initiated

A master fuel trip shall result from any of the following conditions:
(1) Loss of energy supply for boiler control, burner management, or interlock systems.
(2) Cooling water flow for fluidized-bed system components less than minimum.
(3) Plant air or instrument air pressure low (process requirement only).
(4) Bed temperature high — trip to prevent unit damage resulting from excessive temperature.
(5) Furnace pressure falling below the design operating pressure by a value recommended by the manufacturer.

4.6.2.5.3 The sorbent, bed material feed, and bed material drain system shall be permitted to be restarted as necessary.

4.6.2.5.4 The owner shall have the option under conditions where there is low-low drum water level and furnace outlet temperature is above 900°F (482°C) to stop the flow of fluidizing air immediately. Tripping a forced draft fan to accomplish this is acceptable, but not required. The induced draft fan, however, shall not be tripped.

4.6.2.5.5 If the option for tripping fans on a master fuel trip is not exercised, the fans that are operating after the master fuel trip shall be continued in service. The airflow shall not be increased immediately by deliberate manual or automatic control action.

4.6.2.6 Emergency Shutdown — Main Fuel Trip. With the initiation of a main fuel trip due to any of the emergency conditions listed in Table 4.6.2.6(a) or 4.6.2.6(b), all main fuel shall be stopped from entering the boiler.

Table 4.6.2.6(a) Conditions That Result in Mandatory Automatic Main Fuel Trips

A main fuel trip shall result from any of the following conditions:
(1) Master fuel trip.
(2) Inadequate bed temperature as defined by the boiler designer with warm-up burners in service. *[See 4.6.2.1.2(i)(6) and 4.6.2.1.2(j)(4).]*
(3) Inadequate bed temperature as defined by the boiler designer without warm-up burners in service. *[See 4.6.2.2.5.]*
(4) Inadequate airflow to fluidize the bed as defined by the boiler designer.

Note: See Section 4.9 for more details.

Table 4.6.2.6(b) Mandatory Main Fuel Trips — Not Necessarily Automatically Initiated

A main fuel trip shall result from inadequate solids inventory.

4.6.2.7 Procedure for Purging after an Emergency Shutdown.

4.6.2.7.1 Fans that are operating after the master fuel trip shall be continued in service. The airflow shall not be increased or decreased by automatic control action. Changes in the airflow shall be performed in accordance with established operating procedures.

4.6.2.7.2 When the emergency trip was caused by loss of induced draft fans or induced draft fans also have tripped, all dampers in the air and flue gas passages of the unit shall be opened slowly to the fully open position in order to create as much natural draft as possible to ventilate the unit. Opening fan dampers shall be timed or controlled to ensure that positive or negative furnace pressure transients beyond design limits do not occur during fan coast-down. It shall be permitted to start the fan(s) in accordance with 4.5.3 and to increase the airflow gradually to the purge rate.

4.6.2.7.3 The following actions shall be taken after an emergency shutdown:

(1) The unit shall be shut down in accordance with 4.6.2.3.
(2) If conditions for a hot restart in accordance with 4.6.2.4.1 exist following an emergency shutdown, a restart in accordance with 4.6.2.4 shall be permitted.

4.6.3 Emergency Conditions Not Requiring Shutdown or Trip.

4.6.3.1 Installations that include multiple induced draft fans, forced draft fans, or both shall have a control system capable of reducing the fuel flow to match the available airflow in the event of a loss of a fan or fans. Otherwise, tripping of the unit is mandatory.

4.6.3.2 If an air deficiency develops while firing the main fuel, the fuel shall be reduced until the specified air/fuel mixture ratio has been restored.

4.6.3.3 Momentary interruptions in the main fuel supply or changes in fuel quality shall not require a unit trip, provided the bed temperature remains above the limits defined in 4.6.2.2.5. Use of warm-up burners shall be permitted to maintain bed material temperature. Use of lances also shall be permitted, provided the bed temperature is above the minimum sustained ignition value for that fuel. It is permitted to return to service a fuel feeder subsystem that had malfunctioned before the bed temperature falls below the main fuel temperature trip limit.

4.6.4 General Operating Requirements — All Conditions.

4.6.4.1 Prior to allowing personnel to enter a unit, positive action shall be taken to prevent fuel from entering the furnace.

4.6.4.2 Burners shall not be lighted one from another or from the hot refractory. The igniter for the burner shall always be used.

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

4.6.4.4 The total heat input within a burner or furnace zone, or both, shall not exceed the maximum limits specified for the equipment by the manufacturer or as established by test. The heat input from multiple fuels shall be totalized where a burner or furnace zone, or both, simultaneously fires more than one fuel.

4.7 Sequence of Operations for Gas-Fired Warm-Up Burners.

4.7.1 General. The additional mandatory requirements in Section 4.7 shall apply to burning fuel gas in warm-up burners. All installed piping arrangements shall meet the functional requirements of this code. *[Refer to Figures A.4.7.5.1.1(a) through (e), which show the typical fuel gas piping arrangements on which the text in Section 4.7 is based.]*

4.7.2 Fuel Supply Subsystem – Fuel Gas. The requirements of the fuel gas supply subsystem gas as defined in 4.4.3.1 shall apply for all fuel gas fired warm-up burners.

4.7.3 Requirements for Fuel Gas Warm-Up Burner Subsystem.

4.7.3.1* The warm-up burner subsystem shall be designed so that the burner inputs are supplied to the furnace continuously and within their stable flame limits. Class 1 or Class 2 igniters, as demonstrated by test in accordance with 4.4.3.5 and 4.7.3.2, shall be permitted to be used to maintain stable flame.

4.7.3.2 The limits of stable flame for each burner subsystem producing a separate flame envelope shall be determined by tests without the ignition subsystem in service. These tests shall verify that transients generated in the fluidized bed and the fuel and air subsystems do not adversely affect the burners in operation. These tests shall also include the expected range of fuels and shall be repeated after any combustion process modification such as the addition of overfire air, low NO_x burners, and after switching to any fuel not previously tested.

4.7.3.3 Provision shall be made for visual observation of conditions at the burner ignition zone. Additional provisions shall be made for flame detection equipment.

4.7.3.4 Where Class 1 and Class 2 igniters are used, the tests required 4.4.3.5 and 4.7.3.2 also shall be performed with the igniter subsystem in service to verify that the igniters furnished meet the requirements of the class specified in the design. The resulting extended turndown range shall be permitted when Class 1 igniters are in service and flames have been proved.

4.7.3.5 The burner equipment shall be located in an environment that allows convenient access for maintenance. Special attention shall be given to fire hazards imposed by leakage or rupture of piping at the burner. The requirements of housekeeping described in Chapter 1 shall be practiced.

4.7.3.6 All burner safety shutoff valves shall be located close to the burner to minimize the volume of fuel left in the burner lines downstream of the burner valves.

4.7.4 Flame Monitoring and Tripping System.

4.7.4.1 Each burner shall be supervised individually. Upon detection of loss of burner flame, the safety shutoff valve for the burner experiencing the loss shall automatically close.

4.7.4.2 Upon detection of loss of all warm-up burner flame or partial loss of flame to the extent that hazardous conditions exist, a trip of the warm-up burner system shall be automatically initiated.

4.7.5 Sequence of Operations.

4.7.5.1 General.

4.7.5.1.1* The sequence of operations in 4.7.5 shall be followed whether the burner is operated manually or certain functions are accomplished by interlocks or automatic controls. *[Refer to Figures A.4.7.5.1.1(a) through (e), which show the typical fuel oil piping arrangements on which the text in Section 4.7 is based.]*

4.7.5.1.2 Burners shall be placed in service in a sequence specified by operating instructions and verified by actual experience. Burners shall be placed in service as necessary, with fuel flows and individual registers or dampers positioned for light-off in accordance with established operating procedures.

4.7.5.1.3 The fuel pressure at the burner header for all burners served by a single control valve shall be permitted to be used as a guide in maintaining the necessary fuel flow for each burner and shall be maintained automatically within prescribed limits as additional burners are placed in service. The total number of burners placed in service shall be the number necessary to accomplish both of the following within the rate of rise limits specified by the boiler manufacturer:

(1) Raise boiler pressure or temperature.
(2) Raise bed temperature.

4.7.5.1.4 Each burner shall be tested during initial start-up to determine whether any modifications to the procedures specified in 4.7.5.2 are needed in order to establish ignition or to satisfy other design limitations during light-off and warm-up. For burners that are purged with the registers in the normal operating position, it shall be permissible to momentarily close the registers of the burner being lighted if required to establish ignition. Modifications in the basic procedures shall be allowed only if they are required to obtain light-off. However, 4.6.1.5.1(a) to (f) shall also be followed, thereby satisfying the basic objectives in 4.6.1.5.

4.7.5.2 Functional Requirements.

4.7.5.2.1 Cold Start.

4.7.5.2.1.1 Preparation for starting shall include a thorough inspection and shall verify the following:

(a) All safety shutoff valves are closed; all sparks are deenergized.

(b) Oil ignition systems shall meet the requirements of Section 4.8.

(c) Fuel system vents are open and venting to atmosphere outside the boiler room; lines are drained and cleared of condensate and other foreign material.

(d) The correct drum water level is established in drum-type boilers; and circulating flow is established in forced circulation boilers; or minimum water flow is established in once-through boilers as established by the boiler manufacturer.

(e) Burner elements and igniters are positioned in accordance with the manufacturer's specification.

(f) Energy is supplied to the control and interlock systems.

(g) Meters or gauges are indicating fuel header pressure to the unit.

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

(a)*An operational leak test of each fuel header piping system shall be performed in accordance with established procedures while maintaining at least purge rate airflow. Successful completion of the leak test shall be performed prior to placing the gas system into operation.

(b) The fuel control valve(s) shall be closed, and the main safety shutoff valve(s) shall be opened once the requirements of 4.7.5.2.1.2(a) for leak test performance and 4.9.3.2 for permissive conditions in the furnace purge system have been satisfied.

(c) It shall be determined that the burner fuel control valve is in the light-off position, and the burner fuel bypass control valve, if provided, is set to maintain burner header fuel pressure within predetermined limits for light-off. The burner headers shall be vented in order to be filled with gas and to provide a flow (if necessary) so that the fuel and bypass fuel control valves function to regulate and maintain the correct pressure for burner light-off. The fuel control valve shall be opened when necessary. The time needed to vent for control of header pressure after header charging shall be evaluated and minimized.

(d) The igniter header safety shutoff valve(s) shall be opened, and it shall be confirmed that the igniter fuel control valve is holding the manufacturer's recommended fuel pressure necessary for the igniter to operate at design capacity. The igniter headers shall initially be vented in order to be filled with gas and to provide a flow (if necessary), so that the igniter fuel control valve(s) functions to regulate and maintain the fuel pressure within the design limits specified by the manufacturer for lighting the igniters. The time needed to vent for control of header pressure after header charging shall be evaluated and minimized.

(e) The air register or damper on the burner selected for light-off shall be adjusted to the position recommended by the manufacturer or the established operating procedure in accordance with the requirements of this section.

(f) The spark or other source of ignition for the igniter(s) on the burner(s) to be lit shall be initiated. The individual igniter safety shutoff valve(s) shall be opened, and all igniter system atmospheric vent valves shall be closed. If flame on the first igniter(s) is not established within 10 seconds, the individual igniter safety shutoff valve(s) shall be closed and the cause of failure to ignite shall be determined and corrected. With airflow maintained at purge rate, repurge shall not be required, but at least 1 minute shall elapse before attempting a retrial of any igniter. Repeated retrials of igniters without investigating and correcting the cause of the malfunction shall be prohibited.

(g) Where Class 3 special electric igniters are used, the procedures described in 4.7.5.2.1.2(a) through (c), (e), and (h) through (k) shall be used, recognizing the requirements for individual burner flame supervision.

(h) After making certain that the igniter(s) is established and is providing the required level of ignition energy for the warm-up burner(s), the individual burner safety shutoff valve(s) shall be opened, and the individual burner atmospheric vent valves shall be closed. A master fuel trip shall be initiated when the bed temperature falls below the main fuel ignition temperature as specified in 4.6.1.5.1(f) and when the flame detection system(s) indicates that ignition has not been obtained within 5 seconds following the actual entry of fuel into the burner. Purging shall be repeated, and the condition(s) that caused the failure to ignite shall be corrected before another light-off attempt is made. For the following burner and all subsequent burners placed in operation, failure to ignite or loss of ignition for any reason on any burner(s) shall cause the fuel flow to that burner(s) to stop. All conditions required by the manufacturer or established operating procedures for light-off shall exist before restarting a burner.

(i) After stable flame is established, the air register(s) or damper(s) shall slowly be returned to its operating position, making certain that ignition is not lost in the process. The air register shall be permitted to be opened simultaneously with the burner safety shutoff valve.

(j) Class 3 igniters shall be shut off at the end of the time trial for proving the main flame. It shall be verified that the stable flame continues on the burner(s) after the igniters are shut off. Systems that allow the igniters to remain in service on either an intermittent or a continuous basis shall have been tested to meet all the requirements of Class 1 igniters or Class 2 igniters with associated interlocks in service.

(k) After the burner flame is established, the burner header atmospheric vent valve shall be closed. If the charging valve is used, the burner header atmospheric vent valve shall be closed. The fuel bypass control valve shall automatically control the burner header gas pressure.

(l) The procedures of 4.7.5.2.1.2(e) through (j), for placing additional burners in service, shall be followed, as necessary, to increase bed temperature, raise steam pressure, or carry additional load. Automatic control of burner fuel flow and burner airflow during the lighting and start-up sequence is recommended and, if used, shall be in accordance with the requirements of 4.7.5.2.1.2(m). The fuel flow to each burner (as measured by burner fuel header pressure, individual burner flows, or other equivalent means) shall be maintained at a controlled value that is compatible with the established airflow through the corresponding burner. Total furnace airflow shall not be reduced below purge rate airflow and shall be at least that which is necessary for complete combustion in the furnace.

(m) The burner combustion control system shall not be placed in automatic until the following have been accomplished:

(1) A predetermined minimum warm-up burner fuel input has been attained.
(2) The burner fuel and airflow are adjusted as necessary.
(3) Stable flame has been established.

Exception No. 1: Each individual flow control burner shall be provided with an individual combustion control system that maintains the correct air/fuel ratio, a stable flame, and a fire rate in accordance with the demand for the full operating range of the burner.

Exception No. 2: Where on-line burner combustion control is designed specifically for start-up procedures.

(n) It shall be permitted to place a multiple number of igniters in service simultaneously from a single igniter safety shutoff valve, provided that the igniters are supervised, so that failure of one of the group to light causes the fuel to all igniters of the group to be shut off.

(o) It shall be permitted to place in service, simultaneously, a multiple number of burners served by their corresponding multiple igniters from a single burner safety shutoff valve, provided that the burners are supervised, so that failure of one of the group to light causes the fuel to all burners of the group to be shut off.

4.7.5.2.2 Normal Operation.

4.7.5.2.2.1 The firing rate shall be regulated by increasing or decreasing the fuel and air supply simultaneously to all operating burners, maintaining the air/fuel ratio within predetermined operating limits continuously at all firing rates. This shall not eliminate the requirements for air lead and lag during changes in the fuel firing rate.

Exception No. 1: This requirement shall not apply to systems provided with metering of air and fuel to each burner and designed specifically for individual burner modulating control.

Exception No. 2: In the case of a duct burner, the firing rate shall be regulated by increasing or decreasing the fuel flow. An interlock shall be provided to prevent airflow to the duct burner from falling below the minimum required for combustion as recommended by the manufacturer.

4.7.5.2.2.2 The firing rate shall not be regulated by varying the fuel to individual burners by means of the individual burner safety shutoff valve(s). The individual burner safety shutoff valve(s) shall be fully open or completely closed. Intermediate settings shall not be used.

4.7.5.2.2.3 Air registers shall be set at firing positions determined by tests.

Exception: This shall not apply to systems provided with metering of air and fuel to each burner and designed specifically for individual burner modulating control.

4.7.5.2.2.4 The burner fuel and air flows shall be maintained within a range between the maximum and minimum limits as determined by trial, or, if trial results do not exist, as specified by the combustion equipment manufacturer(s). These trials shall test for minimum and maximum limits and stable flame under both of the following conditions:

(1) With all burners in service and combustion control on automatic
(2) With different combinations of burners in service and combustion control on automatic

Where changes to any of the minimum and maximum limits because of equipment modifications, operating practices, or fuel conditions, retesting shall be required.

4.7.5.2.2.5 On loss of an individual burner flame, that individual burner's safety shutoff valve shall be automatically closed and its vent opened immediately. The burner register shall be closed where it interferes with the air/fuel ratio supplied to any other individual burner flame.

4.7.5.2.2.6 Total airflow shall not be reduced below the purge rate.

4.7.5.2.3 Normal Shutdown.

4.7.5.2.3.1 The reverse procedure of that used during start-up shall be followed during shutdown. Burners shall be shutdown sequentially, as the need for warm-up energy is reduced, by closing the individual burner safety shutoff valves, leaving the registers on these burners in firing position.

4.7.5.2.3.2 As the fuel is reduced, a sequential shutdown of the burners shall be accomplished by closing the individual burner safety shutoff valves and opening the vent valves. Registers shall be placed in the position prescribed by the established operating procedure(s).

4.7.5.2.3.3 When the last individual burner safety shutoff valves are closed, the main safety shutoff valve shall be closed.

4.7.5.2.3.4 All atmospheric vent valves shall be opened to minimize the possibility of gas leaking into the boiler enclosure.

4.7.5.3 Mandatory Automatic Fuel Trip for Gas-Fired Warm-Up Burners. A warm-up burner system fuel trip of each group of burners serviced by a single control valve shall result from any of the following conditions:

(1) Fuel pressure at the burner below the minimum established by the burner manufacturer or by trial
(2) Loss of air supply fan or inadequate airflow to the burner
(3) Loss of all flame
(4) Last individual burner safety shutoff valve closed
(5) High fuel gas pressure at the burner
(6) Master fuel trip
(7) High duct burner discharge temperature

4.7.5.4 Emergency Conditions Not Requiring Shutdown or Trip. If an air deficiency develops while flame is maintained at the burners, the fuel shall be reduced until the required air/fuel ratio has been restored. If fuel flow cannot be reduced, airflow shall be increased slowly until the required air/fuel ratio has been restored.

4.7.5.5 General Operating Requirements — All Conditions.

4.7.5.5.1 The igniter for the burner shall be used to light the burner. Burners shall not be lighted one from another, from hot refractory, or from bed material.

4.7.5.5.2 Where operating at low capacity with multiple burners controlled by one master flow control valve, the burner fuel pressure shall be maintained above minimum by reducing the number of burners in service as necessary.

4.7.5.5.3 Before maintenance is performed on the gas header, the header shall be purged in accordance with NFPA 54, *National Fuel Gas Code.*

4.8 Sequence of Operations for Oil-Fired Warm-Up Burners.

4.8.1 General. The additional mandatory requirements in Section 4.8 shall apply to burning fuel oil in warm-up burners. All installed piping arrangements shall meet the functional requirements of this code. *[Refer to Figures A.4.8.5.1.1(a) through (h), which show the typical fuel oil piping arrangements on which the text in Section 4.8 is based.]*

4.8.2 Fuel Supply Subsystem – Fuel Oil. The requirements of the fuel oil supply subsystem as defined in 4.4.3.2 shall apply for all fuel oil fired warm-up burners.

4.8.3 Requirements for Fuel Oil Warm-Up Burner Subsystem.

4.8.3.1* The warm-up burner subsystem shall be designed so that the burner inputs are supplied to the furnace continuously and within their stable flame limits. Class 1 or Class 2 igniters, as demonstrated by test in accordance with 4.4.3.5, shall be permitted to be used to maintain stable flame.

4.8.3.2 The limits of stable flame for each burner subsystem producing a separate flame envelope shall be determined by tests without the ignition subsystem in service. These tests shall verify that transients generated in the fluidized bed and the fuel and air subsystems do not affect the burners adversely during operation. These tests shall also include the expected range of fuels and shall be repeated after any combustion process modification such as the addition of overfire air, low NO_x burners, and after switching to any fuel not previously tested.

4.8.3.3 Where Class 1 and Class 2 igniters are used, the tests described in 4.4.3.5 and 4.8.3.2 also shall be performed with the ignition subsystem in service to verify that the igniters furnished meet the requirements of the class specified in the design. The resulting extended turndown range shall be permitted when Class 1 igniters are in service and flames have been proved.

4.8.3.4 Provisions shall be made for visual observation of conditions at the burner ignition zone. Additional provisions shall be made for flame detection equipment.

4.8.3.5 Provisions shall be made for cleaning of the burner nozzle and tip.

4.8.3.6 The burner equipment shall be located in an environment that allows convenient access for maintenance. Special attention shall be given to the fire hazards imposed by leakage or rupture of piping at the burner. Particular attention shall be given to the integrity of flexible hoses or swivel joints. The requirements of housekeeping described in Chapter 1 shall be practiced.

4.8.3.7 All burner safety shutoff valves shall be located close to the burner to minimize the volume of oil left downstream of the burner valves in the burner lines or that flows by gravity into the furnace on an emergency trip or burner shutdown.

4.8.3.8 Atomizing Subsystem.

4.8.3.8.1 Where the fuel is to be atomized with the assistance of another medium, the atomizing medium shall be free of contaminants that could cause an interruption of service. For steam atomizing, insulation and traps shall be included to ensure dry atomizing steam to the burners.

4.8.3.8.2 The atomizing medium shall be provided and maintained at the specified pressure necessary for operation.

4.8.3.8.3 Provisions shall be made to ensure that fuel does not enter the atomizing medium line during or after operation.

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Check valves for this function have not proven dependable in heavy oil service.

4.8.3.8.4 The atomizing subsystem shall be designed for convenient cleaning and maintenance.

4.8.4 Flame Monitoring and Tripping System.

4.8.4.1 Each burner shall be supervised individually. Upon detection of loss of burner flame, the safety shutoff valve for the burner experiencing the loss shall automatically close.

4.8.4.2 Upon detection of loss of all warm-up burner flame or partial loss of flame to the extent that hazardous conditions exist, a trip of the warm-up burner system shall be automatically initiated.

4.8.5 Sequence of Operations.

4.8.5.1 General.

4.8.5.1.1* The sequence of operation in 4.8.5 shall be followed whether the burner is operated manually or certain functions are accomplished by interlocks or automatic controls. *[Refer to Figures A.4.8.5.1.1(a) through (h), which show the typical fuel oil piping arrangements on which the text in Section 4.8 is based.]*

4.8.5.1.2 Burners shall be placed in service in a sequence specified by operating instructions and verified by actual experience. Burners shall be placed in service as necessary, with fuel flows and individual registers or dampers positioned for light-off in accordance with established operating procedures.

4.8.5.1.3 The fuel pressure at the burner header for all burners served by a single control valve shall be permitted to be used as a guide in maintaining the necessary fuel flow for each burner and shall be maintained automatically within prescribed limits as additional burners are placed in service. The total number of burners placed in service shall be the number necessary to accomplish both of the following within the rate of rise limits specified by the boiler manufacturer:

(1) Raise boiler pressure and temperature.
(2) Raise bed temperature.

4.8.5.1.4 Each burner shall be tested during initial start-up to determine whether any modifications to the procedures specified in 4.8.5.2 are needed in order to establish ignition or to satisfy other design limitations during light-off and warm-up. For burners that are purged with the registers in the normal operating position, it shall be permissible to momentarily close the registers of the burner being lighted, required to establish ignition. Modifications to the basic procedures shall be allowed only if they are required to obtain light-off. However, 4.6.1.5.1(a) to (f) shall also be followed, thereby satisfying the basic objectives in 4.6.1.5.

4.8.5.2 Functional Requirements.

4.8.5.2.1 Cold Start.

4.8.5.2.1.1 Preparation for starting shall include a thorough inspection and shall verify the following:

(1) Energy is supplied to the control system and to the interlock systems.
(2) All safety shutoff valves are closed; all sparks are deenergized.
(3) Gas ignition systems shall meet the requirements of Section 4.7.
(4) Circulating valves are open to provide and maintain hot oil in the burner headers.
(5) The proper drum water level is established in drum-type boilers, and circulating flow is established in forced circulation boilers or minimum water flow is established in once-through boilers.
(6) Burner guns have been checked to ensure that the correct burner tips and sprayer plates and gaskets are in place to ensure a safe operating condition.
(7) Burner elements and igniters are positioned in accordance with the manufacturer's specification.
(8) Meters or gauges indicate fuel header pressure to the unit.

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

(a) The following leak test shall be performed on all oil headers before the oil system is placed in service by establishing a predetermined pressure on the oil header. The predetermined pressure shall be established with the main and individual burner safety shutoff valves and the recirculating valves closed. If this oil pressure remains within predetermined limits for a predetermined amount of time, the individual burner safety valves are properly sealing off their burners.

(b) The oil temperature or viscosity shall be verified to be within predetermined limits to ensure atomization will occur. The circulating valve and throttle recirculating valve, if necessary, shall be closed to allow establishment of burner header pressure within manufacturer's limits as specified in 4.8.5.2.1.2(a).

(c) All fuel valve(s) shall be closed and the safety shutoff valve(s) shall be opened, but only after the requirements of 4.9.3.2 for permissive conditions in the furnace purge system have been satisfied.

(d) It shall be determined that the burner fuel control valve is in the light-off position, and that the burner fuel bypass control valve, if provided, is set to maintain burner header fuel pressure within predetermined limits for light-off.

(e) The igniter header safety shutoff valve(s) shall be opened, and it shall be confirmed that the igniter fuel control valve is holding the manufacturer's recommended fuel pressure necessary for the igniter to operate at design capacity.

(f) The air register or damper on the burner selected for light-off shall be adjusted to the position recommended by the manufacturer or the established operating procedure in accordance with the requirements of this section.

(g) The spark or other source of ignition for the igniter(s) on the burner(s) to be lit shall be initiated. The individual igniter safety shutoff valve(s) and all igniter system atmospheric vent valves (gas igniters only) shall be closed. If flame on the first igniter(s) is not established within 10 seconds, the individual igniter safety shutoff valve(s) shall be closed and the cause of failure to ignite shall be determined and corrected. With airflow maintained at purge rate, repurge shall not be required, but at least 1 minute shall elapse before attempting a retrial of any igniter. Repeated retrials of igniters without investigating and correcting the cause of the malfunction shall be prohibited.

(h) Where Class 3 special electric igniters are used, the procedures described in 4.8.5.2.1.2(a) through (d), (f), and (i) through (l) shall be used, recognizing the requirements for individual burner flame supervision.

(i) After making certain that the igniter(s) is established and is providing the required level of ignition energy for the warm-up burner(s), the individual burner safety shutoff valve(s) shall be opened. A master fuel trip shall be initiated when the bed temperature falls below the main fuel ignition temperature as specified in 4.6.1.5.1(f) and when the flame detection system(s) indicates that ignition has not been obtained within 5 seconds following the actual entry of fuel into the burner. Purging shall be repeated, and the condition(s) that caused the failure to ignite shall be corrected before another light-off attempt is made. For the following burner and all subsequent burners placed in operation, failure to ignite or loss of ignition for any reason on any burner(s) shall cause the fuel flow to that burner(s) to stop. All conditions required by the manufacturer and established operating procedures for light-off shall exist before restarting a burner.

(j) After stable flame is established, the air register(s) or damper(s) shall be adjusted slowly to its operating position, making certain that ignition is not lost in the process. With automatic burner management systems, the air register shall be permitted to be opened simultaneously with the burner safety shutoff valve.

(k) Class 3 igniters shall be shut off at the end of the time trial for proving the main flame. It shall be verified that the stable flame continues on the burner(s) after the igniters are shut off. Systems that allow the igniters to remain in service on either an intermittent or a continuous basis shall have been tested to meet all the requirements of Class 1 igniters or Class 2 igniters with associated interlocks in service.

(l) The procedures of 4.8.5.2.1.2(f) through (k) shall be followed when placing additional burners in service, as necessary, to increase bed temperature or steam pressure or to carry additional load. Automatic control of burner fuel flow and burner airflow during the lighting and start-up sequence is recommended, and if used, shall be in accordance with the requirements of 4.8.5.2.1.2(n). The fuel flow to each burner (as measured by equivalent means) shall be maintained at a controlled value that is compatible with the established airflow through the corresponding burner. Total furnace airflow shall not be reduced below purge rate airflow and shall be at least that which is necessary for complete combustion in the furnace.

(m) After a predetermined number of burners have been placed in service to allow control of the header fuel flow and temperature, the recirculating valve shall be closed, unless the system is designed for continuous recirculation.

(n) The burner combustion control (unless designed specifically for start-up procedures) shall not be placed in service until the following have been established:

(1) A predetermined minimum warm-up burner fuel input has been attained.
(2) The burner fuel and airflow are adjusted as necessary.
(3) Stable flame has been established.

Exception No. 1: Each individual flow control burner shall be provided with an individual combustion control system that maintains the correct air/fuel ratio, a stable flame, and a firing rate in accordance with the demand for the full operating range of the burner.

Exception No. 2: Where on-line burner combustion control is designed specifically for start-up procedures, automatic operation shall be permitted.

(o) It shall be permitted to place a multiple number of igniters in service simultaneously from a single igniter safety shutoff valve, provided the igniters are supervised so that failure of one of the group to light causes the fuel to all igniters of the group to be shut off.

(p) It shall be permitted to place in service simultaneously a multiple number of burners served by their corresponding multiple igniters from a single burner safety shutoff valve, provided the burners are supervised so that failure of one of the group to light causes the fuel to all burners of the group to be shut off.

4.8.5.2.2 Normal Operation.

4.8.5.2.2.1 The firing rate shall be regulated by increasing or decreasing the fuel and air supply simultaneously to all operating burners, maintaining the air/fuel ratio within predetermined operating limits continuously at all firing rates. This shall not eliminate the requirements for air lead and lag during changes in the fuel firing rate.

Exception No. 1: This requirement shall not apply to systems provided with metering of air and fuel to each burner and designed specifically for individual burner modulating control.

Exception No. 2: In the case of a duct burner, the firing rate shall be regulated by increasing or decreasing the fuel flow. An interlock shall be provided to prevent airflow to the duct burner from falling below the minimum required for combustion as recommended by the manufacturer.

4.8.5.2.2.2 The firing rate shall not be regulated by varying the fuel to individual burners by means of the individual burner safety shutoff valve(s). The individual burner safety shutoff valve(s) shall be fully open or completely closed. Intermediate settings shall not be used.

4.8.5.2.2.3 Air registers shall be set at firing positions determined by tests.

Exception: This shall not apply to systems provided with metering of air and fuel to each burner and designed specifically for individual burner modulating control.

4.8.5.2.2.4 The burner fuel and airflow shall be maintained within a range between the maximum and minimum limits as determined by trial or, if trial results do not exist, as specified by the combustion equipment manufacturer(s). These trials shall test for minimum and maximum limits and for stable flame under both of the following conditions:

(1) With all burners in service and combustion control on automatic
(2) With different combinations of burners in service and combustion control on automatic

Where changes to any of the minimum and maximum limits because of equipment modifications, operating practices, or fuel conditions, retesting shall be required.

4.8.5.2.2.5 On loss of an individual burner flame, that individual burner's safety shutoff valve shall be automatically closed. The burner register shall be closed where it interferes with the air/fuel ratio supplied to any other individual burner flame.

4.8.5.2.2.6 Total airflow shall not be reduced below the purge rate.

4.8.5.2.3 Normal Shutdown.

4.8.5.2.3.1 As the fuel is reduced, the remaining burners shall be shut down sequentially using the reverse procedure of that used during start-up.

Each oil burner shall be shut down in the following sequence:

(1) Registers shall be placed in the position prescribed by the established operating procedure(s).
(2) The igniter shall be placed into service on the particular burner to be shut down.
(3) If the oil passages of the igniter are to be cleared into the furnace, the spark or other ignition source for the igniter shall be initiated before opening the steam (or air) clearing valve.
(4) The clearing steam (or air) shall be left in service for a predetermined length of time that has proven adequate to remove all oil so as to ensure there will be no carbonization or pluggage of the burner tip.
(5) The igniter shall be removed from service, and the oil gun shall be removed or retracted.

Exception: Oilgun removal or retraction is not required when cooling is provided.

(6) When the last individual burner safety shutoff valve is closed, the oil header safety shutoff valve shall be closed.

4.8.5.2.3.2 Where fuel recirculation in the burner header is to be established, the following shall be completed:

(1) Confirmation that individual burner safety shutoff valves are closed and that flame is out on each burner shall be made.
(2) Confirmation that the main safety shutoff valve is closed shall be made.
(3) The circulating valve and recirculating valve shall be opened.

4.8.5.3 Mandatory Automatic Fuel Trip for Oil-Fired Warm-Up Burners. A warm-up burner system fuel trip of each group of burners serviced by a single control valve shall result from any of the following conditions:

(1) Fuel pressure and temperature (heated oil only) outside operating limits necessary to accomplish proper atomization as established by trial or by the burner manufacturer
(2) Atomizing medium outside operating limits established by trial or by the burner manufacturer

Exception: This interlock is not required on mechanically atomized oil burners.

(3) Loss of air supply fan or inadequate airflow to the burner
(4) Loss of all flame
(5) Last individual burner safety shutoff valve closed
(6) Master fuel trip
(7) High duct burner discharge temperature

4.8.5.4 Emergency Conditions Not Requiring Shutdown or Trip.

4.8.5.4.1 If an air deficiency develops while flame is maintained at the burners, the fuel shall be reduced until the proper air/fuel ratio has been restored. Where fuel flow cannot be reduced, the airflow shall be increased slowly until the proper air/fuel ratio has been restored.

4.8.5.4.2 Burners with poor atomization shall be shut down.

4.8.5.5 General Operating Requirements — All Conditions.

4.8.5.5.1 The igniter for the burner shall always be used. Burners shall not be lighted one from another, from hot refractory, or from bed material.

4.8.5.5.2 Where operating at low capacity with multiple burners controlled by one master flow control valve, the burner fuel pressure shall be maintained above minimum by reducing the number of burners serviced by that control valve as necessary.

4.8.5.5.3 Where clearing oil passages into the furnace, igniters shall be in service, with ignition established.

4.8.5.5.4 The following leak test shall be performed on all oil headers before the oil header is placed in service. A predetermined pressure on the oil header shall be established with the main and individual burner safety shutoff valves and the recirculating valve valves closed. If this oil pressure remains within predetermined limits for a predetermined amount of time, the individual burner safety valves shall be assumed to be leak tight.

4.9 Interlock System.

4.9.1 General.

4.9.1.1* The basic requirement of an interlock system for a unit shall be to protect personnel from injury and also to protect the equipment from damage. The interlock system shall function 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.

4.9.2 Functional Requirements.

4.9.2.1 The operation of any interlock that causes a trip shall be annunciated.

4.9.2.2 An interlock system shall be installed, adjusted, and tested to confirm design, function, and required timing. Periodic testing and maintenance shall be performed to keep the interlock system functioning in accordance with manufacturer's specifications.

4.9.2.3 The design of an interlock system shall be predicated on the following fundamentals:

(a) The starting procedure and operation shall be supervised to ensure proper operating practices and sequences.

(b) The minimum amount of equipment shall be tripped in the required sequence where the safety of personnel or equipment is jeopardized.

(c) The cause of the trip shall be indicated and shall prevent restarting of any portion of the affected equipment until nonhazardous conditions are established.

(d) The required fuel safety subsystems related to duct burner, lance, warm-up burner, solid fuel and master fuel trip and their related trip devices shall be functionally coordinated into an overall unit interlock system.

(e) Where automatic equipment is not available to accomplish the intended function, instrumentation shall be provided to enable the operator to complete the required operating sequence.

(f) The design shall provide as much flexibility with respect to alternate modes of operation as is consistent with good operating practice.

(g) Preventive maintenance shall be provided in accordance with manufacturer's recommendations.

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

(i)* The mandatory automatic master fuel trip and mandatory automatic main fuel trip systems, including sensing elements and circuits, shall be functionally independent from all other control system functions. The warm-up burner fuel trip system, sensing elements, and circuits shall be functionally independent from all other control system functions.

Exception No. 1: Individual burner flame failure devices also shall be permitted to be used for initiating master fuel trip systems.

Exception No. 2: Airflow measurement and auctioneered furnace draft signals from the boiler control system shall be permitted to be used for a master fuel trip, provided all the following requirements are met:

(a) These interlocks are hardwired into the burner management system.

(b) Tripping set points are protected from unauthorized changes.

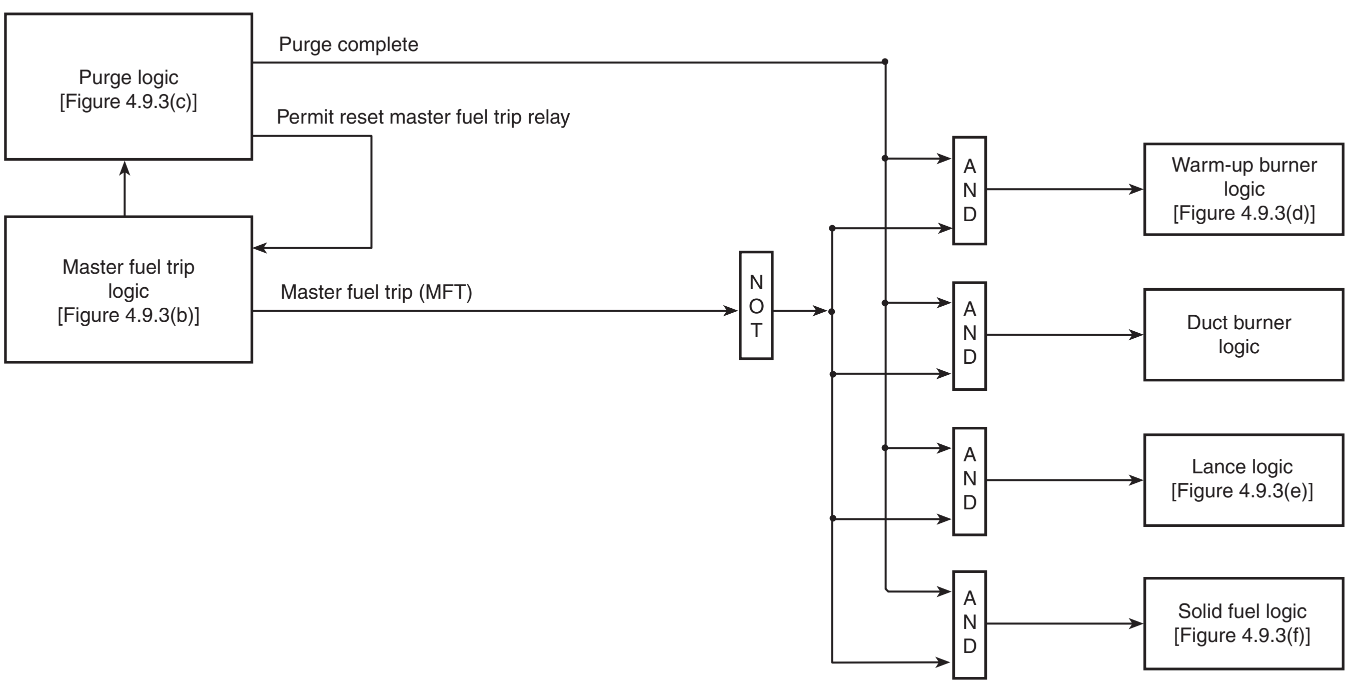
(c) Any single component failure of these sensing elements and circuits does not prevent a mandatory master fuel trip.

(j) The misoperation of the interlock system or related equipment due to interruption and restoration of the interlock power supply shall be prevented.

4.9.2.4 The actuation values and time of action of the initiating devices shall be adjusted 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.

4.9.3 System Requirements. Interlocks shall be required as shown in Figures 4.9.3(a) through 4.9.3(f) to provide the basic furnace protection for fluidized-bed boilers. The use of the logic flow paths shown in these figures shall reflect the sequence of operations described in Sections 4.6, 4.7, and 4.8 for either a cold start or a hot restart.

FIGURE 4.9.3(a) Interlock system overview.



4.9.3.1 The master fuel trip logic that initiates the tripping of all fuel supplies through a master fuel trip device shall be as shown in Figure 4.9.3(b) and shall be in accordance with Section 4.6. The master fuel trip device shall remain tripped until reset by either the successful completion of the purge cycle or the main fuel temperature permissive from the fuel release logic as shown in Figure 4.9.3(c). Each source of operation of the master fuel trip devices shall actuate a "cause of trip" indication that informs the operator of the initiating cause of trip impulse.

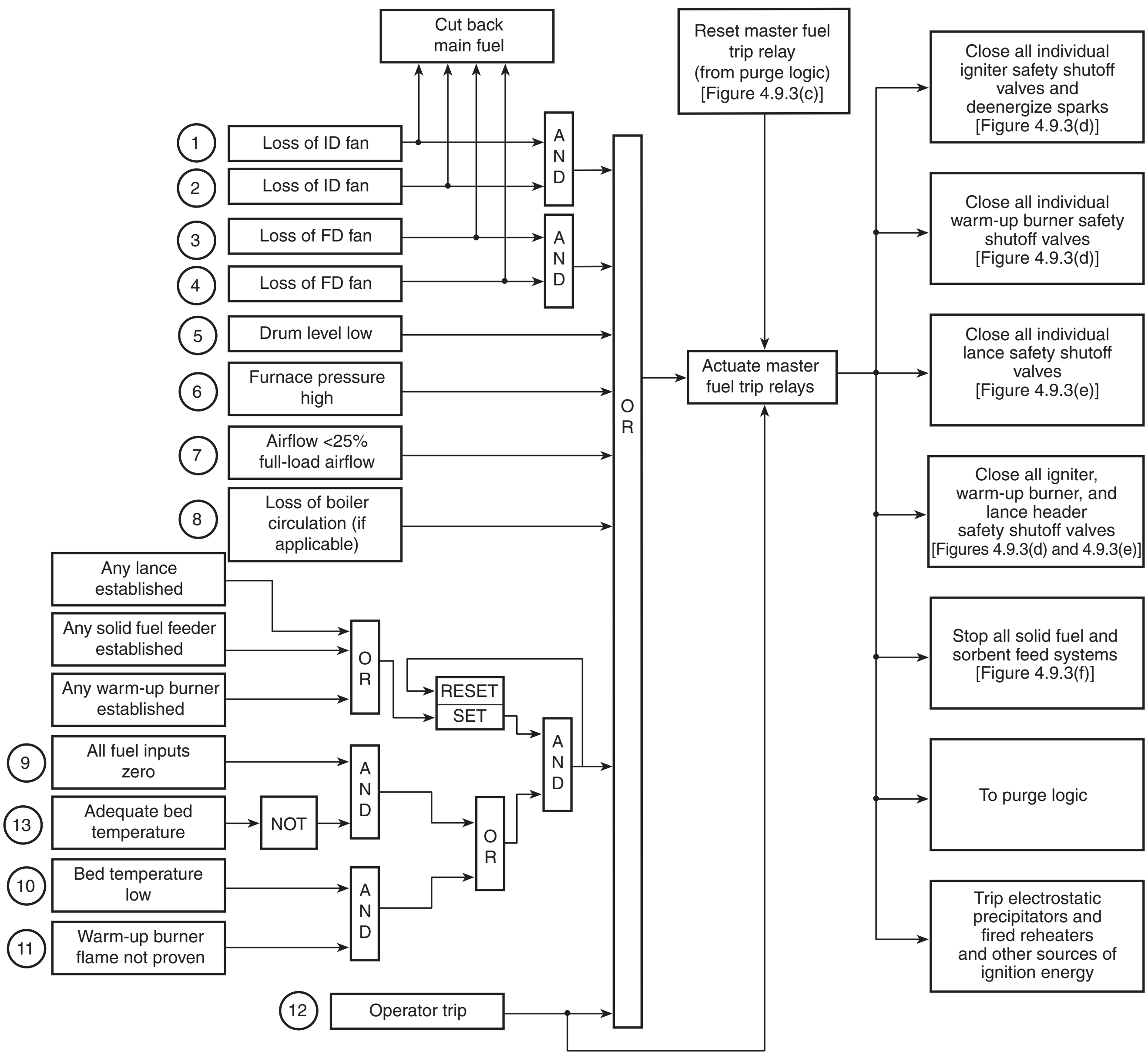
4.9.3.1.1 As shown in blocks 1 through 4 of Figure 4.9.3(b), the loss of all induced draft fans or all forced draft fans shall operate the master fuel trip device.

4.9.3.1.2 The loss of an individual induced draft fan or forced draft fan shall cause an immediate runback in unit fuel input in order to maintain the air/fuel ratio within the required limits. This shall be permitted to be interlocked or made a part of the combustion control system.

4.9.3.1.3 Furnace pressure high [block 6 in Figure 4.9.3(b)] shall be interlocked with the master fuel trip device to protect against abnormal furnace conditions, such as those resulting from a tube rupture or damper failure.

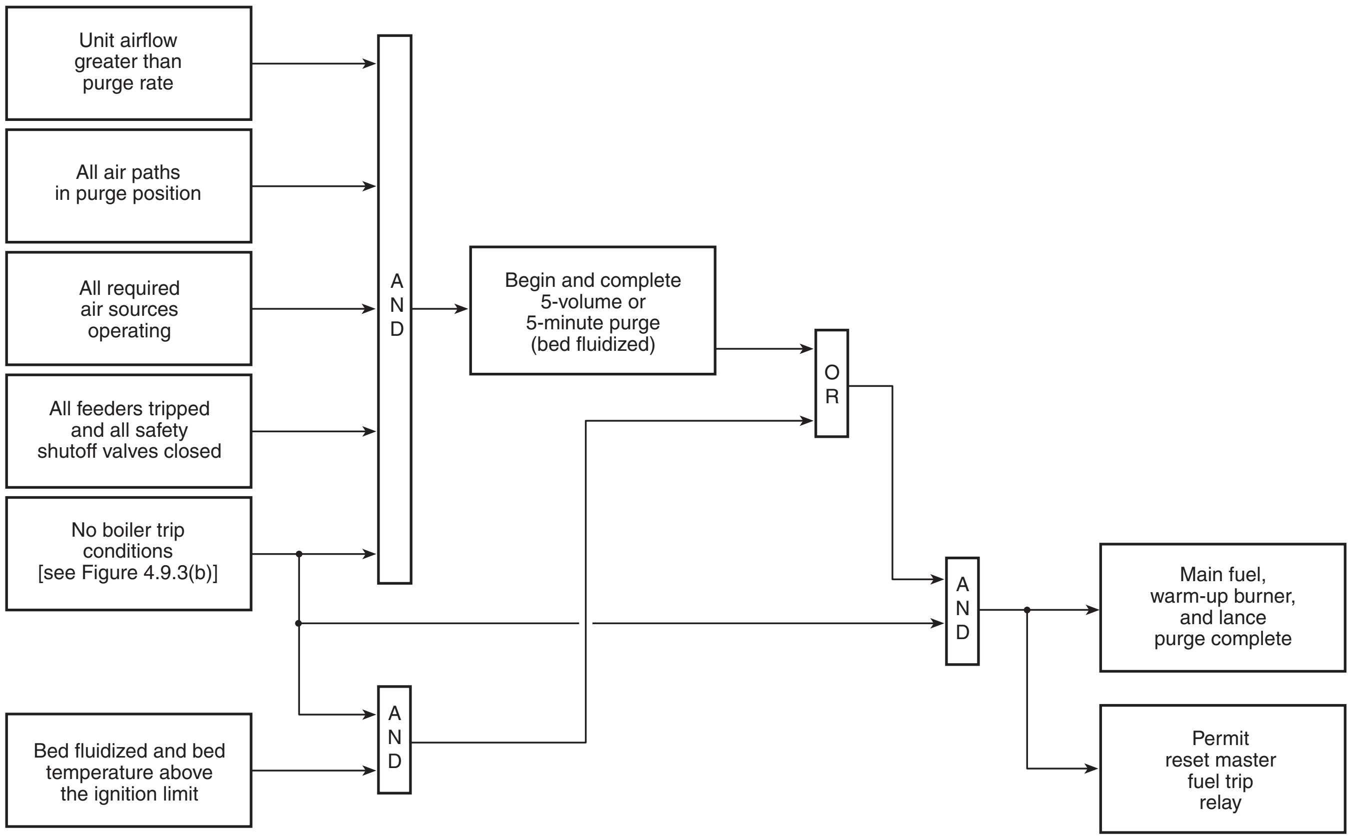
4.9.3.1.4 A manual trip switch [block 12 in Figure 4.9.3(b)] shall be provided for operator use in an emergency. The manual trip switch shall actuate the master fuel trip relay directly.

FIGURE 4.9.3(b) Boiler trip logic.



Notes:
1. Mandatory automatic trips per Table 4.6.2.5.2(a) shown.
2. Two induced draft and forced draft fans are assumed for this diagram.

FIGURE 4.9.3(c) Purge logic.



4.9.3.1.5* Bed temperature low [block 10 in Figure 4.9.3(b)], as defined in 4.6.1.5.1(f), and warm-up burner flame not proven (block 11) shall be interlocked with the master fuel trip device in order to prevent the further admission of fuel into the furnace under "no-flame" conditions.

4.9.3.1.6 All Fuel Inputs Zero (block 9 in Figure 4.9.3(b)). A mandatory master fuel trip shall occur once any fuel has been admitted to the unit, all fuel sources are subsequently isolated, and bed temperature is less than the main fuel operating permissive (block 13) as defined in 4.6.2.2.5. This trip shall be permitted to be reset and bypassed once the bed temperature exceeds the temperature permissive level for admitting fuel.

4.9.3.1.7 Other trips, as required by 4.6.2.5.2, and additional automatic master fuel trips required for a particular boiler design shall actuate the master fuel trip relay.

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

4.9.3.1.9 The master fuel trip device shall be of the type that remains tripped until the boiler purge system permits it to reset. When actuated, the master fuel trip device shall trip all sources of solid fuel input directly, close all safety shutoff valves, deenergize all igniter sparks, and deenergize all other ignition sources within the unit and flue gas path.

4.9.3.2 Unit Purge. A required purge of the unit shall be ensured by successfully completing a series of successive purge permissive interlocks, which are functionally outlined in Figure 4.9.3(c). This series of interlocks shall ensure that the unit purge has been completed with all sources of fuel admission proven isolated, all required air sources proven in service, all air paths in purge position, and no boiler trip conditions in existence prior to or during the purge cycle. Fuel gas system vent valves shall be proven not closed. Where the igniter capacity is 5.0 MBtu/hr (1.465 MW) or less, proof of closure of individual igniter safety shutoff valves by means other than valve position shall be permitted.

4.9.3.2.1 Interruption of the furnace purge either by the master fuel trip interlock logic or through the loss of any required purge interlocks shall cause the purge sequence to reset, and a complete and successful repurge of the unit shall be required prior to admitting fuel.

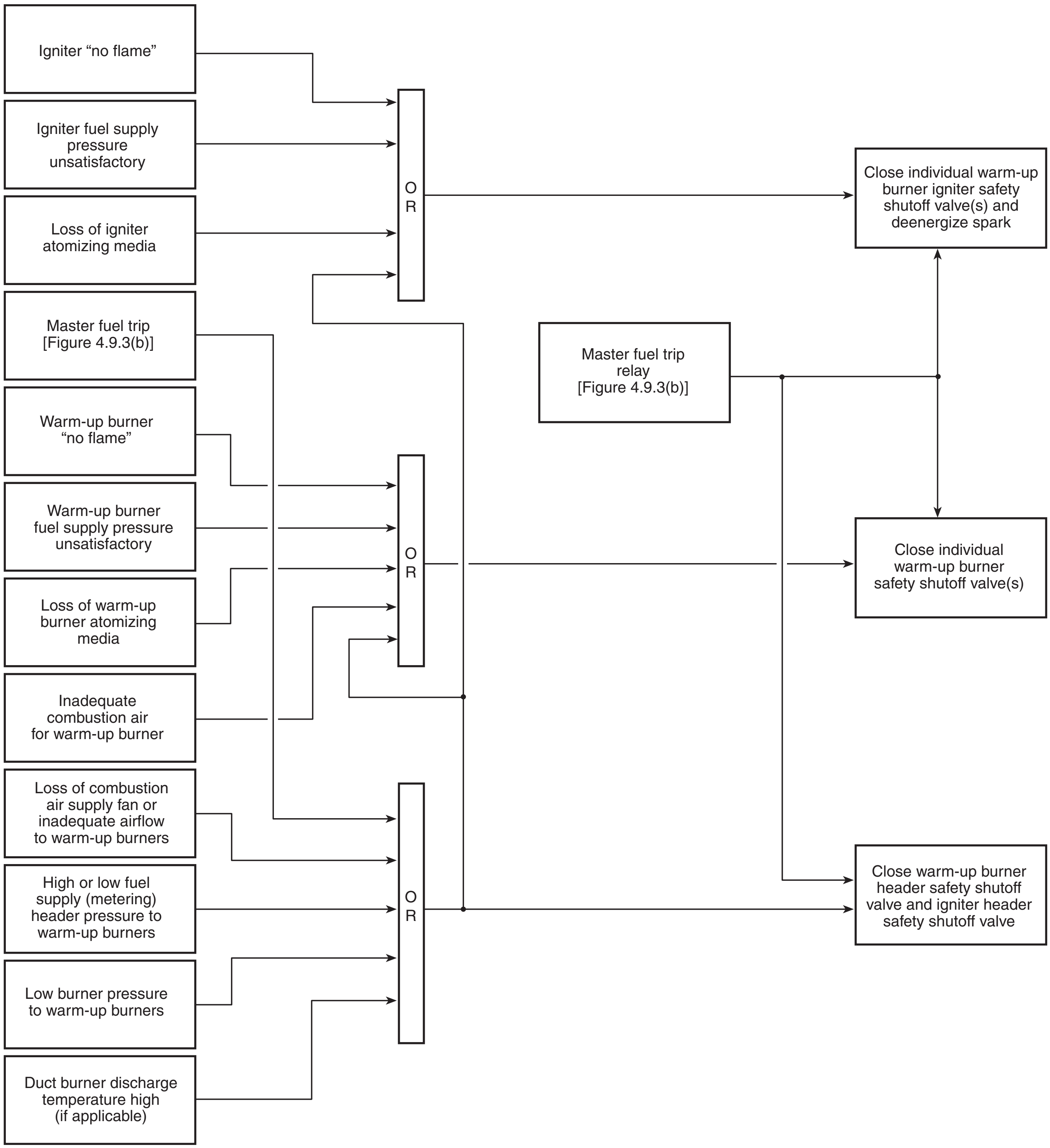
4.9.3.2.2 Cold Start. During initial start-up, or if the bed temperature is less than either the main fuel or the auxiliary fuel permissives *(see 4.6.2.1)*, a complete purge of the unit as outlined in Figure 4.9.3(c) shall be required.

4.9.3.2.3* Hot Restart. If operating conditions at the time of reset are such that the bed temperature permissives for the main fuel are satisfied *(see 4.6.2.4)*, a purge bypass shall be permitted. Fuel oil or gas header leak test shall not be required under this condition.

4.9.3.2.4 Upon the successful completion of the purge or following the completion of the purge bypass and reset, the master fuel trip device shall be reset.

4.9.3.3* Warm-Up Burners. The warm-up burners shall not be placed in service until the master fuel trip relay has been reset. *[See Figure 4.9.3(d).]*

FIGURE 4.9.3(d) Warm-up burner safety subsystem.



Note: A specific fuel system might not require all the trips shown.

FIGURE 4.9.3(e) Lance safety subsystem.

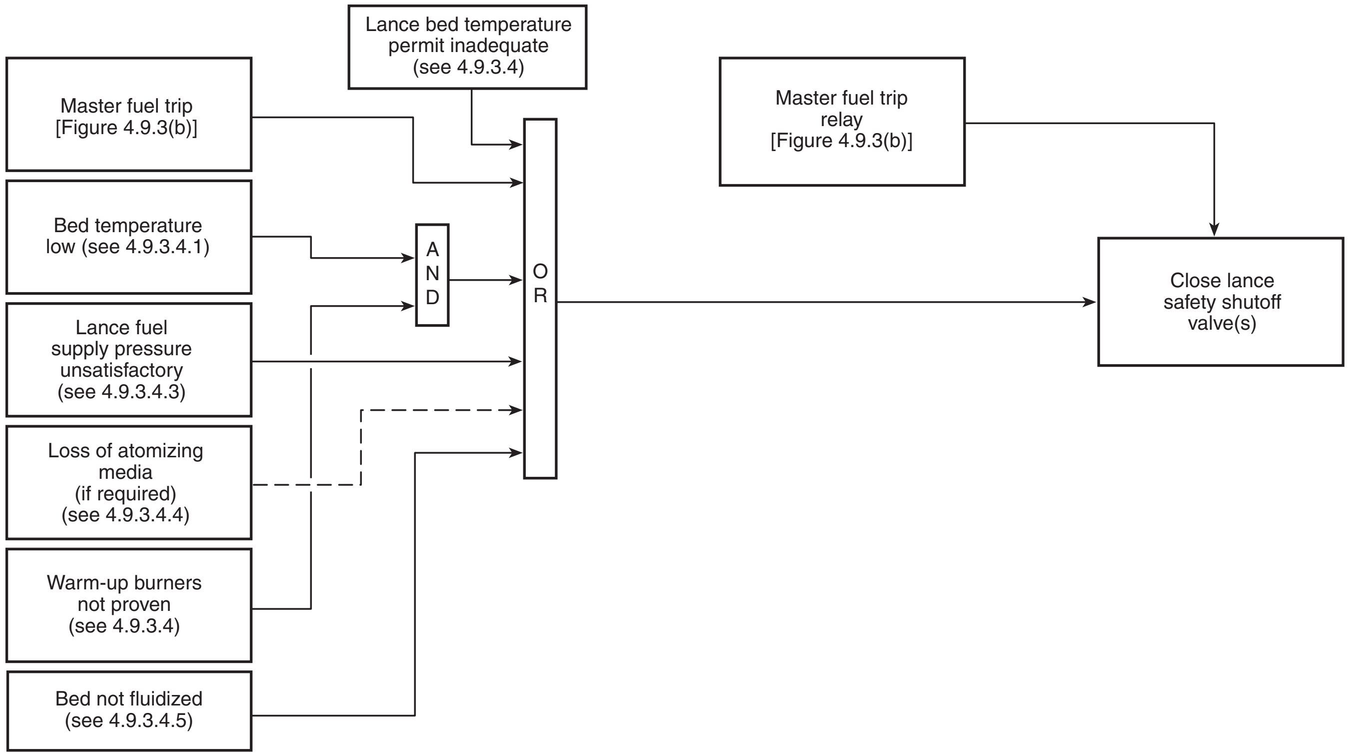
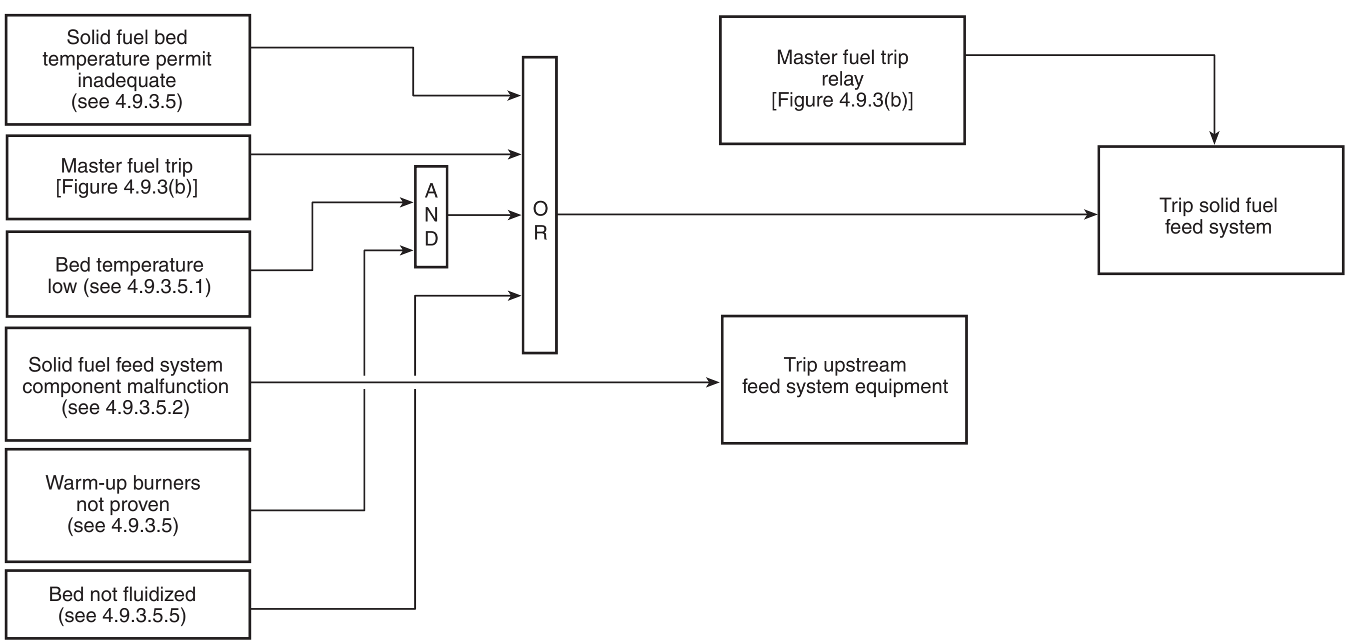


FIGURE 4.9.3(f) Solid fuel safety subsystem.



4.9.3.3.1 Loss of an individual warm-up burner flame shall initiate the tripping of the individual burner safety shutoff valve(s) and its individual igniter safety shutoff valve(s) and shall deenergize associated sparks.

4.9.3.3.2* Improper warm-up burner fuel pressure shall be interlocked to initiate the tripping of the individual warm-up burner safety shutoff valve(s) and deenergize the associated sparks. Where gas is used for fuel, both high and low pressure shall be interlocked. Where oil is used, low pressure shall be interlocked. Burner fuel pressure shall be monitored to ensure each warm-up burner is being operated within its capacity and stability limits as designated by the burner manufacturer and demonstrated by test.

4.9.3.3.3 For gas-fired warm-up burners, improper gas supply (metering) pressure shall initiate tripping of the burner header and individual warm-up burner safety shutoff valves and igniter header and individual igniter safety shutoff valves and shall deenergize associated sparks. *[See Figure A.4.7.5.1.1(a).]*

4.9.3.3.4 Where oil is used as an igniter fuel with air or steam for atomization, loss of atomizing media shall trip the igniter header and individual igniter safety shutoff valves and shall deenergize the associated sparks. The associated warm-up burners also shall be tripped if in service and no other proof of flame exists.

4.9.3.3.5 Where oil is used as a warm-up burner fuel with air or steam for atomization, loss of atomizing media shall trip the burner header and individual warm-up burner safety shutoff valves and igniter header and individual igniter safety shutoff valves and shall deenergize associated sparks.

4.9.3.3.6 A master fuel trip shall trip all warm-up burner header and all individual warm-up burner safety shutoff valves and all igniter header and all individual igniter safety shutoff valves and shall deenergize all associated sparks.

The master fuel trip relay shall trip all warm-up burner header and all individual warm-up burner safety shutoff valves directly and all igniter header and all individual igniter safety shutoff valves and shall deenergize all associated sparks.

4.9.3.3.7 If individually flow-controlled burners are used and the fuel flow or airflow falls below the manufacturer's recommended minimum flow, the burner shall be tripped immediately.

4.9.3.4 Lances. Lances shall not be placed in service until the master fuel trip relay has been reset and the bed temperature has reached the ignition temperature for the fuel being fired in the lance. *[See 4.6.1.5.1(f), 4.6.2.1.2(i)(6), 4.6.2.1.2(j)(4), and Figure 4.9.3(e).]*

4.9.3.4.1 Loss of the bed temperature permissive shall cause the individual lance safety shutoff valves to close. *(See 4.6.2.2.5.)*

4.9.3.4.2 For gas-fired lances, low or high gas supply (metering) pressure shall initiate tripping of the lance header and individual lance safety shutoff valves. *[See Figure A.4.7.5.1.1(a).]*

4.9.3.4.3 Lance fuel pressure shall be interlocked to ensure each lance is being operated within its capacity as designated by the lance manufacturer and shall initiate a trip of the individual lance safety shutoff valves.

Lance fuel pressure shall be monitored to ensure that each lance is being operated within its capacity as designated by the lance manufacturer. The monitoring of header pressure to multiple lances with individual flow control capability shall not be construed to satisfy this requirement.

4.9.3.4.4 Where oil is used as a lance fuel with air or steam for atomization, loss of atomizing media shall trip the header and safety shutoff valve(s).

4.9.3.4.5 Loss of airflow to fluidize the bed shall result in a trip of the lance header and individual lance safety shutoff valves.

4.9.3.4.6 A master fuel trip shall trip all lance header and individual lance safety shutoff valves.

4.9.3.4.7 The master fuel trip relay shall trip all lance header and individual lance safety shutoff valves directly.

4.9.3.5 Solid Fuel. The solid fuel feed system shall not be placed in service until the master fuel trip relay has been reset and the bed temperature has reached the ignition temperature of the solid fuel being fired. *[See 4.6.1.5.1(f), 4.6.2.1.2(i)(6), 4.6.2.1.2(j)(4), and Figure 4.9.3(f).]*

4.9.3.5.1 Loss of the required bed temperature permissive shall cause all solid fuel feed systems to trip. *(See 4.6.2.2.5.)*

4.9.3.5.2 Solid fuel feed system operation shall be interlocked to trip upstream solid fuel feed train components following a solid fuel system component malfunction.

4.9.3.5.3 A master fuel trip shall trip the solid fuel feed system.

4.9.3.5.4 The master fuel trip relay shall trip the solid fuel feed system directly.

4.9.3.5.5 Loss of airflow needed to fluidize the bed shall result in a solid fuel trip.

4.10 Alarm System.

4.10.1* Functional Requirements.

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

4.10.1.2 Alarm systems shall be designed so that, for all required alarms, the operator receives an audible as well as visual indication of the condition. The visual indication shall identify the source or cause of the alarm. Means shall be permitted to silence the audible alarm after actuation, but the visual indication shall continue until the condition has been resolved.

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

4.10.1.4 The design shall eliminate all nuisance alarms to the extent possible.

4.10.2 Required Alarms. In addition to the alarms required by this section, the alarms of 4.6.2.5 and 4.9.2.1 shall be provided.

4.10.2.1* General.

(a) *High or low furnace pressure.* An alarm shall warn the operator of furnace pressure outside the predetermined range of normal operation and approaching a trip condition.

(b) *Loss of operating forced draft fan.* This condition shall be sensed and alarmed only when the fan is not operating at the times expected.

(c) *Loss of operating induced draft fan.* This condition shall be sensed and alarmed only when the fan is not operating at the times expected.

(d) *Boiler airflow (low).* This condition shall be sensed and alarmed when total airflow nears the predetermined minimum purge rate.

(e) *Loss of interlock power.* This condition shall be sensed and alarmed and shall include all sources of power necessary to complete interlock functions. If multiple sources of power, including compressed air, are required for an interlock system, then loss of each power source shall be annunciated separately.

(f) *Loss of control power.* This condition shall be sensed and alarmed to include all sources of power, including compressed air, for the combustion control or the fluidized-bed boiler interlocks detailed in 4.9.3.

(g) *Bed temperature out of limits.* The bed temperature shall be monitored and alarmed when it is out of the predetermined operating range and when it is approaching a trip condition.

(h) *High ash cooler discharge material temperature.* An alarm shall indicate when the material temperature about to be discharged from the ash cooler reaches a predetermined high limit.

(i) *Low oxygen.* An alarm shall warn the operator when oxygen level in the flue gas is below a predetermined value.

(j) *Initiation of fan directional blocking or runback action.* An alarm shall indicate when fan override action or directional blocking is used to adjust draft regulating control element in response to a large furnace draft error for furnace pressure excursion prevention.

(k) *Redundant transmitter deviations within the furnace pressure control system.* An alarm shall indicate when any one of three furnace pressure measurements deviates from the others.

(l) *Axial flow fan (if used) nearing stall line.* An alarm shall indicate when an axial fan operating condition approaches the fan stall line to permit adjustments to be made to prevent uncontrolled changes in air or flue gas flow.

(m) *Fan override action.* An alarm shall indicate when the draft regulating control element is adjusted automatically as the result of a large furnace draft error.

4.10.2.2* Fuel Gas.

(a) *Fuel gas supply pressure (high and low).* The gas pressure supplied to the plant shall be monitored at a point as far upstream of the final constant fuel pressure regulator(s) as practicable.

(b) *Fuel gas burner header pressure (high and low).* Each burner header served by a single flow control valve shall monitor gas pressure as close to the burners as practicable.

(c) *Fuel gas meter pressure (high and low).* The pressure at the fuel gas meter shall be monitored at the upstream tap if the fuel gas flowmeter is part of the combustion control system and is not pressure compensated.

(d) *Ignition fuel header pressure (high and low).* Each ignition fuel header served by a single control valve shall monitor gas pressure as close to the igniters as practicable.

(e) *Burner safety shutoff or supervisory shutoff valves not closed.* The closed position of all individual burner safety shutoff valves and fuel header shutoff valves shall be monitored, and failure of any valve to close shall be alarmed. For fuel gas systems, the position of all vent valves shall also be monitored, and failure of any vent valve to leave the closed position shall be alarmed.

(f) *Loss of combustion air to burners.* For individually controlled burners, the combustion air to each burner shall be monitored and alarmed if the burner register is closed, the air supply fan is tripped, or the airflow is low.

(g) *Burner discharge temperature (high).* The discharge temperature from a burner, such as a duct burner, that is designed to maintain a desired discharge temperature shall be monitored and shall be alarmed when the temperature exceeds the maximum operating temperature.

(h) *Loss of flame.* A partial or total loss of a flame envelope still receiving fuel shall be monitored and alarmed.

(i) *Lance fuel header pressure (high and low).* The lance fuel header pressure shall be monitored as close to the lances as practicable in order to warn the operator of abnormal pressure in advance of conditions that lead to a trip.

(j) *Lance valve not closed.* The closed position of all individual lance safety shutoff valves and fuel header shutoff valves shall be monitored, and failure of any valve to close shall be alarmed. The position of all vent valves shall also be monitored, and failure of any vent valve to leave the closed position shall be alarmed.

4.10.2.3* Fuel Oil.

(a) *Main oil supply pressure (low).* The oil supply pressure shall be monitored at a point as far upstream as practicable.

(b) *Fuel oil burner header pressure (low).* Each burner header served by a single flow control valve shall monitor oil pressure as close to the burners as practicable.

(c) *Main oil viscosity (high).* Each burner header served by a single flow control valve shall monitor oil temperature to warn that the fuel oil temperature is dropping.

(d) *Atomizing steam or air pressure (low).* For steam burners and air-assisted burners, an alarm shall be provided on each burner atomizing media header served by a single control valve to warn that the steam or air pressure is outside of the prescribed operating range.

(e) *Igniter atomizing steam or air pressure (low).* For steam igniters and air-assisted igniters, an alarm shall be provided to warn that steam or air pressure is outside of the operating range

(f) *Ignition fuel header pressure (high and low).* Each igniter fuel header served by a single control valve shall monitor pressure as close to the igniters as practicable.

Exception: For oil fired igniters, only low ignition fuel header pressure shall be required to be monitored.

(g) *Burner safety or supervisory shutoff salves not closed.* The closed position of all individual burner safety shutoff valves and fuel header shutoff valves shall be monitored, and failure of any valve to close shall be alarmed.

(h) *Loss of combustion air to burners.* For individually controlled burners, the combustion air to each burner shall be monitored and alarmed if the burner register is closed, the air supply fan is tripped, or the airflow is low.

(i) *Duct burner discharge temperature (high).* The discharge temperature from a burner, such as a duct burner, that is designed to maintain a desired discharge temperature shall be monitored and alarmed when the temperature exceeds the maximum operating temperature in order to warn the operator in advance of the temperature that leads to a trip.

(j) *Loss of flame.* A partial or total loss of a flame envelope still receiving fuel shall be monitored and alarmed.

(k) *Lance atomizing steam or air pressure (low).* To avoid poor atomization by steam- or air-assisted lances, an alarm shall be provided to warn that steam or air pressure are outside of the predetermined operating parameters.

(l) *Lance fuel header pressure (high and low).* The lance fuel header pressure shall be monitored as close to the lances as practicable in order to warn the operator of abnormal pressure in advance of conditions that lead to a trip.

(m) *Lance valve not closed.* The closed position of all individual lance safety shutoff valves and fuel header shutoff valves shall be monitored, and failure of any valve to close shall be alarmed

4.10.2.4 Solid Fuel.

(a) *Solid fuel feeder tripped.* An alarm shall indicate when a feeder has tripped.

(b) *Solid fuel transport air fan tripped.* An alarm shall indicate when a transport air fan has tripped.

(c) *Loss of solid fuel.* An alarm shall indicate when the feeder is running and the fuel flow detecting device(s) indicates no fuel flow.

Chapter 5 Heat Recovery Steam Generators

5.1 Scope.

5.1.1* Chapter 5 shall apply to the design, installation, operation, and maintenance of heat recovery steam generator (HRSG) systems.

5.1.2 Purge requirements shall apply to all fired and unfired heat recovery steam generator (HRSG) systems regardless of the fuel(s) used.

5.1.3 Chapter 5 shall apply to combustion turbines that fire fuels either alone or in combination, as designed by the combustion turbine manufacturer.

5.1.4 Chapter 5 shall apply to unfired HRSGs, and to fired HRSGs using fuels either alone or in combination, as specified by the HRSG manufacturer.

5.1.5 Chapter 5 shall not dictate the methods or details of the combustion turbine manufacturer's product or control system. Chapter 5 shall identify specific functional considerations for proper interfacing related to the safety aspects of the combined combustion turbine and the HRSG.

5.1.6 Chapter 5 shall not address multiple combustion turbines exhausting into a single HRSG, nor does it address single or multiple combustion turbines exhausting into multiple HRSGs through a header. Any system applying this concept shall require special design considerations that are not addressed in Chapter 5.

5.1.7 Where conflicts exist between Chapter 1 and Chapter 5, the requirements of Chapter 5 shall be followed.

5.2 Purpose.

5.2.1 The purpose of this chapter shall be as follows:

(1) To contribute to operating safety
(2) To prevent explosions, implosions, and uncontrolled fires in HRSG sections and exhaust ductwork
(3) To establish minimum requirements for the design, installation, operation, and maintenance of heat recovery steam generators and their fuel-burning, air supply, and combustion products removal systems
(4) To require the coordination of operating procedures and components, control systems, interlocks, and structural design
(5) To require the establishment of training programs in equipment operation and maintenance, for both new and existing personnel, to ensure that minimum standards for operation and maintenance are understood and followed

5.2.2* The user of this code shall recognize the complexity of firing with regard to the type of equipment used and the characteristics of the fuel.

5.2.3 Emphasis shall be placed on the importance of component coordination and on knowledge of expected operating conditions.

5.3* Fin-Metal Tube Fires.

5.3.1 The initial response to a fire inside the HRSG shall include the removal of all fuel from the combustion turbine and the HRSG.

5.3.2 A procedure shall be provided to contain, confine, or seal off a fin-metal tube fire and to protect the buildings and adjacent equipment.

5.4 HRSG Implosions. For HRSGs that use an induced draft fan where the potential exists for excessively low HRSG enclosure gas side pressures, the HRSG design shall conform to the requirements of Chapter 3, Multiple Burner Boilers, Section 3.5.

5.5 Project Coordination.

5.5.1 General.

5.5.1.1 The ability of the combustion turbine to satisfy the flow requirements through the HRSG enclosure as required in 5.11.4 shall be confirmed in the basic design phase.

5.5.1.2 The HRSG system shall be designed to meet the user's specified modes of operation.

5.5.1.3 Systems components and control loops shall be compatible and capable of stable operation and control during both steady-state and transient conditions.

5.5.2 Project Inception. In the project inception phase, the following shall be accomplished to ensure a plant design that meets expected operating modes and reliability needs:

(1) Establishment of plant operating parameters
(2) Identification of site-related constraints
(3) Review of the steam cycle, including generation of a family of heat balance diagrams for the expected operating ranges and modes
(4) Conceptualization of plant layout to provide for personnel safety, operability, and maintenance needs
(5) Definition and verification of requirements of worst-case operating transients, including start-ups
(6) Definition of required test program
(7) Definition of start-up criteria and goals
(8) Identification of the authority having jurisdiction. If multiple authorities having jurisdiction are identified, the scope of each authority having jurisdiction shall be defined.

5.5.3 Design.

5.5.3.1* The project approach shall include full evaluation of all systems and components to ensure compatibility, interface requirements, system dynamics, and the ability to meet all plant operating parameters.

5.5.3.2* This evaluation shall use dynamic simulation, prior operating experience, or both before equipment is selected.

5.5.3.3 Electrical area classifications shall be established by the owner or the owner's designated representative and shall be provided to the HRSG system designer prior to commencing detailed design.

5.5.4* Project coordination, including proper integration of the various system components, shall be the responsibility of the owner's designated representative from system inception through commercial operation in order to enhance equipment reliability and personnel safety.

5.6 Equipment.

5.6.1 General. Equipment required by this code shall be approved or shall have a demonstrated history of reliable operation for the specified service.

5.6.2 Combustion Turbine.

5.6.2.1* Fuel Supply.

5.6.2.1.1 For liquid fuels, two stop valves or equivalent valves in series, with proof of closure, shall be provided in each fuel line to the combustion turbine. Means shall be provided to prevent or relieve excess pressure between these valves.

5.6.2.1.2 For gaseous fuels, two stop valves or equivalent valves in series, with proof of closure, shall be provided in the line to the combustion turbine. An automatic vent valve shall be provided between the two valves.

5.6.2.2 Purge.

5.6.2.2.1 The combustion turbine shall have means for purging in accordance with 5.11.4.

5.6.2.2.2 During the purge sequence, means shall be provided to prevent fuel from entering the combustion turbine system downstream of the combustion turbine fuel stop valves.

5.6.2.3* Interlocks.

5.6.2.3.1 The HRSG manufacturer's required interlocks shall prevent starting of the combustion turbine unless the HRSG starting conditions are satisfied. These shall include but not be limited to the following:

(1) The water levels in drum(s), if provided, are within the defined start-up range.
(2) The feedwater supply system is available to respond to demand.
(3) The pressure in steam or water spaces is not high.
(4) The exit temperature of duct burner(s), if provided, is not high.
(5) The position of stack closure, if provided, is correct.
(6) The pressure in the HRSG enclosure is not high.
(7) The augmented air supply, if provided, is in operation *(refer to 5.11.4.2.4)*.

5.6.2.3.2 Signals shall be provided to the combustion turbine control system to initiate a change in the combustion turbine operating mode if HRSG safety conditions deviate beyond preset safety limits. A combustion turbine trip is very costly in terms of its effect on combustion turbine life expectancy and shall be performed only under conditions that result in a safety hazard or equipment damage. Typical HRSG conditions that warrant a combustion turbine operational response and their corresponding responses shall include the following as listed in Table 5.6.2.3.2.

Table 5.6.2.3.2 Typical HRSG Interlock Conditions and Responses

Condition	Response
Water in drum(s) below minimum permitted level	Reduce combustion turbine load or trip combustion turbine as required by HRSG manufacturer
Pressure in combustion turbine exhaust plenum high	Trip combustion turbine
Position of stack closure (if provided) not correct	Trip combustion turbine

5.6.2.4 Operating Interfaces.

5.6.2.4.1 Combustion turbine loading and low-load hold/soak periods shall be established based on the following HRSG parameters:

(1) Tube and drum metal temperatures
(2) Differential metal temperatures within a particular component (i.e., steam drum)
(3) Rate of change of critical temperatures
(4) Drum water level

5.6.2.4.2 The control system or the operator shall trip the combustion turbine in the case of an emergency that would lead to a safety hazard or catastrophic failure after the actions of 5.6.2.3.2 have been accomplished.

5.6.3* HRSG Fuel-Burning System.

5.6.3.1 The fuel-burning system shall contain the following subsystems as applicable:

(1) Fuel supply
(2) Main burner
(3) Igniter
(4) Atomizing media supply (if included)
(5) Combustion products removal
(6) Augmented air supply

5.6.3.2 Each igniter/burner element shall have a purged and cooled flame scanner port embodied in the design.

5.6.4 Fuel Supply.

5.6.4.1 General.

5.6.4.1.1 The fuel supply equipment shall be sized and arranged to ensure a continuous fuel flow for all operating requirements of the unit. This shall include coordination of the main fuel control valve, burner safety shutoff valves, and associated piping volume to ensure against fuel pressure transients that exceed burner limits for stable flame as a result of placing burners in service or taking them out of service.

5.6.4.1.2 The fuel supply equipment shall be designed to prevent contamination of the fuel. Maintenance access to fuel system components shall be provided. Drains shall be provided at low points in the piping.

5.6.4.1.3 The fuel supply equipment shall be capable of continuing the design fuel flow during anticipated exhaust gas pressure pulsations at the burner.

5.6.4.1.4 The fuel supply equipment shall be designed for the operating environment and ambient conditions, including external conditions such as fire or mechanical damage.

5.6.4.1.5 The integrity of flexible hoses or swivel joints shall be maintained.

5.6.4.1.6 The fuel piping materials and system design shall be in accordance with ASME B 31.1, *Power Piping*, or ASME B 31.3, *Process Piping*.

5.6.4.1.7* A manual emergency shutoff valve that is accessible in the event of fire shall be provided in the HRSG area.

5.6.4.1.8 Tightness tests of the main safety shutoff valves and the individual burner safety shutoff valves shall be performed. Permanent provisions shall be included in the fuel piping to allow testing for this leakage.

5.6.4.1.9 Where provided, individual burner safety shutoff valves shall be located close to the burner to reduce the volume of fuel left in the burner lines located downstream of the valves.

5.6.4.2 Additional Requirements for Gaseous Fuels.

5.6.4.2.1* The portion of the fuel supply system upstream of the fuel control valve shall be designed so as to prevent exceeding design pressure in the fuel-burning system, even in the event of failure of the main supply constant fuel pressure regulator(s). Where full relieving capacity is not installed, the piping system shall be designed for the full supply pressure up to and including all individual burner and igniter safety shutoff valves.

5.6.4.2.2* Leakage of gaseous fuel into an idle HRSG shall be prevented. An atmospheric vent shall be installed between redundant shutoff valves in any header for the main or igniter gaseous fuel supply.

5.6.4.3 Additional Requirements for Liquid Fuel.

5.6.4.3.1 In addition to the requirements of NFPA 30, *Flammable and Combustible Liquids Code*, the fill and recirculation lines to storage tanks shall discharge below the liquid level to prevent free fall, which generates static electrical charges and increases vaporization.

5.6.4.3.2 Strainers, filters, traps, sumps, or other such items shall be provided to remove harmful contaminants.

5.6.4.3.3 Means shall be provided to prevent or relieve excess pressure from expansion of entrapped liquid in the fuel system.

5.6.4.3.4 Relief valve outlets, vents, drains, and tell-tales shall be provided with piping to allow safe discharge of liquid or vapors and shall be designed for the expected range of external temperatures and protected against mechanical damage.

5.6.4.3.5 Instrument and control piping and tubing containing liquid fuel shall be designed for the expected range of external temperatures and protected against mechanical damage.

5.6.4.3.6 Leakage of liquid fuel into an idle HRSG shall be prevented.

5.6.4.3.7* Liquid fuel shall be delivered to the burners at a temperature and pressure recommended by the burner manufacturer, to ensure that the liquid fuel is at the viscosity necessary for proper atomization.

5.6.4.3.8 If heating of liquid fuel is necessary, it shall be accomplished without contamination or coking.

5.6.4.3.9 For heated systems, recirculation provisions shall be incorporated for controlling the viscosity of the liquid fuel to the burners. These systems shall be designed and operated to prevent vapor-binding of pumps and interruption of the fuel supply.

5.6.4.3.10 Liquid fuel shall be prevented from entering the burner header system through recirculating valves, particularly from the fuel supply system of other equipment. Check valves shall not be used for this purpose in heavy oil service.

5.6.4.3.11 Atomizing media, where required, shall be supplied free of contaminants and shall meet the requirements of the burner manufacturer.

5.6.4.3.12 Provisions shall be made to ensure that fuel cannot enter the atomizing media line at any time.

5.6.4.3.13 The atomizing subsystem shall be designed to allow cleaning and maintenance.

5.6.4.4 Burner.

5.6.4.4.1 Ignition.

5.6.4.4.1.1 Igniter parts exposed to combustion turbine exhaust gas, radiation, or flame shall be designed and fabricated of materials capable of withstanding the operating conditions.

5.6.4.4.1.2 Igniters shall be shielded from the effects of the combustion turbine exhaust gas to ensure a stable flame under all operating conditions.

5.6.4.4.1.3 Ignition devices shall be removable for maintenance while the HRSG is in service. Precautions shall be taken for personnel protection when removing such parts during operation.

5.6.4.4.1.4 Ignition transformers shall be housed in an enclosure complying with the relevant requirements of NFPA 70, *National Electrical Code*®, regarding electrical classification and environment and shall be located adjacent to the igniter.

5.6.4.4.1.5 The ignition transformer shall not be energized before the HRSG enclosure purge is completed. The ignition transformer shall be deenergized at the end of the igniter trial for ignition period.

5.6.4.5 Main Burner.

5.6.4.5.1 Burner Elements.

5.6.4.5.1.1 The burner elements shall be designed for operation with the fuel(s) specified. The burner shall be designed to produce a stable flame for its operating range.

5.6.4.5.1.2 Burner parts exposed to turbine exhaust gas, radiation, or flame shall be designed and fabricated of materials capable of withstanding the operating conditions.

5.6.4.5.1.3 Provision shall be made for visual observation of the burner flame, including the ignition zone.

5.6.4.5.1.4 Access shall be provided to the burner components and hardware.

5.6.4.5.1.5* The main burner subsystem shall be designed so that the fuel inputs are supplied to the HRSG continuously during burner operation and within stable flame limits.

5.6.4.5.1.6* The limits of stable flame for each burner subsystem producing a separate flame envelope shall be determined by tests without the ignition subsystem in service. These tests shall verify that transients generated in the fuel and combustion turbine exhaust gas subsystems or maldistribution of the combustion turbine exhaust gas do not adversely affect the burners in operation. These tests shall include the expected range of available fuels.

Exception: The requirement to perform tests without the ignition subsystem in service shall not apply to burner systems that require the igniter to be in service any time the burner is being operated.

5.6.4.5.1.7 Where Class 1 or Class 2 igniters are used, the tests in 5.6.4.5.1.6 also shall be performed with the ignition subsystem in service to verify that the igniters that are furnished meet the requirements of the class specified in the design. Any resulting extended turndown range shall be available only when Class 1 igniters are in service and flame is proven.

5.6.4.5.2 Additional Burner Requirements for Liquid Fuel.

5.6.4.5.2.1 Provisions shall be made for cleaning of the burner nozzle and tip.

5.6.4.5.2.2 Provisions shall be included for clearing (scavenging) the passages of a liquid fuel burner into the HRSG with that burner's igniter in service. If the igniter is not operational, the burner shall be removed for clearing.

5.6.5* Augmented Air.

5.6.5.1 Where provided, the fan(s) supplying augmented air to the duct burners shall be operated in accordance with the instructions provided by the supplier of the augmented air system or the organization having responsibility for the overall design.

5.6.5.2 Upon failure of the augmented air supply, means shall be provided to prevent hot gases from exiting the HRSG through the augmented air system.

5.7* HRSG Enclosure.

5.7.1* The HRSG, ducts, and stack shall be sized and arranged to maintain combustion turbine exhaust gas back pressure within design limits and to remove the products of combustion at the same rate that they are generated by the fuel-burning process during operation of the unit.

5.7.2 The HRSG and ducts shall be capable of withstanding a transient pressure determined by the HRSG system designer without permanent deformation due to yield or buckling of any support member.

5.7.3* Expansion provision shall be made for the movement of the turbine exhaust duct and the HRSG ducts. These expansion joints shall withstand at least the highest design pressure for which either duct is designed.

5.7.4* Access and drain openings shall be provided.

5.7.5 The HRSG ducts shall be designed so that they cannot contribute to flame pulsations.

5.7.6 Components common to more than one steam generator shall not limit the rate of removal of products of combustion.

5.7.7 The HRSG ductwork between the combustion turbine outlet and the duct burners shall be designed to provide distribution of combustion turbine exhaust gas as required by the burner manufacturer for stable burner operation.

5.7.8 All HRSG units that utilize liquid and heavier-than-air gaseous fuels shall have a duct design that meets the criteria of 5.7.8.1 through 5.7.8.3.

5.7.8.1* All low points shall have slopes to ensure that no dead pockets exist in the bottom of the ducts at points other than a designed low point.

5.7.8.2* Drains shall be installed at the low points to facilitate clearing fuel from the HRSG enclosure.

5.7.8.3 Provisions shall be included in the HRSG design and operation to prevent liquid fuels from being absorbed into the insulation.

5.8* Selective Catalytic Reduction.

5.8.1 Where selective catalytic reduction (SCR) systems are selected for NO_x emission control, they shall be integrated into the HRSG design to operate in the flue gas temperature range required.

5.8.2 Areas in which either anhydrous or aqueous ammonia is stored or piped shall be ventilated to preclude toxic or flammable concentrations.

5.9 Electrical.

5.9.1 Electrical equipment shall be protected against transient voltages according to the manufacturer's specification. As a minimum, the system shall function at voltages up to 10 percent above the nominally rated voltage and up to 10 percent below the nominally rated voltage.

5.9.2 All wiring shall comply with the requirements of NFPA 70, *National Electrical Code*.

5.9.3 All high-voltage equipment shall be marked in accordance with the requirements of NFPA 70, *National Electrical Code*.

5.9.4* Where an area is identified as a hazardous location as defined by Article 500 of NFPA 70, *National Electrical Code*, the type of equipment enclosure and the wiring methods to be used shall be as specified by that code.

5.9.5 The electrical supply to the burner management system and associated subcircuits shall be protected by circuit breakers or fuses.

5.9.6 Upon initiation of a duct burner master fuel trip, failure of an electrical power supply shall not impede the shutdown process.

5.10 Controls, Monitoring, Alarms, and Interlocks.

5.10.1* Control Functions.

5.10.1.1 General.

5.10.1.1.1 A single component failure shall not cause loss of the control system's critical functions identified in 5.10.4.3.

5.10.1.1.2 Equipment shall be designed and procedures established to permit on-line maintenance of the control equipment. Lockout or tag-out procedures shall be followed.

5.10.1.1.3 Procedures for calibrating and testing of controls and interlocks shall be provided.

5.10.1.2 Fuel Control.

5.10.1.2.1 Fuel input shall be controlled to maintain stable firing conditions. Remote manual operation shall be permitted.

5.10.1.2.2 Minimum and maximum limits on the fuel input shall be established to prevent fuel flow beyond the stable limits of the fuel-burning system.

5.10.1.3 Feedwater/Drum Level Control. The water level in each drum shall be maintained automatically. Remote manual operation of the feedwater control device shall be provided.

5.10.2 Monitoring.

5.10.2.1 Information about operating events shall be displayed to the operator.

5.10.2.2 Recording or trend displays of critical parameters listed in 5.10.2.3, taken at intervals no greater than 5 seconds, shall be provided to the operator at the operator location.

5.10.2.2.1 Where accessed through a video display unit (VDU) display in response to an alarm condition, the trend displays shall appear within 5 seconds.

5.10.2.2.2 Where VDU trend displays are used, the displays shall provide data that are current to within the prior 30 minutes at minimum, and the data provided shall have been stored at intervals of not more than 1 second.

5.10.2.3* The following HRSG parameters shall be continuously recorded on charts, or the data shall be logged and trended in accordance with 5.10.2.2.1 and 5.10.2.2.2:

(1) Water level in each steam drum
(2) Fuel pressure at the duct burner(s)
(3) Steam pressure at each pressure level
(4) Duct burner exit temperature before the first tube bank
(5) Atomizing media pressure (for liquid fuels only)
(6) Gas temperature upstream of the emissions control catalyst(s)
(7) HRSG flue gas exit temperature

5.10.3 Alarms.

5.10.3.1 Functional Requirements.

5.10.3.1.1 The alarm system shall alert the operator to specific upset conditions.

5.10.3.1.2 Alarms shall be provided to indicate equipment malfunction, hazardous conditions, or misoperation.

5.10.3.1.3 Alarms shall not be manually defeated.

Exception: Where equipment malfunction makes it necessary to defeat an alarm, it shall be performed by authorized personnel, and the alarm shall be tagged or logged as inoperative in accordance with plant operating procedures.

5.10.3.1.4 Alarm systems shall be designed so that, for the alarms required by 5.10.3.2, the operator receives audible as well as visual signals. The operator shall be permitted to silence the audible signal.

5.10.3.2 Required Alarms.

5.10.3.2.1 General. The following alarms shall be required:

(a) Each interlock trip individually.

(b) HRSG steam pressure (high) — high HRSG pressure at each steam pressure level.

(c) Loss of interlock power. Loss of interlock power shall be sensed and alarmed and shall include all sources of power required to complete interlock functions. For example, if both a 125-V dc electric circuit and a compressed air circuit are required for an interlock scheme, then loss of either shall be annunciated.

(d) Loss of control power. Loss of control power shall be sensed and alarmed to include any sources of power for the control systems. For example, if both a 125-V dc electric circuit and a compressed air circuit are required for control, then loss of either shall be annunciated.

(e) Burner (if provided) safety shutoff valves not closed. The closed position of burner safety shutoff valves shall be monitored, and failure of any valve to close following a trip shall be alarmed.

(f) Steam drum(s) (if provided) water level (low).

(g) Loss of combustion turbine load.

(h) Duct burner (if provided) outlet temperature (high).

(i) Scanner (if provided) cooling air pressure (low).

(j) Loss of augmented air (if provided) supply.

(k) Class 1 or Class 2 ignition fuel header (if provided) pressure (high and low).

5.10.3.2.2 Additional Alarms for Gaseous Fuels. The following additional alarms shall be required when firing gaseous fuels:

(a) *Supply pressure (high and low).* The gas pressure supplied to the plant shall be monitored at a point upstream of the final constant fuel pressure regulator, main fuel control, and main safety shutoff valves.

(b) *Burner header pressure (high and low).*

(c) *Flowmeter pressure (high and low).* The pressure at the gas flowmeter shall be monitored at the upstream tap if the gaseous fuel flowmeter is part of the combustion control system and is not pressure-compensated.

5.10.3.2.3 Additional Alarms for Liquid Fuels. The following additional alarms shall be required when firing liquid fuels:

(1) Fuel supply pressure (low). The fuel supply pressure shall be monitored at a point upstream of the fuel control and safety shutoff valves.
(2) Burner header pressure (low).
(3) Atomizing media pressure (low).
(4) Heated fuel temperature (low) or viscosity (high).

5.10.4 Interlocks.

5.10.4.1 Functional Requirements.

5.10.4.1.1 The HRSG interlocks shall be installed to protect personnel from injury and to protect equipment from damage. The interlock system functions shall limit actions to a prescribed operating sequence or initiating trip device(s).

5.10.4.1.2 Operating personnel shall be made aware of the limitations of the interlock system, given that it is possible to achieve conditions conducive to an explosion without their detection by any of the mandatory automatic trip devices, even though such devices are adjusted and maintained.

5.10.4.1.3 Whenever a safety interlock device has been removed from service for maintenance, testing, or repair, this device shall be tagged and the action governed by operating procedures. Other means shall be substituted to supervise this interlock function.

5.10.4.1.4 The design of an interlock system shall include the following:

(1) Supervision of the starting procedure and operation
(2) Tripping of the minimum amount of equipment in the required sequence when the safety of personnel or equipment is jeopardized
(3) Indication of the initiating cause of the trip and prevention of the start of any portion of the process until operating conditions are established
(4) Coordination of the trip devices into an integrated system
(5) Provisions of instrumentation to enable the operator or automatic equipment to complete the operating sequence
(6) Provision for preventive maintenance
(7) Interlocks that do not require defeating in order to start or operate equipment
(8) The independence of mandatory duct burner master fuel trip sensing elements and circuits from all other control elements and circuits

Exception: Individual burner flame detectors shall be permitted to be used for initiating duct burner master fuel trip systems.

(9) Prevention of the misoperation of the interlock system due to an interruption or restoration of the interlock energy supply

5.10.4.1.5 Interlock functions shall be initiated by one or more of the following:

(1) Switches independent of control functions and signals
(2) Two analog signals with a divergence alarm
(3) Three analog signals employing an auctioneering system and a divergence alarm or other fault diagnostic alarm

5.10.4.2 Flame Detection.

5.10.4.2.1 Each burner element or zone shall be supervised individually. Upon detection of loss of flame, the associated individual burner safety shutoff valve shall close automatically.

5.10.4.2.1.1 Where two flame detectors are fitted to each firing element, the flame scanners shall be arranged to alarm on loss of flame from one scanner and to trip the system on loss of flame from two scanners. With one detector out of service, the remaining detector shall trip the system upon loss of flame detection.

5.10.4.2.1.2 Where Class 1 igniters are provided, the main burner flame shall be proven either by the flame scanner or by proving the igniter. At least one flame detector shall be provided for each burner to detect the burner flame or igniter flame where a Class 1 igniter is provided.

5.10.4.2.1.3 Burners with Class 2 igniters shall have at least two flame detectors. One detector shall detect the main burner flame and shall not detect the igniter flame. The second detector shall detect the igniter flame during prescribed light-off conditions.

5.10.4.2.1.4 Burners with Class 3 igniters shall have at least one flame detector. The detector shall detect the igniter flame. It also shall detect the main burner flame after the igniter is removed from service at the end to the main burner trial for ignition.

5.10.4.2.1.5 Where a self-checking flame scanner is provided to each burner, a burner trip shall occur if the scanner exhibits a self-check fault. Where two self-checking flame scanners are fitted to each burner, the flame scanners shall alarm on loss of flame or the self-check failure of one scanner and shall trip the burner on loss of flame or the self-check failure of two scanners. With one detector out of service, the remaining detector shall trip the burner upon loss of flame or self-check failure.

5.10.4.2.2 Where a hazardous condition results from loss of flame in more than one burner element or zone, a duct burner master fuel trip shall be initiated.

5.10.4.2.3 It is recognized that any fuel input that does not ignite and burn creates a hazard. Regardless of the number or pattern of flame loss indications used for tripping, flame loss indication on a firing element shall initiate an alarm that warns the operator of a potential hazard.

5.10.4.2.4 Field testing shall be required to validate basic functions of flame tripping. These tests shall be performed on representative units. These tests shall not be used to replace an acceptance test related to proof of design, function, and components.

5.10.4.2.5 Field tests shall be performed to establish optimum sighting angles of firing elements or igniters and to check the angular range of the flame detector in relation to the firing elements or igniters.

5.10.4.3 Duct Burner Master Fuel Trip. For an operating duct burner, including the start-up or shutdown sequences, a duct burner master fuel trip shall be initiated by the following conditions:

(1) Low fuel pressure
(2) Combustion turbine exhaust or fresh air (if provided) flow across the duct burner that drops below the minimum required for operation of the duct burner as specified by the burner manufacturer or as proven by trial; it shall be permitted to infer this flow from the operating status of the combustion turbine, fresh air fan (if provided), and damper(s) (if provided) position(s).
(3) Combustion turbine trip

Exception: Systems operating as defined in 5.13.2.4

(4) Loss of all burner flame other than during a normal duct burner shutdown sequence
(5) Partial loss of flame determined to create a hazardous accumulation of unburned fuel at any burner element or zone
(6) Loss of duct burner element(s) resulting in incorrect element firing configuration, in accordance with 5.11.5.8.3
(7) Light-off failure of first burner in multiple burner operation
(8) Failure to prove a safety shutoff valve closed upon command to close
(9) Closing of last individual burner safety shutoff valve other than during a normal duct burner shutdown sequence
(10) High fuel pressure
(11) Low water level on high pressure section of HRSG
(12) Loss of energy supply for boiler control, burner management, or interlock system
(13) Low atomizing media (if provided) supply pressure
(14) Detection of burner management system malfunction
(15) Manual trip *[Refer to 1.9.3.2.2 (8).]*
(16) Loss of augmented air supply where the operation of the duct burner requires augmented air
(17) Fresh air (if provided) transfer failure *(Refer to 5.13.2.4.)*
(18) Expired external watchdog timer time *(Refer to 1.9.3.2.7.)*

5.10.5 Burner management system logic shall be maintained either in nonvolatile storage or in other memory that retains information on the loss of system power.

5.11 Purge, Start-up, Operation, and Shutdown of HRSG Systems.

5.11.1* General.

5.11.1.1 The requirements of 5.11 shall apply where burning gaseous or liquid fuels in HRSG systems. These requirements shall include interlocks for ensuring prescribed action, burner management system trips, flame detection, and an indication of the status of the operating sequences.

5.11.1.2 In addition, the requirements of 5.11 shall apply to the design, installation, and operation of duct burners in HRSG systems. No specific degree of automation beyond the minimum specified safeguards is defined or shall be required, since this is subject to factors such as, but not limited to, physical size of the unit, use of the central control room, degree of reliability required, and experience level of operating personnel.

5.11.1.2.1 A trained operator with access to control equipment shall be stationed to perform the required actions to ensure operation in accordance with the manufacturer's recommendations.

5.11.1.2.2 The start-up of the burner as a first-time function shall be accomplished by an operator at the burner location who has a direct view of the burner. Recycling of the burner in response to steam demand shall be permitted to be an automatic sequence, provided the combustion turbine has not tripped.

5.11.1.2.3 Equipment shall be provided to control HRSG inputs to maintain stable flame throughout the full operating range in accordance with the manufacturer's recommendations.

5.11.2 General Operating Requirements.

5.11.2.1 Prior to Starting. Prior to starting a unit, action shall be taken to prevent fuel from entering the HRSG system.

5.11.2.2 Ignition. The associated igniter for a duct burner shall always be used unless the burner is specifically designed to be lit from an adjacent burner. Burners shall not be lit from any hot surface.

5.11.2.3 Low Capacity Fuel Pressure. Where operating at low capacity, duct burner fuel pressure shall be maintained above the minimum pressure for stable flame by reducing the number of burners in service as necessary.

5.11.2.4 Gaseous Fuel. Before maintenance is performed on the fuel header, it shall be purged. *(Refer to A.1.9.2.)*

5.11.2.5 Liquid Fuel. Before maintenance is performed on the fuel header, it shall be drained and purged. *(Refer to A.1.9.2.)*

5.11.2.6 Liquid Fuel — Scavenging of Liquid Fuel Burner Passages.

5.11.2.6.1 Burner passages shall not be scavenged into a nonoperating HRSG. Combustion turbine exhaust flow shall be functioning and shall be maintained during the scavenging process.

5.11.2.6.2 Igniters, with ignition established, shall be in service when scavenging fuel passages into the HRSG.

5.11.2.7 Sequencing.

5.11.2.7.1 Sequencing shall be required to ensure that operating events occur in the prescribed order. Written procedures shall be provided to sequence the start-up and shutdown of the HRSG system in accordance with this code and the manufacturer's recommendations. Sequencing also shall be utilized when removing burners from operation or adding burners to operation.

5.11.2.7.2* The start-up and shutdown sequence outlined in Section 5.11 shall be followed.

5.11.2.7.3* Duct burners shall be placed in service and removed from service in a sequence specified by operating instructions and verified by actual experience with the unit. Duct burners shall be placed in service with fuel flow as recommended by the manufacturer.

5.11.2.7.4 If the fuel pressure at the burner header is used as a guide in maintaining the necessary fuel flow per burner, it shall be maintained automatically within prescribed limits as additional burners are placed in service.

5.11.2.7.5 Duct burners shall be operated in accordance with the manufacturer's specifications and operating procedures.

5.11.2.7.6 This procedure shall incorporate the following operating objectives:

(1) Purge shall be completed in accordance with 5.11.4 and 5.11.5.
(2) No light-off of the duct burner(s) shall occur until after the combustion turbine has established stable operation with an exhaust gas flow not less than that necessary for duct burner operation.

5.11.2.7.7 Each unit shall be tested during commissioning to determine whether any modifications to the basic procedures are needed to obtain reliable ignition and system operation.

5.11.2.7.8 The unit shall be operated within the specified parameters. Any modifications or deviations shall be made only after the need for such changes has been determined by operating experience and system review.

5.11.3 Cold Start Preparation. Preparation for starting shall include an inspection that includes the following:

(1) A unit free of foreign material and not in need of repair
(2) A unit inspected for accumulated liquid fuel, and draining and cleaning performed if such accumulation present
(3) All personnel evacuated from the unit and associated equipment and all access and inspection doors closed
(4) All duct burner and igniter safety shutoff valves proved closed by valve position and all ignition sources deenergized

Exception: Where the igniter capacity is 5.00 MBtu/hr (1.465 MW) or less, proof of closure of igniter safety shutoff valves by means other than valve position shall be permitted.

(5) Gaseous fuel system vents open and venting to an outside location that does not present a hazard; fuel lines drained of condensate
(6) Circulating valves open to provide and maintain liquid fuel flow in the burner headers
(7) Prescribed drum water levels established in natural and forced circulation HRSGs and prescribed flow established in forced circulation and once-through HRSGs
(8) Burner elements and igniters positioned in accordance with manufacturer's specification
(9) Energy supplied to control systems and to interlocks
(10) Meters or gauges indicating fuel header pressure to the unit
(11) Instrumentation tested and functional
(12) A complete functional check of the interlocks performed after an overhaul or other interlock related maintenance
(13) Verification of an open flow path through the HRSG system

5.11.4 Combustion Turbine Purge and Light-Off.

5.11.4.1* Combustion Turbine Purge. The purge of the combustion turbine shall be in accordance with the manufacturer's instructions and the requirements of 5.11.4.2.

5.11.4.2 Initial Combustion Turbine Purge and Light-Off.

5.11.4.2.1 Purge prior to the light-off of the combustion turbine shall be accomplished by at least five volume changes and for a duration of not less than 5 minutes.

This volume shall be calculated based on the following:

(a) The combustion turbine operating at full load with no supplementary HRSG firing.

(b) The volume from the combustion turbine inlet to the portion of the HRSG where the combustion turbine exhaust gas temperature is reduced to at least 100°F (56°C) below the lowest autoignition temperature of the fuel(s) for which the system has been designed. However, in no case shall this volume be less than the volume of the HRSG enclosure between the combustion turbine outlet and the outlet of the first evaporator section in the HRSG.

5.11.4.2.2 The purge rate shall provide the required velocity within the connecting duct and HRSG enclosure to ensure dilution and removal of combustible gases prior to turbine light-off. The adequacy of this purge rate shall be demonstrated by one of the following methods:

(1) During the purge of the combustion turbine, a flow rate of not less than 8 percent of full-load mass airflow shall be provided through the HRSG, regardless of damper leakage or degradation in the HRSG enclosure
(2)* An engineering model of the system from the outlet of the turbine to the outlet of the HRSG shall be created, and purge adequacy shall be demonstrated with flow testing performed at the equivalent purge conditions

(3) An HRSG system burning fuel(s) of equal density and with the same ductwork and stack geometry has previously been installed and has a documented history of successful start-ups performed in accordance with the manufacturer's recommendations and without occurrences of uncontrolled combustion of fuel accumulations in the HRSG enclosure during turbine light-off
(4) Provision of combustible gas analyzers that would prevent start-up of the combustion turbine if combustible gas concentrations greater than 25 percent of the lower explosive limit (LEL) exist in the HRSG

5.11.4.2.3 In the event that the combustion turbine cannot meet the requirements of 5.11.4.2.2, alternative or supplementary means to satisfy the flow requirements through the HRSG enclosure shall be provided.

5.11.4.2.4 Where augmented air firing is provided, a means shall be supplied for interlocking and purging the augmented air system prior to initiating, and during, the combustion turbine purge.

5.11.4.3 Failure to Start. On failure to start, retrial of the combustion turbine start shall be permitted following a repurge in accordance with 5.11.4.2. In the case of liquid fuel, verification also shall be made that the duct low point(s) is cleared of combustibles *(refer to A.5.7.8.2).*

5.11.4.3.1 When operating experience indicates there are problems in combustion turbine light-off, the light-off attempts shall be terminated and the cause investigated and corrected.

5.11.4.3.2 When firing any liquid fuel or any gaseous fuel that is heavier than air, verification shall be made that the duct low point(s) is cleared of combustibles. This shall be accomplished by one of the following methods:

(1) For a system firing any liquid fuel, the drains shall be checked to verify that they are clear and that no fuel is present. *(Refer to A.5.7.8.2.)*
(2) For a system firing any gas that is heavier than air, the vents shall be checked to verify that no combustible gas is present. *(Refer to A.5.7.8.2.)*

5.11.4.3.3 The second trial to start the combustion turbine with the same or alternate fuel shall be permitted following a repurge in accordance with 5.11.4.2.

5.11.4.3.4 Subsequent trials to start the combustion turbine with the same or alternate fuel shall be permitted following a repurge in accordance with 5.11.4.2 and after proving that combustibles have been removed.

5.11.4.3.5 When analyzing for combustibles, the sampling point(s) shall be selected on the basis of (1) fuel(s), (2) HRSG configuration, and (3) stratification of gases.

5.11.4.4 Post-Purge Airflow. After completing the purge, the airflow through the combustion turbine shall be permitted to be dropped below the purge rate if required by the design to accomplish combustion turbine ignition.

5.11.4.5 Loading of Combustion Turbine. After successful light-off of the combustion turbine, the combustion turbine shall be brought to speed and loaded as necessary to meet system demands. The loading of the combustion turbine shall be performed in accordance with the manufacturer's requirements and any restrictions imposed by HRSG parameters.

5.11.5 Duct Burner Purge and Light-Off.

5.11.5.1 The duct burner purge shall be accomplished with a flow utilizing air or combustion turbine exhaust at not less than 25 percent of full-load mass flow rate or the minimum flow necessary for operation of the duct burners, whichever is greater.

5.11.5.2 The duct burner purge shall accomplish at least eight volume changes of the HRSG enclosure, after combustion turbine exhaust flow in accordance with 5.11.5.1 has been achieved.

5.11.5.3 Purge prior to light-off of the combustion turbine shall not be considered a duct burner purge unless the requirements of 5.11.5.1 and 5.11.5.2 have been satisfied.

5.11.5.4 Where augmented air firing is provided, the augmented air plenum and associated ductwork shall be purged into the HRSG enclosure. This purge shall be performed in addition to the duct burner purge required in 5.11.5.2.

5.11.5.5 A duct burner trip or failure to light off duct burners successfully shall require a repurge in accordance with 5.11.5.1 and 5.11.5.2 prior to attempting a relight.

5.11.5.6 A duct burner purge shall be considered to have been achieved, provided the duct burner purge rate is maintained and all duct burner purge requirements have been satisfied. The duct burner shall be permitted to be lit, or a normal shutdown made, provided that credit for the purge is maintained. Failure of the duct burner purge rate to be maintained or failure to meet any duct burner purge requirement shall require a repurge in accordance with 5.11.5.1 and 5.11.5.2.

5.11.5.6.1 The mass flow of combustion air to the duct burner system shall be maintained at or above its purge rate and within the duct burner design operating range during all operations of the duct burner system.

5.11.5.7 Testing igniters for duct burners shall be conducted in accordance with the following:

(a) Operational tests of each igniter shall be made. The frequency of testing shall be based on the design and operation history of each individual HRSG and ignition system. The test shall be made during each start-up following an overhaul or other igniter-related maintenance.

(b) Individual igniters or groups of igniters shall be permitted to be tested while the unit is in service. Such tests shall be made with no main fuel present in the igniter's associated burner.

5.11.5.8* Starting Sequence.

5.11.5.8.1 The operating sequences described in 5.11.5.8 shall be used for multiple element duct burners operated independently of each other. For installations with a duct burner (single element or multiple element) operated as a single unit, the applicable procedures outlined in 5.11.5.8 shall be followed.

Exception: For duct burners operated as a single unit, sequences of 5.11.5.8 unique to multiple burner operations shall not apply.

5.11.5.8.2 The starting sequence shall be as follows:

(a) All duct burner and igniter safety shutoff valves shall be proven to be closed in accordance with 5.11.3(4).

(b) The main fuel header and the igniter fuel header shall be pressurized up to the individual burner and igniter safety shutoff valves in accordance with established operating procedures.

(c) The individual igniter safety shutoff valve(s) shall be opened, and the ignition transformer(s) shall be energized. If an igniter's flame is not proven within 10 seconds after its igniter safety shutoff valve has been opened, its safety shutoff valve shall be closed. The cause of failure to ignite shall be determined and corrected. With turbine exhaust flow maintained, repurge shall not be required, but at least 1 minute shall elapse before attempting a retrial of any igniter(s).

(d) The main fuel control valve shall be set to and proven to be at the burner light-off position.

(e) Where igniter flames are proven, the individual burner safety shutoff valve(s) shall be opened. If no burner flame is proven within 5 seconds after main fuel enters the duct, a duct burner master fuel trip shall occur. Where flame is not proven on an individual burner, that individual burner's safety shutoff valve and individual igniter safety shutoff valve shall close. The cause for failure to ignite shall be determined and corrected. At least 1 minute shall elapse before the next light-off is attempted.

(f) After each stable burner flame is proven, the igniter shall be shut off unless classified as Class 1 or Class 2. The stability of the burner flame shall be verified.

(g) The associated igniter for a burner shall be used to light the burner unless the burner is specifically designed to be lit from an adjacent burner. Burners shall not be lit from any hot surface.

(h) Second or succeeding igniters shall be lit in accordance with 5.11.5.8.2(c).

(i) Second or succeeding burners shall be lit in accordance with 5.11.5.8.2(e). The main fuel control valve shall not be modulated when bringing second or succeeding burners into service.

(j) After each successive burner light-off, the operator shall verify the flame stability of all operating burners.

5.11.5.8.3 Single burner operation shall be allowed when the burner elements have individual safety shutoff valves. An operating procedure shall be developed to prescribe the number(s) and location(s) of burner elements allowed to be out of service as defined by the HRSG and duct burner manufacturers.

5.11.6 Normal Operation.

5.11.6.1 The HRSG steaming rate shall be regulated by combustion turbine loading and duct burner exhaust temperature.

5.11.6.2 The firing rate shall be regulated by varying the fuel to individual burners by means of a fuel control valve(s) or by staged firing where burners are brought in or taken out of service.

5.11.6.2.1 Individual burner safety shutoff valves shall not be used to vary the fuel rate of the burner elements. All safety shutoff valves shall be fully open or completely closed; intermediate settings shall not be used.

5.11.6.3 The burner fuel shall be maintained within a range between the maximum and minimum limits specified by the burner and HRSG manufacturers or as determined by trial. These trials shall test for minimum load and for stable flame as follows:

(1) With all burners in service and combustion control on automatic
(2) With different combinations of burners in service and combustion control on automatic

When changes occur to the minimum and maximum limits because of various burner combinations and fuel conditions, retesting shall be required.

5.11.6.4 On loss of an individual burner flame, that burner's individual safety shutoff valve and the associated igniter safety shutoff valve shall close.

5.11.7 Normal Shutdown.

5.11.7.1 Burners shall be shut down sequentially by closing the individual burner safety shutoff valves or in unison by closing all safety shutoff valves.

5.11.7.2 The duct burners shall be taken out of service with verification that the safety shutoff valves are secured in the closed position.

5.11.7.3 When taking the unit (combustion turbine and duct burner) out of service, the combustion turbine load shall be reduced in accordance with the manufacturer's shutdown procedures.

5.11.7.4 Required steam flow shall be maintained through the superheater.

5.11.7.5* The coast-down of the combustion turbine shall satisfy requirements of a post-purge of the system.

5.11.7.6 Leakage of fuel into the unit shall be prevented.

5.11.8 Normal Hot Restart.

5.11.8.1 When restarting a hot combustion turbine, the requirements for cold start preparation as described in 5.11.3(4) through (10) and (13) shall be followed.

5.11.8.2 The starting sequences of 5.11.4 and 5.11.5 shall be followed.

5.11.9 Duct Burner Emergency Shutdown.

5.11.9.1 A duct burner master fuel trip shall be initiated by the conditions identified in 5.10.4.3.

5.11.9.2 Gaseous Fuel. A duct burner master fuel trip shall stop all fuel flow to the HRSG from all burners by tripping the main and individual burner safety shutoff valves. All vent valves shall be opened. The igniter safety shutoff valve and individual igniter safety shutoff valves shall be tripped and igniter sparks deenergized. Duct burner master fuel trips shall operate to stop all fuel flow to the burners. All igniters or other ignition sources shall be tripped.

5.11.9.3 Liquid Fuel. A duct burner master fuel trip shall stop all fuel flow to the HRSG from all burners by tripping the main and individual burner safety shutoff valves. The igniter safety shutoff valve and individual igniter safety shutoff valves shall be tripped and igniter sparks deenergized. Duct burner master fuel trips shall operate to stop all fuel flow to the burners. All igniters or other ignition sources shall be tripped.

5.11.9.4 The burners shall not be reignited until the initiating trip condition has been investigated and corrected and a duct burner purge has been completed.

5.12 Combustion Turbine Exhaust Bypass Systems.

5.12.1* General.

5.12.1.1 The requirements of 5.12 shall apply to HRSG systems equipped with HRSG isolation and bypass dampers or a diverter damper.

5.12.1.2 Because the application of dampers in HRSG systems adds to the complexity of the systems and presents hazards, which cause additional safety and property damage exposures, the owner or owner's representative shall evaluate the hazards of the proposed configuration.

5.12.1.3 The owner or owner's representative shall apply safeguards to reduce the exposures identified in 5.12.1.2.

5.12.1.4 The hazard evaluation and proposed measures to reduce the hazards shall be documented and kept on file for review.

5.12.1.5 Requirements of Chapter 1 and preceding sections of Chapter 5 shall be applied, unless amended by Section 5.12, or by the hazard evaluation.

5.12.1.6 The owner or owner's representatives shall address the implications of the following hazards associated with damper applications:

(a) Due to the physical size, shape, and mass, a damper shall not be assumed to fully seal a gas flow path.

(b) A leaking fuel valve or a combustion turbine false start will result in an explosive mixture in the HRSG on either or both sides of a damper during shutdown periods.

(c) Failure to purge an explosive mixture prior to introduction of hot turbine exhaust gas will result in ignition of the mixture. Even at full speed and no load, the combustion turbine exhaust temperatures can be above the autoignition temperatures for combustion turbine and HRSG fuels.

(d) Systems using two stacks (HRSG and bypass), with or without dampers, tend to induce a reverse flow of fresh air through the HRSG as a result of the high temperature gas flow up the bypass stack.

(e) Failure of damper operating mechanisms will allow instantaneous reversal of damper position (from open position to closed position and vice versa) due to aerodynamic effects. Sudden closure of an operating combustion turbine free exhaust path will result in high transient duct internal pressures. These high pressures can cause distortion of the HRSG enclosure and rupture of the duct expansion joints.

(f) Combustion turbine exhaust temperatures are high enough to ignite and sustain the basic iron fire oxidation reaction.

5.12.2 Purge.

5.12.2.1 Unfired HRSG.

5.12.2.1.1 A purge of both the HRSG enclosure and the bypass system shall be completed as required in 5.11.4 prior to admitting combustion turbine exhaust gas into the HRSG.

5.12.2.1.2 Following the purge as required in 5.12.2.1.1, it shall be permitted to interrupt the flow through the HRSG using the gas bypass stack. Combustion turbine exhaust flow shall be permitted to reenter the HRSG at a later time without repurging, provided the combustion turbine has been in continuous operation with no trips or misfires.

5.12.2.1.3 Where HRSG isolation is maintained, the combustion turbine shall be permitted to purge and operate with combustion turbine exhaust through the bypass stack.

Exception No. 1: When HRSG isolation is removed, a purge of the HRSG enclosure shall be performed as required by 5.12.2.1.1. After this purge, an interruption as allowed by 5.12.2.1.2 is again permitted.

Exception No. 2: In the event that HRSG isolation is disabled and the combustion turbine can continue to be operated with an exhaust temperature at least 100°F (56°C) lower than the autoignition temperature of fuels designed for use in the specific combustion turbine, the combustion turbine exhaust gas at this lower temperature shall be permitted to be used to purge the HRSG.

5.12.2.2 Fired HRSG.

5.12.2.2.1 A purge of both the HRSG enclosure and the bypass system shall be completed as required in 5.11.4 prior to admitting combustion turbine exhaust gas into the HRSG.

5.12.2.2.2 Where HRSG isolation is continuously maintained, the combustion turbine shall be permitted to purge and operate with combustion turbine exhaust through the bypass stack.

Exception No. 1: When HRSG isolation is removed, a purge of the HRSG enclosure shall be performed as required by 5.12.2.2.1.

Exception No. 2: In the event that HRSG isolation is disabled and the combustion turbine can continue to be operated with an exhaust temperature at least 100°F (56°C) lower than the autoignition temperature of fuels designed for use in the specific combustion turbine and duct burner, the combustion turbine exhaust gas at this lower temperature shall be permitted to be used to purge the HRSG.

5.12.2.2.3 If damper(s) operation or other cause(s) results in the exhaust mass flow through the HRSG falling below the purge rate required in 5.11.5, a repurge as required in 5.11.5 shall be performed prior to lighting the duct burner.

5.12.2.2.4* When it is desired to bypass the HRSG for a period of time and then return the HRSG to service by means of damper positioning without a power interruption, a continuous flow of at least the purge rate of exhaust or fresh air shall be maintained through the HRSG when the combustion turbine is operating.

5.12.3 Dampers.

5.12.3.1 The requirements of 5.12.3 shall apply regardless of physical hardware, that is, single-bladed diverting damper, two separate dampers (single or multiblade) for isolation or bypass service, or multiple dampers in series with seal air provision.

5.12.3.2 Damper System.

5.12.3.2.1 The gas bypass damper failure mode shall be determined, and the exposed system shall be capable of withstanding the resultant transient design pressure as defined in 5.7.2.

5.12.3.2.2 A means shall be provided for recognizing leakage of combustion turbine exhaust gas past a closed damper and into the HRSG enclosure.

5.12.3.2.3 Where leakage is detected, the HRSG shall be purged at a temperature at least 100°F (56°C) below the autoignition temperature of the fuel before allowing hot combustion turbine gases to enter the HRSG enclosure.

5.12.3.2.4 Where leakage results in an HRSG enclosure temperature above the temperature required to ignite and sustain an iron fire oxidation reaction *(refer to Section 5.3)*, safeguards shall be taken to maintain water supply to the HRSG for tube cooling.

5.12.3.2.5 When HRSG isolation or diverter dampers are utilized, duct burner liquid fuel elements shall be scavenged prior to isolation of the HRSG.

5.12.3.2.6 HRSG isolation shall be provided if either of the following operating conditions are encountered:

(1) Work within the HRSG enclosure is necessary while the combustion turbine is exhausting through the bypass stack.
(2) The HRSG is devoid of water while the combustion turbine is exhausting through the bypass stack.

Exception: An HRSG specifically designed by the HRSG manufacturer to run dry.

5.12.3.2.7 The HRSG enclosure shall be proven free of combustible materials, or the HRSG enclosure that is downstream of the HRSG isolation damper shall be purged to meet the requirements of 5.11.4.

5.12.3.2.8 Where shutoff dampers are utilized, a means to prevent combustible fuel accumulation upstream of the damper shall be provided.

5.12.3.2.9 When HRSG isolation has been implemented, all fuel sources to the duct burner shall be secured using lockout and tag-out procedures.

5.12.3.2.10 During scheduled maintenance outages, the owner or operator shall perform the following inspections and tests:

(1) Inspect the damper system for tightness when the damper(s) is fully closed
(2) Check the damper operating devices for correct operation
(3) Verify correct damper system positioning by functional test during purge, start-up, and shutdown

5.12.4 Monitoring.

5.12.4.1 In addition to the requirements in 5.10.2.3, the position of the damper(s) shall be continuously monitored.

5.12.4.2 In addition to the required alarms in 5.10.3.2, reverse flow through an HRSG (airflow from exhaust stack through an HRSG to bypass stack) shall be alarmed if the bypass damper system can be maintained in an intermediate position.

5.12.5 Interlocks.

5.12.5.1 To satisfy the position of the stack closure correct interlock *[refer to 5.6.2.3.1(5)]*, one of the following conditions shall be met:

(1) The bypass damper proven open, and the HRSG isolation damper closed
(2) Both the HRSG isolation damper and the stack damper (if provided) proven open
(3) Diverter damper proven open to atmosphere
(4) Diverter damper proven open to HRSG, and stack damper (if provided) proven open

5.12.5.2 To satisfy the position of stack closure not correct interlock *(refer to 5.6.2.3.2)*, either of the following conditions shall be met:

(1) The bypass damper proven closed, and either HRSG isolation damper or stack damper (if provided) not proven open

Exception: Where the bypass damper is designed to open to prevent pressurization above the design limit of the combustion turbine exhaust plenum.

(2) The diverter damper proven open to HRSG, and stack damper (if provided) not proven open

5.12.5.3 A duct burner master fuel trip shall be initiated if the bypass damper (if provided) is not proven closed or if the diverter damper (if provided) is not proven fully open to the HRSG *[refer to 5.10.4.3(2)]*.

Exception: If the HRSG system is designed for duct burner operation with intermediate damper position(s), minimum exhaust flow or incorrect damper position shall be interlocked to initiate a duct burner master fuel trip. This position shall be proven by a limit switch and documented during commissioning.

5.13* Combustion Turbine and HRSG with Fresh Air Firing Capability.

5.13.1* General. Fresh air firing (with or without preheating) shall be permitted, provided that the HRSG flow path is reconfigured with dampers and airflow is generated with either a forced draft or induced draft fan. The volume or mass airflow shall not be required to be equal to the combustion turbine exhaust flow.

5.13.1.1 The requirements of Section 5.13 shall apply to fresh air firing operation regardless of equipment configuration. The requirements of Section 5.12 shall apply except where amended in this section.

5.13.1.2 Under no circumstances shall a fresh air–fired HRSG be considered a boiler as defined by Section 1.3 of this code.

5.13.2 Operational Considerations.

5.13.2.1 Because of the lack of standardization of fresh air firing configurations, and because of the potential for injury if the system malfunctions, each system's operational failure modes shall be analyzed and safeguards provided.

5.13.2.2 Each system's operating mode shall be evaluated to ensure safe operation during transfer from combustion turbine operation to fresh air firing mode and from fresh air firing mode to combustion turbine mode.

5.13.2.3 For fresh air firing, the owner or the owner's designated representative shall assess the following operational modes:

(1) The HRSG system with the combustion turbine in operation, with or without duct burner firing
(2) Duct burner system compliance with applicable sections of Chapter 2 or Chapter 3, with the HRSG system in the fresh air firing mode
(3) Compliance with applicable sections of Chapters 2 and 3, as well as the preceding sections of Chapter 5 when combustion turbine is exhausting through a bypass stack with the HRSG operating in the fresh air firing mode system

5.13.2.4 Fresh air firing shall not be combined with operation on combustion turbine exhaust except during periods of transition between modes. The transition period between modes shall be evaluated. The system designer shall incorporate design features and safeguards against the increased hazards.

5.13.2.5 When switching from turbine exhaust gas mode to fresh air firing mode automatically, the duct burner must have been firing and stable flame established according to the previous sections of Chapter 5. Immediately upon a combustion turbine trip, the duct burner fuel flow control valve shall be driven to light-off position. The light-off position switch must be proven within 10 seconds of a combustion turbine trip; otherwise, a duct burner master fuel trip shall be initiated.

5.13.3 Purge.

5.13.3.1 During the system start-up with combustion turbine operation, purge shall be in accordance with the requirements of 5.11.4 and 5.11.5.

5.13.3.2 Equipment used solely for the fresh air firing mode shall be isolated.

5.13.3.3 All plenums or ductwork associated with fresh air firing shall be purged into the HRSG enclosure.

5.13.3.4 During fresh air firing system start-up, a duct burner purge in accordance with 5.11.5 shall be required.

5.13.3.4.1 The combustion turbine shall be isolated to prevent reverse flow to ensure a complete purge.

5.13.3.4.2 A means of ensuring that the combustion turbine ductwork is free of combustible mixtures shall be provided.

5.13.3.5 During transfer from combustion turbine operation to the fresh air firing mode, a credit for the purge shall be maintained as long as the flow rate through the HRSG enclosure is at or above the purge rate. The duct burner may be shut down and immediately relit, provided the flow remains above purge rate.

5.13.3.6 During transfer from the fresh air firing mode to combustion turbine operation, loss of purge credit shall require a combustion turbine purge in accordance with 5.11.4, with purge flow directed through the HRSG enclosure or bypass stack.

5.13.4 Controls, Monitoring, Alarms and Interlocks.

5.13.4.1 In addition to the requirements of 5.10.2.3, the combustion turbine exhaust flow or airflow through the HRSG enclosure shall be monitored.

5.13.4.2 In addition to the requirements of 5.10.3, reverse combustion turbine exhaust flow or airflow through the HRSG enclosure shall be alarmed.

5.13.4.3 The following additional duct burner permissives shall be provided for fresh air firing:

(1) The damper in the correct position
(2) The fresh air fan operating
(3) Fresh airflow greater than the purge rate specified in 5.11.5

5.13.4.4 A combustion turbine trip shall cause a duct burner master fuel trip unless flow through the HRSG enclosure is maintained at or above the purge rate. During the automatic transition from turbine exhaust gas to fresh air firing mode, all dampers must be proven in the correct position for fresh air firing within a time limit as determined and documented during commissioning.

5.13.4.5 If a combustion turbine trip occurs and flow is at or above the purge rate, the duct burner firing rate shall be reduced to a predetermined minimum.

5.13.4.6 The system shall be reviewed to confirm that applicable portions of Chapters 2, 3, and 5 are satisfied.

Chapter 6 Pulverized Fuel Systems

6.1 Scope.

6.1.1 This chapter shall apply to pulverized fuel systems, beginning with the raw fuel bunker, which is upstream of the pulverizer, and the point at which primary air enters the pulverizing system, and terminating at the point where pressure can be relieved by fuel being burned or collected in a device that is built in accordance with this code. The pulverized fuel system shall include the primary air ducts, which are upstream of the pulverizer, to a point where pressure can be relieved by application of a suitable vent or other means.

6.1.2 This chapter shall cover only those fuels having reactivities greater than that of Pennsylvania anthracite with a volatile content of 8 percent on a dry basis. Reactivity of a fuel, relative to this base, shall be determined by the pulverizer manufacturer utilizing the manufacturer's own technique, and applicability of the code shall be determined and agreed to by the user.

6.1.3 This chapter shall exclude those systems that have an oxygen content greater than 21 percent, which require special attention.

6.2 Purpose.

6.2.1 The purpose of this chapter shall be to establish minimum requirements for design, installation, operation, and maintenance of pulverized fuel systems.

6.2.2 This chapter shall apply to any retrofit that involves replacement of the entire pulverized fuel system as defined in 6.4.5.1 and 6.4.5.2. For less than total system replacement, components shall meet the requirements of this chapter or the original code or standard of construction.

6.3 General.

6.3.1* Functional Requirements.

6.3.1.1 Because fires and explosions are most likely to occur during start-up or shutdown or after an emergency trip, pulverized fuel systems and their components shall be designed for and capable of continuous operation. Interruptions shall be kept to an absolute minimum because of the combustible and explosive nature of the pulverized fuels.

6.3.1.2 The pulverized fuel system shall be designed to meet the demands of the system that it serves over the required range of operation.

6.3.2* Hazards in Pulverized Fuel Systems. Design, operation, and maintenance of a pulverized fuel system shall address inherent hazards.

6.4 Design.

6.4.1 Introduction. General requirements for pulverized fuel systems shall be covered by this section. Specific requirements for only the more commonly used direct-fired unit systems and storage systems are covered in detail. *(For other types of systems, refer to Section 6.6.)*

6.4.2 System Arrangement Requirements.

6.4.2.1 The system arrangement shall be such that it provides only one possible direction of flow (i.e., from the points of entrance of fuel and air to the point of discharge), which can be either a furnace or a transport and collection system.

6.4.2.1.1 Means shall be provided to resist the passage of air or gas from the pulverizer through the feeder into the bunker. A vertical and cylindrical column of fuel shall be sized to withstand pulverizer operating pressures, but it shall be no less than 3 pipe diameters.

6.4.2.1.2 The primary air or flue gas supply shall be taken from a source with a pressure that is equal to or higher than that against which fuel will be discharged from the system.

6.4.2.2 The system shall include indicators and annunciators that provide the operator with all necessary information about significant operating conditions, both normal and abnormal, throughout the system.

6.4.3 Piping Arrangement.

6.4.3.1 Piping shall be arranged to prevent hazardous accumulation of fuel.

6.4.3.2 Where the air/fuel stream is directed into multiple pipes, the system shall divide the air/fuel mixture into design ratio among various pipes.

6.4.3.3 Positive means shall be provided to ensure that all pipe velocities are equal to or above the minimum velocity required for fuel transport and to prevent flashback from the burners. Testing during initial start-up and retesting as appropriate shall be performed to verify that individual pipe velocities are adequate.

6.4.3.4 All piping system components shall be capable of being cleared of pulverized fuel using transport air.

6.4.4 Inerting Arrangement.

6.4.4.1 Where an inerting system is required in accordance with 6.4.6.8, it shall be permanently installed and equipped with connections, which shall be a minimum of 1-in. (2.54-cm) diameter. Injection shall be controlled by readily operable valves or dampers. *(Refer to NFPA 69, Standard on Explosion Prevention Systems.)*

6.4.4.2 Operation of these valves shall be accomplished at a location that is remote from the pulverized fuel system.

6.4.5 System Arrangements.

6.4.5.1 Direct-Fired Systems.

6.4.5.1.1 These systems, as shown in Figures 6.4.5.1.1(a) through (f), shall be permitted to have the fan located either following or ahead of the pulverizer. If auxiliary air is used, a damper shall be in this line. The usual direct-firing pulverized fuel system shall be permitted to be comprised of the following components:

(1) Raw fuel bunker
(2) Raw fuel gate
(3) Raw fuel feeder
(4) Flow control of raw fuel
(5) Feeder discharge piping
(6) Air-swept pulverizer
(7) Classifier
(8) Foreign material–collecting hopper
(9) Pulverizer air fan or exhauster
(10) Source of hot air
(11) Source of tempering air
(12) Temperature control of air
(13) Flow control of air
(14) Piping and ducts
(15) Valves
(16) Dampers
(17) Burners
(18) Means of inerting
(19) Safety interlocks and alarms

6.4.5.1.2 Valve Requirements.

6.4.5.1.2.1 For a suction furnace that can be fired by other main fuels or is connected to two or more pulverizers or exhausters, valves — as shown in Figure 6.4.5.1.2.1 details (c), (d), (e), (f), (g), (h), and (i) — shall be installed to isolate all burner lines. This requirement shall be permitted to be met with one dusttight and one barrier valve or with two dusttight valves. A dusttight valve shall be installed in the burner pipe close to the furnace. The second valve shall be installed close to the pulverizer. The valves shall be closed prior to entering a pulverizer, exhauster, or fuel piping.

FIGURE 6.4.5.1.1(a) Direct-firing pulverized fuel exhauster system for suction furnace.

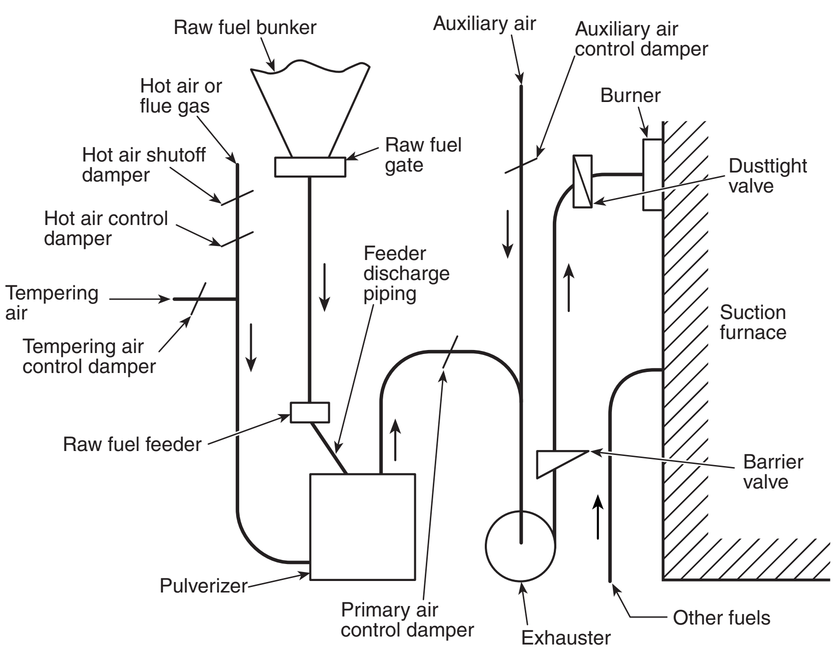


FIGURE 6.4.5.1.1(b) Direct-firing pulverized fuel hot primary air fan system for suction furnace.

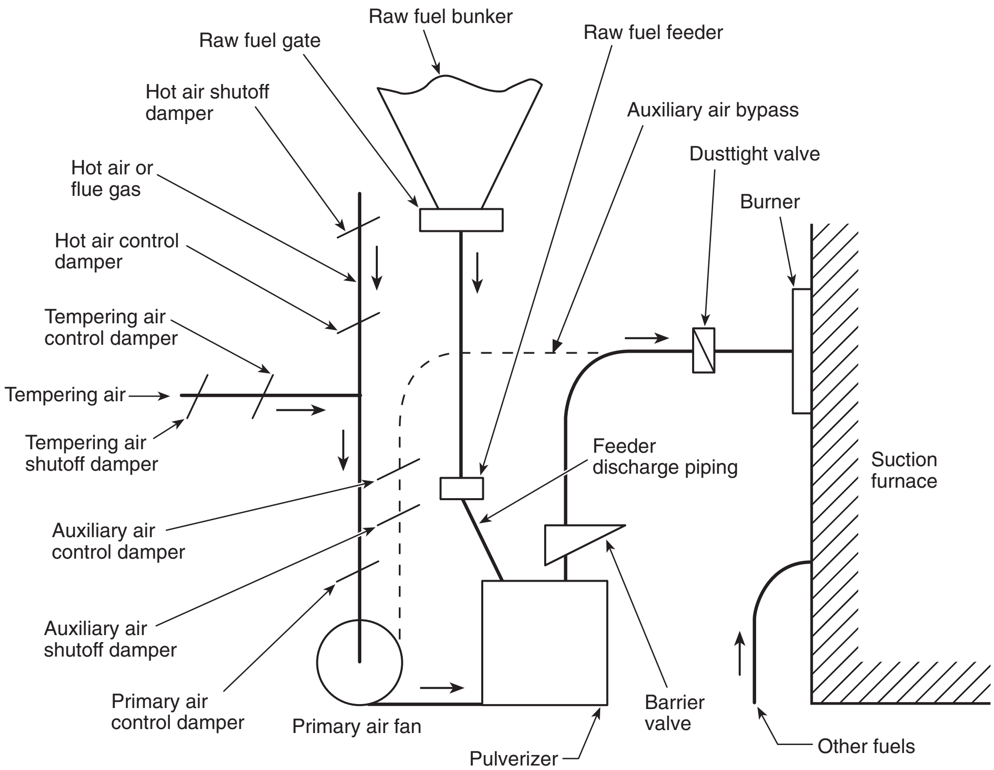


FIGURE 6.4.5.1.1(c) Direct-firing pulverized fuel exhauster system for positive pressure furnace.

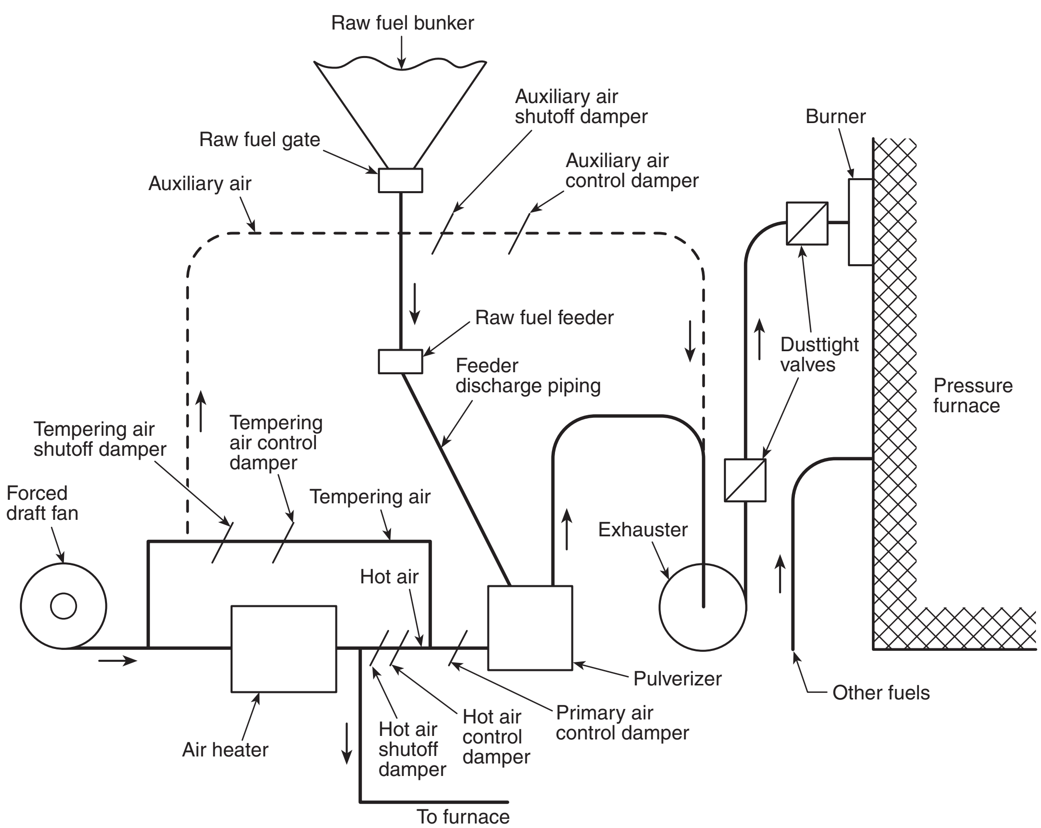


FIGURE 6.4.5.1.1(d) Direct-firing pulverized fuel hot primary air fan system for pressure furnace.

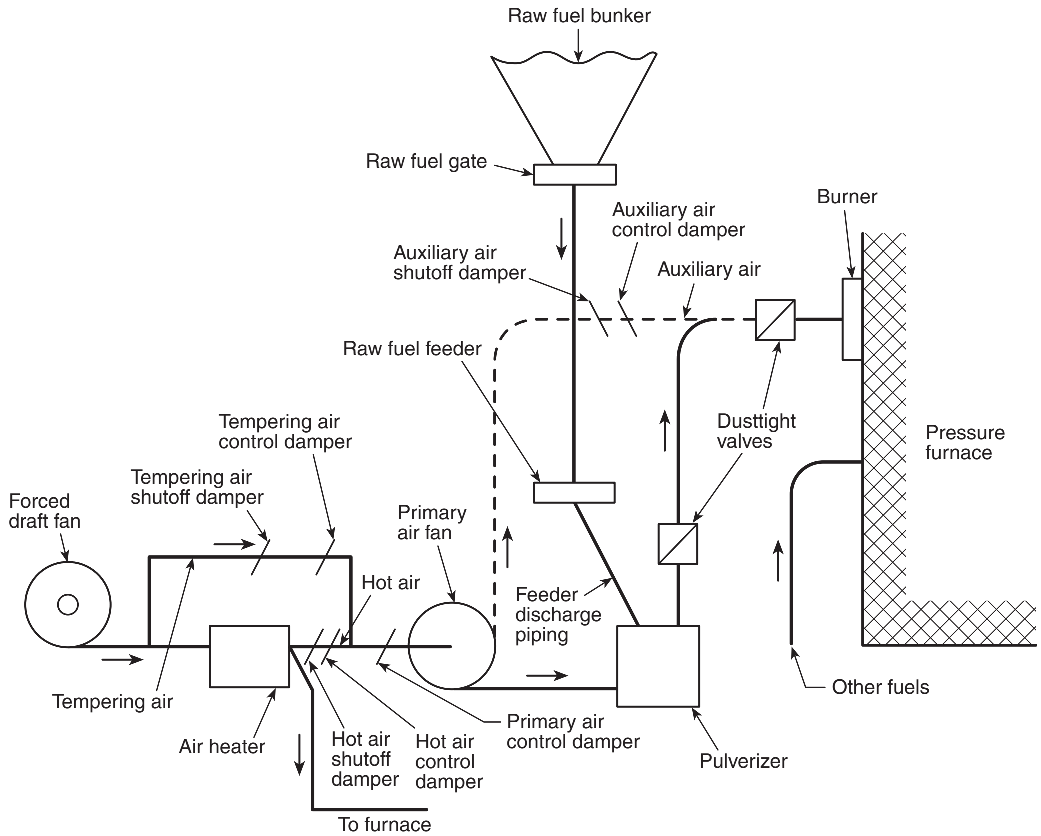


FIGURE 6.4.5.1.1(e) Direct-firing pulverized fuel cold primary air fan system for pressure furnace.

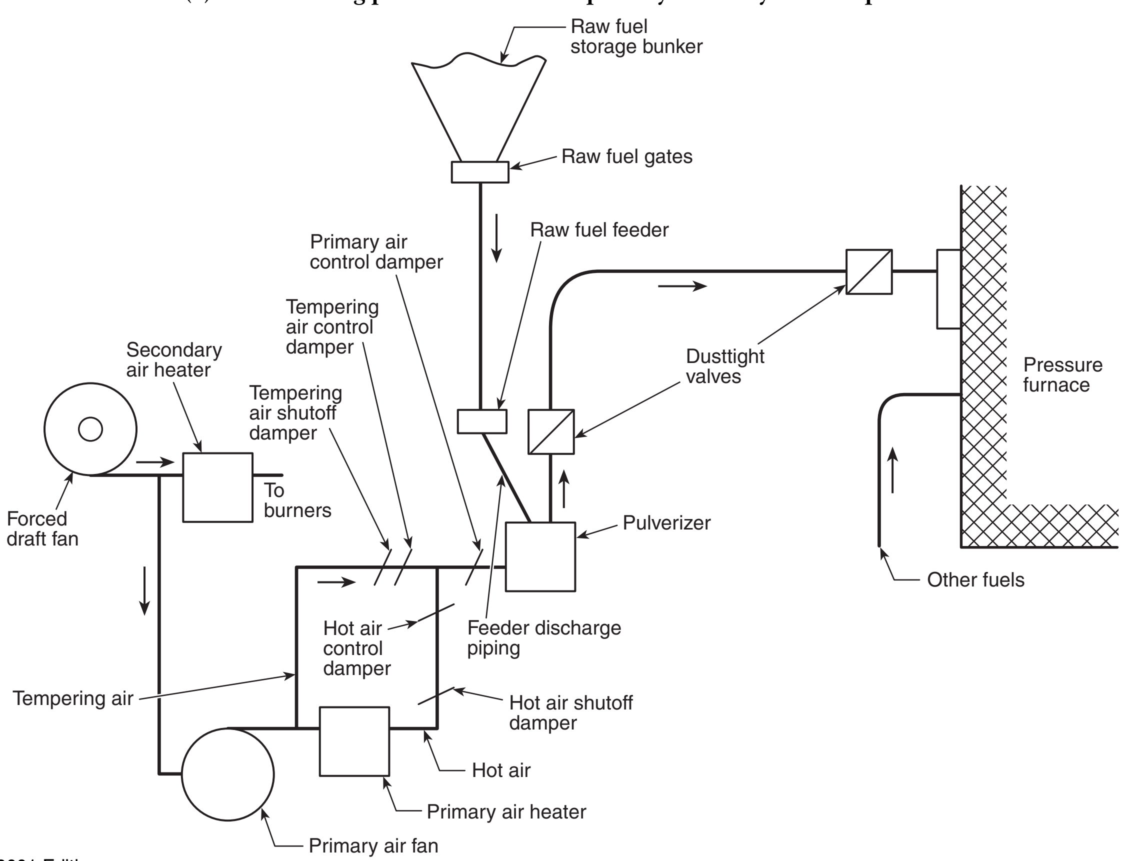
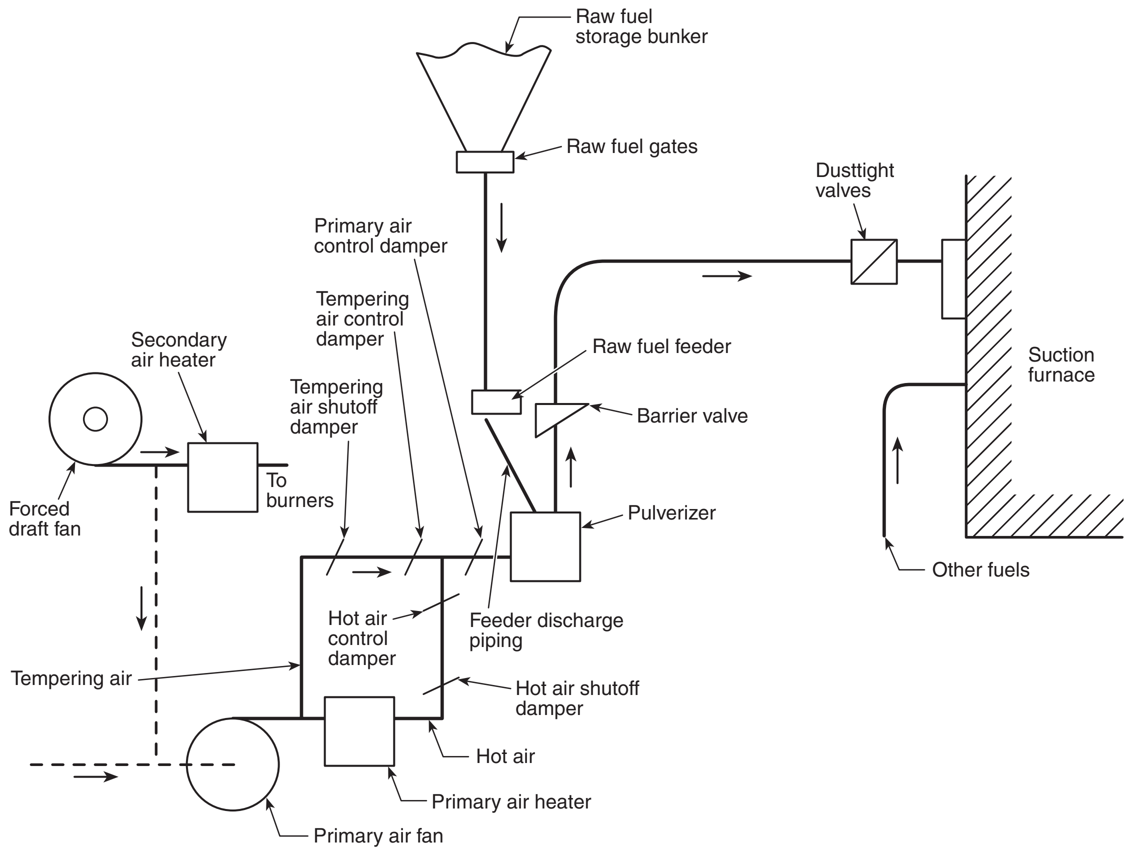


FIGURE 6.4.5.1.1(f) Direct-firing pulverized fuel cold primary air fan system for suction furnace.



6.4.5.1.2.2 For a pressure furnace that can be fired by other main fuels or is connected to two or more pulverizers or exhausters, a dusttight valve, as shown in Figure 6.4.5.1.2.1, details (j), (k), and (l), shall be installed to isolate all burner lines. In addition, a second dusttight valve shall be installed close to the furnace. Both valves shall be closed prior to entering a pulverizer, exhauster, or fuel piping

6.4.5.1.2.3 One of the valves in 6.4.5.1.2.1 and 6.4.5.1.2.2 shall be quick closing.

6.4.5.1.2.4 If one valve is used to isolate more than one burner line, means shall be provided to prevent circulation between those lines or burners.

6.4.5.1.2.5 Two dusttight valves or one dusttight valve and one barrier valve, as shown in Figure 6.4.5.1.2.1, details (g), and (h), shall be provided in each burner pipe if one or more pulverizers is connected to more than one suction furnace at a time.

6.4.5.1.2.6 When one or more pulverizers, as shown in Figure 6.4.5.1.2.1, detail (l), is connected to two or more pressure furnace(s) at the same time, valve requirements of 6.4.5.1.2.2 shall apply.

6.4.5.1.2.7 Two dusttight valves or one dusttight valve and one barrier valve, as shown in Figure 6.4.5.1.2.1, detail (i), shall be installed in the burner piping when the discharge pipes from separate exhausters or pulverizers are connected to the same burner nozzle of a suction furnace.

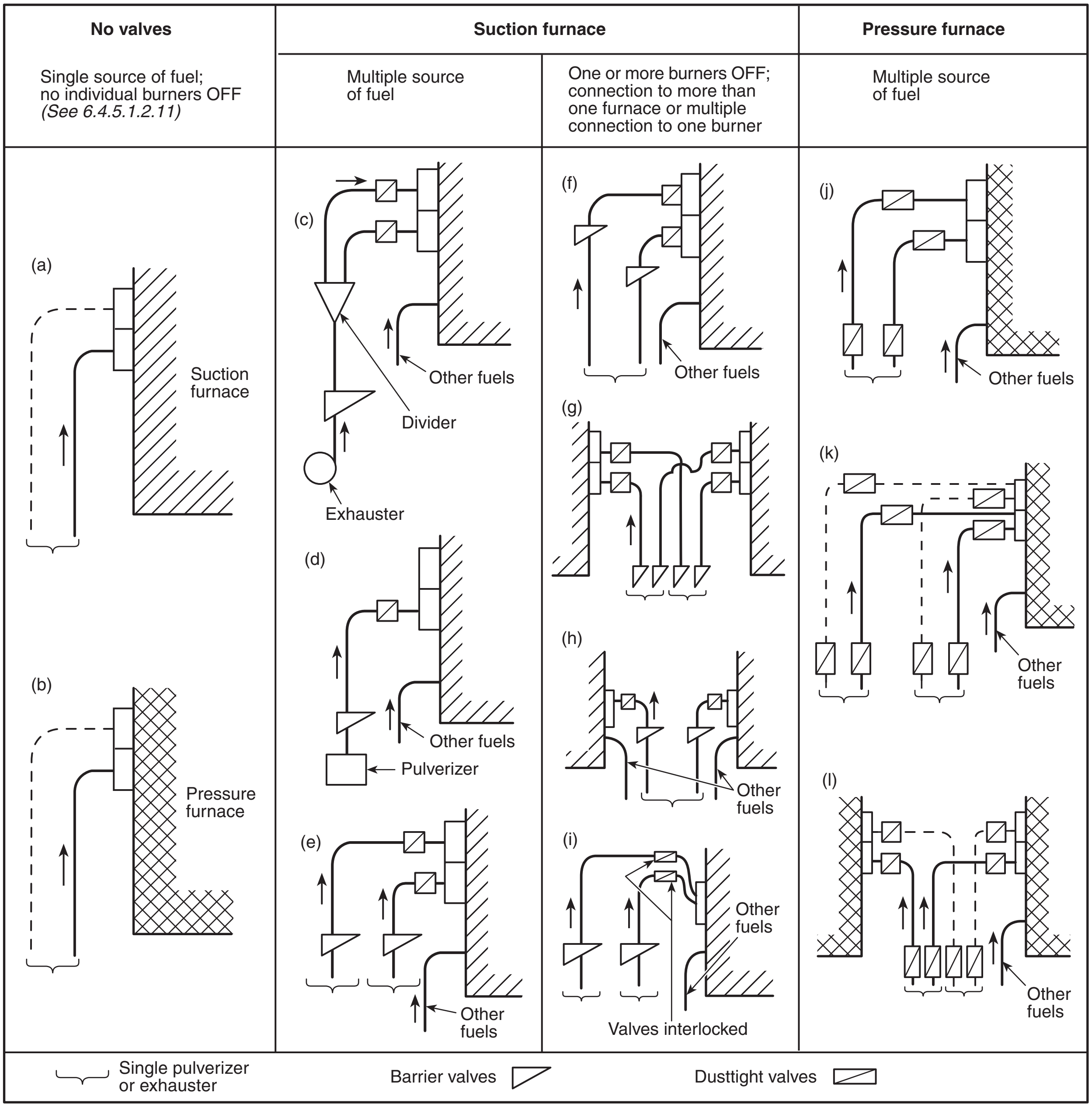
6.4.5.1.2.8 Two dusttight valves, as shown in Figure 6.4.5.1.2.1, detail (k), shall be installed in the burner piping when the discharge pipes from separate exhausters or pulverizers are connected to the same burner nozzle of a pressure furnace.

6.4.5.1.2.9 The valve that is located nearest to the pulverizer shall be so positioned that pulverized fuel accumulations above the valve will drain into the exhauster or pulverizer when the valve is opened. Other valves shall be located so as to prevent accumulation of pulverized fuel.

6.4.5.1.2.10 Figures 6.4.5.1.1(a) through (f), Figure 6.4.5.1.2.1, details (a) through (l), and the accompanying text illustrate and specify requirements for the usual combinations of equipment; if other combinations are used, they shall conform to the principles set forth in this code.

6.4.5.1.2.11 Unless required by the inerting system, valves shall not be required between the pulverizer and the burners for a single pulverizer or exhauster connected to one or more burners in a furnace that cannot be fired by any other main fuel, provided that the combustion air to individual burners cannot be shut off *[Figure 6.4.5.1.2.1, details (a) and (b)]*. If combustion air can be shut off to individual burners, 6.4.5.1.2.1 and 6.4.5.1.2.2 shall apply.

FIGURE 6.4.5.1.2.1 Direct-firing pulverized fuel system's valve requirements in burner piping.



6.4.5.1.3 Air Supply Isolation Requirements.

6.4.5.1.3.1 For pressurized pulverizers and suction pulverizers with pressurized air supply installations, there shall be a means for tight shutoff of the hot air supply and a means for shutting off the primary air supply to each pulverizer.

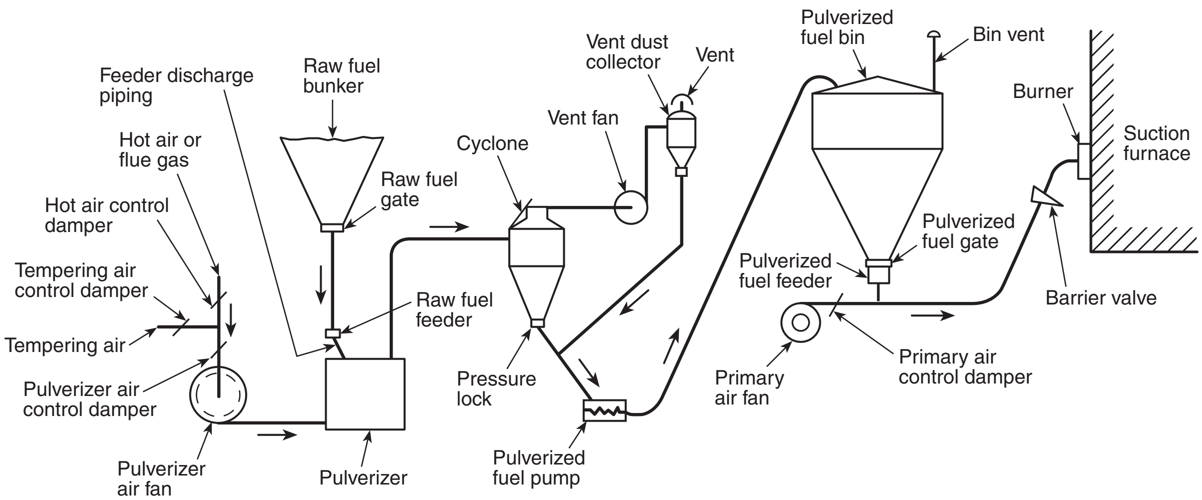
6.4.5.1.3.2 For suction pulverizer installations with an atmospheric tempering air supply, there shall be a means for shutting off the hot air supply.

6.4.5.2 Storage-Firing Systems.

6.4.5.2.1 These systems, as shown in Figures 6.4.5.2.1(a) through (g), shall be arranged to permit partial or complete venting of the pulverizer air and water vapor after separating the pulverized fuel in cyclones or other types of dust collectors. The separated fuel is transported to storage bins for subsequent supply to the burners. In addition to the components of a direct-fired system as listed under 6.4.5.1, a typical storage system shall include some or all of the following special equipment:

(1) Cyclone separator
(2) Dust collector (e.g., cyclone vent collector)
(3) Vent fan
(4) Cyclone pressure lock
(5) Transport system (e.g., pulverized fuel pump, piping, and valves)
(6) Pulverized fuel bins
(7) Pulverized fuel feeders
(8) Auxiliary air damper
(9) Primary air fan

FIGURE 6.4.5.2.1(a) Pulverized fuel storage firing system.



Note: Pulverizer fan or vent fan might not be required.

FIGURE 6.4.5.2.1(b) Pulverized fuel storage firing system for pressure furnace.

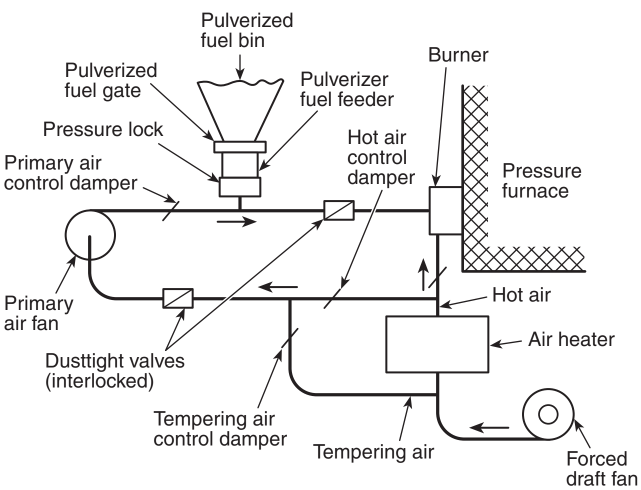


FIGURE 6.4.5.2.1(c) Pulverized fuel storage firing system (partial recirculation — vented air to stack).

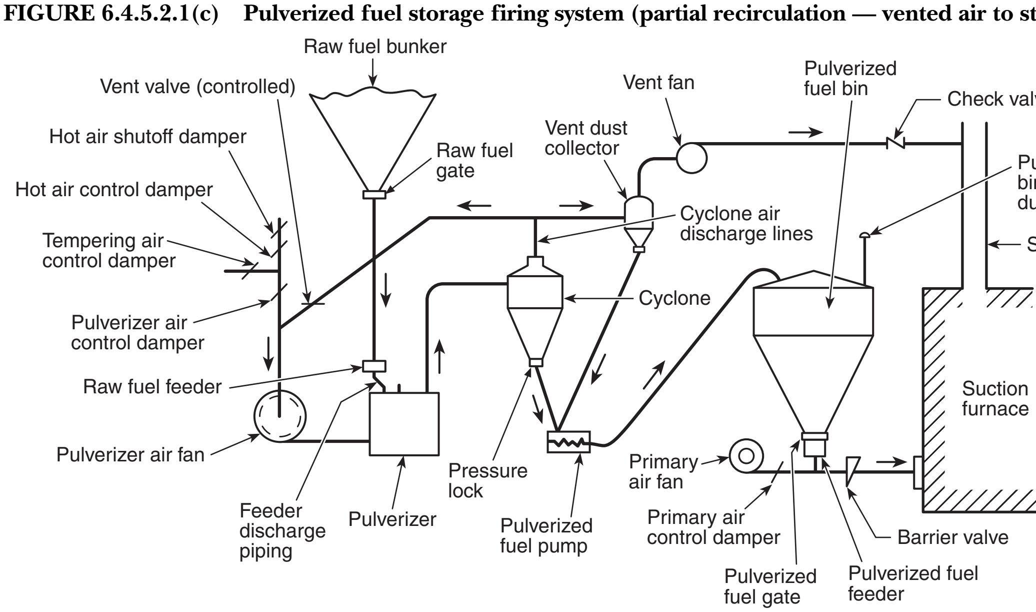
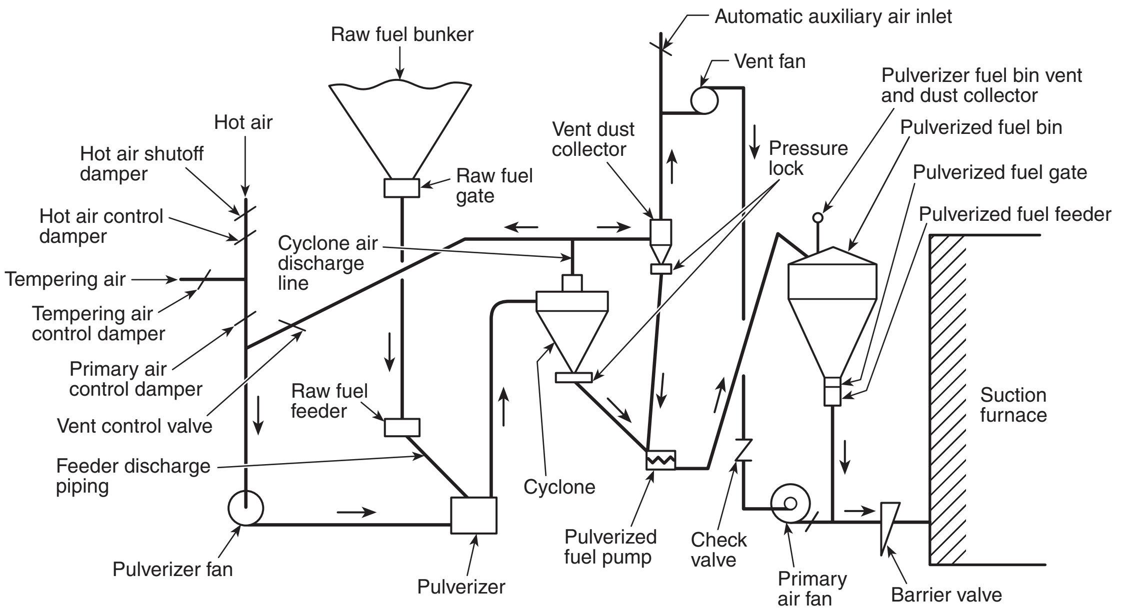
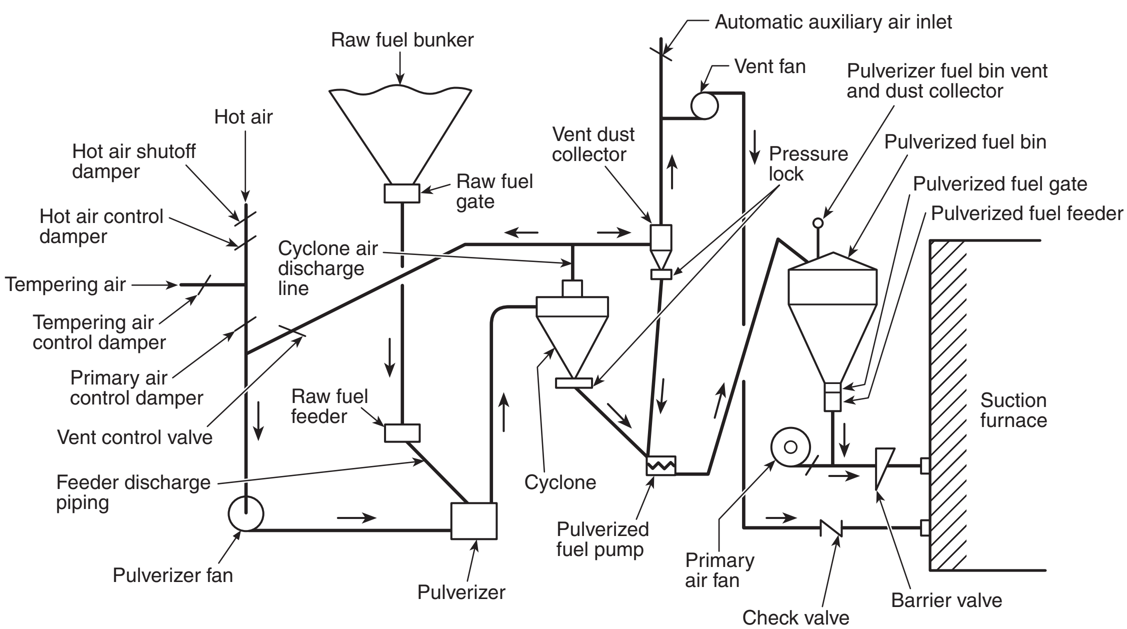


FIGURE 6.4.5.2.1(d) Storage firing system (partial recirculation — vented air to primary air fan).



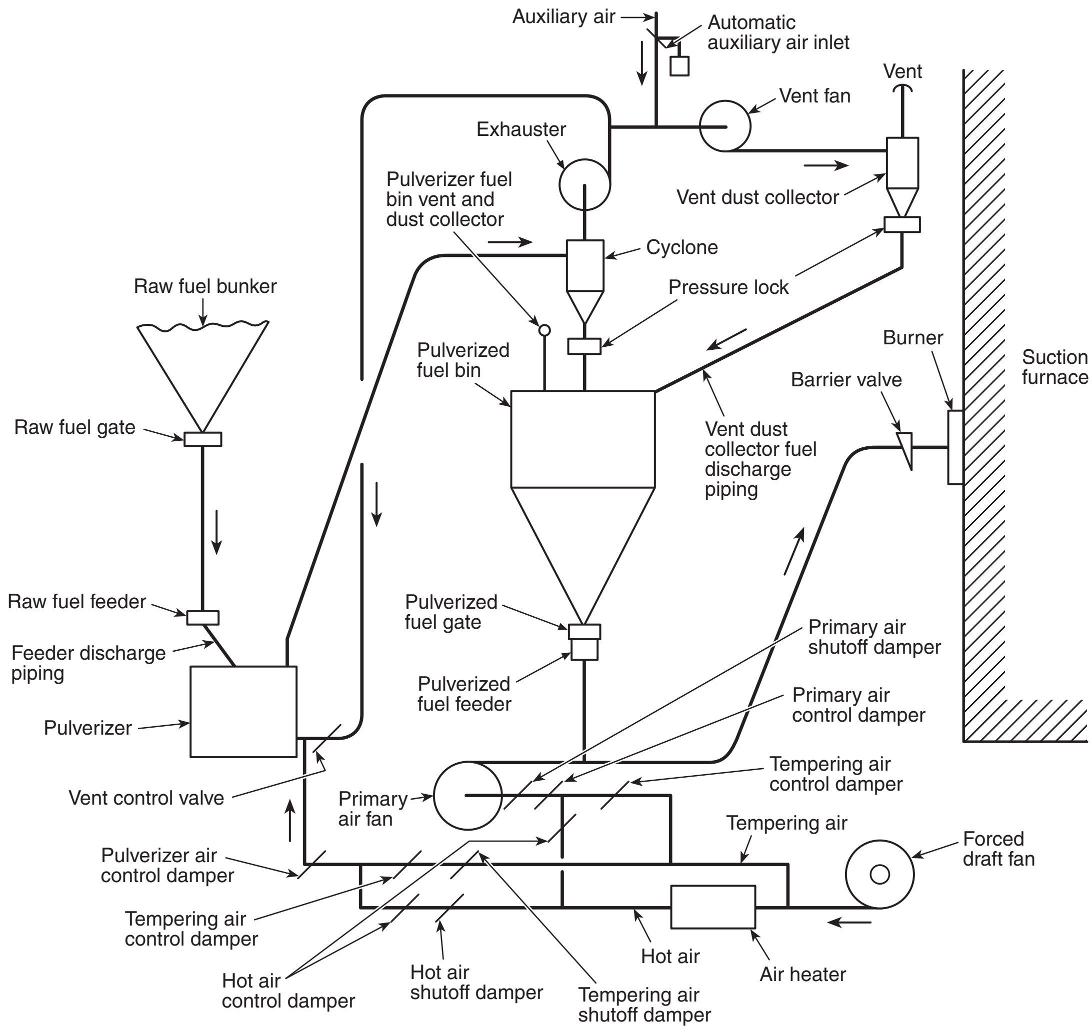
Note: Vent dust collector can be omitted.

FIGURE 6.4.5.2.1(e) Storage firing system (partial recirculation — vented air to furnace).



Note: Vent dust collector can be omitted.

FIGURE 6.4.5.2.1(f) Storage firing system (partial recirculation).



6.4.5.2.2 Valve Requirements.

6.4.5.2.2.1 Barrier valves, as shown in Figures 6.4.5.2.1(a) and (c) through (g), shall be provided in the piping between pulverized fuel feeders and burners of a storage system that is connected to one or more burners of a suction furnace.

6.4.5.2.2.2 A check valve, as shown in Figures 6.4.5.2.1(c), (d), (e), and (g), shall be installed in each vent pipe connecting the cyclone or dust collector of a storage system to the primary air fan or to any portion of the furnace or stack of a suction furnace.

6.4.5.2.2.3 A dusttight valve, as shown in Figure 6.4.5.2.1(b), shall be installed in each burner pipe between the pulverized fuel feeder and the burner for a storage system that is connected to one or more burners of a pressure furnace These valves shall not be opened until the primary air pressure is established.

6.4.5.2.2.4 A pressure lock, as shown in Figure 6.4.5.2.1(b), shall be installed at each fuel outlet of a pulverized fuel bin (if required) that is connected to a pressure furnace, to permit feeding of fuel into the burner lines at a higher pressure and to prevent the flow of primary air into the bin.

6.4.5.2.2.5 A pressure lock, as shown in Figures 6.4.5.2.1(a) and (c) through (g), shall be installed at each cyclone outlet if more than one cyclone is connected to a single pulverized fuel pump or if the cyclone is arranged for direct gravity discharge into the pulverized fuel bin. A pressure lock shall not be required at the cyclone outlet if only one cyclone is connected to the pulverized fuel pump.

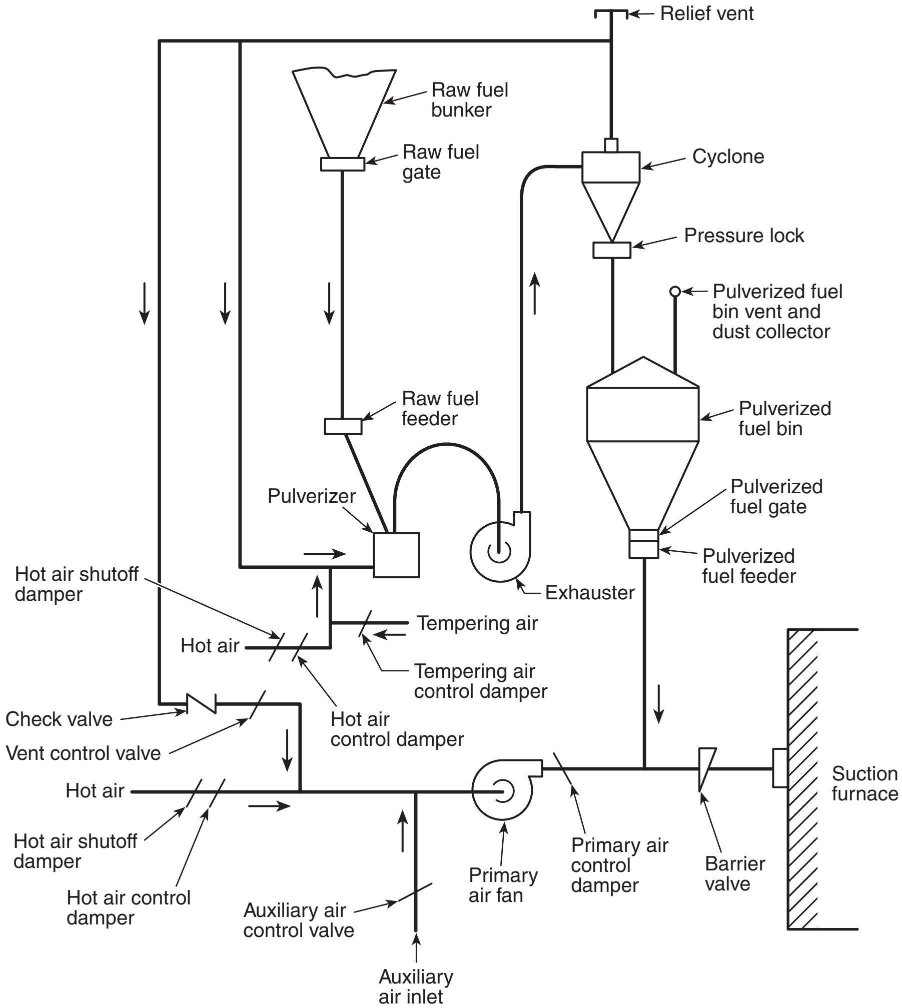
6.4.5.2.3 Primary Air Connections of Pressure Furnace Firing. For pressure furnace firing, a dusttight valve, as shown in Figure 6.4.5.2.1 (d) shall be installed between the forced draft system and the inlet for the primary air fan. A minimum stop shall be provided on the primary air control damper to prevent its being completely closed unless the shutoff dampers in the burner pipes are closed.

6.4.5.2.4 Venting.

6.4.5.2.4.1 Partial venting shall be used to control humidity in the pulverized fuel system, to minimize quantity of vented air or gas, or to conserve heat.

6.4.5.2.4.2 Total venting shall be used where there is no further use for the transport air or gas.

FIGURE 6.4.5.2.1(g) Storage firing system (no vent fan, with exhauster).



6.4.5.2.4.3 Both vent systems shall have the following common requirements:

(1) There shall be no venting to a pressure furnace.

(2) Venting to a suction furnace shall be permitted when it is delivered to a zone where combustion is active and injection line velocities are maintained at least 50 percent above the maximum flame propagation rate of the fuel.

(3) Venting to a stack, flue, or breeching shall be permitted when it is done to a zone where the temperature does not exceed two-thirds of the ignition temperature of the fuel in degrees Fahrenheit and the design of the entire vent system is such that there will be no hazardous accumulation of combustible fuel dust.

(4) Venting to the primary air fan shall be permitted when the primary air fan is operating and the following conditions are met:

a. A means is provided to prevent reverse flow.

b. The primary air system can handle the total amount of air.

c. The primary air fan is discharging to a zone of active combustion.

(5) When venting to the atmosphere, the vented air or gas shall be sufficiently clean of combustible material so as not to create fire or an explosion hazard. The vented air or gas shall not interfere with the proper operation of other systems within the area.

(6) Check valves, where required, shall be located near the source of possible reverse flow into the system.

6.4.5.2.4.4 When the vented air from the cyclone, as shown in Figure 6.4.5.2.1(a), is discharged to the atmosphere, the vent shall discharge at a height above the building roof to prevent accumulations on the roof.

6.4.5.2.4.5 When the vented air is discharged into the stack, flue, or breaching, the connection shall be made at a point where the pressure is less than that of the room in which the pulverizer is located, and each vent line shall have a check valve that opens in the direction of the flow.

6.4.5.2.4.6 Vent connections shall be located downstream of the recirculated gas inlet connection in such a manner that any combustible dust that is carried by the vented air cannot be entrained in the recirculated gas for possible introduction into a zone of high furnace temperature.

6.4.6 Pulverizer System Component Design Requirements.

6.4.6.1 Strength of Equipment.

6.4.6.1.1 All components of the pulverized fuel system as described below that are designed to be operated at no more than gauge pressure of 2 psi (13.8 kPa) shall be designed to withstand an internal explosion gauge pressure of 50 psi (344 kPa) for containment of possible explosion pressures. For operating gauge pressures in excess of 2 psi (13.8 kPa), the equipment as described below shall be designed to withstand an internal explosion pressure 3.4 times the absolute operating pressure.

6.4.6.1.2 Equipment design strength shall incorporate the combined stresses from mechanical loading, operating, and explosion and implosion pressures plus an allowance for wear, which shall be determined by agreement between the manufacturer and the purchaser.

6.4.6.1.3 Some parts of the pulverized fuel system, such as large flat areas and sharp corners, can be subjected to shock wave pressures. These pressures shall be included in the design, based on their locations in the system.

6.4.6.1.4 The components falling within the requirements of 6.4.6.1.1, 6.4.6.1.2, and 6.4.6.1.3 for a direct-fired system shall begin at a point that is 2 ft (0.61 m) above the inlet of the raw fuel feeder, at the point of connection of ductwork to the pulverizer, and at the seal air connections to the pulverizer system. They shall end at the discharge of the pulverizer, external classifier, or exhauster. These components shall include the following and any other associated devices:

(1) Raw fuel feeding devices, discharge hoppers, and feed pipes to the pulverizer
(2) All parts of the pulverizer that are required for containment of internal pressure
(3) Exhauster and connecting piping from the pulverizer
(4) External classifiers and connecting piping from the pulverizer
(5) Foreign material–collecting hoppers that are connected to the pulverizer
(6) The raw fuel bunker and mechanical components, including but not limited to seals, gears, bearings, shafts, and drives, shall not be required to meet these requirements.

6.4.6.1.5 Explosion vents shall not be used on any component of the system that is described in 6.4.6.1.4.

6.4.6.1.6 All ductwork, from the hot and tempering air supply ducts to individual pulverizers, including damper frames, expansion joints, supports, and hot primary air fans, shall be designed to contain the test block capability of the pulverizer air supply fan. This ductwork is exposed to explosion pressures from the pulverizer in the event of an explosion.

6.4.6.1.7 If a pulverized fuel storage system is started and operated with an inert atmosphere in all parts of the system in accordance with NFPA 69, *Standard on Explosion Prevention Systems*, the strength requirements of 6.4.6.1.1 shall not apply. Any component of the system that is started and operated with an inert atmosphere shall not be required to comply with the strength requirements of 6.4.6.1.1.

6.4.6.1.8 A pulverized fuel storage system that is not started and operated with an inert atmosphere in accordance with NFPA 69, *Standard on Explosion Prevention Systems*, shall meet the requirements of 6.4.6.1.1. The components falling within these requirements are those described in 6.4.6.1.4, plus any or all of the following which are included in the system:

(1) Lock hoppers
(2) Circulating fans
(3) Transport systems
(4) Pulverized fuel feeders
(5) Primary air fans handling fuel-laden air
(6) Vent fans if not located downstream of a dust collector that is vented in accordance with 6.4.6.1.9

6.4.6.1.9 In a pulverized fuel storage system that is not started and operated with an inert atmosphere in accordance with NFPA 69, *Standard on Explosion Prevention Systems*, the following equipment shall meet the requirements of 6.4.6.1.1 or shall be equipped with suitable vents. *(Refer to NFPA 68, Guide for Venting of Deflagrations.)*

(1) Cyclone
(2) Dust collectors
(3) Pulverized fuel bins

6.4.6.1.10 Explosion vents shall not be used on the feeder or pulverizer of any system.

6.4.6.2 Piping. For systems that are normally operated at a gauge pressure no more than 2 psi (13.8 kPa), the pulverized fuel piping from the outlet of the equipment, as defined in 6.4.6.1.4 and 6.4.6.1.9, to the pulverized fuel burner or storage bin shall comply with 6.4.6.1. Systems that are operated at a gauge pressure greater than 2 psi (13.8 kPa) shall be designed to withstand an internal explosion of 3.4 times the absolute operating pressure.

6.4.6.2.1 There shall be an allowance for wear in excess of the strength requirements of 6.4.6.2. Elbows are especially vulnerable to wear, but all parts of the system shall be designed for wear as determined by agreement between the manufacturer and the purchaser.

6.4.6.2.2 Pulverized fuel piping shall provide smooth flow and have bend radii not less than one pipe diameter. Wherever possible, radii in excess of one pipe diameter shall be used.

6.4.6.2.3 Flexible joints and split clamp couplings shall conform to 6.4.6.2 except that the junction of two sections shall be permitted to be sealed with flexible material. There shall be no separation of the pipe joint in case of failure of the flexible material. Positive mechanical connections shall be provided between the two sections to prevent serious misalignment or separation.

6.4.6.2.4 At operating temperatures encountered in the service of the equipment, piping materials shall satisfy the strength requirements of 6.4.6.2 and shall comply with 6.4.6.6.2 for allowable stresses.

6.4.6.2.5 This requirement shall apply only to new installations. Brittle materials shall not be used for piping except as abrasion-resistant linings and where no credit is taken for the structural strength of the lining. Brittle materials are those having a plastic elongation of less than 8 percent prior to tensile rupture.

6.4.6.2.6 Piping support systems shall be designed and installed in accordance with Chapter 2, Part 5, of ASME B 31.1, *Power Piping Code*, so that combined stresses will not be in excess of those specified in 6.4.6.6.2.

6.4.6.2.7 Pipe that is lined with abrasion-resistant material shall have casing thickness and flange size that is designed for the strength requirements in 6.4.6.2 with no required allowance for wear.

6.4.6.2.8 Prior to initial operation or after piping system renovation, an in-service leak test shall be performed in accordance with the following procedure:

(1) The system shall be gradually brought up to operating pressure and temperature.
(2) The system shall be continuously held at the conditions described in 6.4.6.2.8(1) for 10 minutes.
(3) Examination for leakage shall be made of all joints and connections.
(4) The system shall show no visual evidence of weeping or leakage.

6.4.6.3 Valves. All valves in the pulverized fuel system from a point within 2 ft (0.61 m) above the inlet of raw fuel feeder to the point of consumption of the pulverized fuel shall have construction that is capable of withstanding pressures as defined in 6.4.6.1.1, 6.4.6.2, or 6.4.6.4, depending on the application. These components shall include the following and any other pulverized fuel system valves:

(1) Barrier valve
(2) Dusttight valve
(3) Check valve
(4) Pressure/air lock
(5) Raw fuel gate

6.4.6.4 Interconnections. Valves at points of interconnection between pulverized fuel system components requiring different design pressures shall comply with the strength requirements of the lower pressure of the two.

6.4.6.5 Bunker and Hopper Designs.

6.4.6.5.1 The raw fuel bunker structural material shall be made of noncombustible material. It shall be designed to provide the following mass flow and self-cleaning flow characteristics:

(1) An uninterrupted flow of fuel being handled at a controlled rate
(2) A flow pattern in which arching and ratholing (piping) are avoided

6.4.6.5.1.1 The bunker outlet feeder(s) shall be coordinated with the bunker to avoid the probability that incorrect feeder selection will result in altering the bunker flow characteristics as specified in 6.4.6.5.1(1) or (2).

6.4.6.5.1.2 Provisions shall be made to prevent the accumulation of flammable mixtures of air, fuel dust, and combustible gases within the bunker.

6.4.6.5.2 Pulverized fuel bins shall conform to strength requirements as specified in 6.4.6.1 with exceptions as outlined in 6.4.6.1.7 and 6.4.6.1.9. These bins shall be designed to permit fuel discharge at an uninterrupted, controlled rate. Internal construction shall minimize stagnant deposits. Open-top bins shall not be used.

6.4.6.5.2.1 Provisions shall be made to prevent accumulation of flammable mixtures of air, fuel dust, and combustible gases within the bin.

6.4.6.5.2.2 Bins shall be equipped with high- and low-level fuel detectors.

6.4.6.5.3 Pulverized fuel lock hoppers shall be designed for 3.4 times the absolute operating pressure. These hoppers shall be designed to permit fuel discharge at an uninterrupted controlled rate. Internal construction shall minimize accumulations.

6.4.6.5.4 Lock hoppers shall be equipped with high- and low-level fuel detectors.

6.4.6.6 Construction Materials for Pressure Containment.

6.4.6.6.1 Materials that are used to meet strength requirements shall be ferrous materials and shall satisfy the strength requirements of 6.4.6.1 at design operating temperatures.

Exception: Raw coal bunkers of concrete construction.

6.4.6.6.2 If made of steel or other ductile metals, the allowable stress values shall be determined as follows:

(a) *Tension.* The maximum allowable direct (i.e., membrane) stress shall not exceed the lesser of $^1/_4$ of the ultimate strength or $^5/_8$ of the yield strength of the material.

(b) *Combined bending and membrane stress (where bending stresses are not self-limiting).* The maximum allowable value of combined bending and membrane stress shall not exceed the lesser of the yield strength or $^1/_2$ the ultimate strength of the material.

(c) *Combined bending and membrane stress (where bending stresses are self-limiting).* The maximum allowable values of combined self-limiting and non-self-limiting bending stresses plus membrane stress shall not exceed the ultimate strength of the material.

(d) *Compressive stress.* For components in which compressive stresses occur, in addition to the requirements of 6.4.6.6.2(a), (b), and (c), the critical buckling stress shall be taken into account.

(e) *Fatigue analysis.* On components subject to cyclic loading, fatigue analysis shall be made to guard against possible fatigue failures. Both mechanical and thermal loading shall be analyzed.

6.4.6.6.3 If made of cast iron or other nonductile materials, the allowable stress shall not exceed $^1/_4$ of the ultimate strength of the material for all parts. When cast iron or other nonductile materials are used for flat areas exceeding 1 ft^2 (0.0929 m^2), the surface shall be strengthened by ribbing or other means. An evaluation of the possibility of buckling and fatigue failures shall be made.

6.4.6.6.4 To ensure casting quality, nondestructive examination shall be made to detect significant defects at locations of high stress, at abrupt changes of section, and at sharp angles. The choice of such a quality assurance program shall be the responsibility of the designer.

6.4.6.6.5 The justification of new materials or improved analytical methods shall be the responsibility of the designer. If such materials and methods are used for the design of pulverized fuel system components, they shall meet the requirements of 6.4.6.1 and 6.4.6.2. The materials that are used shall be capable of withstanding the conditions that could occur during abnormal incidents, such as pulverized fuel fires.

6.4.6.7 Electrical Equipment.

6.4.6.7.1 All electrical equipment and wiring shall conform to NFPA 70, *National Electrical Code.*

6.4.6.7.2 Locations where completely dusttight pulverized fuel systems are installed in compliance with this code shall not be considered a hazardous location for electrical equipment as defined in NFPA 70, *National Electrical Code.*

6.4.6.8 Inerting System.

6.4.6.8.1 Pulverizers and pulverized fuel storage systems shall be equipped with an inerting system that is capable of maintaining an inert atmosphere as required to meet the provisions of 6.5.4.2.1. *(Refer also to NFPA 69, Standard on Explosion Prevention Systems.)*

6.4.6.8.2 Provisions shall be made for verification of flow of inerting media when the system is activated.

6.4.6.9 Fire-Extinguishing System.

6.4.6.9.1 Pulverizers and pulverized fuel–collecting systems shall be equipped with connections for fire extinguishing. These connections shall be at least 1 in. (25 mm) in diameter and shall be adequate to pass the amount of required extinguishing material.

6.4.6.9.2 Provisions shall be made for verification of flow of fire-extinguishing media when the system is activated.

6.4.7 Safety Interlock Systems.

6.4.7.1 The safety interlocks required in this section shall be coordinated with the boiler, furnace, or other related devices to which the pulverized fuel system is connected.

6.4.7.2 Permissive sequential-starting interlocks for direct-fired systems shall be arranged so that, after furnace or other connected apparatus interlocks have been satisfied, the pulverizer can be started only in the following sequence:

(1) Start ignition system in accordance with Chapter 3.
(2) Start primary air fan or exhauster.
(3) Establish minimum air flow.
(4) Start pulverizer.
(5) Start raw fuel feeder.

Exception: Items (2) and (4) shall be permitted to be simultaneous.

6.4.7.3 Interlocks for direct-fired pulverized fuel systems shall be arranged to trip in the following sequence:

(a) Failure of primary airflow to below manufacturer's minimum shall trip the pulverizer and burner shutoff valve or equivalent and the feeder. The manufacturer's requirements regarding the burner's shutoff valve operation shall be followed.

(b) Failure of pulverizer shall trip the feeder and primary airflow.

(c) Closure of all fuel line valves shall trip the pulverizer, primary airflow, and raw fuel feed.

(d) Failure of the feeder shall initiate an alarm; restarting of the feeder shall be blocked until feeder start-up conditions are reestablished.

Means to indicate loss of fuel feed to the pulverizer or fuel input to the furnace shall be installed.

6.4.7.4 Permissive sequential-starting interlocks for pulverized fuel storage systems shall be arranged so that the system components can be started only in the following sequence:

(1) Start pulverized fuel pump or conveyor.
(2) Start cyclone and dust collector pressure locks.
(3) Start vent fan.
(4) Start pulverizer exhauster or air fan.
(5) Start pulverizer.
(6) Start raw fuel feeder.

Exception: Items (4) and (5) shall be permitted to be simultaneous.

6.4.7.5 Interlocks for pulverizers of storage systems shall be arranged to trip as follows:

(1) The full pulverized fuel bin shall trip the fuel pump or conveyor and the raw fuel feeder.
(2) Failure of the fuel pump or conveyor shall trip the vent fan on the cyclone or dust collector and pressure locks upstream of the fuel pump or conveyor.
(3) Failure of the vent fan shall trip the pulverizer exhauster or air fan.
(4) Failure of the pulverizer exhauster or air fan shall trip the raw fuel feeder.
(5) Failure of the pulverizer shall trip the raw fuel feeder.

6.4.7.6 For pressure furnaces that are firing from storage or semistorage systems, the dusttight valve in the burner pipe that is after the pulverized fuel feeder shall be interlocked so that it cannot be opened unless the dusttight damper in the primary air supply is open.

6.5 Operation.

6.5.1 Operation of All Pulverized Fuel Systems.

6.5.1.1 Preparation for Starting.

6.5.1.1.1 Preparation for every start-up shall include checks for the following conditions:

(1) The pulverizer system sealing air, if required, is in service.
(2) Energy is supplied to the control system and to the safety interlocks.
(3) All pulverizer system gates, valves, and dampers are in start-up positions.

6.5.1.1.2 After maintenance or outage, the following inspections and checks shall be made:

(1) Pulverizers, ducts, and fuel piping are in good repair and free from foreign material.
(2) Pulverizers, ducts, and fuel piping are evacuated by all personnel, all access and inspection doors are closed, and all personnel protection devices are reinstalled.
(3) All pulverizer air or flue gas dampers are operated through the full operating range.
(4) Pulverizers, feeders, controls, and associated equipment are in a condition ready for service.
(5) A complete functional check is made of all safety interlocks.

6.5.2 Operation of Direct-Fired Systems.

6.5.2.1 Starting Sequence. The starting sequence shall consist of the following steps. All steps shall be included. It shall be permitted to vary the sequence of steps (2) through (9) as recommended by the system designer.

(1) Start all necessary light-off equipment as per Chapter 3 requirements.
(2) Open the pulverizer tempering air damper.
(3) Start the primary air fan or exhauster, if driven separately from the pulverizer.
(4) Open the primary airflow control damper to a setting that provides a burner line transport velocity greater than or equal to the established minimum.
(5) Open the pulverizer burner line valves.
(6) Start the pulverizer.
(7) Open the pulverizer hot air damper and maintain pulverizer outlet temperature within the specified range (as dictated by the system designer or field tests).
(8) Start the raw fuel feeder.
(9) Place the pulverizer outlet temperature, primary airflow, and raw fuel feed controls on automatic.

6.5.2.2* Normal Operation.

6.5.2.2.1 The pulverizer output shall be regulated by adjusting its fuel and air supplies in accordance with the manufacturer's procedures or as determined by field tests.

6.5.2.2.2 Individual burner shutoff valves, if provided, shall be wide open or completely closed. They shall never be placed at intermediate settings.

6.5.2.2.3* Burner line transport velocities shall be maintained at or above minimum for all pulverizer loading conditions.

6.5.2.2.4 A pulverizer shall not be operated below its minimum air or fuel stop setting.

6.5.2.3 Normal Shutdown. The pulverizer shutdown sequence shall consist of the following steps. All steps shall be included. It shall be permitted to vary the sequence of steps (a) through (f) as recommended by the system designer.

(a) Reduce pulverizer output and establish required combustion system conditions for shutdown as required in Chapter 3.

(b) Reduce the hot air, and increase the cold air to cool the pulverizer to a predetermined minimum outlet temperature as recommended by the system designer or as determined by test.

(c) When the pulverizer is cooled, stop the feeder and continue operation of the pulverizer with the minimum established airflow to remove all fuel from the pulverizer and burner lines. Maintain minimum outlet temperature (typically requires shutoff of hot air supply when feeder is stopped).

(d) Shut the pulverizer down after a predetermined time as required to empty the pulverizer as determined by field tests.

(e) Position burner line shutoff valves in accordance with the manufacturer's instructions.

(f) Stop primary air flow.

6.5.3 Operation of Storage Systems.

6.5.3.1 Operation of Fuel-Burning Equipment.

6.5.3.1.1 Starting Sequence. The starting sequence shall be as follows:

(1) Coordinate the fuel-burning portion with the furnace in accordance with Chapter 3.
(2) Start the primary air fan(s).
(3) Open all burner and primary air shutoff valves for the burners to be started.
(4) Open the pulverized fuel gate, and start the pulverized fuel feeder for these burners.

6.5.3.1.2 Normal Operation.

6.5.3.1.2.1 Individual burner valves shall be wide open or completely closed. They shall never be placed at intermediate settings.

6.5.3.1.2.2 Fuel flow shall be controlled by adjusting the pulverized fuel feeder speed.

6.5.3.1.2.3 Primary airflow shall be maintained at all times to prevent settling of coal dust in burner pipes.

6.5.3.1.3 Normal Shutdown. The shutdown sequence shall be as follows and in accordance with Chapter 3.

(1) Establish the required combustion system conditions for shutdown.
(2) Stop the pulverized fuel feeder.
(3) When the burner flame is extinguished, close the burner and primary air shutoff valves, unless primary air valves supply air to all burners during operation.
(4) Stop the primary air fan after the last burner that is served by that fan is shut down.

6.5.3.2 Operation of Pulverizing Equipment of Storage Systems.

6.5.3.2.1 Starting Sequence. The basic principle to be followed is that of starting equipment in sequence from the storage bin "upstream" toward the point of pulverizer air supply and then finally the raw fuel supply as shown in Figures 6.4.5.2.1(a) through (g). The starting sequence shall be as follows:

(1) Start the pulverized fuel pump or conveyor, if provided.
(2) Start the cyclone pressure lock, if provided.
(3) Start the cyclone or dust collector vent fan or exhauster and/or the primary air fan, and open the burner and primary air shutoff valves if used to convey the vent stream and burners are not in service, in accordance with 6.4.5.2.4.
(4) Start the pulverizer exhauster or fan and adjust the control dampers to obtain proper air flow and temperature.
(5) Start the pulverizer.
(6) Start the raw fuel feeder.
(7) Readjust the control damper(s) to obtain required pulverizer air/fuel outlet temperature and airflow.

6.5.3.2.2 Normal Shutdown. The shutdown sequence shall be as follows:

(1) Close the hot air damper and open the cold air, or flue gas, damper to cool down the pulverizer.
(2) Stop the raw fuel feeder.
(3) Operate the pulverizer for a predetermined time as required to empty the pulverizer of fuel and make it cool. Stop the pulverizer.
(4) Stop the pulverizer exhauster or fan.
(5) Stop the cyclone and dust collector vent fan or exhauster and/or the primary air fan if used to convey the vent stream and all burners are shut down.
(6) Stop cyclone pressure lock.
(7) Stop pulverized fuel pump or conveyor.

6.5.4 Abnormal Pulverizer System Conditions.

6.5.4.1 When a fire is suspected in the pulverizer system or abnormal operating conditions are encountered, all personnel shall be cleared from the area near the pulverizer, primary air duct, burner pipes, burners and feeder, or other pulverized fuel system components before the operating conditions are changed.

6.5.4.2 Pulverizer Tripping.

6.5.4.2.1 Inerting.

6.5.4.2.1.1 A pulverizer that is tripped under load shall be inerted and maintained under an inert atmosphere until confirmation that no burning/smoldering fuel exists in the pulverizer or the fuel is removed.

6.5.4.2.1.2 The inerting procedure shall be established by the pulverizer equipment manufacturer and the purchaser. They shall consider fuel characteristics, pulverizer temperature and size, and arrangement of the pulverizer.

6.5.4.2.1.3 Inerting media shall be selected from, but not limited to, the following:

(1) Carbon dioxide
(2) Steam
(3) Nitrogen

6.5.4.2.2 Fuel-Clearing Procedures.

6.5.4.2.2.1 For pulverizers that are tripped and inerted while containing a charge of fuel in accordance with 6.5.4.2.1.1, the following procedure shall be used to clear fuel from the pulverizer and sweep the transport lines clean as soon as possible after it has been tripped and there is confirmation that there is no burning or smoldering fuel.

(1) Start up one pulverizer in accordance with the principles and sequences as listed in 6.5.2.1(1) through (9).
(2) Isolate from the furnace all shutdown or tripped pulverizers.
(3) Continue to operate the pulverizer until empty and in normal condition for shutdown. When the operating pulverizer is empty of fuel, proceed to another pulverizer and repeat the procedure until all are cleared of fuel.

Exception: Exception to (c): Restart feeder and return pulverizer to normal operation if furnace conditions allow such operation.

6.5.4.2.2.2 In the event that there are indications of burning or smoldering fuel in an out-of-service pulverizer, the pulverizer shall not be restarted under the normal procedure. Fire-extinguishing procedures shall be followed, or removal of residual fuel shall be accomplished under inert conditions by taking one of the following steps:

(1) Remove fuel through the pyrites removal system. When this procedure is followed, the pulverizer shall be opened and inspected prior to restarting.
(2) Start the pulverizer with an inert medium, using the starting sequences in 6.5.2.1(1) through (9).

Due to the danger of an explosion when opening and cleaning, pulverizers shall not be cleaned manually until they and their contents have been cooled to ambient temperature. The procedures of 6.5.4.3 shall be followed.

6.5.4.3 Fires in Pulverized Fuel Systems.

6.5.4.3.1 Indication of a fire in any part of a pulverized fuel system is a serious condition and shall be dealt with promptly. Extinguishing media shall be water or inert solids or shall be in accordance with 6.5.4.2.1.3.

6.5.4.3.2 The following procedures for fighting fires shall be used with modifications for specific systems, specific locations of fire, or requirements of the equipment manufacturer.

(a) If sufficient flow capacity of inerting media is provided (at least 50 percent by volume of the minimum primary airflow for the system), inert the pulverizer air/fuel flow, and shut off the fuel feed, empty the pulverizer of fuel, and shut down and isolate the pulverizer.

(b) Stop the primary airflow, trip the pulverizer and feeder, isolate the system, and inert. Do not disturb any accumulation of dust within the pulverizing equipment. Do not open any access doors to the pulverizer until the fire is extinguished and all temperatures have returned to ambient. After isolation of the pulverizer is verified, follow the procedures as outlined in 6.5.4.3.5 and 6.5.4.3.6.

(c) A fire that is detected in an operating low-storage pulverizer shall be extinguished by shutting off the hot air, increasing the raw fuel feed as much as possible without overloading the pulverizer, and continuing to operate with tempering air.

(d) Introduce water into the raw fuel or tempering air stream, or both. The water must be added in such quantities and at such locations as not to cause hang-up or interruption of raw fuel feed or to stir up any deposit of combustible material. When all evidence of fire has disappeared, shut off the water, trip the pulverizer, isolate, and inert.

6.5.4.3.3 When fires are detected in other parts of a direct-fired system, such as burner lines, the procedures as outlined in 6.5.4.3.2(a), (b), or (c) shall be followed.

6.5.4.3.4 When fires are detected in storage system components, including but not limited to cyclones, dust collectors, pulverized fuel bins, the affected components shall be isolated and inerted.

6.5.4.3.5 If fire is detected in an out of service pulverizer, it shall be kept out of service and isolated. All air supply to the pulverizer shall be shut off. Access doors to a pulverizer shall not be opened until the fire is extinguished by water or other extinguishing media and all temperatures have returned to ambient.

6.5.4.3.6 Pulverizing equipment shall be inspected internally following fires in pulverizing systems. All coke formations and other accumulations shall be removed to reduce the potential for future fires. If the pulverizer is wet, it shall be dried. In no case shall a compressed air jet be used. All components shall be inspected, and damaged items, including but not limited to, gaskets, seals, lubricants, and liners, shall be replaced.

6.6 Special Systems.

6.6.1 Introduction. Specific systems, as defined in this section, shall meet the specific requirement of this section. *(For general design, operating, and safety requirements of these systems, refer to Sections 6.4 and 6.5.)*

6.6.2 Semi-Direct-Firing System.

6.6.2.1 Description. This system, as shown in Figures 6.6.2.1(a) and 6.6.2.1(b), shall consist of an air-swept pulverizer located near the point of use. The fuel shall be separated from the air in a cyclone or other type of dust collector. Fuel shall discharge from the cyclone through a rotary valve and shall be picked up by air from a primary air fan and blown into the furnace. The primary air fan shall take suction from the pulverizer air fan or from other sources. If the primary air fan does not utilize all of the pulverizer air, a vent fan shall be required.

6.6.2.2 System Arrangement. This system shall be permitted to include the following special equipment:

(1) A cyclone separator or other type of dust collector
(2) A pressure lock
(3) A primary air fan
(4) A vent fan and dust collector, if required
(5) A pulverized fuel pickup

6.6.2.3 Valve Requirements.

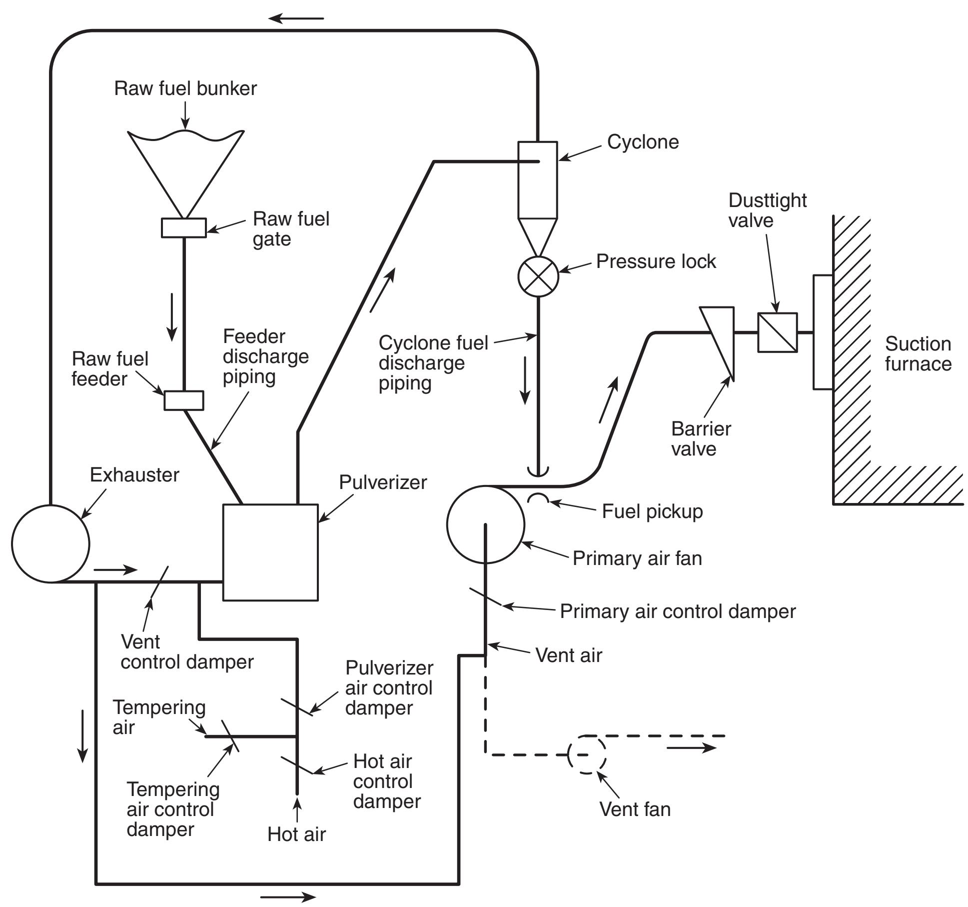
6.6.2.3.1 A barrier valve and a dusttight valve shall be installed between each fuel pickup point and the burner for a suction furnace that can be fired by other fuels.

6.6.2.3.2 Two dusttight valve(s) shall be installed between the fuel pickup point and the burner for a pressurized furnace if the furnace can be fired by other fuels.

6.6.2.3.3 One of the valves described in 6.6.2.3.1 and 6.6.2.3.2 shall be quick closing.

6.6.2.3.4 Valves shall not be required between the pulverizer and the cyclone.

FIGURE 6.6.2.1(a) Semi-direct-firing pulverized fuel system.



6.6.2.4 Isolation Requirements. See 6.4.5.1.3.

6.6.2.5 Operation.

6.6.2.5.1 Starting Sequence. The starting sequence shall be as follows:

(1) Start up all necessary combustion system auxiliaries in the proper sequence.
(2) Start the forced draft fan (for the pressure furnace only).
(3) Start the primary air fan.
(4) Open all valves in lines to burners to be started, including barrier valves and dusttight valves.
(5) Adjust the primary airflow to the desired value, at least sufficient to provide minimum burner line velocity.
(6) Start pressure locks.
(7) Start the pulverizer air fan.
(8) Start the pulverizer.
(9) Start the vent fan, if required.
(10) Start the raw fuel feeder.
(11) Adjust the dampers and controls as in 6.5.2.1(9).

6.6.2.5.2 Normal Operation. Follow the procedures of 6.5.2.2.

6.6.2.5.3 Normal Shutdown. The normal shutdown procedure shall be as follows:

(1) Follow the procedures of 6.5.2.3.
(2) When the pulverizer is empty and cool, stop the pulverizer and the pulverizer air fan or exhauster.
(3) Stop the pressure locks.
(4) Stop the vent fan.
(5) Stop the primary air fan.

6.6.2.5.4 Interlocking.

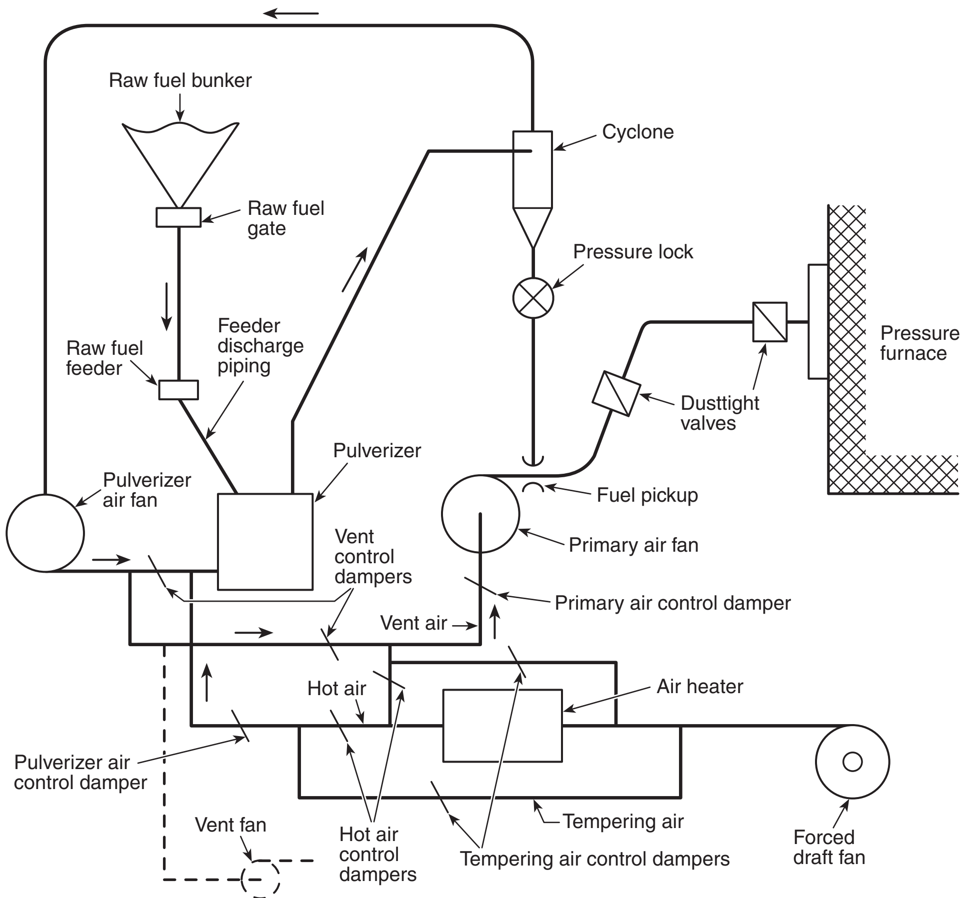
6.6.2.5.4.1 Interlocking shall be as outlined in 6.4.7.

6.6.3 Pulverized Fuel System for Blast Furnace Injection.

6.6.3.1 Description. This system, as shown in Figure 6.6.3.1, shall consist of an air-swept pulverizer. The fuel shall be separated from the air in a cyclone or other type of dust collector. Fuel shall discharge from the cyclone through a pressure lock valve and be collected, stored, and batch-pressurized to a pressure that is higher than the blast furnace pressure. The pressurized fuel shall then be transported and distributed to the furnace tuyeres. This system shall have the following three major subsystems:

(1) A fuel grinding and collecting system
(2) An inert gas, pressurized fuel, storage, and feeding system
(3) Pulverized fuel transportation and distribution system

FIGURE 6.6.2.1(b) Semi-direct-firing pulverized fuel system.



6.6.3.2 System Arrangement. The pulverizer and pulverized fuel–collecting, –pressurizing, and –feeding equipment shall be located remotely from the blast furnace unless other design requirements locate it close to the furnace. The distribution system shall be located close to the blast furnace. The pulverizer fan shall be located ahead of the air heater and pulverizer, between the air heater and pulverizer, at the pulverizer outlet, or at the cyclone or dust collector vent. This system shall include the following special equipment:

(1) A pulverizer air heater
(2) A cyclone separator or other type of dust collector
(3) A cyclone pressure lock
(4) A pulverized fuel bin
(5) Pulverized fuel feed tanks
(6) Pressure-tight isolation valves
(7) An injection air system
(8) An inert gas system
(9) Fuel injection lances
(10) Flow control of air or flue gas
(11) A vent dust collector

6.6.3.3 Valve Requirements.

6.6.3.3.1 Pressure locks shall be installed at the pulverized fuel discharge of the cyclone separator or vent dust collector return lines.

6.6.3.3.2 Special dusttight valves shall be installed at each fuel outlet of the pulverized fuel bin, at the fuel discharge outlet of each feed tank, and at each fuel outlet of the pulverized fuel distributors. These valves shall be tight at a pressure that is 1.5 times the required pressure in the feed tanks.

6.6.3.4 Isolation Requirements. Isolation damper(s) shall be provided upstream of the pulverizer and at the discharge of the cyclone separator to permit inerting in this system.

6.6.3.5 Operation.

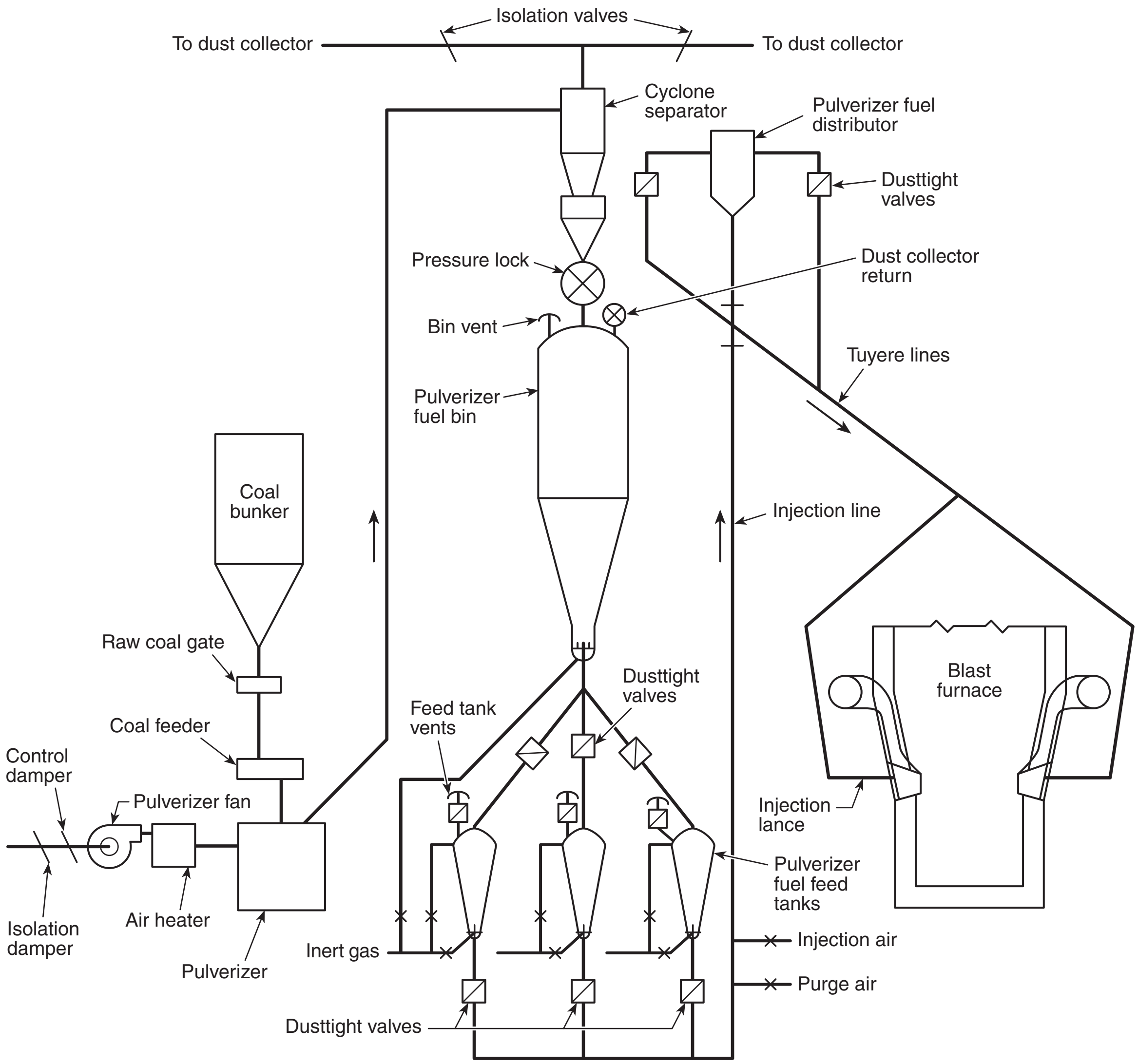
6.6.3.5.1 Operating procedures for handling pulverized fuel being injected to the blast furnace shall be established to avoid fires and explosions in the pulverized fuel injection system.

6.6.3.5.2 Operation of Fuel-Pulverizing Equipment. The principles and procedures of 6.5.3 shall apply to this storage-grinding system.

6.6.3.5.3 Operation of fuel injection equipment shall be as follows:

(1) Ascertain that the blast furnace is in service before starting the pulverized fuel injection system.
(2) Start the inert gas source.
(3) Start the injection air system blower or compressor, and pressurize the injection line to the distributor.
(4) Pressurize the filled pulverized fuel feed tank with inert gas.
(5) Open the dusttight valves in lines leaving the distributors.
(6) Establish transport airflow.
(7) Open the discharge dusttight valves from the pulverized fuel feed tank.

FIGURE 6.6.3.1 Blast furnace pulverized fuel injection system.



6.6.3.5.4 Inert gas shall be used to fluidize and pressurize the feed tank system. Pulverized fuel flow shall be controlled by regulating the pressure drop across the system.

6.6.3.6 Normal Shutdown.

6.6.3.6.1 The shutdown sequence shall be as follows:

(1) Empty the fuel bin and feed tanks of pulverized fuel.
(2) Purge the injection and distribution system.
(3) Close the distributor dusttight valves.

6.6.3.6.2 If all pulverized fuel cannot be removed from the system, inert gas shall be provided for the feed hoppers and pulverized fuel bin when the system is idle.

6.6.3.7 Interlocking. In addition to the interlocking requirements of 6.4.7.4, the following shall be included:

(1) Failure of the pulverizer airflow trips the separately fired air heater.
(2) Failure of the cyclone separator or other type of dust collector pressure lock trips the raw coal feeder.
(3) Power failure closes all valves that are required to isolate the system.

6.6.4 Firing System for Rotary Kilns.

6.6.4.1 Description of Direct-Firing System. This system is a form of direct firing as described in 6.4.5.1 and shown in Figures 6.6.4.1(a) and (b). The only special equipment is a dust collector with a pressure lock for cleaning hot air or gas (optional).

FIGURE 6.6.4.1(a) Direct-fired pulverized fuel systems for rotary kilns (with pressure pulverizer).

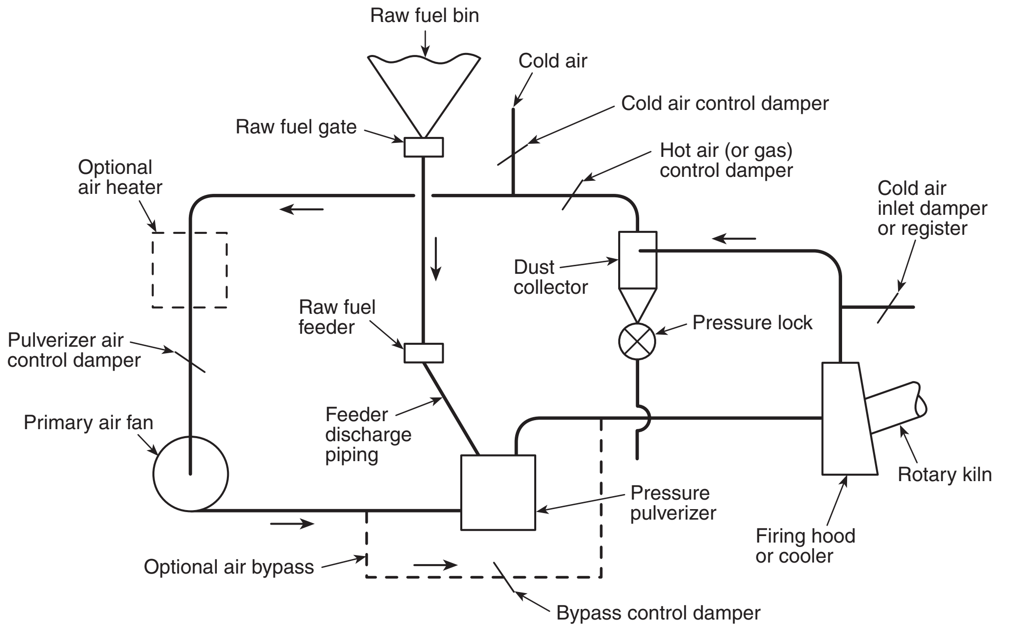
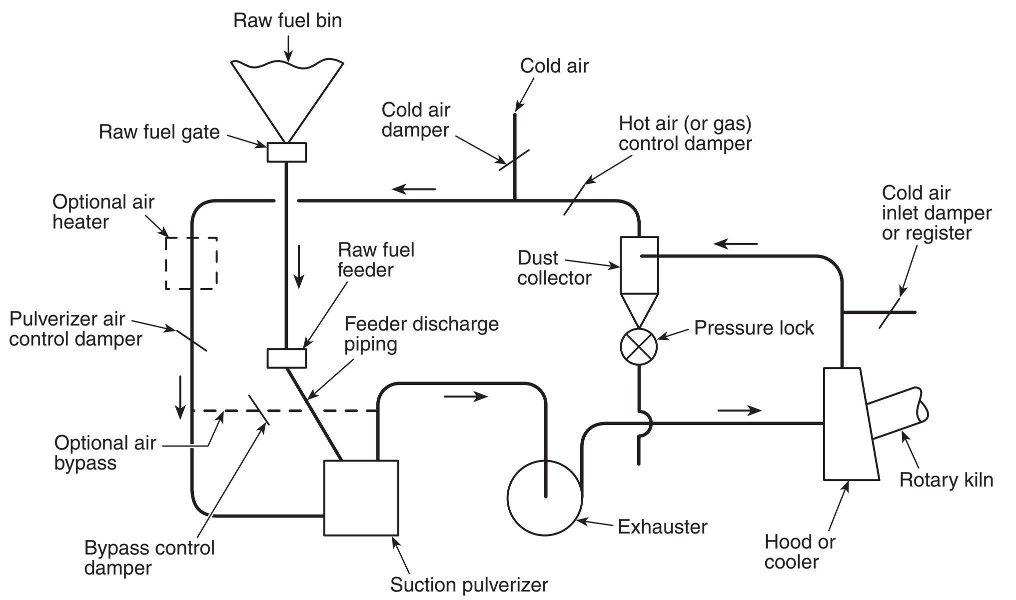


FIGURE 6.6.4.1(b) Direct-fired pulverized fuel systems for rotary kilns (with suction pulverizer).



6.6.4.1.1 Isolation Requirements.

(1) When a bypass air system is used, a bypass control damper shall be installed.
(2) A tempering damper shall be installed near the kiln hood to protect the hot gas duct.

6.6.4.1.2 Operation.

6.6.4.1.2.1 Starting Sequence. The starting sequence shall be as follows:

(1) Start the pressure lock.
(2) Start the primary air fan or exhauster.
(3) Start the air heaters, if furnished.
(4) Start the pulverizer.
(5) Start the raw fuel feeder.
(6) Adjust the primary air and fuel to the desired value.

6.6.4.1.2.2 Normal Operation. Normal operation shall be as described in 6.5.2.2.

6.6.4.1.2.3 Normal Shutdown. The normal shutdown procedure shall be as follows:

(1) Shut off the hot air.
(2) When the pulverizer is cool, stop the raw fuel feeder.
(3) When the pulverizer is empty, stop the pulverizer.
(4) Stop the primary air fan or exhauster.
(5) Stop the pressure lock.

6.6.4.1.3 Interlocking. Interlocking shall be as described in 6.4.7.

Chapter 7 Stokers

7.1 Scope.

7.1.1 This chapter shall apply to boilers using a stoker to fire the following fuels:

(1) Coal
(2) Wood
(3) Refuse-derived fuel (RDF)
(4) Municipal solid waste (MSW)
(5) Other solid fuels

When solid fuel is fired simultaneously with other fuels (e.g., a solid fuel stoker fired in combination with gas, oil, or pulverized auxiliary fuel), additional controls and interlocks shall include those covered in Chapters 2, 3, and 6.

Exception No. 1: The purge requirements of Chapters 2 and 3 shall not be required when the stoker is firing and the boiler is on-line. In those cases, if no cooling air is being provided to the auxiliary burners, a purge of their associated air supply ducts shall be provided.

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

7.2* Purpose.

7.2.1 The purpose of this chapter shall be to establish minimum requirements for the design, installation, operation, and maintenance of stoker-fired boilers, their fuel-burning systems, and related control equipment in order to contribute to operating safety. The requirements of Chapter 1 shall apply unless they conflict with the requirements of Chapter 7.

7.2.2 Instrumentation, safety interlocks and protective devices, operating sequences, and a clear understanding of furnace explosions by designers and operators shall be utilized to reduce the risks and actual incidents.

7.3* Fuel-Burning System. *(See Appendix G.)*

7.3.1 System Requirements.

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

7.3.1.2 The stoker fuel-burning system shall include the following:

(a) Air supply subsystem *[Refer to 1.9.2.3.2(b).]*

(b) Fuel supply subsystem

(1) The fuel supply equipment shall be properly sized and arranged to ensure a continuous, controlled fuel flow adequate for all operating requirements of the unit.
(2) The fuel unloading, storage, transfer, and preparation facilities shall be designed and arranged to size the fuel properly, to remove foreign material, and to minimize interruption of fuel supply. This shall include fuel sizing equipment and magnetic separators where necessary.
(3)* Mass-fired MSW systems shall incorporate fire-detection and fire-extinguishing systems into and over the feed system to extinguish and control the flashbacks of fuel as it is being fed into the furnace. Extinguishing systems shall be capable of being used repeatedly without taking the unit out of service.

(c)* Furnace subsystem

(1) The furnace shall be sized and arranged with respect to the grate subsystem so that the grate is fired to maintain stable combustion and minimize furnace pressure fluctuations.
(2) Observation ports shall be provided to permit inspection of the furnace and grate.
(3) Observation ports and lancing doors for mass-fired MSW units shall be provided with vision ports that permit observation and operation of the unit while puffs are expected and occurring. Glasses shall be replaceable without taking the unit out of service. Lancing ports with aspirators or other devices to safely permit lancing of the fuel bed without restricting operations shall be provided when required by operating conditions.
(4) Relatively high induced draft fan head capability is required by flue gas cleaning equipment. The maximum negative furnace pressure is determined primarily by the maximum head characteristic of the induced draft fan; an objective of the final design shall be to limit the maximum head capability of draft equipment to that necessary for satisfactory operation. Fan selection and arrangement of ductwork shall be designed to limit the effect of negative head. *(Refer to Section 3.5.)*
(5) The furnace and flue gas removal system shall be designed so that the maximum head capability of the induced draft system with ambient air does not exceed the design pressure of the furnace, ducts, and associated equipment. This design pressure shall be defined the same as the wind and seismic stresses of the American Institute of Steel Construction (AISC) Manual of Steel Construction, Section A-5-2.

(d) Ash removal subsystem

(1) The grate subsystem and flue gas cleaning subsystem shall be sized and arranged so as 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.

7.4 Combustion Control System.

7.4.1 System Requirements.

7.4.1.1 Furnace input shall be controlled to respond to the energy demand under all operating conditions.

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

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

7.4.1.4 Furnace draft shall be maintained at the desired set point in the combustion chamber.

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

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

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

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

(1) Control of the blower outlet pressure using a manual set point
(2) Control of overfire air in parallel with undergrate airflow

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

7.5 Operation.

7.5.1 General. This section shall apply to typical stoker operation. Manufacturers' recommendations shall be consulted.

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

(1) Furnace and gas passages in good repair and free of foreign material
(2) Evacuation of boiler enclosure and associated ductwork by all personnel and closing of all access and inspection doors
(3) Supply of energy to control system and to safety interlocks
(4) Verification that the grate is clear of foreign material and operational
(5) Verification that the fuel feed system is clear of foreign material and is operational
(6) Feeder control is operational through full range
(7) All air and flue gas control dampers operational through full range
(8) Establishment of proper drum level with clean, treated, and deaerated water
(9) Satisfactory operation of oxygen and combustible analyzers, where provided
(10) Setting of vent and drain valves in accordance with the boiler manufacturer's instructions

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

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

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

(c) From outside the furnace, spray the bed with a light coat of distillate oil, or place oil-soaked rags or kindling on fuel bed. Gasoline, alcohol, or other highly volatile material shall not be used for light-off.

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

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

Caution: Excessive negative draft will, in some cases, cause fuel to be pulled from the feeders onto the grate.

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

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

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

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

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

7.5.3.1 When starting up and firing high-moisture fuel, the operation of auxiliary fuel burners shall be evaluated.

7.5.3.2 Where a boiler is equipped with auxiliary gas or oil burners, it shall be permitted to put the boiler on the line using this auxiliary fuel and then to feed the solid fuel up on the grate, where it will ignite from radiant heat of the auxiliary burners. Care shall be taken to protect the grate from overheating.

7.5.3.3 Start-up procedures for other fuels as described in Appendix F are dependent on the characteristics of the particular fuel. In all cases, manufacturers' instructions shall be consulted.

7.5.4 Normal Operation.

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

7.5.4.2 Each stoker shall be equipped with adjustments for the distribution of the fuel. Manual adjustments for the distribution of fuel shall be made from visual appearance of the fuel bed, furnace, and flue gas analyzer. Visual observations of the fuel bed conditions through open doors shall be made with extreme care

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

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

7.5.5 Normal Shutdown. The normal shutdown procedure shall be as follows:

(1) The boiler load shall be reduced manually to minimum load.
(2) The fuel shutoff gates, where furnished above the fuel feeders, shall be closed.
(3) The remaining fuel downstream from the shutoff gate shall be burned out.
(4) Normal furnace draft shall be maintained throughout this process.
(5) The overfire air fan shall be left running.

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

(6) After fuel feed ceases and the fire is burned out, the overfire air and forced draft fan shall be operated in accordance with the manufacturer's recommended cool-down rate. The overfire air fan shall be left running until the furnace and boiler are sufficiently cool to prevent damage to the overfire system from a backflow of hot gases.
(7) Where the forced draft fan is shut off, a natural draft flow of air through the grates shall be provided.
(8) For spreader stokers, fuel feeders with rotating devices shall be left running to maintain even temperature until the furnace has cooled sufficiently to prevent damage to the rotating devices.

7.5.6 Normal Hot Start.

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

(1) Verify that the fuel feed system is clear of foreign material and is operational.
(2) Keep the feeder control operational through full range.
(3) Keep all air and flue gas control dampers operational through full range.
(4) Establish the drum level.
(5) Set the vent and drain valves in accordance with the boiler manufacturer's instructions.
(6) Verify an open flow path from the inlet of the FD fan to the stack. Where the natural draft is insufficient for initial firing, the induced draft fan shall be started and normal furnace draft maintained.
(7) Fill the feeder hopper with fuel, start a feed mechanism, establish a bed of fuel on the grate, and ignite it.
(8) When the bed of fuel has ignited, start the ID fan (where the ID fan is not in operation), and place the draft control in automatic mode of operation.
Caution: Excessive negative draft will, in some cases, cause fuel to be pulled from the feeders onto the grate.
(9) Undergrate air pressure shall always be greater than furnace pressure to prevent reverse flow.
(10) When the fuel bed is actively burning, start the FD fan with dampers at minimum position.
(11) The overfire air fan shall be started immediately to prevent damage from gases passing through the ductwork.
(12) Start the fuel feed. Observe the operation, and adjust the fuel rate and air as required until boiler steam pressure is at the desired operating pressure.
(13) Place the fuel and air in the automatic mode of operation.

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

(1) Establish the drum level.
(2) Set the vent and drain valves in accordance with the boiler manufacturer's instructions.
(3) Verify an open flow path from the inlet of the FD fan to the stack. Where the natural draft is insufficient for initial firing, the ID fan shall be started and normal furnace draft maintained.
(4) Fill the feeder hopper with fuel.
(5) Start the ID fan (where the ID fan is not in operation), and place the draft control in automatic mode of operation.
Caution: Excessive negative draft will, in some cases, cause fuel to be pulled from the feeders onto the grate.
(6) Ensure that undergrate air pressure is always greater than furnace pressure in order to prevent reverse flow.
(7) Start the FD fan with dampers at minimum position when the fuel bed is actively burning.
(8) Start the overfire air fan immediately to prevent damage from gases passing through the ductwork.
(9) Start the fuel feed. Observe the operation and adjust the fuel rate and air as required until boiler steam pressure is at the desired operating pressure.
(10) Place fuel and air in automatic mode of operation.

7.5.7 Emergency Shutdown. In the situations in 7.5.7.1 through 7.5.7.5, manufacturer's emergency procedures shall be followed.

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

7.5.7.2 Loss of the ID fan shall require the following:

(1) The ID damper going into the full open position
(2) The fuel feed being immediately shut off
(3) The forced draft fan being shut down
(4) The forced draft damper going into the closed position
(5) The overfire air fan remaining running and the overfire airflow dampers being placed in the closed position

Exception: Paragraph 7.5.7.2 shall not apply to boilers where manufacturer's recommendations state otherwise.

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

Caution: Excessive negative draft will, in some cases, cause fuel to be pulled from the feeders onto the grate.

7.5.7.4 An emergency shutdown caused by loss of feedwater shall require immediate completion of the following:

(1) The fuel feed shall be shut down.
(2) The forced draft fan shall be shut down.
(3) Normal furnace draft shall be maintained.
(4) The overfire air fan shall remain running, and overfire airflow dampers shall be placed in the closed position.

Exception: This rule shall not apply to boilers where manufacturers' recommendations state otherwise.

This emergency shutdown procedure shall be permitted to vary. See manufacturer's recommendations.

7.5.7.5 Critical Emergency Situations. The following critical emergency situations shall require action:

(a) Low drum level

(1) Stop all fuel feed(s).
(2) Stop fan(s) that supply combustion air to the unit.
(3) Continue running the ID fan with the combustion air damper at minimum setting to limit continued combustion of the residual fuel bed.
Caution: Excessive negative draft will, in some cases, cause fuel to be pulled from the feeders onto the grate.

(b) High operating steam pressure

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

7.5.8* Multifuel Firing.

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

7.5.8.2 Excess air shall be maintained at all times by continuously observing the burner flames, the air/fuel ratio, or an oxygen indicator, where provided.

7.6 Furnace Inspection.

7.6.1 Personnel shall be prevented from entering the furnace until slag deposits have been removed. Personnel shall be protected from falling objects.

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

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

7.8 Access Doors or Observation Ports.

7.8.1 Protective clothing and face shields shall be used while viewing the furnace through access doors or observation ports and while manipulating the fuel or ash bed.

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

7.9 Ash Hopper Access Doors.

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

7.9.2 Precautions shall be taken when opening ash hopper access doors after shutdown. Hot or smoldering fly ash that has bridged over the ash removal connection will cascade out the door if disturbed. Because fly ash will smolder long after unit shutdown, precautions shall be taken to avoid stepping into accumulated ash while inspecting equipment.

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

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

Chapter 8 Referenced Publications.

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

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

NFPA 30, *Flammable and Combustible Liquids Code*, 2000.

NFPA 31, *Standard for the Installation of Oil-Burning Equipment,* 1992 edition.

NFPA 31, *Standard for the Installation of Oil-Burning Equipment,* 2001.

NFPA 51, *Standard for the Design and Installation of Oxygen–Fuel Gas Systems for Welding, Cutting, and Allied Processes,* 1997.

NFPA 51B, *Standard for Fire Prevention During Welding, Cutting, and Other Hot Work,* 1999.

NFPA 54, *National Fuel Gas Code*, 1999.

NFPA 58, *Liquefied Petroleum Gas Code*, 2001.

NFPA 69, *Standard on Explosion Prevention Systems*, 1997.

NFPA 70, *National Electrical Code®*, 1999.

NFPA 77, *Recommended Practice on Static Electricity*, 2000.

NFPA 241, *Standard for Safeguarding Construction, Alteration, and Demolition Operations*, 2000.

NFPA 497, *Recommended Practice for the Classification of Flammable Liquids, Gases, or Vapors and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*, 1997.

NFPA 499, *Recommended Practice for the Classification of Combustible Dusts and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*, 1997.

NFPA 850, *Recommended Practice for Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations*, 2000.

8.1.2 Other Publications.

8.1.2.1 ABMA Publication. American Boiler Manufacturers Association, 950 North Glebe Road, Arlington, VA 22203.

ABMA, *Combustion Control Guidelines for Single Burner Firetube and Watertube Industrial/Commercial Institutional Boilers*

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

AISC M016, *Manual of Steel Construction Allowable Stress Design,* 1989.

8.1.2.3 ANSI Publication. American National Standards Institute, Inc., 11 West 42nd Street 13th floor, New York, NY 10036.

ANSI B31.1, *Power Piping*, 1998.

8.1.2.4 API Publication. American Petroleum Institute, 1220 L Street, NW, Washington, DC 20005.

API RP 500A, *Classification of Locations for Electrical Installations in Petroleum Facilities Classified as Class I, Division I, and Division 2*, 1997.

8.1.2.5 ASME Publications. American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016-5990.

ASME B 31.1, *Power Piping Code*, 1998.

ASME B 31.3, *Process Piping*, 1999.

8.1.2.6 ASTM Publications. American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM D 388, *Standard Classification of Coals by Rank*, 1988.

ASTM D 396, *Standard Specification for Fuel Oils*, 1998.

ASTM D 409, *Standard Test Method for Grindability of Coal by the Hardgrove-Machine Method*, 1997.

ASTM D 1655, *Standard Specification for Aviation Turbine Fuels (Jet B)*, 1998.

ASTM D 2880, *Standard Specification for Gas Turbine Fuel Oils*, 1998.

Appendix A Explanatory Material

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

A.1.1 Technological advances in recent years and, in particular, the pervasiveness of microprocessor-based hardware make it even more important that only highly qualified individuals be employed in applying the requirements of this code to operating systems. Each type of hardware has its own unique features and operational modes. It is vital that the designer of the safety system be completely familiar with the features and weaknesses of the specific hardware and possess a thorough understanding of this code and its intent.

It is not possible for this code to encompass all specific hardware applications, nor should this code be considered a “cookbook” for the design of a safety system. Where applying any type of equipment to a safety system, the designer should consider carefully all of the possible failure modes and the effect that each might have on the integrity of the system and the safety of the unit and personnel. In particular, no single point failure should result in an unsafe or uncontrollable condition or a masked failure of a microprocessor-based system that could result in the operator unwittingly taking action that could lead to an unsafe condition.

When using this code, the sections that apply to all fuels covered should be used in conjunction with those covering the specific fuel utilized.

A.1.1.6 Users of equipment covered by this code should adopt those features that they consider applicable and practical for existing installations. Physical limitations could cause disproportionate effort or expense with little increase in protection. In such cases, the authority having jurisdiction should be satisfied that reasonable protection is provided.

In existing units, any condition that represents a serious combustion system hazard should be mitigated by application of appropriate safeguards.

A.1.2.1

A. Combustion Explosions.

I. The basic cause of uncontrolled fires or combustion explosions is the ignition of an accumulated combustible mixture within the confined space of a furnace, HRSG, or pulverizer, or the associated passes, ducts, and fans that convey the gases of combustion to the stack.

II. A dangerous combustible mixture within the boiler, HRSG, or pulverizer enclosure consists of the accumulation of an excessive quantity of combustibles mixed with air in proportions that result in rapid or uncontrolled combustion when an ignition source is supplied. An explosion can result from ignition of this accumulation if the quantity of combustible mixture and the proportion of air to fuel are such that an explosive force is created within the enclosure. The magnitude and intensity of the explosion depends on both the relative quantity of combustibles that has accumulated and the proportion of air that mixes with the combustibles at the moment of ignition. Explosions, including “puffs,” are the result of improper operating procedures by personnel, improper design of equipment or control systems, or malfunction of the equipment or control system.

III. Numerous conditions can arise in connection with the operation of a system that produce explosive conditions. The most common of these are as follows:

(1) An interruption of the fuel or air supply or ignition energy sufficient to result in momentary loss of flames, followed by restoration and delayed reignition of an accumulation
(2) Fuel leakage into an idle combustion chamber and the ignition of the accumulation by a spark or other source of ignition
(3) Repeated unsuccessful attempts to light-off without appropriate purging, resulting in the accumulation of an explosive mixture
(4) The accumulation of an explosive mixture of fuel and air as a result of loss of flame or incomplete combustion and the ignition of the accumulation by a spark or other ignition source, such as could occur when attempting to relight a burner(s)
(5) Purging with an airflow that is too high, which stirs up smoldering combustible materials

IV. The conditions favorable to an explosion described in III are typical examples, and an examination of numerous reports of explosions suggests that the occurrence of small explosions, “puffs,” or near-misses has been far more frequent than usually is 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 incidence of explosions.

V. In a boiler or HRSG, upset conditions or control malfunction can lead to an air/fuel mixture that could result in a flameout followed by reignition after a combustible air/fuel ratio has been re-established.

VI. Dead pockets might exist in a pulverized fuel system or in a boiler or HRSG enclosure or other parts of the unit, where combustible mixtures can accumulate under upset conditions. These accumulations could ignite with explosive force in the presence of an ignition source.

B. Furnace or HRSG Implosions

I. An implosion is the result of the occurrence of excessively low gas side pressure, which causes equipment damage.

II. Two conditions that have caused implosions follow:

(1) A maloperation of the equipment regulating the gas flow, including air supply and flue gas removal, resulting in exposure to excessive induced draft fan head capability
(2) The rapid decay of gas temperatures and pressure resulting from either a rapid reduction in fuel input or a master fuel trip

III. A combination of the two conditions indicated in II has resulted in the most severe implosion incidents.

A.1.3.2.3 Excess Air. This is not the same as Air-Rich as defined in 1.3.4.

A.1.3.8 Approved. The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization that is concerned with product evaluations and is thus in a position to determine compliance with appropriate standards for the current production of listed items.

A.1.3.13 Authority Having Jurisdiction. The phrase “authority having jurisdiction” is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

A.1.3.14 Autoignition Temperature. For units covered by this code, a spark or flame can be considered as the heating or heated element. Published autoignition temperatures are based on laboratory conditions. Consideration should be given to the effect of actual operating conditions, including temperature, pressure, and oxygen concentration.

A.1.3.27 Burner Management System. The burner management system may include the following functions as specified in this code: interlock system, fuel trip system, master fuel trip system, master fuel trip relay, flame monitoring and tripping systems, ignition subsystem, main burner subsystem, warm-up burner subsystem, bed temperature subsystem, and duct burner system.

A.1.3.36 Code. The decision to designate a standard as a "code" is based on such factors as the size and scope of the document, its intended use and form of adoption, and whether it contains substantial enforcement and administrative provisions.

A.1.3.93 Listed. The means for identifying listed equipment may vary for each organization concerned with product evaluation; some organizations do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

A.1.3.99 Master Fuel Trip. For HRSGs, a master fuel trip does not shut off fuel to the combustion turbine.

A.1.4 Manufacture, Design, and Engineering.

Project inception phase. Safety in any plant is directly influenced by an extensive up-front effort in the engineering, design, and selection of equipment for each individual application. In the project inception phase, the following should be accomplished to ensure a plant design that meets expected operating modes and reliability needs:

(1) Establishment of plant operating parameters
(2) Identification of site-related constraints
(3) Review of steam cycle, including generating a family of heat balance diagrams for the expected operating ranges and modes
(4) Conceptualization of plant layout to provide for personnel safety, operability, and maintenance needs
(5) Definition and verification of requirements of worst-case operating transients, including start-ups
(6) Definition of required test program
(7) Definition of start-up criteria and goals
(8) Identification of the authority having jurisdiction. If multiple authorities having jurisdiction are identified, the scope of each authority having jurisdiction should be determined.
(9) Establishment of electrical area classifications by the owner or the owner's designated representative in conjunction with the boiler or HRSG system designer

Equipment planning. The project should consider the use of dynamic simulation, prior operating experience, or both before equipment is selected. Dynamic simulation, where utilized, should include development of the following:

(1) Configuration and data initialization
(2) Plant behavior knowledge
(3) Preliminary control system design and tuning
(4) Validation of operating requirements (system performance)
(5) Transients and ramps for intended and unintended operation

A.1.4.3 The maximum number of automatic trip features does not necessarily provide for maximum overall safety. Some trip actions result in additional operations that increase exposure to hazards.

A.1.6.1 *Human error.* Statistics indicate that human error is a contributing factor in the majority of explosions. It is important to consider whether the error was a result of any of the following:

(1) Lack of understanding of, or failure to use, proper operating procedures, safeguards, and equipment
(2) Unfavorable operating characteristics of the equipment or its control
(3) Lack of functional coordination of the various components of the steam-generating system and its controls

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

A.1.6.2 Integration of the various components of these systems is accomplished by the following:

(1) Design and operating personnel who possess a high degree of competence in this field and who are mandated to achieve these objectives
(2) Periodic analysis of the plant with respect to evolving technology so that improvements can be made to make the plants safer and more reliable
(3) Documentation of the plant equipment, systems, and maintenance

A.1.7.1 *Safety.*

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

II. Special safety precautions. Severe injury and property damage can result from careless handling of unconfined pulverized fuel; therefore, extreme caution should be used in cleaning out plugged burners, burner piping, pulverized fuel bins, feeders, or other parts of the system.

Welding and flame cutting. (Refer to NFPA 51, Standard for the Design and Installation of Oxygen-Fuel Gas Systems for Welding, Cutting, and Allied Processes; NFPA 51B; Standard for Fire Prevention During Welding, Cutting, and Other Hot Work; and NFPA 241, Standard for Safeguarding Construction, Alteration, and Demolition Operations. For work on pulverized fuel systems, refer to Chapter 6 of this document.)

(a) Fire-resistant blankets or other approved methods should be used in a manner so as to confine weld spatter or cutting sparks.

(b) A careful inspection of all areas near welding or cutting areas, including the floors above and below, should be made when the job is finished or interrupted, and such areas should be patrolled for a period sufficient to make certain that no smoldering fires have developed.

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

Either ground-fault protected or specially approved low-voltage (3-volt to 6-volt or 12-volt) extension cords and lighting should be used for all confined spaces and where moisture might be a hazard.

Explosion-operated tools and forming techniques should not be used where flammable dust or dust clouds are present. Where such operations are necessary, all equipment, floors, and walls should be cleaned, and all dust accumulation should be removed by an approved method. A careful check should be made to ensure that no cartridges or charges are left in the work area.

III. Confined Space. A confined space is any work location or enclosure in which any of the following could possibly exist:

(1) The dimensions are such that a person 6 ft (1.8 m) tall cannot fully stand up in the middle of the space, or that person's arms cannot be extended in all directions without hitting the enclosure.
(2) 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.
(3) Confined spaces include, but are not limited to, ducts, heaters, windboxes, cyclones, dust collectors, furnaces, bunkers, or bins.

Specific procedures that provide the following should be developed for and used by personnel entering a confined space:

(1) Positive prevention of inadvertent introduction of fuel, hot air, steam, or gas.
(2) Positive prevention of inadvertent starting or moving of mechanical equipment or fans.
(3) Prevention of the accidental closing of access doors or hatches.
(4) Inclusion of tags, permits, or locks to cover confined space entry.
(5) Determination of the need for ventilation or self-contained breathing apparatus where the atmosphere might be stagnant, depleted of oxygen, or contaminated with irritating or combustible gases. Tests for an explosive or oxygen-deficient atmosphere should be made.
(6) Provision of a safety attendant. The safety attendant should remain outside of the confined space with appropriate rescue equipment and should be in contact (preferably visual contact) with those inside.
(7) Provision of safety belts or harnesses, which should be tied off where such use is practical.

IV. Raw fuel bunkers. In addition to the general safety precautions of A.1.7.1.1, additional specific provisions for entering and working in fuel bunkers or bins should be made, recognizing the high probability of the presence of combustible or explosive gases and the hazards associated with shifting or sliding fuel.

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

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

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

Tests should be made for the presence of an explosive and oxygen-deficient atmosphere in a bunker or bin. If such an atmosphere is found, positive ventilation should be provided, and entry should be prohibited until the atmosphere returns to safe limits. Sufficient retests should be made during the course of the work to ensure a safe atmosphere. If a safe atmosphere is not maintained, the bunker should be evacuated. However, a nonexplosive, oxygen-deficient atmosphere should be permitted to be entered with suitable breathing apparatus.

No person should enter a bunker containing burning fuel.

No person should enter a bunker or walk on the fuel unless the safety attendant is present and the person is equipped with a safety belt or harness and lifeline. The lifeline should be secured to an adequate support above the person and should have only sufficient slack to permit limited movement necessary to perform the job. The lifeline should be manila rope at least $^1/_2$ in. (12.7 mm) in diameter, or equivalent, and in good condition.

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

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

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

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

A.1.7.1.1 An example of an inspection and maintenance schedule is as follows:

(a) *Daily.* Flame failure detection system, low water level cutout, and alarm

(b) *Weekly.* Igniter and burner operation

(c) *Monthly.* Fan and airflow interlocks, fuel safety shutoff valves for leakage, high steam pressure interlock, fuel pressure and temperature interlocks for oil, high and low fuel pressure interlocks, and gas strainer and drip leg for gas

(d) *Semiannually.* Burner components, flame failure system components, piping, wiring, and connections of all interlocks and shutoff valves, calibration of instrumentation and combustion control system

A.1.7.2.1.1 The operator training program should consist of one or more of the following:

(1) A review of operating manuals and videotapes
(2) Programmed instruction
(3) Testing
(4) Use of simulators
(5) Field training
(6) Others (as agreed to by the manufacturers and the users)

A.1.7.2.2.1 The maintenance training program should consist of one or more of the following:

(1) A review of maintenance manuals and videotapes
(2) Programmed instruction
(3) Testing

(4) Field training
(5) Others (as agreed to by the manufacturers and the users)

A.1.8.5 The minimum airflow value (25 percent for most boilers) is based on historical experience in reducing the occurrence of explosions. This value is based on safety considerations and could be in conflict with economic considerations or emission limits. Factors considered in establishing the minimum airflow include the following:

(1) Removal of combustibles and products of combustion
(2) Cooling requirements for burners out of service
(3) Accuracy of total burner airflow, individual burner airflow, and other airflow measurements
(4) Accuracy of burner air and main burner fuel distribution
(5) Effect of thermal and pressure transients within the combustion chamber on the air and main burner fuel flows
(6) Impact of air leakage
(7) Wear and deterioration of the unit and equipment
(8) Operational and control margins

A.1.9.1 The transient internal design pressure defined in 1.9.1 should be taken into consideration in the design of the air and gas flow path from the FD fan discharge through the stack.

A.1.9.1.1 Examples: If the test block capability of the forced draft fan at ambient temperature is +25 in. of water (+6.2 kPa), then the minimum positive design pressure is +25 in. of water (+6.2 kPa).

If the test block capability of the forced draft fan at ambient temperature is +40 in. of water (+9.9 kPa), then the minimum positive design pressure is +35 in. of water (+8.7 kPa).

Caution: Furnace design pressure greater than those specified in 1.9.1.1 could result in a more severe energy release of the furnace enclosure if a fuel explosion occurs.

A.1.9.1.2 The induced draft fan head capability increases due to significant draft losses beyond the air heater or for other reasons such as excessive induced draft fan test block margins. Where the induced draft fan test block capability is more negative than –35 in. of water (–8.7 kPa), consideration should be given to an increased negative design pressure.

Examples: If the test block capability of the induced draft fan at ambient temperature is –15 in. of water (–3.7 kPa), then the minimum negative design pressure is –15 in. of water (–3.7 kPa).

If the test block capability of the induced draft fan at ambient temperature is –40 in. of water (–9.9 kPa), then the minimum negative design pressure is –35 in. of water (–8.7 kPa).

A.1.9.2 Common hazards are involved in the combustion of liquid and gaseous fuels. In addition, each of these fuels has special hazards related to its physical characteristics.

A. Gas firing. The following items should be considered in the design of the fuel gas firing systems:

(a) Gas is colorless; therefore, a leak usually cannot be detected visually. Also, reliance cannot be placed on detection of a gas leak by means of the presence of odor.

(b) Potentially hazardous conditions are most likely to occur within buildings, particularly where the gas piping is routed through confined areas. In the latter instance, adequate ventilation should be provided. Outdoor steam generators tend to minimize confined area problems.

(c) Natural gas can be either "wet" or "dry." A wet gas usually implies the presence of distillate, which could be characteristic of a particular source. In the case of such a wet gas, the carryover of distillate into the burners could result in a momentary flameout and possible reignition. Reignition could result in an explosion. Therefore, special precautions should be taken with wet gas supply systems. *(See NFPA 54, National Fuel Gas Code.)*

(d) Discharges from relief valves or from any other form of atmospheric vents can become hazardous unless special precautions are taken.

(e) Maintenance and repair of gas piping can be hazardous unless proper methods are used for purging and recharging the line before and after making the repairs. *(See NFPA 54, National Fuel Gas Code.)*

(f) Most natural gas that is supplied to boilers typically is lighter than air and presents no special problems in the atmosphere over and above those addressed in this code. Because of developing energy cost considerations, many boilers are using a gas or a mixture of gases with heavier-than-air characteristics. These heavier-than-air gases, such as propane/air mixtures, refinery gases, and so forth, require special consideration in storing, handling, and venting to prevent accumulations in depressions or in confined areas.

(g) The nature of gas fuel creates the possibility of severe departures from design air/fuel ratios without any visible evidence at the burners, furnace, or stack that could escalate into a progressively worsening condition. Therefore, combustion control systems that respond to reduced boiler steam pressure or steam flow with an impulse for more fuel, unless protected or interlocked to prevent a fuel-rich mixture, are potentially hazardous. This would also apply to firing with fuel or air on manual without the aforementioned interlocks or alarms.

(h) Widely different characteristics of gas from either single or multiple sources could result in a significant change in heat input rate to the burners without a corresponding change in airflow.

(i) Relief valves and atmospheric vents should discharge into areas away from building ventilation systems, sources of ignition, or other areas where the discharge gases create a hazard.

(j) Gas piping should be purged prior to, and after, maintenance and repair as defined in NFPA 54, *National Fuel Gas Code.*

B. Oil Firing. The following items should be considered in the design of the fuel oil firing systems:

(a) Firing of oil fuel into an HRSG can create a special hazard by causing soot accumulations in low-temperature sections.

(b) Small oil leaks can result in serious fire damage.

(c) Water or sludge in fuel oil storage tanks or improperly located suction takeoffs from the storage tank can result in hazardous interruptions or pulsations of the fuel supply to the burners. A flameout, either immediately or at a later time, can result because of plugged strainers or burner tips.

(d) Widely different characteristics of fuel oil from either a single source or multiple sources can result in a significant change in heat input rate to the burner(s) without an equivalent change in airflow or without an appropriate change in fuel oil temperature to restore the flowing viscosity to the proper value. Different shipments of fuel oil with dissimilar characteristics can cause a precipitation of sludge that can lead to hazards.

(e) Inserting an oil gun in the burner assembly without a tip, new gaskets, or a sprayer plate is a constant hazard. This can result in an unsafe operating condition.

(f) Clear distillate fuels have low rates of conductivity and generate static electrical charges in the fuel stream that can be dangerous unless flowing velocities are limited. *(See NFPA 77, Recommended Practice on Static Electricity, and API RP 2003, Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents.)*

(g) Maintenance and repair of oil piping can be hazardous unless proper methods are used for purging and recharging the line before and after making repairs. *(See NFPA 31, Standard for the Installation of Oil-Burning Equipment.)*

(h) The incompressibility of fuel oil can create very rapid transients in oil flow through operating burners when the following occurs:

(1) Rapid operation of the oil supply valve
(2) Rapid operation of individual burner shutoff valves
(3) Rapid operation of the regulating valve in the return oil line from the burner header (on systems using this type of control)

(i) Where firing oils that need preheating, the viscosity of oil flowing to the burners should be held within limits to maintain proper atomization.

(j) On installations designed to fire both heated and unheated fuel oils, consideration should be given to the design of the burner control system to ensure proper interlocks are activated for the selected fuel oil. Similar considerations should also be given to the fuel oil piping supply to the burner as well as the oil recirculating piping to the fuel storage tanks, depending on the arrangement of the equipment provided.

(k) Proper pumping and atomization of fuel oils are dependent upon control of viscosity. Changes in viscosity in relation to temperature vary for different oils and blends of oils. Close attention should be given to the design and operation of viscosity control systems for each fuel where its source or properties are variable.

(l) The operation of air heater sootblowers should be in accordance with the recommendations of the air heater manufacturer. Initial firing of oil fuel in a cold boiler can create a special hazard by causing fires in air heaters.

C. Fuel oil — general considerations.

(a) The term *fuel oil* refers to liquid fuels with widely differing characteristics. A fuel oil burning system is designed for a specific range of oil characteristics. Attempting to burn an oil whose characteristics differ widely from those for which the system is designed can cause serious operating difficulties and potential safety hazards. Therefore, care should be exercised to ensure that fuel oil received at a plant is within the specified range of the handling and burning equipment.

(b) The more important characteristics of fuel oils are provided in ASTM specifications. It is relatively simple to identify oils that require special provisions for storing and functions such as heating, pumping, and atomizing. Generally speaking, Grades 2 and 4 have lower viscosities and less water and sediment than Grades 5 or 6 and so require fewer special provisions to ensure proper handling and burning. However, most boiler fuel oil systems are designed for Grades 5 and 6, which are heavier; therefore, such systems include provisions for preheating these usually viscous fuels. Furthermore, more care is necessary in the design and operation of fuel oil systems supplied with Grade 6 oil than with the other ASTM grades. Care should be taken to avoid flameouts attributable to interruptions or pulsation of the fuel supply or plugging of strainers or burner tips.

(c) The following characteristics can affect the proper and safe burning of fuel oils:

(1) Fuel oil is a complex mixture of hydrocarbons of differing molecular weights and differing boiling and freezing points. When subjected to sufficiently high temperature, accumulations of the fuel partially decompose and volatilize, thus creating new liquid, gaseous, and solid fuels with unpredictable properties.
(2) Fuel oil should be introduced into the furnace as an extremely fine mist in order to mix intimately with the combustion air so that it can burn quickly and completely. In boilers, this is accomplished by spraying the fuel oil through small orifices with high-pressure drops (mechanical atomization) or by using steam or air to break up small oil streams. Viscosity and volatility are characteristics of the oil that indicate ease of atomization.
(3) Viscosity affects ease of pumping and atomization. Temperature significantly affects viscosity.
(4) *Flash point* is an indicator of volatility and, thus, of potential for combustible vapors.
(5) Some fuel oils contain constituents that, when overheated, can decompose and form solids or can solidify when exposed to low ambient temperatures. The presence of such solids in the fuel can cause interruptions.
(6) Excessively heated oil can create vapor-lock, which can prevent continuous operation. Cold oil can prevent satisfactory atomization.
(7) Contaminants in fuel can include salt, sand, sludge, water, and other abrasive or corrosive constituents. Some fuels contain waxy materials that precipitate out, clogging filters and other elements of the fuel system.
(8) Low temperature can increase viscosity, inhibit flow, or precipitate waxy materials. High temperatures can cause carbonization or excessive pressures and leakage due to fluid expansion in "trapped" sections of the system.

D. Coal firing.

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

To ensure that the type of coal and its preparation are suitable for the equipment, a proper definition is needed that is acceptable to the equipment designer, the purchasing agency responsible for procuring the fuel, and the operating department that burns the fuel. Volatility, moisture and ash content, size of raw coal, grindability, and other characteristics are to be given close attention. The following factors influence the ultimate suitability of a particular coal:

(1) Coal is an abrasive and corrosive substance. The level of necessary equipment maintenance, therefore, could be several orders of magnitude greater than is needed for liquid and gaseous fuels.
(2) Coal changes when it is exposed to the atmosphere. It is common practice to ship and stockpile coal without protection from the weather. The properties of stored coal

can change, possibly necessitating special consideration. Coal with high surface moisture can freeze in shipment or in storage. This could necessitate special handling equipment. Changes in moisture in the coal can affect the safety and performance of the pulverizers and burners.

(3) Changes in grindability of the coal affect the capacity of the pulverizers and could affect the performance of the burners.
(4) Because coal has a high ash content, special attention should be given to problems associated with slag and ash deposits.
(5) Coal is capable of spontaneous combustion and self-heating from normal ambient temperature. This tendency increases radically when the temperature is increased. Blended or mixed coals can heat more rapidly than any of the parent coals.
(6) Volatile matter is given off by the coal. This volatile matter is a gaseous fuel that causes additional hazards.

(b) Unburned or incompletely burned coal can settle out in low velocity areas of the boiler. Often this hot material lies dormant and covered with a thin layer of fly ash. Personnel stepping into or disturbing such deposits have experienced severe injuries. Prior to entry, cleaning of all surfaces where such combustibles can accumulate is recommended.

(c) It takes as little as 3 lb (1.36 kg) of pulverized coal in 1000 ft^3 (28.31 m^3) of air to form an explosive mixture. Since a large boiler burns 100 lb (45.4 kg) or more of coal per second, the safe burning of pulverized coal necessitates strict adherence to planned operating sequences. *(Subsection 3.8.5 defines Sequences of Operation.)*

(d) The raw coal delivered to the plant can contain foreign substances such as scrap iron, wood shoring, rags, excelsior, and rock. Much of this foreign material can interrupt coal feed, damage or jam equipment, or become a source of ignition within a pulverizer. The presence of foreign material could constitute a hazard by interrupting coal flow. This could cause a total or partial flameout and possible reignition accompanied by a "puff" or explosion. Wet coal can cause a coal hangup in the raw coal supply system. Wide variations in the size of raw coal can result in erratic or uncontrollable coal feeding.

(e) Other personnel hazards are involved with coal-fired systems similar to those outlined in Chapter 6.

E. Crude oil — general considerations.

Nature of crude oils. Crude oil is petroleum that is withdrawn from the ground and treated in separators, as necessary, to remove most of the dirt and water and sufficient gaseous constituents to allow safe and convenient shipping.

With regard to safety, the basic difference between crude oils and the grades of fuels defined in ASTM D 396, *Standard Specification for Fuel Oils*, is that crude oils contain dissolved light combustible hydrocarbons. These light, volatile materials are released during storage, handling, or when heated. Because of this, appropriate and adequate provisions are to be made to handle, store, and burn crude oils safely in steam boiler plants. Failure to observe the necessary design, installation, operating, and maintenance procedures could result in disastrous fires or explosions or personal injury, including possible inhalation of toxic (hydrogen sulfide) gas.

Crude oil properties vary considerably. Therefore, it is desirable that flexibility be built into the facility to accommodate the expected range of properties.

Crude oil characteristics are classified according to the results of laboratory tests, and the seller and buyer are to agree on all limitations. This is in contrast to fuel oils, whose properties are controlled within limits by "refining" to meet internationally recognized standards.

The flash points of crude oils can range from below zero (0) to over 150°F (65.6°C). Most crude oils contain volatile light ends not present in fuels meeting the requirements of ASTM D 396, *Standard Specification for Fuel Oils*. Some of these volatile hydrocarbons, such as propane, butane, and pentane, can volatilize crude oil to the atmosphere; because it is heavier than air, this vaporized material can travel for considerable distances and accumulate as a hazardous concentration.

Storage and handling of crude oils. Extensive treatment of storage and handling of crude oils is beyond the scope of this code. However, the safety aspects are so broad that some clarification is essential. Additional general background information can be found in A.3.7.1.

Special attention is directed to the following considerations:

(a) Adequate ventilation is essential in areas where oil leakage could occur (e.g., at pumps, heaters, strainers, and burner fronts, or where maintenance is performed). Confined fuel-handling areas and burner fronts are to be ventilated adequately, and forced air ventilation is to be used where necessary.

(b) Tanks for crude oil storage usually conform to one of the following documents:

API 620, *Standard for Design and Construction of Large, Welded, Low-Pressure Storage Tanks*
API 650, *Standard for Welded Steel Tanks for Oil Storage*

(c) Open-top or covered floating-roof tanks are recommended to minimize possible fires and explosions and to reduce combustible vapor losses, particularly where the flash point is below 100°F (37.8°C).

In fixed-roof tanks, the internal space above the liquid could contain an explosive vapor when in crude oil service. For protection, a fixed-roof tank can be provided with an internal cover floating on the oil, and the space between the cover and the roof can be vented adequately in accordance with API 650, Appendix H. Spacing and fire protection is based on fixed-roof tank requirements *(see also API RP 2003, Recommended Practice for Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents, subsection 3.5.1)*. Existing fixed-roof tanks without internal floating covers may be permitted to be inert-gas blanketed if the flash point could be below 100°F (37.8°C).

Tanks should be spaced and storage areas graded, drained, and diked in accordance with NFPA 30, *Flammable and Combustible Liquids Code*, to contain spills in the event of tank rupture or overflow.

(d) Plant layout and tank location should include consideration of boilover hazards, particularly with fixed-roof tanks. Diking is not a complete protection against the boilover fire phenomenon. Therefore, adequate fire protection and provisions for emergency flow paths should be included.

(e) Consideration should be given to agitation or other means to prevent settling of sludge in crude oil storage tanks.

(f) Piping and valves for crude oil should be of steel. Items such as steel-cased pumps and strainers are recommended to resist possible fire damage and release of fuel into the flames.

(g) Pump selection criteria should include consideration of oil vapor pressure, abrasive and corrosive contaminants, mechanical shaft seals to minimize leakage, and lubricity of the oils. In particular, pump suction pressures need to be high enough to preclude vaporization and cavitation with the oils to be handled.

(h) Ignition sources should be minimized. All piping should be bonded and grounded in accordance with NFPA 77, *Recommended Practice on Static Electricity*.

(i) Consideration should be given to detecting and monitoring combustible gases in areas where they are likely to accumulate.

(j) Access to crude oil–handling areas should be restricted; smoking should be prohibited in designated locations. Work likely to involve flame or sparks, such as welding or burning, should be performed only after the area is checked for safety. Cutting and welding precautions should be in accordance with NFPA 51, *Standard for the Design and Installation of Oxygen–Fuel Gas Systems for Welding, Cutting, and Allied Processes*, and NFPA 51B, *Standard for Fire Prevention During Welding, Cutting, and Other Hot Work*. Each area is to be checked with a portable combustible gas tester before starting work that could involve possible flames or ignition sources.

(k) Where potential toxic gas hazards might exist, personnel protection is to be provided where performing such tasks as cleaning strainers, replacing pumps, and gauging or sampling tanks. Appropriate operating procedures and personnel training are essential.

A.1.9.2.3.2(d) Many factors affect the classification of the igniters, including the characteristics of the main fuel, the combustion chamber and the burner design, and the igniter capacity and location relative to the main fuel burner.

A.1.9.2.4.1 Atmospheric vent valves located between shutoff valves are intended to relieve any gas pressure that builds up due to failure of the first (upstream) shutoff valve. This minimizes the potential for leakage into an idle furnace or HRSG. To perform properly, these valves should be large enough to relieve gas to the atmosphere at a rate equal to the potential leakage rate. In the absence of other justification, vent pipe sizes should conform to Table 1.9.2.4.1. Special precautions should be taken to safely vent heavier-than-air gases.

A.1.9.3.2 Some items are not applicable to specific types of logic systems (e.g., relay).

A.1.9.4.2.4 Methods and equipment used to reduce the emission of air pollutants affect the burner flame, selection of the flame detector, and location/sighting of the flame detector.

A.1.9.5 The user of this code is encouraged to use judgment in the application of these guidelines for all process and safety functions contained in a distributed control system.

(a) Data Transmission

(1) Every input should be sampled at an interval no longer than 1 second. Every output should be updated at an interval no longer than 1 second.
(2) For protective actions, the system should be able to convert a changed input sensor value to a completed output control action in less than 25 milliseconds.
(3) Changes in displayed data or status should be displayed within 5 seconds.
(4) Data acquisition and transmission systems should be protected from noise pickup and electrical interference.
(5) In redundant systems, the data links should be protected from common mode failures. Where practical, redundant data links should be routed on separate paths to protect against physical damage that disables both data links.

(b) Hardware

(1) The hardware selected should have adequate processor capacity to perform all the functions required for start-up sequencing, normal operation alarming, monitoring, and shutdown of the controlled equipment. Capacity also should be available for data storage and sorting; this can be permitted to be located in a separate processor.
(2) Selection should take into consideration the requirements for reliability, maintainability, and electrical classification.
(3) The hardware should provide for automatic tracking between auto-manual functions to allow for immediate seamless transfer.
(4) The hardware should be capable of stable dynamic control.
(5) The hardware should be capable of thorough self-diagnosis.
(6) Consideration should be given to all levels and types of electrical interference that can be tolerated by the hardware without compromising its reliability or effectiveness.
(7) Fail-safe operation should be obtained through a thorough and complete analysis of each control loop and by providing for a failure of that loop (i.e., valve/actuator) to cause a fail-safe position.

(c) Software

(1) The software package should be designed to include all logic to provide a safe and reliable control system. When the software calls for the operation of a field safety device, a feedback signal should be provided to prove that the requested operation has taken place, and an alarm should be actuated if the action is not confirmed in a specified time.
(2) The software package should be checked to ensure that no unintended codes or commands are present (e.g., viruses or test breaks). The software package should be tested and exercised before being loaded into the plant site computers or processors.
(3) The software system should be protected from inadvertent actions from operators and also should be tamper proof.
(4) Written procedures should specify the functions that can and cannot be accessed by the operator and those functions that require additional authorization for access.
(5) The software should be permitted to provide for authorized on-line changes of the timers and set points, provided the safety of the operating equipment is not compromised.
(6) The software should implement and enhance the self-diagnostic hardware that has been enhanced.

A.1.9.5.2.8 Continuous on-line analysis of the oxygen, combustibles, and carbon monoxide content of the flue gas stream are valuable tools for use as an operating guide and for control.

A.1.9.5.3.3 HRSGs maintain a minimum of 25 percent combustion turbine exhaust flow, beyond which there is no automatic control of airflow.

A.1.9.7.4 A sequence of events recorder, where provided, should time-tag events with a resolution of 10 milliseconds or less.

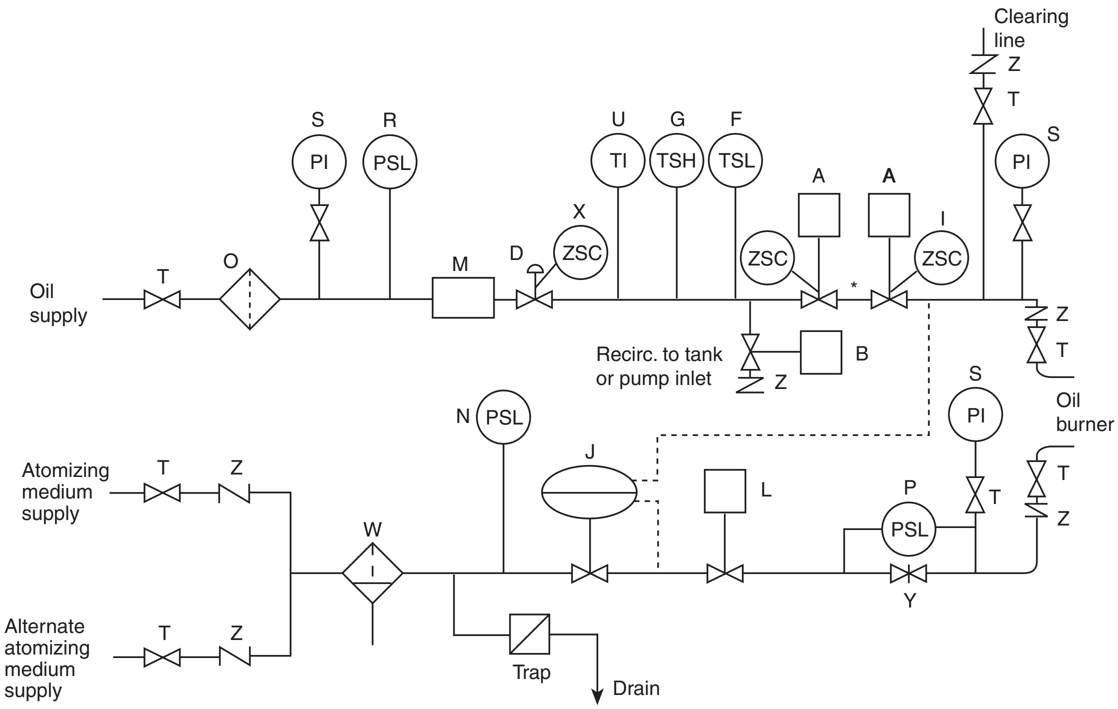
A.2.3.1.8 See Figure A.2.3.1.8 for typical main oil burner system arrangement.

A.2.3.2 For additional information, see NFPA 54, *National Fuel Gas Code*, and NFPA 58, *Liquefied Petroleum Gas Code*.

A.2.3.2.3 *Main burner gas supply*. Refer to Figure A.2.3.2.3 for a typical main gas burner system arrangement.

A.2.3.4.1 See Figure A.2.3.4.1 for typical ignition system arrangements for a gas-/oil-fired burner.

FIGURE A.2.3.1.8 Typical fuel and atomizing medium supply systems and safety controls for oil burner.



A Safety shutoff valve, spring closing (NC)
B Oil recirculation valve atomizing (NO) (optional for unheated oil)
D Oil flow control valve
F Low oil temperature switch (not applicable for unheated oil)
G High oil temperature switch (not applicable for unheated oil)
I Closed position interlock on safety shutoff valve
J Atomizing medium differential control valve
L Automatic atomizing medium shutoff valve
M Oil meter (optional)
N Low atomizing medium pressure switch
O Oil strainer
P Atomizing medium flow interlock differential switch, or pressure interlock switch
R Low pressure switch
S Pressure gauge
T Manual shutoff valve
U Oil temperature gauge (optional for unheated oil)
W Atomizing medium strainer
X Low fire start switch
Y Atomizing medium flow orifice
Z Check valve

Note: NC = normally closed, deenergized
NO = normally open, deenergized

* Caution: Refer to the requirements of 2.3.1.8.

Safety shutdown interlocks (not shown)

Flame detector(s)
Excessive steam pressure interlock
Auxiliary low water cutoff (one required)
Combustion air supply interlock

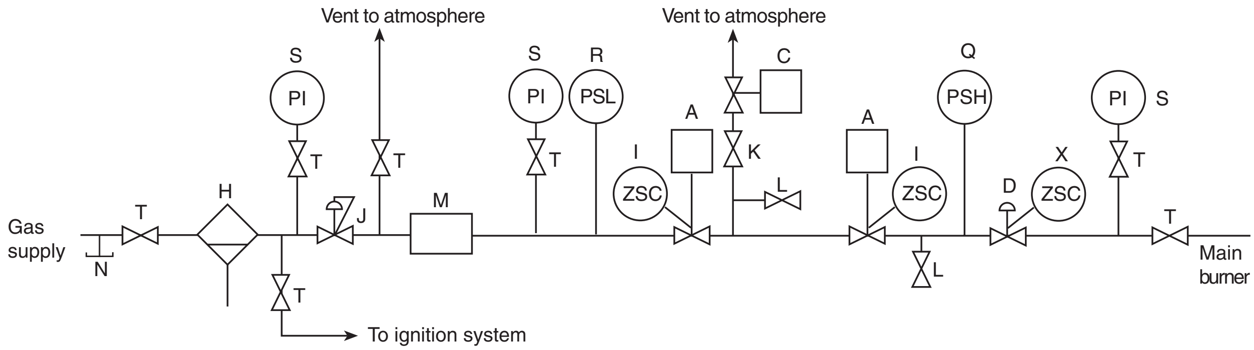
A.2.3.4.1.3 *Heavier-than-air gases and gas-fired igniters.* Many oil-fired boilers are equipped with propane or other liquefied petroleum gas-fired (LPG) igniters. Special precautions are required in locating the vent pipe from the automatic bleed valve so that heavier-than-air, vented gases do not accumulate in depressions or in confined areas. An alternative to the automatic venting of heavier-than-air gases is to eliminate the igniter vent valve from between the two igniter safety shutoff valves.

A.2.3.4.6.1 Tall stacks can produce furnace draft conditions adversely affecting flame stability and could require special draft control provisions.

A.2.3.5 American Boiler Manufacturers Association publication *Combustion Control Guidelines for Single Burner Firetube and Watertube Industrial/Commercial/Institutional Boilers* contains additional information on this subject. This reference is for information only and should not be considered to be part of the requirements of this code.

A.2.3.5.3 Consideration should be given to the effects of fuel and air pressure and temperature fluctuations as related to the airflow and the performance of the fuel flowmeter in regulating the fuel/air ratio.

FIGURE A.2.3.2.3 Typical fuel supply systems and safety controls for gas burner.



A Safety shutoff valve, spring closing (NC)
C Vent valve, spring opening (NO)
D Gas flow control valve
H Gas strainer
I Closed position interlock on valve safety shutoff
J Constant gas pressure regulator valve
K Vent line manual shutoff valve for leakage testing (locked or sealed open)
L Leakage test connection
M Gas meter (optional)
N Drip leg
Q High gas pressure switch
R Low gas pressure switch
S Pressure gauge
T Manual shutoff valve
X Low fire start switch

Note: NC = normally closed, deenergized
NO = normally open, deenergized

Safety shutdown interlocks (not shown)

Flame detector(s)
Excessive steam pressure interlock
(excessive water temperature and pressure interlock for hot water boilers)
Auxiliary low water cutoff (one required)
Combustion air supply interlock

A.2.3.6.6 The use of safety control circuit voltages of greater than 120 volt nominal is not recommended.

A.2.3.8.1 Locations at which natural gas, propane, or fuel oil systems are installed in compliance with this code normally are not considered hazardous locations for electrical equipment as defined in NFPA 70, *National Electrical Code.*

A.2.3.9.1 *Low NO_x operation — special problems.*

(a) Air pollution control regulations require that new installations meet NO_x emission limits that are lower than emissions now obtained from many of the presently installed firing systems and furnace designs, which are using past operating procedures. In addition, air quality regulations in some local areas require a reduction of NO_x emissions from existing boilers.

(b) To achieve these reductions, one or more of the following methods should be used:

(1) Low excess air firing (i.e., less than the “normal” 10 percent to 25 percent excess air)
(2) Multistage air admission, involving the introduction of combustion air in two or more stages partly at the fuel nozzle, which could be less than stoichiometric air, and partly by independent admission through special furnace ports; and a second stage of air admission within the same burner housing
(3) Flue gas recirculation into all or a portion of the secondary air
(4) Reduced secondary air temperature
(5) Fuel staging
(6) On new units, introduction of new burner and furnace designs by equipment manufacturers

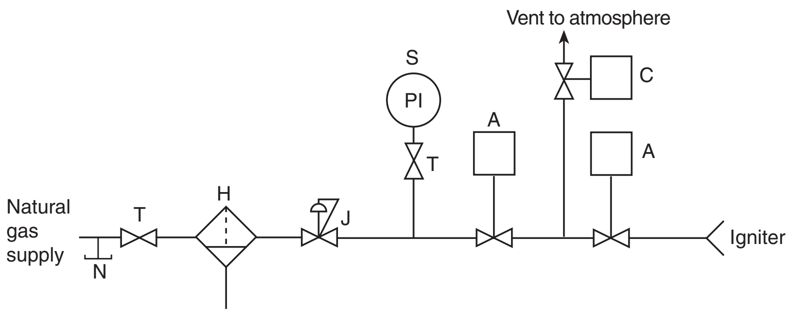
(c) Generally, the effect of all of these methods is to produce lower flame temperatures and longer, less turbulent flames, which result in lower NO_x.

Hazards of low NO_x firing methods.

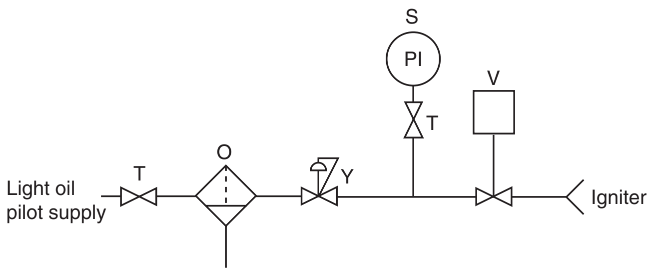
(a) These methods have important implications with regard to furnace safety, particularly for existing units, and could introduce unacceptable risks if proper precautions are not taken.

(1) Fuel-firing systems that are designed to reduce NO_x emissions tend to reduce the margins formerly available to prevent or minimize accumulations of unburned fuel in the furnace during combustion upsets or flameouts. Thus, it is important to trip fuel on loss of flame.
(2) These methods can narrow the limits of stable flames that are produced by the burner system. The tests, which are specified in 2.3.4.2.3, should be repeated on existing units when any of these methods are employed.
(3) When flue gas recirculation is used, equipment should be provided to assure proper mixing and uniform distribution of recirculated gas and the combustion air. When flue gas recirculation is introduced into the total combustion air stream, equipment should be provided to monitor either the ratio of flue gas to air or the oxygen content of the mixture. When flue gas recirculation is introduced so that only air and not the mixture is introduced at the burner, proper provisions should be made to ensure the prescribed distribution of air and the recirculating flue gas/air mixture.

FIGURE A.2.3.4.1 Typical ignition systems for gas-/oil-fired burner.



A Safety shutoff valve, spring closing (NC)
C Vent valve, spring opening (NO) (optional)
H Gas strainer
J Constant gas pressure regulator
N Drip leg
S Pressure gauge
T Manual shutoff valve



O Igniter oil strainer
S Pressure gauge
T Manual shutoff valve
V Pilot oil safety shutoff valve, spring closing (NC)
Y Pilot oil pressure regulator (optional)

Note: NC = normally closed, deenergized
NO = normally open, deenergized

(4) All of the methods tend to increase the possibility of an unstable flame and unburned combustibles throughout the unit and ducts. Therefore, recommendations of the boiler, burner, and instrument manufacturers should be followed, or tests should be conducted to verify operating margins.

(b) Any change in flame characteristics to reduce NO_x emissions can require changing either or both the type and location of flame detectors on existing units.

A.2.4.3.1.2 Refer to Figure A.2.3.1.8 for a diagram of a typical design for alternate atomizing air supply.

A.2.5.1 *Manual systems for watertube boilers.* It is recognized that with adequate and uninterrupted supplies of fuel and air, certain operating functions can be performed by a trained operator as well as by control devices. Typical controls and interlocks provided on a manual system include the following:

(a) *Controls and interlocks.*

(1) Class 2 or 3 igniters.
(2) Safety shutoff valves, as follows:
   a. *Gas firing.* Two automatic safety shutoff valves, spring-closing, in gas line to the main burner, with intermediate spring opening automatic vent valve
   b. *Oil firing.* Two automatic spring-closing safety shutoff valves in oil line to burner

   Caution: Means shall be provided to prevent or relieve excess pressure between these valves.

   c. *Gas-fired igniter.* Two spring-closing automatic safety shutoff valves in the gas line to the igniter, with intermediate, spring-opening automatic vent valve
(3) Manual shutoff valve(s) in the fuel line(s) adjacent to the burner. For gas firing, this shutoff valve should be proved closed before the spark to the igniter can be energized and the igniter and main gas safety shutoff valves can be opened.
(4) Changes in firing rate are made by the simultaneous adjustment of fuel and air supplies at a pre established, optimum air/fuel ratio by the manipulation of a single control device.
(5) Limits on fuel and air to prevent reducing the furnace input below the point of stable burner operation are provided. The minimum and maximum points of stable burner operation are defined by the burner manufacturer and verified by operating investigation.
(6) Safety shutdown interlocks include the following:
   a. Low oil pressure
   b. High gas pressure

c. Low gas pressure
d. Loss of combustion air supply

Caution: Excessive recycling to achieve a burner light-off could lead to accumulation of a hazardous amount of fuel in the furnace and should be avoided.

(7) Where oil heating is provided, the following conditions sound an alarm:

a. Low oil temperature
b. High oil temperature

A.2.5.2.4.2(2) For ultraviolet flame detection systems, it is recommended that early spark termination be used.

A.2.5.2.4.3(2) For ultraviolet flame detection systems, it is recommended that early spark termination be used.

A.2.5.2.4.4(2) For ultraviolet flame detection systems, it is recommended that early spark termination be used.

A.2.5.2.4.9 *Supplemental recommendations and precautions.*

(a) In addition to the requirements in 2.5.2.4.9(a), it is recommended that an evaluation be performed to determine the need for protection against high oil burner pressure.

(b) *Recovering from a fuel-rich furnace condition.* If an air deficiency should develop while flame is maintained at the burners, the fuel should be reduced until the normal air/fuel ratio has been restored. If fuel flow cannot be reduced, airflow should be increased slowly until normal air/fuel ratio has been restored.

(c) *Fuel quality.* It should be recognized that fuels that are available today contain unexpected constituents. Therefore, engineering systems and material designs must take into consideration these potential variables.

A.2.5.4.2.2(2) For ultraviolet flame detection systems, it is recommended that early spark termination be used.

A.2.5.4.2.7 *Supplemental recommendations and precautions.*

(a) In addition to the requirements in 2.5.4.2.7(a), it is recommended that an evaluation be performed to determine the need for protection against high oil burner pressure.

(b) *Recovering from a fuel-rich furnace condition.* If an air deficiency should develop while flame is maintained at the burners, the fuel should be reduced until the normal air/fuel ratio has been restored. If fuel flow cannot be reduced, airflow should be slowly increased until normal air/fuel ratio has been restored.

(c) *Fuel quality.* It should be recognized that fuels that are available today contain unexpected constituents. Therefore, engineering systems and material designs must take into consideration these potential variables.

A.2.5.6.1 For ultraviolet flame detection systems, it is recommended that early spark termination be used.

A.2.5.6.4 In addition to the requirements in 2.5.6.4, it is recommended that an evaluation be performed to determine the need for protection against high oil burner pressure.

A.2.5.7.1 For ultraviolet flame detection systems, it is recommended that early spark termination be used.

A.2.6.1 In addition to the hazards related to gas firing alone and to oil firing alone that are described in A.1.9.2, simultaneous firing of gas and oil increases the potential for the following hazardous conditions:

(1) A fuel-rich condition
(2) An abrupt change in the air/fuel ratio
(3) Overfiring of a boiler

A.2.6.5.3 In addition to the requirements in 2.6.5.3, it is recommended that an evaluation be performed to determine the need for protection against high oil burner pressure.

A.2.7.1 In addition to the hazards related to gas firing alone and to oil firing alone that are included in A.1.9.2, simultaneous firing of gas and oil for transfer only increases the potential for the following hazardous conditions:

(1) A fuel-rich condition
(2) An abrupt change in the air/fuel ratio
(3) Overfiring of a boiler

A.2.8.1 In addition to the hazards related to oil firing alone that are included in A.1.9.2, the changeover from one oil atomizer to an auxiliary oil atomizer and back increases the potential for the following hazardous conditions:

(1) A fuel-rich condition
(2) An abrupt change in the air/fuel ratio

Care should be taken to prevent a fuel-rich condition during the changeover period.

A.3.2.2 No code guarantees the elimination of furnace explosions and implosions in multiple burner boilers. Technology in this area is evolving constantly, and this is reflected in revisions to this code.

A.3.3.2.1 Examples: If the test block capability of the forced draft fan at ambient temperature is +25 in. of water (+6.2 kPa), then the minimum positive design pressure is +25 in. of water (+6.2 kPa).

If the test block capability of the induced draft fan at ambient temperature is −15 in. of water (−3.7 kPa), then the minimum negative design pressure is −15 in. of water (−3.7 kPa).

If the test block capability of the forced draft fan at ambient temperature is +40 in. of water (+9.9 kPa), then the minimum positive design pressure is +35 in. of water (+8.7 kPa).

If the test block capability of the induced draft fan at ambient temperature is −40 in. of water (−9.9 kPa), then the minimum negative design pressure is −35 in. of water (−8.7 kPa).

Caution: Furnace design pressure greater than those specified in 3.3.2.1.1 could result in a more severe energy release of the furnace enclosure, should a fuel explosion occur.

A.3.3.2.1.2 The induced draft fan head capability increases due to significant draft losses beyond the air heater or for other reasons such as excessive induced draft fan test block margins. Where the induced draft fan test block capability is more negative than −35 in. of water (−8.7 kPa), consideration should be given to an increased negative design pressure.

The transient internal design pressure defined in 3.3.2.1 should be taken into consideration in the design of the air and gas flow path from the FD fan discharge through the stack.

A.3.4.2 Unattended operation of larger units is not recommended.

A.3.4.3.1.1 The mandatory automatic trips specified in 3.4.3.3 represent that portion of automatic trips for which sufficient experience has been accumulated to demonstrate a high probability of successful applications for all units. The use of additional automatic trips, while not mandatory, is recommended.

A.3.4.3.3.1 (Block 8): Partial loss of flame is potentially more hazardous at lower load levels. The decision regarding specific requirements or implementation of this trip should be a design decision based on furnace configuration, total number of burners, number of burners affected as a percentage of burners in service, arrangement of burners affected, interlock system, and load level. This trip is interlocked through flame supervisory equipment.

A.3.4.3.3.6 For the trip specified in 3.4.3.3.6(e), a short time delay might be necessary to prevent tripping on rapid transients that do not present a hazard.

A.3.4.3.3.6(a) Variable speed and axial flow fans require special provisions.

A.3.4.3.3.7 For the trips specified in 3.4.3.3.7(e) and (f), a short time delay might be necessary to prevent tripping on rapid transients that do not present a hazard.

A.3.4.3.3.7(a) Variable speed and axial flow fans require special provisions.

A.3.4.3.3.9.2(c) Several means are available to indicate loss of coal feed to the pulverizer, loss of coal stored within the pulverizer, and loss of coal input to the burners. At least one of these means, but preferably a combination, must be used to indicate loss of coal.

The conditions under which the igniters are to ignite the input should be established before restarting the feeder. *(See 3.8.5.4.3.)*

A.3.4.3.3.10(8) This signal should be based on steam flow, main fuel flow, turbine load, burners in service, or any combination thereof, or on other means to ensure that temperatures in the reburn zone are greater than the auto-ignition temperature of the reburn fuel.

A.3.4.4.2 Recommended Additional Alarms and Monitors.

A. Alarms. In addition to the required alarms, the following alarms are recommended to indicate abnormal conditions and, where applicable, to alarm in advance of an emergency shutdown. It is recommended that provisions be made in the design for possible future conversion to automatic trips in the interlock system.

(a) *Burner register closed.* This provides control room indication or alarm for the condition that all secondary air burner dampers are closed on an operating burner.

(b) *Combustibles or carbon monoxide (high).* This warns the operator of a possible hazardous condition by alarming when measurable combustibles are indicated and by providing a second alarm when combustibles reach a dangerous level.

(c) *Oxygen (low).* This warns the operator of a possible hazardous condition.

(d) *Flue gas analyzer failure.* This warns the operator that some failure has occurred in the detection or sampling system and that the associated reading or alarms cannot be trusted.

(e) *Change in calorific content of the fuel gas.* In the event that the gas supply is subject to heating value fluctuations in excess of 50 Btu/ft^3 (1861 kJ/m^3), a meter in the gas supply or an oxygen meter on the flue gas should be provided.

(f) *Air/fuel ratio (high and low).* If proper metering is installed, this may be permitted to be used to indicate a potentially hazardous air/fuel ratio with an alarm indicating approach to a fuel-rich condition and a second alarm indicating approach to a hazardous fuel-rich condition.

(g) *Flame detector trouble.* This warns the operator of a flame detector malfunction.

(h) *Main oil viscosity (high).* If the viscosity of the fuel supply is variable, it is recommended that a viscosity meter be used to provide the alarm. Interlocking to trip on high viscosity also shall be considered in such cases.

(i) *Ignition fuel supply pressure (low).* Monitor the ignition fuel supply pressure at a point as far upstream of the control and safety shutoff valves as practicable.

(j) *Main oil temperature (high).* This is used for heated oils only.

(k) *No load on pulverizer.* This warns when the pulverizer-indicated coal load is substantially below normal and the feeder is running.

(l) *Pulverizer overload.* This warns when the pulverizer-indicated coal load is above the normal range.

B. Monitors furnace conditions (television).

(a) *Furnace television.* A properly designed and installed furnace television can be of significant value as a supplementary indication of flame and other conditions in some furnace designs. It is of particular value during start-up in viewing igniters and individual burners for proper ignition. This is an aid to, but not a substitute for, visual inspection.

(b) *Flame detector indication.* This provides a means for operator observation of flame detector output signal strength.

A.3.5.1 Furnace implosion protection. No code can guarantee the elimination of furnace implosions. Section 3.5 provides a balance between the complications of reinforcement of equipment and the limitations and reliability of operating procedures, control systems, and interlocks in order to minimize the occurrence of the conditions leading to furnace implosions.

If worst-case conditions are assumed (e.g., cold air, high head induced draft fan, forced draft fan flow shutoff, induced draft control dampers open with induced draft fan operating), the furnace cannot be protected by reasonable structural design.

Using the provisions outlined in Section 3.5, the likelihood of furnace damage is remote, provided the induced draft fan has reasonable head capability. If the induced draft fan head capability is increased significantly, special consideration should be given to induced draft fan characteristics, special duct arrangements, or special instrumentation or control.

A.3.5.2.3(1) Excessive speed can cause undesirable hunting and overshooting of automatic controls and create damaging negative pressure transients downstream. Excessive speed also might be unsuitable for manual control.

Where variable speed or axial fans are used, the rate of response is slower than with constant speed centrifugal fans, and special consideration must be given to the design of the furnace draft control system to ensure a satisfactory rate of response.

A.3.5.3.2(a)1 On installations with multiple induced draft fans and forced draft fans, during any individual fan's starting sequence, its associated flow control devices and shutoff dampers are permitted to be closed.

A.3.5.3.2(b) After the first induced draft fan and forced draft fan are started and are delivering air through the furnace, the shutoff damper(s) of the remaining idle fans are permitted to be closed.

A.3.6.3.1.6 Atmospheric vent valves located between shutoff valves are intended to relieve any gas pressure that builds up due to failure of the first (upstream) shutoff valve. This minimizes the potential for leakage into an idle furnace. To perform properly, these valves should be large enough to relieve gas to the atmosphere at a rate equal to the potential leakage rate. In the absence of other justifications, vent pipe sizes and vent valve port diameters should conform to Table A.3.6.3.1.6.

Table A.3.6.3.1.6 Vent Line Sizes

Gas Supply Line Size (NPS)	Shutoff System Minimum Vent Port Size (NPS)
≤1 $^{1}/_{2}$	$^{3}/_{4}$
2	1
2 $^{1}/_{2}$ to 3	1 $^{1}/_{4}$
3 $^{1}/_{2}$	1 $^{1}/_{2}$
4 to 5	2
5 $^{1}/_{2}$ to 6	2 $^{1}/_{2}$
8	3 $^{1}/_{2}$
> 8	15% of supply line cross-sectional area

A.3.6.3.1.9 When vents are manifolded from safety shutoff systems, the cross-sectional area of the manifold pipe should be equal to or greater than the sum of the cross-sectional areas of the two largest vents involved.

A.3.6.3.2.1 Variations in the burning characteristics of the fuel, and in the normal variations in fuel-handling equipment and fuel-burning equipment, introduce unreliability to the lower operating limits of the main fuel subsystem in any given furnace design.

II. Small Number of Burners.

(a) Boilers with a small number of burners can be subject to hazardous air/fuel ratios, particularly where placing a burner into service or taking it out of service, where one burner is tripped.

(b) The smaller the number of burners (e.g., only two burners) the greater the potential hazard.

(c) Specific recommendations for the design and operation of two-burner boilers are provided in 3.6.7 and 3.7.7. These same principles can be applied to boilers with more than two burners, but generally less than six burners, that are subject to this hazard.

A.3.6.3.2.2 Such transients are generated by means such as burner shutoff valves and dampers that operate at speeds faster than the speed of response of other components in the system.

A.3.6.3.2.5 Special recognition should be given to the fire hazards imposed by leakage or rupture of piping at the burner.

A.3.6.3.4.3 Various types of fuel reburn systems are being applied across many types of multiple burner boilers for control of NO_x. A limited accumulation of operating history with reburn systems prompted the Technical Committee on Multiple Burner Boilers to provide redundant safety requirements. These redundant requirements utilize either reburn flame sensors or boiler furnace gas temperature monitoring. Reburn flame sensing or furnace gas temperature monitoring provides direct supervision of variables critical to operating safety of reburn systems. These measured variables augment the other requirements of 3.4.3.3.10.

A.3.6.4.4 Field tests will be used to validate the basic flame-tripping concepts. These tests, performed on representative units, can be applied to other units of similar size and arrangement, including burners/nozzles of substantially the same capacity using similar fuels.

A.3.6.5.1.2 Sequences of operation are based on the typical fuel supply system shown in Figures A.3.6.5.1.2(a) and (b). As permitted in 3.6.3.1, variations in these piping arrangements are allowed provided all of the functional requirements of this code are met by the arrangement.

A.3.6.5.1.5 Although NO_x and other emissions during start-up and extremely low load operation are low, they might not comply with increasingly stringent emission limits. Deviation from the open register light-off procedure, continuous purge, and minimum airflow requirements defined in this code to meet these limits is not recommended. There are insufficient data and operating experience to justify changes to this standard.

A.3.6.5.2.1.1(2) Such an inspection is particularly important for a cold start where the fuel burned prior to shutdown contained volatile vapors heavier than air.

FIGURE A.3.6.5.1.2(a) Typical gas igniter system.

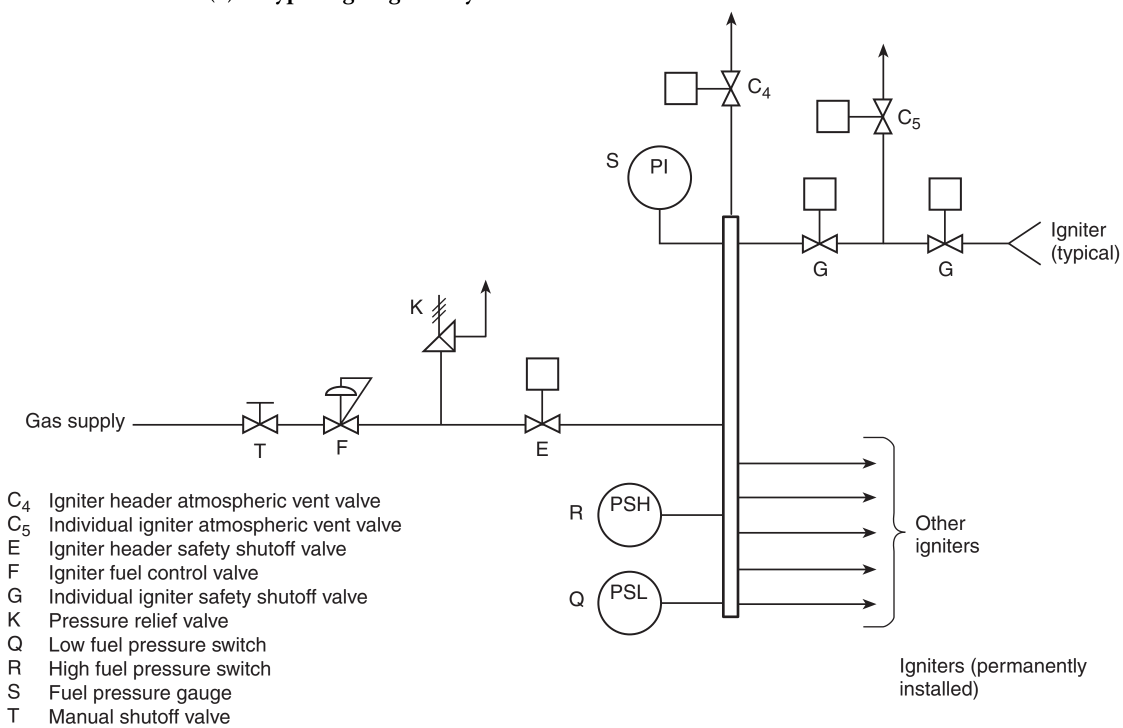
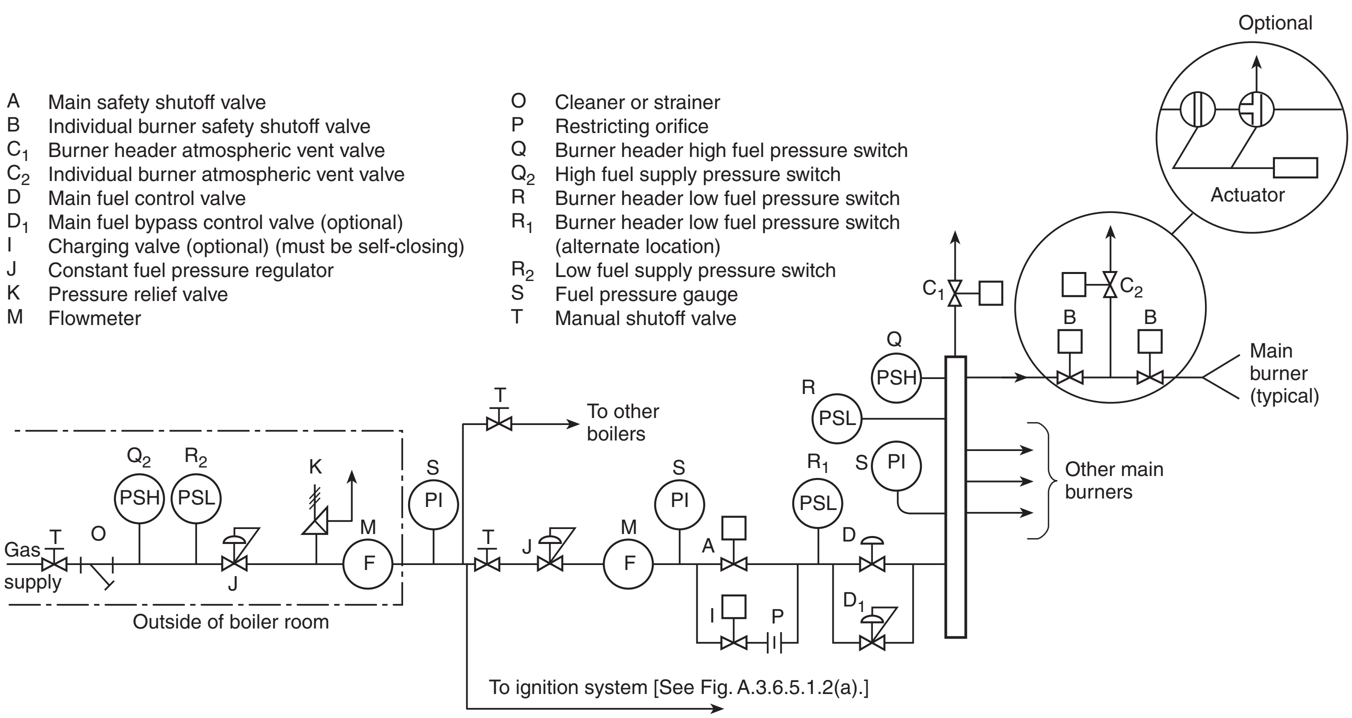


FIGURE A.3.6.5.1.2(b) Typical main burner fuel supply system for fuel gas–fired multiple burner boiler.



A.3.6.5.2.1.1(15) The frequency of testing depends on the design and operating history of each individual boiler and ignition system. As a minimum, the test should be made at each start-up following an igniter overhaul or other significant maintenance that could have affected the igniter.

A.3.6.5.2.1.1(17) The importance of reliable igniters and ignition systems cannot be overstressed.

A.3.6.5.2.1.3(o) Automatic control of burner fuel and burner airflow during the lighting and start-up sequence is recommended.

A.3.6.5.2.2.1 *High air pressure drop burners.* For burners having a high airside pressure drop [generally greater than 4 in. (102 mm) water column at full boiler load], one way to indicate proper air/fuel ratio is to compare burner airflow with burner fuel flow as determined by windbox-to-furnace differential and burner header pressure. The ratio thus determined plus the open register procedure provides a guide for proper operation of burners under start-up conditions where flows might be out of the range of other meters. Windbox-to-furnace differential taps, where provided, should be located at the burner level.

A.3.6.5.2.5.3 *Procedure for purging after an emergency shutdown.* Immediate or fast airflow changes are not allowed following an emergency shutdown due to the likelihood of creating an air/fuel ratio outside the manufacturer's required limits in some sections of the unit before all of the combustibles have exited the unit.

A.3.6.5.2.8.1 This signal should be based on steam flow, main fuel flow, turbine load, burners in service, any combination thereof, or other means to ensure that temperatures in the reburn zone are greater than the auto-ignition temperature of the reburn fuel.

A.3.6.5.3.2 A trip of the fuel during a fuel-rich condition while flame is being maintained results in a sudden increase in the air/fuel ratio, which can create a greater hazard.

A.3.6.7.1.1 These boilers are subject to hazardous air/fuel ratio upsets at either burner during light-off and fuel transfer and when one of the two burners automatically trips during operation.

A.3.6.7.2.1.1(b) The result of this operation is that the remaining operating burner maintains its air/fuel ratio within manufacturer's suggested limits after the fuel is shut off to the failed burner.

A.3.7.1 Fuel Oil — General Considerations. Refer to A.1.9.2(C).

A.3.7.2 Hazards peculiar to crude oil firing. Refer to A.1.9.2(E).

A.3.7.2(d) Refer to A.1.9.2(B)(d).

A.3.7.2(h) NFPA 77, *Recommended Practice on Static Electricity,* and API RP 2003, *Recommended Practice for Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents,* provide design parameters.

A.3.7.2(i) Refer to A.1.9.2(B)(h).

A.3.7.2(j) Initial firing of fuel oil in a cold boiler can create a special hazard by causing fires in air heaters.

A.3.7.3.1.3 Free fall can generate static electricity and increase vaporization of fuel.

A.3.7.3.1.4 Refer to A.1.9.2(C)(c)(7).

A.3.7.3.1.5 Refer to A.1.9.2(C)(c)(8).

A.3.7.3.1.7 This is especially important for crude oil.

A.3.7.3.1.8 This piping might need to be heat traced.

A.3.7.3.1.10 The use of interface fluids or sealing diaphragms might be necessary with this instrumentation.

A.3.7.3.2.1 Variations in the burning characteristics of the fuel, and in the normal variations in fuel-handling equipment and fuel-burning equipment, introduce unreliability to the lower operating limits of the main fuel subsystem in any given furnace design.

A.3.7.3.2.2 Such transients are generated by means such as burner shutoff valves and dampers that operate at speeds faster than the speed of response of other components in the system.

A.3.7.3.2.6 Special recognition should be given to the fire hazards imposed by leakage or rupture of piping at the burner. Particular attention should be given to the integrity of flexible hoses and swivel joints.

A.3.7.3.5.3 Various types of reburn systems are being applied across many types of multiple burner boilers for control of NO_x. A limited accumulation of operating history with reburn systems prompted the Technical Committee on Multiple Burner Boilers to provide redundant safety requirements. These redundant requirements utilize either reburn flame sensors or boiler furnace gas temperature monitoring. Reburn flame sensing or furnace gas temperature monitoring provides direct supervision of variables critical to operating safety of reburn systems. These measured variables augment the requirements of 3.4.3.3.10.

A.3.7.4.4 Field tests will be used to validate the basic flame tripping concepts. These tests, performed on representative units, can be applied to other units of similar size and arrangement, including burners/nozzles of substantially the same capacity using similar fuels.

A.3.7.5.1.2 Sequences of operation are based on the typical fuel supply system shown in Figures A.3.7.5.1.2(a) through (d). As permitted in 3.7.3.1, variations in these piping arrangements are allowed, provided all of the functional requirements of this code are met by the arrangement.

A.3.7.5.2.1.1(2) Such an inspection is particularly important for a cold start where the fuel burned prior to shutdown contained volatile vapors heavier than air.

A.3.7.5.2.1.1(16) The frequency of testing depends on the design and operating history of each individual boiler and ignition system. As a minimum, the test should be made at each start-up following an igniter overhaul or other significant maintenance that could have affected the igniter.

A.3.7.5.2.1.1(18) The importance of reliable igniters and ignition systems cannot be overstressed.

A.3.7.5.2.1.3 Automatic control of burner fuel and burner airflow during lighting and the start-up sequence is recommended.

A.3.7.5.2.5.5 *Procedure for purging after an emergency shutdown.* Immediate or fast airflow changes are not allowed following an emergency shutdown due to the likelihood of creating an air/fuel ratio outside the manufacturer's required limits in some sections of the unit before all of the combustibles have exited the unit.

FIGURE A.3.7.5.1.2(a) Typical mechanical atomizing light oil igniter system.

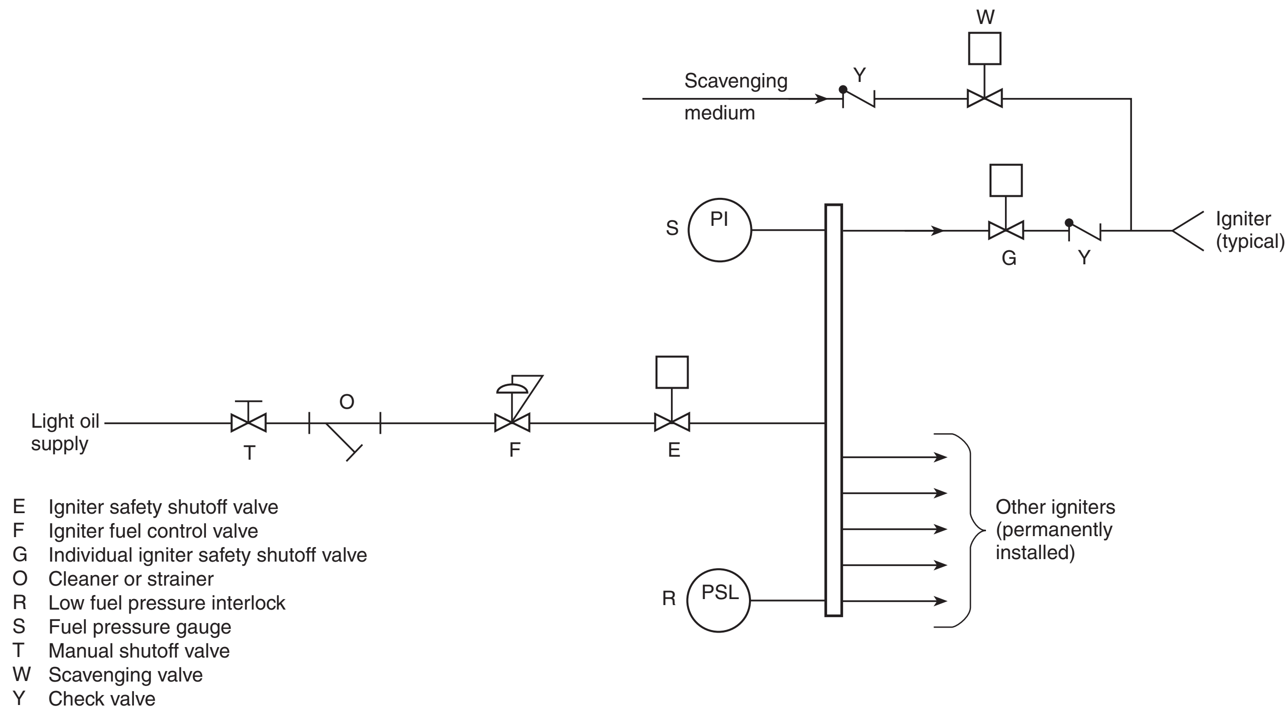


FIGURE A.3.7.5.1.2(b) Typical steam or air atomizing light oil igniter system.

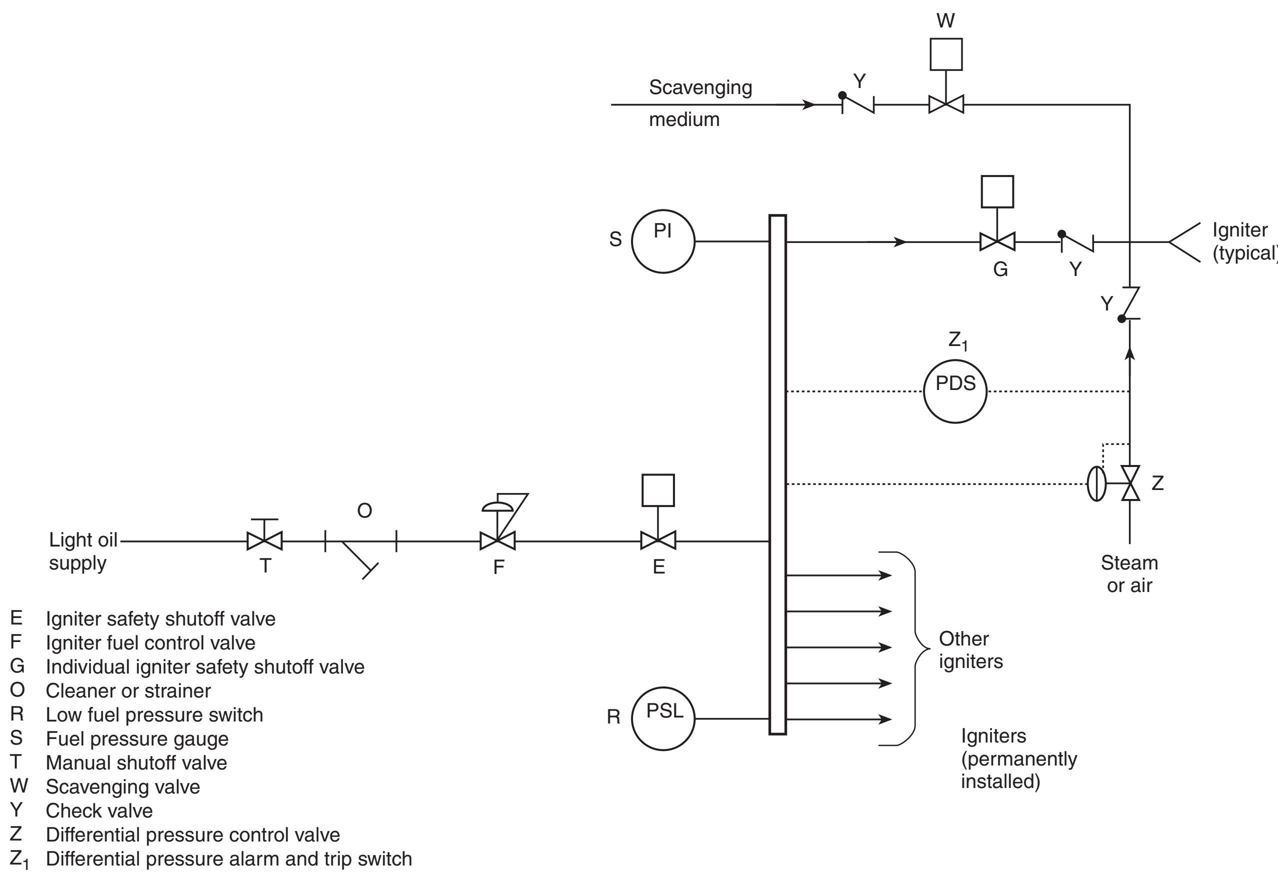
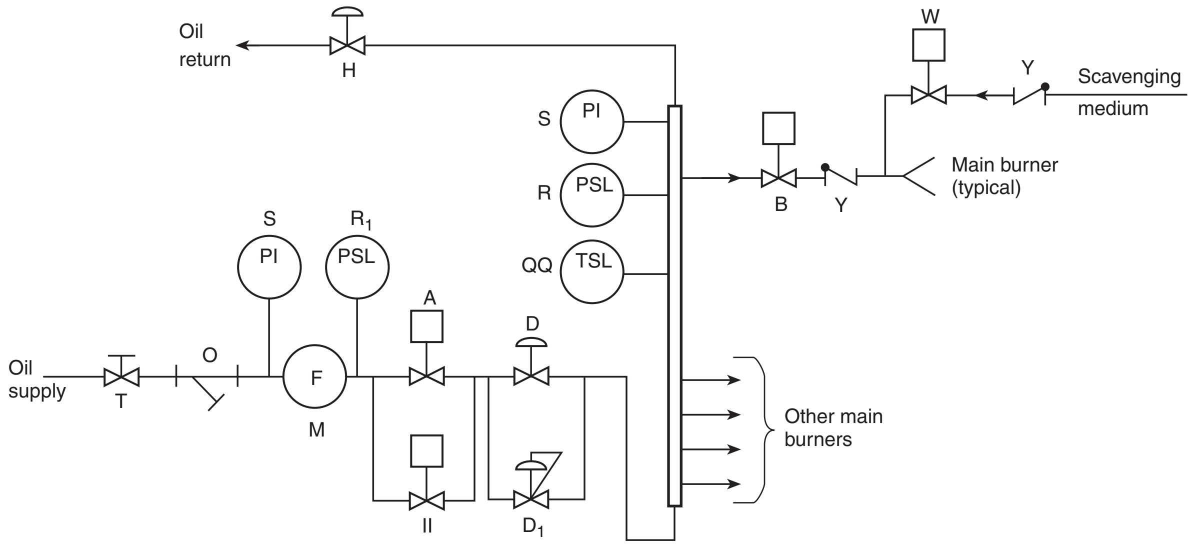
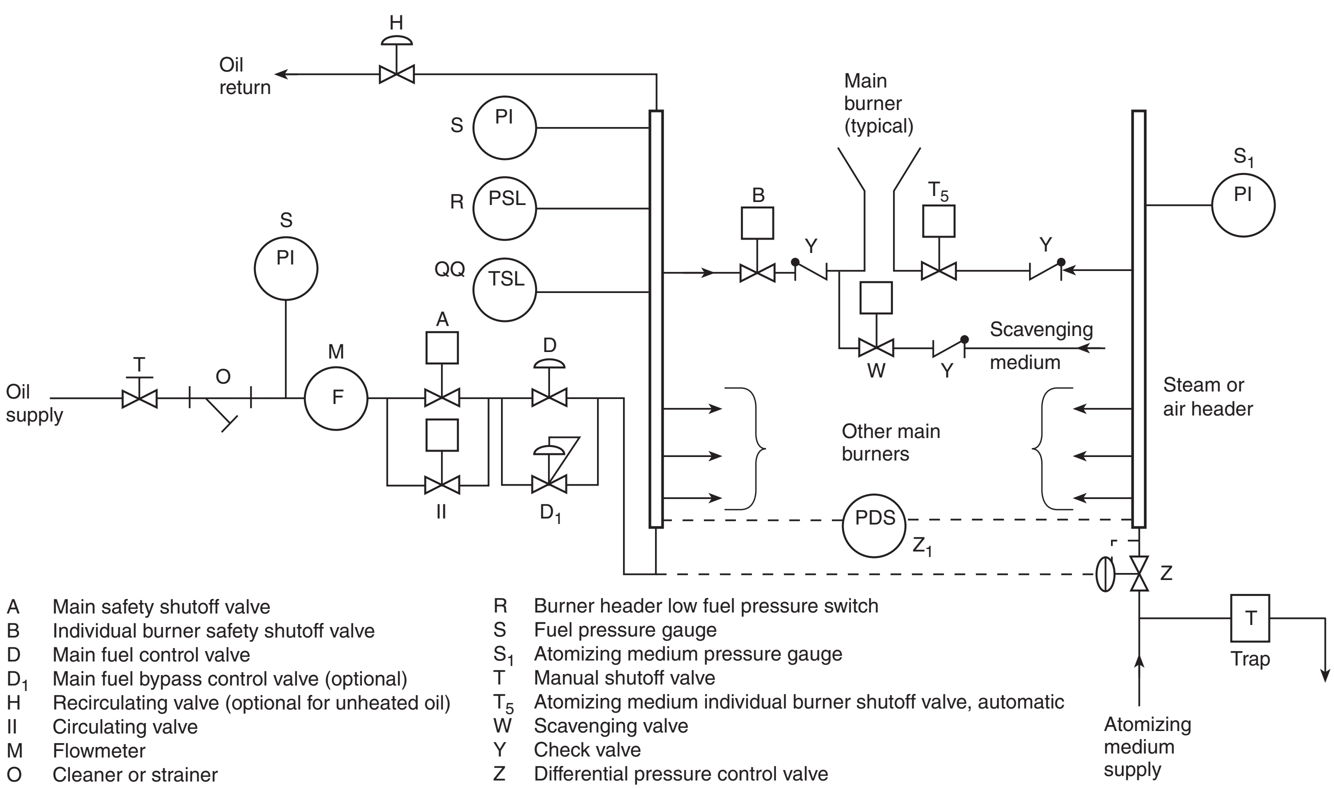


FIGURE A.3.7.5.1.2(c) Typical mechanical atomizing main oil burner system.



A	Main safety shutoff valve
B	Individual burner safety shutoff valve
D	Main fuel control valve
D_1	Main fuel bypass control valve (optional)
H	Recirculating valve
II	Circulating valve
M	Flowmeter
O	Cleaner or strainer
QQ	Low-temperature or high-viscosity alarm switch
R	Burner header low fuel pressure switch
R_1	Low fuel pressure switch
S	Fuel pressure gauge
T	Manual shutoff valve
W	Scavenging valve
Y	Check valve

FIGURE A.3.7.5.1.2(d) Typical steam or air atomizing main oil burner system.



A	Main safety shutoff valve
B	Individual burner safety shutoff valve
D	Main fuel control valve
D_1	Main fuel bypass control valve (optional)
H	Recirculating valve (optional for unheated oil)
II	Circulating valve
M	Flowmeter
O	Cleaner or strainer
QQ	Low-temperature or high-viscosity alarm switch
R	Burner header low fuel pressure switch
S	Fuel pressure gauge
S_1	Atomizing medium pressure gauge
T	Manual shutoff valve
T_5	Atomizing medium individual burner shutoff valve, automatic
W	Scavenging valve
Y	Check valve
Z	Differential pressure control valve
Z_1	Differential pressure alarm and trip switch

A.3.7.5.2.8.1 This signal should be based on steam flow, main fuel flow, turbine load, burners in service, any combination thereof, or other means to ensure that temperatures in the reburn zone are greater than the auto-ignition temperature of the reburn fuel.

A.3.7.5.3.2 A trip of the fuel during a fuel-rich condition while flame is being maintained results in a sudden increase in the air/fuel ratio, which can create a greater hazard.

A.3.7.5.4.7 Air Heater. The initial firing of fuel oil in a cold boiler can create a special hazard by causing fires in air heaters.

A.3.7.5.4.8 Leaks have been known to develop in the oil valves due to temperature changes.

A.3.7.7.1.1 These boilers are subject to hazardous air/fuel ratio upsets at either burner during light-off and fuel transfer and when one of the two burners automatically trips during operation.

A.3.7.7.2.1.1(b) The result of this operation is that the remaining operating burner maintains its air/fuel ratio within manufacturer's suggested limits after the fuel is shut off to the failed burner.

A.3.8.2 Coal Firing — Special Problems. Refer to A.1.9.2(D).

A.3.8.2.1(b) Coal undergoes considerable processing in several independent subsystems that need to operate together. Failure to process the fuel properly in each subsystem increases the potential explosion hazard.

A.3.8.2.1(c) Methane gas released from freshly crushed or pulverized coal can accumulate in enclosed spaces.

A.3.8.2.1(d) The raw coal delivered to the plant can contain such foreign substances as scrap iron, wood shoring, rags, excelsior, and rock. Much of this foreign material can interrupt coal feed, damage or jam equipment, or become a source of ignition within a pulverizer. The presence of foreign material could constitute a hazard by interrupting coal flow. This could cause a total or partial flameout and possible reignition accompanied by a dangerous furnace puff or explosion. Wet coal can cause a coal hang-up in the raw coal supply system. Wide variations in the size of raw coal can result in coal feeding that is erratic or uncontrollable.

A.3.8.2.1(e) Pulverized coal is conveyed through pipes from the pulverizer to the burner by transport air. Improper operation can introduce multiple hazards. For example, improper removal of a burner from service can introduce the following:

(1) The settling out of pulverized coal in the burner pipes to inoperative burners, which, on restarting of the burner, can cause a furnace puff
(2) A leakage of pulverized coal from the operating pulverizer through the burner valve into the idle burner pipe
(3) Leakage of gas or air through a burner valve, thereby causing a fire in an idle pulverizer.

Subsection 3.8.5 provides precautions to minimize such hazards.

A.3.8.2.1(f) Pulverizer system explosions have resulted from the accumulation of pulverized coal in the hot air, tempering air, and coal pipe seal air supply system that are shared by a group of pulverizers. Provisions are to be made in the design of the system to prevent these occurrences and to allow periodic inspections.

A.3.8.2.1(i) It is necessary to dry coal for proper pulverizer operation and combustion. This usually is accomplished by supplying hot air to the pulverizer. Temperature control normally is maintained by mixing tempering air with the hot air from the air heater. An outlet temperature that is too low impedes pulverization. An outlet temperature that is too high causes coking or overheating of burner parts and increases the possibility of pulverizer fires. Maintaining a controlled outlet temperature also aids in controlling the relationship between the fuel and the primary air.

A.3.8.2.2.2 Coal is subject to wide variations in analysis and characteristics. The change in the percent of volatile constituents affects the ignition characteristics of the coal and can affect the permitted turndown ratio of a particular burner design. Coals having high volatile content (above 28 percent, as fired) are easier to ignite than coals having low volatile content (below 20 percent, as fired). As the volatile content decreases, the minimum permitted firing rate can increase significantly. The fineness of pulverized coal also can affect the permitted turndown ratio. Therefore, it is necessary to establish minimum firing rates for the range of volatility and fineness expected. A firing rate that is too low could result in a gradual buildup of coke or slag on the burner tip or on the furnace floor and must be avoided.

A.3.8.2.2.3 Where operating with pulverized coal for an extended time at reduced loads, incomplete combustion can cause large quantities of unburned combustible dust to settle in hoppers and on horizontal surfaces. If this dust is disturbed by a rapid increase in airflow or by sootblowing, an explosive mixture can result. This condition has been the cause of several explosions.

A.3.8.2.3.1 The restrictions described in 3.8.2.2 might limit the turndown ratio significantly. This might make it necessary to light off the burner at higher loads than is necessary for either oil or gas. As a result, the procedures of the open register/purge rate light-off system advocated in this code are somewhat different from those for oil or gas.

A.3.8.2.3.2 Wide variation in coal quality and spare pulverizer capability lead to large burner throats; therefore, the turbulence necessary for good mixing of coal and air is significantly restricted as the load is reduced. These factors can restrict the turndown ratio when all pulverizers are in service.

A.3.8.2.3.3 With gas and fuel oil, it usually is possible to purge and light off with the idle registers in the normal firing position by momentarily closing the registers on burners to be lit in order to establish initial ignition. Although, in the case of some coal-fired boilers, this identical procedure is possible, there are other installations where the windbox-to-furnace differential necessary to obtain the desired turbulence for purge and light-off is best obtained with all registers open to an intermediate (light-off) position; the registers then are opened progressively to the normal firing position immediately after each group of burners has been lit.

A.3.8.3.3.1 Variations in the burning characteristics of the fuel, and in the normal variations in fuel-handling equipment and fuel-burning equipment, introduce unreliability to the lower operating limits of the main fuel subsystem in any given furnace design.

A.3.8.3.3.2 Such transients are generated by means such as burner shutoff valves and dampers that operate at speeds faster than the speed of response of other components in the system.

A3.8.3.3.6 Special recognition should be given to the fire hazards imposed by leakage or rupture of piping near the burner.

A.3.8.3.5.3 There are various types of reburn systems being applied across many types of multiple burner boilers for control of NO_x. A limited accumulation of operating history with reburn systems prompted the Technical Committee on Multiple Burner Boilers to provide redundant safety requirements. These redundant requirements utilize either reburn flame sensors or boiler furnace gas temperature monitoring. Reburn flame sensing or furnace gas temperature monitoring provides direct supervision of variables critical to the operating safety of reburn systems. These measured variables augment the requirements of 3.4.3.3.10.

A.3.8.4.1 It is not always possible with coal firing to maintain consistently detectable flame at each flame envelope (or burner), even where combustion is maintained. Several factors contribute to the development of a realistic tripping philosophy.

The flame stability of each individual burner normally is comparable to that at all the other burners associated with a single pulverizer. Where ignition energy and detection is proven for a number of burners, there is less concern regarding random or intermittent indications of loss of flame by individual detectors associated with that pulverizer.

It is recognized that any fuel input that does not ignite and burn on a continuous basis creates a hazard.

A.3.8.4.3 The three principal furnace configurations are as follows:

(1) Wall-fired configuration
(2) Angular downshot–fired configuration
(3) Tangentially fired configuration

A.3.8.4.4.1 The purpose of this interlock is to prevent operating a pulverizer/burner system with an insufficient number of burners for each pulverizer for stable pulverizer/burner operation.

A.3.8.5.1.2 Sequences of operation are based on the typical fuel supply system shown in Figures A.3.8.5.1.2(a), (b), and (c).

A.3.8.5.2.1.1(b) Such an inspection is particularly important for a cold start where the fuel burned prior to shutdown contained volatile vapors heavier than air.

A.3.8.5.2.1.1(m) The frequency of testing depends on the design and operating history of each individual boiler and ignition system. As a minimum, the test should be made at each start-up following an igniter overhaul or other significant maintenance that could have affected the igniter.

A.3.8.5.2.1.1(o) The importance of reliable igniters and ignition systems cannot be overstressed.

A.3.8.5.2.1.3(q) Furnace explosions commonly are caused by placing igniters into service where there has been a flameout of an operating burner.

A.3.8.5.2.5.3 *Procedure for purging after an emergency shutdown.* Immediate or fast airflow changes are not allowed following an emergency shutdown due to the likelihood of creating an air/fuel ratio outside the manufacturer's required limits in some sections of the unit before all of the combustibles have exited the unit.

A.3.8.5.2.8.1 This signal should be based on steam flow, main fuel flow, turbine load, burners in service, any combination thereof, or other means to ensure that temperatures in the reburn zone are greater than the auto-ignition temperature of the reburn fuel.

A.3.8.5.3.1 When tripped, a residual charge occurs, primarily in the pulverizer but also in the burner piping and nozzles. This accumulation in a hot pulverizer generates volatiles that are combustible and explosive. The charge also has the potential to create unpredictable light-off conditions.

A.3.8.5.4.2 A trip of the fuel during a fuel-rich condition while flame is being maintained results in a sudden increase in the air/fuel ratio, which can create a greater hazard.

A.3.8.5.4.3 Raw coal hang-ups ahead of the feeder that cause unstable or intermittent firing and wet coal or changing coal quality that causes flame instability are common emergencies that can arise where firing pulverized coal. These emergencies can create hazardous conditions by allowing unburned fuel to accumulate in the furnace.

FIGURE A.3.8.5.1.2(a) Typical direct-fired pulverizing subsystem, integral transport type.

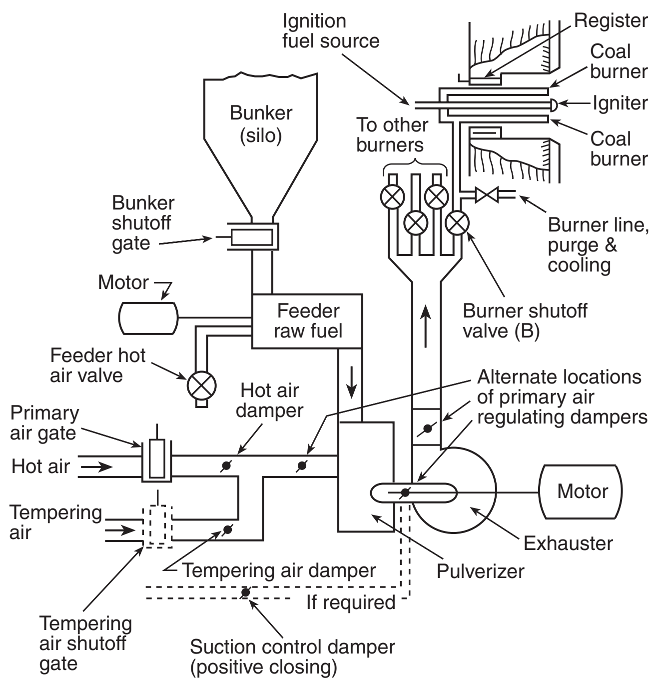


FIGURE A.3.8.5.1.2(b) Typical direct-fired pulverizing subsystem, individual external transport type.

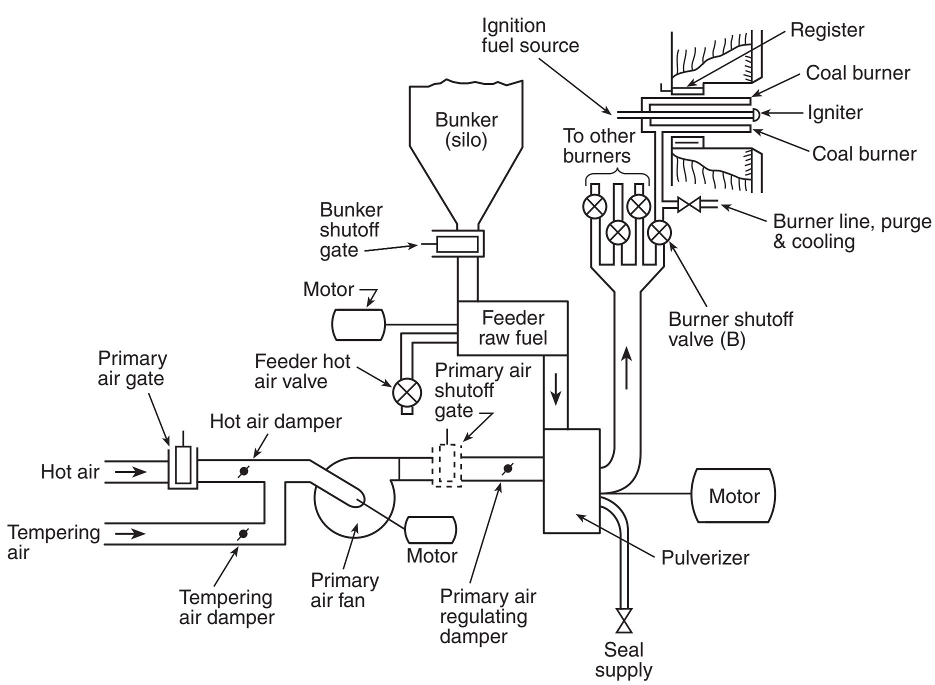
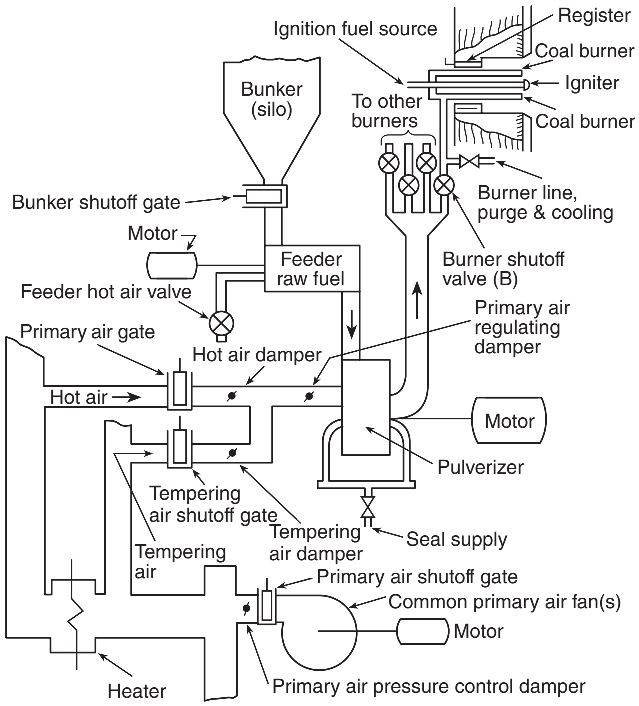


FIGURE A.3.8.5.1.2(c) Typical direct-fired pulverizing subsystem, common external transport type.



A.4.3.1.1 By virtue of the more consistent ignition source available from the mass of high-temperature bed material during normal operation, a fluidized-bed combustion system is less susceptible to furnace puffs and flameouts than burner combustion; however, during unit warm-up or operation using a slumped or semi-fluidized bed, the unit does not benefit from these mitigating factors.

Fluidized-bed combustion systems produce carbon-containing flyash *(see Char)*, which may accumulate in dunes on horizontal surfaces in the gas path. Some systems use cyclone dust collectors with hoppers below that can store a substantial mass of combustible carbon particles. A carbon-rich mass may continue to combust slowly for hours after a plant shutdown and will provide an ignition source if disturbed by an increased air flow. Combustibles may also accumulate in the windbox and be ignited by hot bed material that flows down through air nozzles when the bed is first fluidized.

A.4.3.1.1(2) An inadvertent accumulation of fuel in an idle fluidized bed that is still hot will lead to the distillation of combustible vapors that may lead to an explosive mixture when the bed is fluidized as in a purge sequence.

A.4.3.2 Furnace Implosion. No standard can guarantee the elimination of furnace implosions. Section 4.5 provides a balance between the complications of reinforcement of equipment, limitations and reliability of operating procedures, control systems, and interlocks to minimize the occurrence of the conditions leading to furnace implosions.

If worst case conditions are assumed (e.g., cold air, high head induced draft fan, forced draft fan flow shutoff, induced draft control dampers open with induced draft fan operating), the furnace cannot be protected by reasonable structural design.

Using the provisions outlined in Section 4.5, the likelihood of furnace damage is believed to be remote, provided the induced draft fan has reasonable head capability. If the induced draft fan head capability is increased significantly, then special consideration of induced draft fan characteristics or special duct arrangements or special instrumentation or control should be investigated.

The rapid decrease in furnace gas temperatures and pressure resulting from either a rapid reduction in fuel input or a master fuel trip, which is a cause of implosions in non-fluidized-bed boilers, is not likely to occur in a fluidized-bed boiler. This is because of the resistance to fast temperature changes provided by hot bed material and refractory.

A.4.3.7.2 Although many fluidized-bed combustion boiler designs provide for reinjection of elutriated char into the bed, a certain amount of unburned carbon is carried in the flue gas through the boiler's heat transfer surfaces and ductwork to the baghouse or other dust collection equipment. Combustible particles that accumulate can become an ignition source during a start-up or change in load.

A.4.3.7.7 *Special hazards in fluidized-bed combustion (FBC) systems.* FBC boilers differ from conventional boilers in important features. Some of these differences can lead to special hazards, several of which are included in the following discussion. These hazards include large quantities of hot, solid materials, significant concentrations of reactive compounds in the solids, and hazardous gaseous species.

Extensive treatment of these special hazards is beyond the scope of this code. Because FBC technology is still relatively new, recognition of these hazards is warranted. The boiler manufacturer, the plant designer, and the operator have responsibility for mitigating these hazards to the extent practicable.

(a) *Hot solids — description of hazard.* Fluidized-bed combustion systems contain large quantities of granular solids. A typical 100-MW(e) FBC boiler can contain as much as 100 tons of free-flowing solids at 1500°F (815°C) or higher. These hot solids can spill out of the furnace or other components because of equipment failures, poor design, or misoperation. There have been several such incidents in operating plants. In the event of uncontrolled hot-solid spills, personnel can be injured, equipment damaged, or both.

Recommendations are as follows:

(1) The designers of the boiler and related plant equipment should identify the potential sources of hot solids and associated hazards and make recommendations for personnel safety.
(2) The designer should give careful consideration to the selection of materials that come into direct contact with hot solids.
(3) Clean-out ports, fittings that might be used as clean-out ports, and spool pieces that might be removed for rodding out blockages should be positioned so that a sudden rush of hot solids does not lead to personnel injury. Components that are removable for maintenance when the plant is out of service but that should not be removed when the plant is in service because of the risk of hot spills should be marked clearly.
(4) Instrumentation and wiring needed for the safe operation of the plant should not be routed near potential sources of hot solids. If such routing is necessary, the wiring should be protected from the direct flow of the solids.
(5) Fuel lines should not be located near potential sources of hot solids. The fuel lines should be protected from the direct flow of the solids.

(6) Plant personnel should be trained in the potential sources of hot solids, associated hazards, and the corresponding safety procedures.

(7) Procedures should be developed for cleaning obstructions that provide safety to personnel and equipment. Protective clothing and eye protection should be provided for personnel who rod out obstructions.

(8) Components that might contain hot solids should be inspected frequently.

(9) Water-cooled screws have failed when suddenly flooded with hot bed material following the removal of an upstream blockage. The sudden transfer of large amounts of heat has resulted in overpressurizing the cooling water passages. The operators should be trained adequately and the systems designed with appropriate instrumentation, interlocks, and pressure relief devices to mitigate the risks associated with this type of event.

(10) An FBC's furnace and connected components will contain substantial quantities of hot solids for some time after an MFT.

a. Hot solids stored in a furnace-connected space may suddenly flow into another space. Care should be taken to assure that personnel do not enter a furnace or connected space that could still contain hot solids or be connected to a space that contains hot solids.

b. Solids stored in the cyclone or loop seal — for example, due to blockage — could suddenly be released and flow into another space when the blockage "fails" or the solids cool and their fluidization characteristics change.

c. Operation of a forced or induced draft fan or other fans might not rapidly cool stored solids because the moving air could bypass the bulk of a heap of hot particles.

d. While a surface could appear cool, because of rapid heat loss due to radiation, the bulk of the heap could still be hot because a heap of hot solids is self-insulating. A large heap of solids could require many hours to cool to a safe temperature.

e. Water may enter a body of hot solids from any of a number of sources, including a boiler tube leak. Water pouring onto the solids might not immediately wet the hot solids (recall putting a drop of water on a hot griddle). When the solids suddenly become "wet," rapid generation of steam (steam explosion) could occur. In the event of a steam explosion, hot solids could flow upward as well as in other directions.

f. Large hot clinkers or hot refractory could suddenly be released from the cyclone and flow into the loop seal and connected spaces with the assistance of smaller fluidizable particles.

(b) *Lime — description of hazard.* Limestone is normally fed to fluidized-bed boilers to reduce the emissions of sulfur dioxide. More limestone should be added to comply with emission limits than is theoretically needed to react with all of the fuel's sulfur. A significant amount of the limestone is not converted to calcium sulfate and exists as calcium oxide, commonly referred to as quicklime. Where calcium oxide (CaO) is present in the solids, care should be used to prevent equipment damage or injury to personnel. CaO reacts with water or water vapor to generate heat and reacts with moisture on skin or eyes to cause chemical burns.

Recommendations are as follows:

(1) Where limestone is used as an initial bed charge, it is quickly calcined to CaO (quicklime) before a large fraction reacts to $CaSO_4$. In some instances, where limestone has been used for the initial charge, personnel have experienced chemical burns when entering the furnace because the limestone had turned to quicklime. Because of the likelihood that, during initial plant start-ups, a number of plant problems necessitate that personnel enter the FBC, the boiler manufacturer should recommend that the initial charge of bed material be comprised of sand, coal ash, or other chemically inert material rather than limestone.

(2) Where three parts lime are wet with approximately one part water, the highest temperature is reached due to a chemical reaction. Where the reaction of pure, reactive lime occurs within a large volume (providing insulation), temperatures of about 600°F (315°C) can be reached. This temperature is sufficiently high to ignite paper, for example, which, in turn, could lead to a plant fire. Also, equipment designed for ambient temperature and pressure can fail when heated by a large lime–water reaction. Therefore, relevant plant components should be designed to perform safely at high temperatures, and means of avoiding pressure buildup should be provided. Provisions should be made for detecting high temperatures within tanks and other components.

(3) Waste conditioning systems do mix FBC wastes with water. The designers of these components should be made aware of the likelihood and effects of lime–water reactions by the system integrator, normally an architect, an engineer, or the plant owner.

(4) While the plant is in service, lime–water reactions could occur in "dead zones" due to the humidity in air or flue gas. These reactions might or might not lead to particularly high temperatures, but they often do lead to hard blockages. These blockages might disable safety instrumentation, ash removal systems, or other components. Designers should anticipate this problem and provide a means to detect the presence of blockages, especially in instrument lines, as well as a means to remove blockages safely.

(5) The safety equipment necessary for dealing with lime should be provided, including breathing masks, protective clothing, and eye protection. First-aid facilities needed for chemical burns, especially for eyes, should be provided. Operators should be trained to test for the presence of quicklime before entering an enclosure filled with solids. One simple test can be performed by sampling the solids. The sample is placed in a metal (not glass) container, wearing gloves and eye protection. An approximately equal volume of water is added, the solution is stirred, and approximately 15 minutes are allowed to pass in order to detect a temperature rise.

(c) *Hydrogen sulfide — description of hazard.* Fluidized-bed boilers that operate substoichiometrically in the lower combustion zone can produce hydrogen sulfide (H_2S) as an intermediate product before the sulfur is fully oxidized. Because of the positive pressure in the lower combustion zone, H_2S can leak out of the furnace and into an area where personnel are working. Hydrogen sulfide is heavier than air and concentrates in poorly ventilated low points in the plant, creating the potential for personnel injury.

Recommendations are as follows:

(1) Adequate seals/gaskets on components that can be opened or disassembled and that are located in the dense bed region should be provided. Weld components that do not need to be opened or disassembled should be sealed.
(2) Written guidelines on H_2S should be provided with the equipment manuals.
(3) Operators should be trained to anticipate the presence of H_2S.
(4) Means for measuring the concentration of H_2S in the boiler house and other plant facilities should be provided.

(d) *Calcium sulfide — description of hazard.* The bottom ash (and under some modes of misoperation, fly ash) from a fluidized-bed boiler could contain some calcium sulfide, which is a reaction product of H_2S with limestone in the absence of sufficient oxygen. Calcium sulfide can react with CO_2 and H_2O, which are constituents of air, and release H_2S. If this occurs — for example, in a waste storage silo — the silo's environment can reach a hazardous concentration of H_2S.

Recommendations. Calcium sulfide in FBC waste products could lead to the release of H_2S in waste storage silos and piles. Operators should be trained in the proper procedures for entry of enclosed spaces.

A.4.3.7.8(1) An operating FBC boiler, either bubbling or circulating, contains as the bed a large quantity of hot, granular solids. In some designs, there is also substantial hot refractory. Both the bed and refractory store large quantities of heat, which cause the behavior of an FBC boiler to differ from that of other fuel combustion systems.

Because ignition energy is supplied by the hot bed, an FBC boiler can be operated at fuel/air ratios much higher than can be sustained in a suspension burner. Consequently, an inventory of unburned fuel can accumulate within the boiler enclosure.

An operating FBC boiler continues to produce steam after a fuel supply trip if the air supply continues to operate. The source of heat might not be the fuel remaining in the bed after the fuel supply trip but, rather, could come from the heat stored in the granular bed material and refractory. Experience has demonstrated that, while steam production drops, it can continue at above 50 percent of the full-load rating for several minutes after a fuel supply trip. However, if the air supply is stopped and the bed defluidized, the heat removal from the bed becomes very low because the bed material is a good insulator, and steam production drops to less than 10 percent of full-load production in a matter of seconds.

A.4.3.7.8(8) Bed material will sift through the air nozzles at the base of the furnace during low-load operation when the pressure drop across the nozzles is low. This occurs most frequently during start-up and shutdown. Carbon particles contained in the siftings may ignite as has happened in several plants. Additionally, accumulated material could result in structural overload, improper airflow distribution, or interference with duct burner operation. The following should be considered in the design: (a) an air nozzle system that reduces the potential for sifting; (b) startup and shutdown procedures that minimize the time spent at low airflow; (c) means to observe the contents of the windbox, e.g., quartz windows; and (d) means for removing any accumulation.

A.4.4.1.1.1 The following equations provide an example of boiler enclosure structural design as shown in Figure A.4.4.1.1.1:

(a) *Area A:* Normal operating pressure = +4.0 in. w.g. (+1.0 kPa).

(1) +4.0 in. w.g. (+1.0 kPa) × 1.67 = 6.7 in. w.g. (+1.7 kPa).
(2) The higher of +35 in. w.g. (+8.7 kPa) or +6.7 in. w.g. (+1.7 kPa) is selected.
(3) The lower of the result of item 2 or the forced draft maximum head capability at ambient conditions is selected.
(4) Area A of furnace is designed to +35 in. w.g. (+8.7 kPa) at yield.

(b) *Area B:* Normal operating pressure = +20 in. w.g. (+5.0 kPa).

(1) +20 in. w.g. (+5.0 kPa) × 1.67 = +33.4 in. w.g. (+8.3 kPa).
(2) The higher of +35 in. w.g. (+8.7 kPa) or +33.4 in. w.g. (+8.3 kPa) is selected.
(3) The lower of the result of item 2 or the forced draft maximum head capability at ambient conditions is selected.
(4) Area B of furnace is designed to +35 in. w.g. (+8.7 kPa) at yield.

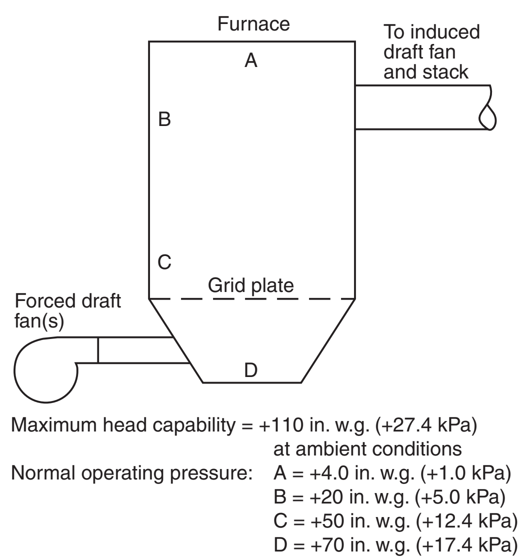
(c) *Area C:* Normal operating pressure = +50 in. w.g. (+12.4 kPa).

(1) +50 in. w.g. (+12.4 kPa) × 1.67 = +83.5 in. w.g. (+20.8 kPa).
(2) The higher of +35 in. w.g. (+8.7 kPa) or +83.5 in. w.g. (+20.8 kPa) is selected.
(3) The lower of the result of item 2 or the forced draft maximum head capability at ambient conditions is selected.
(4) Area C of furnace is designed to +83.5 in. w.g. (+20.8 kPa) at yield.

(d) *Area D:* Normal operating pressure = +70 in. w.g. (+17.4 kPa).

(1) +70 in. w.g. (+17.4 kPa) × 1.67 = +116.9 in. w.g. (+29.1 kPa).
(2) The higher of +35 in. w.g. (+8.7 kPa) or +116.9 in. w.g. (+29.1 kPa) is selected.
(3) The lower of the result of item 2 or the forced draft maximum head capability at ambient conditions is selected.
(4) Area D of the furnace is designed to +110 in. w.g. (+27.4 kPa) at yield.

FIGURE A.4.4.1.1.1 Structural design diagram of boiler enclosure.



A.4.4.1.1.1(2) The induced draft fan head capability increases due to significant draft losses beyond the boiler enclosure or for other reasons, such as excessive induced draft fan test block margins. Where the induced draft fan test block capability is more negative than −35 in. (−8.7 kPa) of water, consideration shall be given to an increased negative design pressure.

A.4.4.2.1.2(d) The following additional hazards should be considered in the design of solid fuel feed systems:

(a) The bunker should be designed to facilitate discharge of material at a controlled rate. The purchaser or the purchaser's designated representative should be aware of the wide range in material-handling characteristics of fuel that are related to differences in moisture, size distribution, and consolidation characteristics. The probable range in these characteristics for the fuels to be used and a determination of time consolidation shear values over these ranges are prerequisites for obtaining a bunker design that provides the desired flow characteristics over the range of fuels to be used.

(b) Abnormally hot, smoldering, or burning raw fuel that is ahead of the feed system is serious and should be dealt with promptly.

(c) Fuel systems can create hazardous conditions when fuel escapes into the surrounding atmosphere or when air enters an inerted system.

(d) Oxidation can raise a fuel's temperature to a point where autocombustion or spontaneous combustion can occur. This characteristic can constitute a special hazard with certain fuels and fuel mixtures.

(e) Gases can be released from freshly crushed fuel, and accumulations of flammable or explosive mixtures can occur in bins or other enclosed areas.

(f) Hot air can flow back into the fuel bunker.

A.4.4.3.3.2.2 Many factors affect the classification of igniters, including the characteristics of the warm-up fuel, the furnace and burner design, and the igniter capacity and location relative to the warm-up fuel burner.

A.4.4.3.3.2.3(d) It is recognized that any fuel input that does not ignite and burn on a continuous basis creates a hazard.

A.4.4.3.4.2.1(c) Special attention should be given to fire hazards posed by leakage or rupture of piping near the lance. Good housekeeping practices should be enforced.

A.4.4.3.5 Transients that can adversely affect burner operation are often generated by components such as burner shutoff valves or dampers that operate at speeds faster than the speed of response of other components in the system.

A.4.4.4.3 Determination of Bed Temperature for Operational Permissives. *Bed temperature* refers to the average bed temperature of a fluidized-bed combustion (FBC) boiler at which certain steps can be taken. This appendix provides general guidelines for the measurement of bed temperatures.

The requirement is for the FBC designer to furnish a temperature measuring system and logic to provide a reliable bed temperature value during the various conditions of operation, including start-up, hot restart, low load, and normal operation.

A system that has been shown to satisfy the requirement consists of a number of thermowells, roughly proportional to the capacity of the FBC, positioned in the nominally vertical walls surrounding the bed at elevations below and above the level of the slumped bed. A penetration of a well at a location 2 in. (5.1 cm) from the wall provides a reliable bed temperature measurement without extensive erosion of the well. Materials are selected that are appropriate for temperature elevation, erosion, and corrosion potentials.

Where the bed is fluidized, the measurements above and below the slumped bed level fall within a narrow range. Rather than taking an average of these temperatures, a method is used in which an established minimum percentage of each of the upper and the lower bed temperature elevations exceeds the established permissive in order to meet interlock requirements.

Because of variations in FBC designs, each supplier is responsible for meeting the requirements for a reliable bed temperature measurement and logic system.

A.4.4.4.4.1.3 The use of gravimetric-type or calibrated volumetric-type feeders with the use of combustion airflow measurement and monitoring of the flue gas percent oxygen and low-range combustibles is an acceptable method of controlling the air/fuel ratio.

A.4.4.4.4.2.9 *Accumulated fuel in bed.* Fluid bed combustors under certain abnormal operating conditions can accumulate significant quantities of unburnt fuel without an obvious indication of abnormality. Such conditions can occur when the fuel input exceeds the available air for combustion over an extended period of time. This condition is of particular concern where nonhomogeneous fuel of widely varying heating values is fired. The combustion control system is currently required to include features to reduce the likelihood of this occurrence.

The continuous indication of critical process variables referred to in 1.9.7 is a key aid to the operators in avoiding ongoing operation while fuel input exceeds air input.

Oxygen analyzers are necessary for fluidized bed combustion in order to keep the fuel input calibrated to true air demand for comparison to actual air input. Oxygen analyzers also advise the operator when air input rate relative to fuel input falls below the acceptable range.

Combustibles analyzers are recommended as an aid in avoiding excess fuel operation. Combustibles analyzers provide valuable data in addition to the previously described measurements and information. The deficiency of air might not always deplete flue gas oxygen before high levels of combustible products are observed. Particularly in the event of inadequate bed mixing, flue gas oxygen and flue gas combustibles can coexist and actually present a more difficult situation than a purely air-deficient circumstance.

A.4.4.4.4.2.12 This requirement provides indexes of total fuel versus total airflow and is for use as an operating guide.

A.4.5 *Furnace Pressure Excursions.* Furnace structural damage could result from the occurrence of excessively high or low gas side pressure.

A condition that is likely to cause furnace pressure excursions in a fluidized-bed boiler is maloperation of the equipment regulating the boiler gas flow, including the air supply and flue gas removal systems. This could result in exposure of the furnace to excessive fan head capability.

The rapid decrease in furnace gas temperatures and pressure resulting from either a rapid reduction in fuel input or a master fuel trip, which is a cause of implosions in nonfluidized-bed boilers, is not likely to occur in a fluidized-bed boiler because of the resistance to fast temperature changes provided by hot bed material and refractory.

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

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

No standard can guarantee the elimination of furnace implosions. Section 4.5 provides a balance between the complications of reinforcement of equipment, limitations and reliability of operating procedures, control systems, and interlocks to minimize the occurrence of the conditions leading to furnace implosions.

If worst-case conditions are assumed (e.g., cold air, high head induced draft fan, forced draft fan flow shutoff, induced draft control dampers open with induced draft fan operating), the furnace cannot be protected by reasonable structural design.

Using the provisions outlined in Section 4.5, the likelihood of furnace damage is believed to be remote, provided the induced draft fan has reasonable head capability. If the induced draft fan head capability is increased significantly, then special consideration of induced draft fan characteristics or special duct arrangements or special instrumentation or control should be investigated.

A.4.5.1 For the purpose of discussion within Section 4.5, the generic term *forced draft fan* is used to refer to a number of combustion air sources commonly found on fluidized-bed boilers. Due to the diverse nature of the air supply systems provided on fluidized-bed boilers, a careful study of the specific design is recommended in order to apply the provisions of this section properly to a specific unit. Some special considerations include the following:

(1) Multiple air sources at different locations (e.g., primary air fans, secondary air fans)
(2) The isolating effect of a slumped bed
(3) High-pressure blowers

A.4.5.2.3(1) Excessive speed could cause undesirable hunting and overshooting of automatic controls and create damaging negative pressure transients downstream. Excessive speed also might be unsuitable for manual control.

Where variable speed or axial fans are used, special consideration should be given to the design of the furnace draft control system to ensure a satisfactory rate of response.

A.4.6.1.3 Provided that the average bed temperature remains above the ignition point, ignition energy remains in the bed material and refractory to ensure total burnout of combustible volatile matter after the master fuel trip. *(See also A.4.6.2.4.1.)*

A.4.6.2.1.1(n) The use of an inert material such as sand reduces the hazard of calcium oxide to maintenance personnel if it becomes necessary to reenter the unit shortly after start-up. *[See A.4.3.7.7(b).]*

A.4.6.2.2.5 The intent of 4.6.2.2.5 is to require tripping the main fuel if the bed temperature drops below a predefined value. This trip temperature is higher than the light-off permit due to differences in operation monitoring. During start-up, main fuel is being fed under carefully controlled conditions and under the direct, constant attention of an operator *[see 4.6.2.1.2(i)6 and 4.6.2.1.2(j)4]*. This condition might not occur during normal operation.

A.4.6.2.4.1 The bed temperature measurement is only valid where the bed is fluidized.

A.4.6.2.4.2 Under certain unusual operating, start-up, or shutdown conditions, it is possible to accumulate combustibles in the windbox and ductwork.

A.4.6.2.5 If the forced draft fan(s) trips with fuel in the bed and an induced draft fan remains running, a forced draft fan should be restarted at a low output sufficient to pressurize the combustion air ducts, the furnace pressure, or both using the induced draft fan. If all forced draft and induced draft fans trip with fuel in the bed, it is recommended, but not required, that an induced draft fan be restarted and a lower-than-design set point furnace pressure be established. These actions are intended as immediate actions to prevent backflow of gaseous combustibles into the combustion air ductwork. Long-term corrective actions should be taken after an assessment of the boiler condition.

A.4.7.3.1 Variations in the burning characteristics of the fuel, and in the normal variations in fuel-handling equipment and fuel-burning equipment, introduce unreliability to the lower operating limits of the main fuel subsystem in any given furnace design.

A.4.7.5.1.1 Sequences of operation are based on the typical fuel supply systems shown in Figures A.4.7.5.1.1(a) through (e). As permitted in 4.7.1, variations in these piping arrangements are allowed, provided all of the functional requirements of this code are met by the arrangement.

A.4.7.5.2.1.2(a) If a charging valve (recommended to be self-closing) on the main gas supply is furnished, it should be opened to bypass the main safety shutoff valve; otherwise the main safety shutoff valve should be opened. The main fuel control valve should be opened as needed. The burner header should be vented until it is filled with gas. The burner header atmospheric vent valve should be closed. The charging or main safety shutoff valve should be left open to establish a nominal pressure on the burner header. The charging or main safety shutoff valve then should be closed. It may be permitted to be concluded that the safety shutoff valves do not leak if the nominal pressure remains within specified limits.

A.4.8.3.1 Variations in the burning characteristics of the fuel, and in the normal variations in fuel-handling equipment and fuel-burning equipment, introduce unreliability to the lower operating limits of the main fuel subsystem in any given furnace design.

A.4.8.5.1.1 Sequences of operation are based on the typical fuel supply systems shown in Figures A.4.8.5.1.1(a) through (h). As permitted in 4.8.1, variations in these piping arrangements are allowed, provided all of the functional requirements of this code are met by the arrangement.

Note: Some designs for steam/air atomized igniters require differential pressure control between the igniter fuel oil pressure and the atomizing media. In this instance, a differential pressure control valve and differential pressure interlock are required in lieu of the constant pressure regulating valve and static pressure interlock.

FIGURE A.4.7.5.1.1(a) Typical fuel gas supply to power house.

The following legend applies to Figures A.4.7.5.1.1(a) through A.4.7.5.1.1(e).

A Burner header shutoff valve
B Individual burner safety shutoff valve
C_1 Burner header atmospheric vent valve
C_2 Individual burner atmospheric vent valve
C_4 Igniter header atmospheric vent valve
C_5 Individual igniter atmospheric vent valve
D Burner header fuel control valve
D_1 Burner header fuel bypass control valve
E Igniter header safety shutoff valve
F Igniter fuel control valve
G Individual igniter safety shutoff valve
H Recirculating valve
I Charging valve (optional — required to be self-closing)
J Constant fuel pressure regulator
K Pressure relief valve
L Leakage test connection
M Flowmeter
N Low atomizing media pressure switch
O Strainer or cleaner
P Restricting orifice
Q Low fuel pressure switch
Q_1 Low fuel supply pressure switch
R High fuel pressure switch
R_1 High fuel pressure switch (alternate location)
R_2 High fuel supply pressure switch
S Pressure gauge
T Manual shutoff valve
U Temperature indicator
V Burner header atmospheric vent valve, manual
W Scavenging valve
Y Check valve
Z Atomizing media pressure regulator
II Circulating valve
QQ Low temperature or high viscosity alarm switch
SS Individual burner supervisory shutoff valve
T_5 Atomizing media shutoff valve

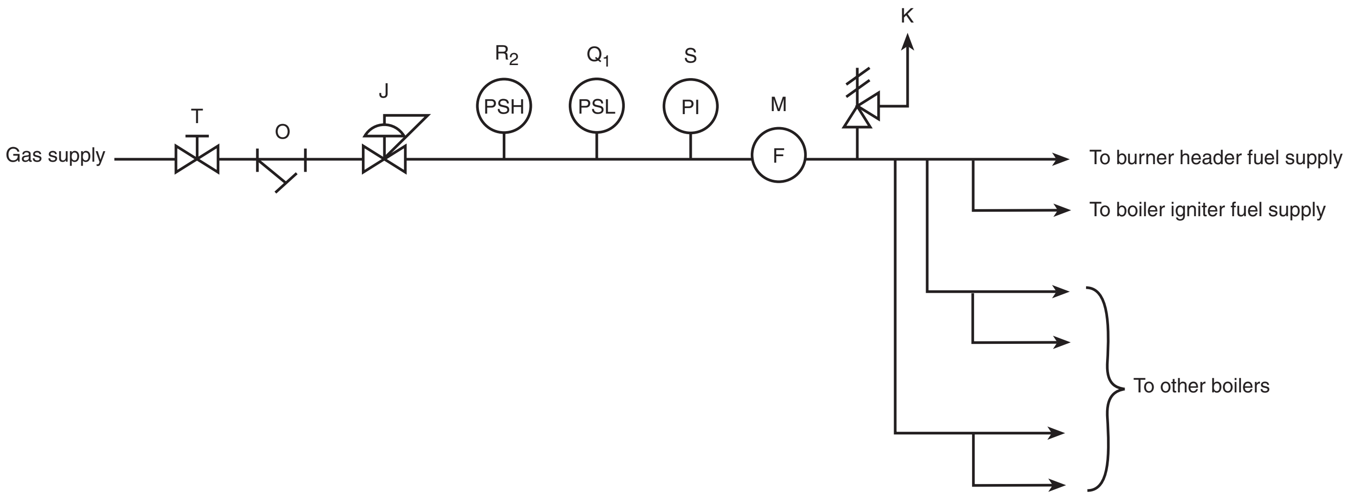


FIGURE A.4.7.5.1.1(b) Typical fuel gas ignition system — multiple igniters supplied from a common header (automatic).

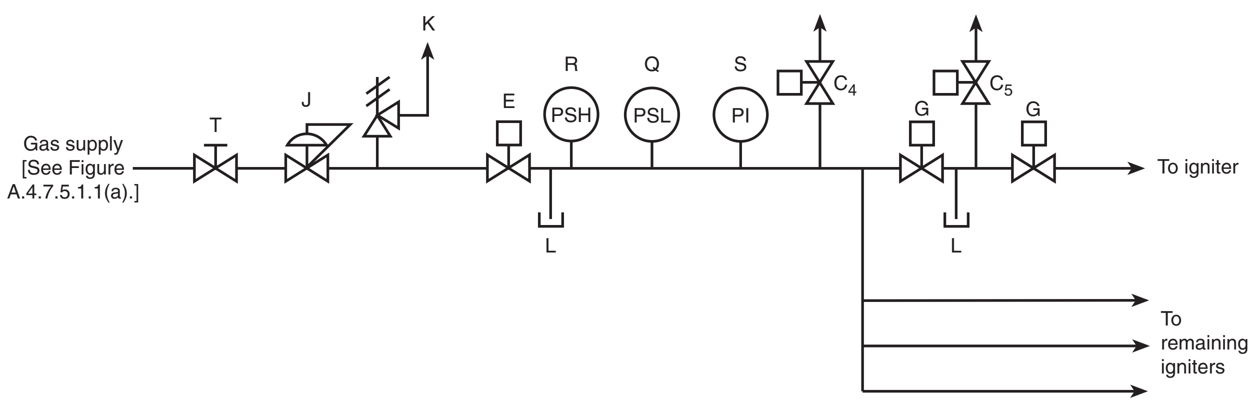


FIGURE A.4.7.5.1.1(c) Typical fuel gas ignition system — individually controlled igniters (automatic).

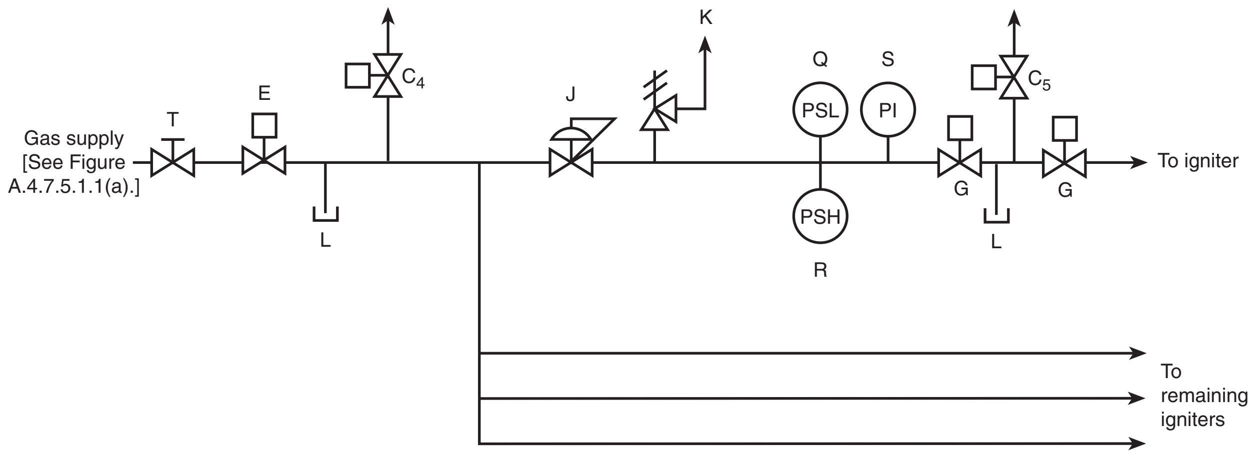


FIGURE A.4.7.5.1.1(d) Typical fuel gas burner/lance system master flow control valve for multiple burners (automatic).

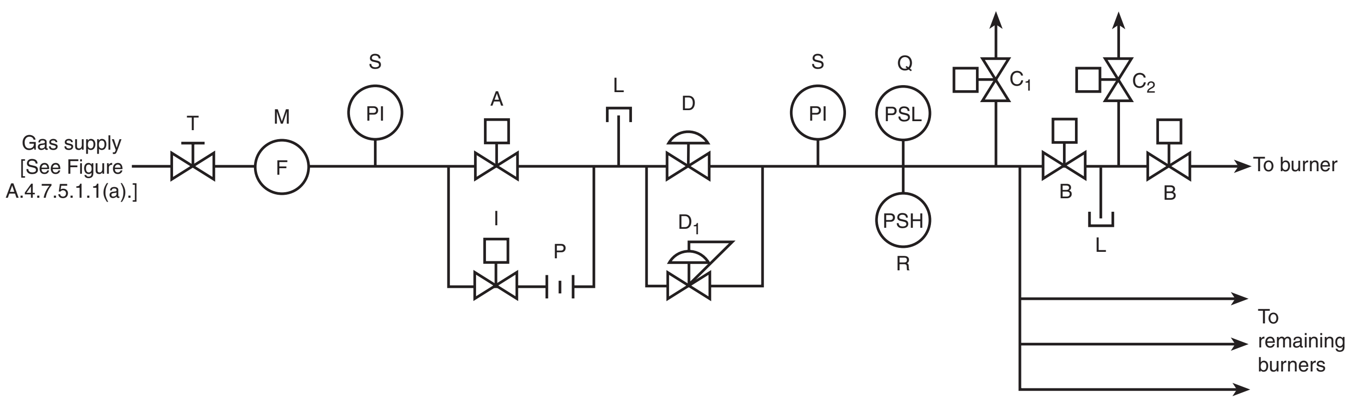


FIGURE A.4.7.5.1.1(e) Typical fuel gas burner/lance system individual fuel control valve (automatic).

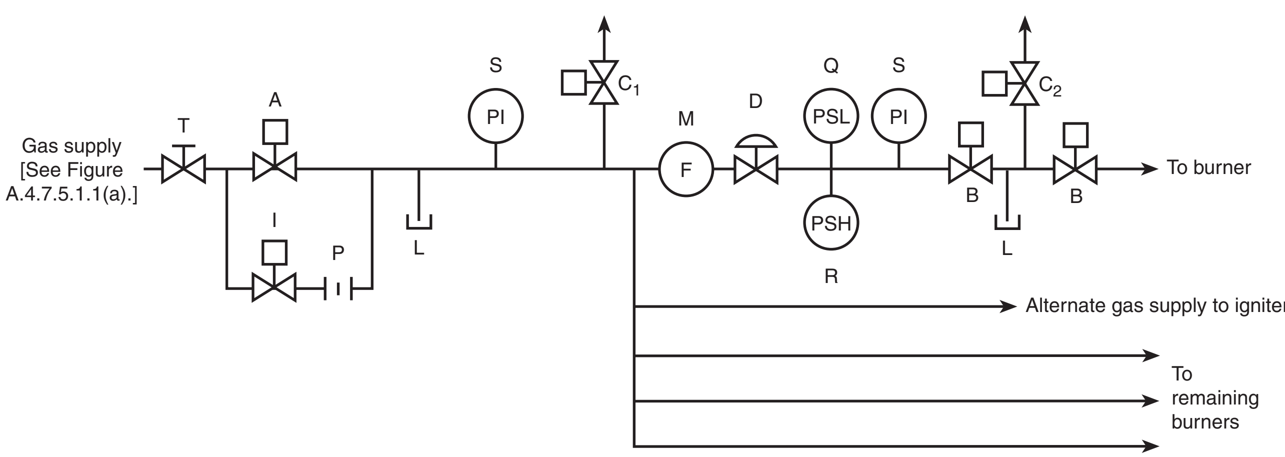


FIGURE A.4.8.5.1.1(a) Typical light oil ignition system — multiple mechanically atomized igniters supplied by a common header (automatic).

The following legend applies to Figures A.4.8.5.1.1(a) through A.4.8.5.1.1(h).

A Burner header safety shutoff valve
B Individual burner safety shutoff valve
C_1 Burner header atmospheric vent valve
C_2 Individual burner atmospheric vent valve
C_4 Igniter header atmospheric vent valve
C_5 Individual igniter atmospheric vent valve
D Burner header fuel control valve
D_1 Burner header fuel bypass control valve
E Igniter header safety shutoff valve
F Igniter fuel control valve
G Individual igniter safety shutoff valve
H Recirculating valve
I Charging valve (optional — required to be self-closing)
J Constant fuel pressure regulator
K Pressure relief valve
L Leakage test connection
M Flowmeter
N Low atomizing media pressure switch
O Strainer or cleaner
P Restricting orifice
Q Low fuel pressure switch
Q_1 Low fuel pressure switch (alternate location)
Q_2 Low fuel supply pressure switch
R High fuel pressure switch
R_1 High fuel pressure switch (alternate location)
R_2 High fuel supply pressure switch
S Pressure gauge
T Manual shutoff valve
U Temperature indicator
V Burner header atmospheric vent valve, manual
W Scavenging valve
Y Check valve
Z Atomizing media pressure regulator
II Circulating valve
QQ Low-temperature or high-viscosity alarm switch
SS Individual burner supervisory shutoff valve
T_5 Atomizing media shutoff valve

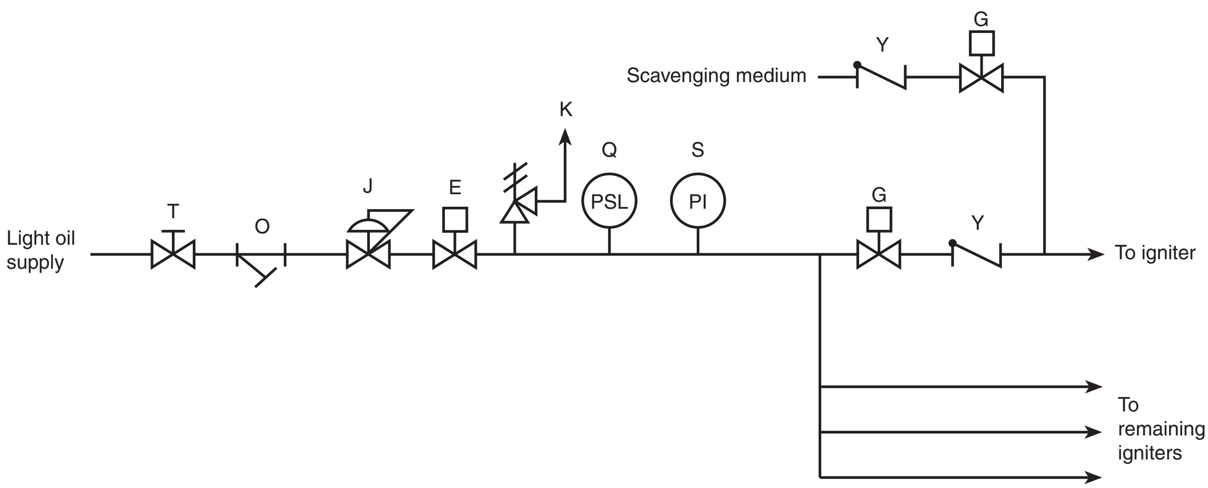


FIGURE A.4.8.5.1.1(b) Typical light oil ignition system — individually controlled mechanically atomized igniters (automatic).

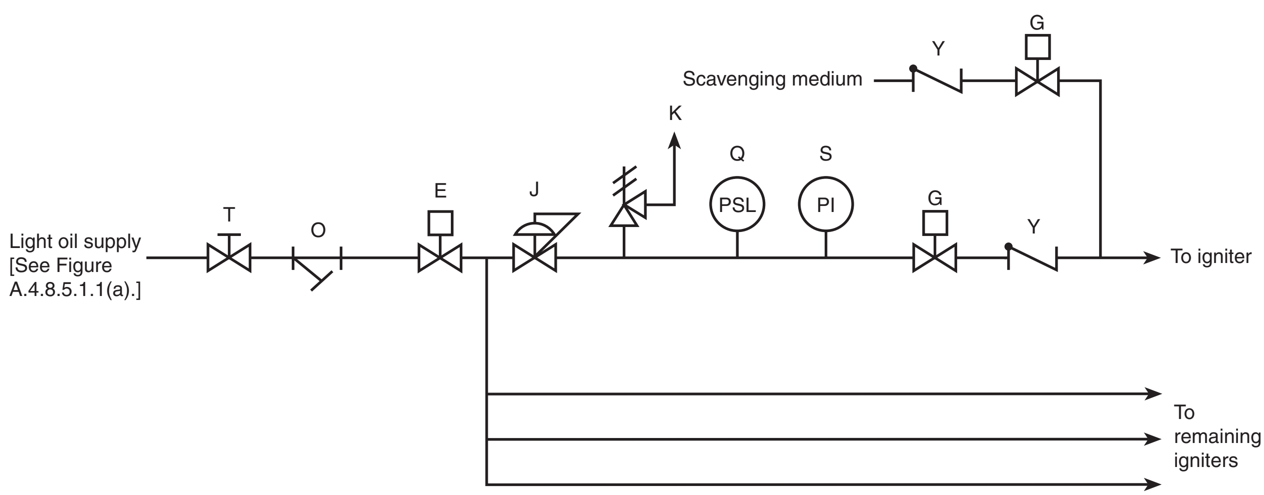


FIGURE A.4.8.5.1.1(c) Typical light oil system — steam/air atomized igniters supplied from a common header (automatic).

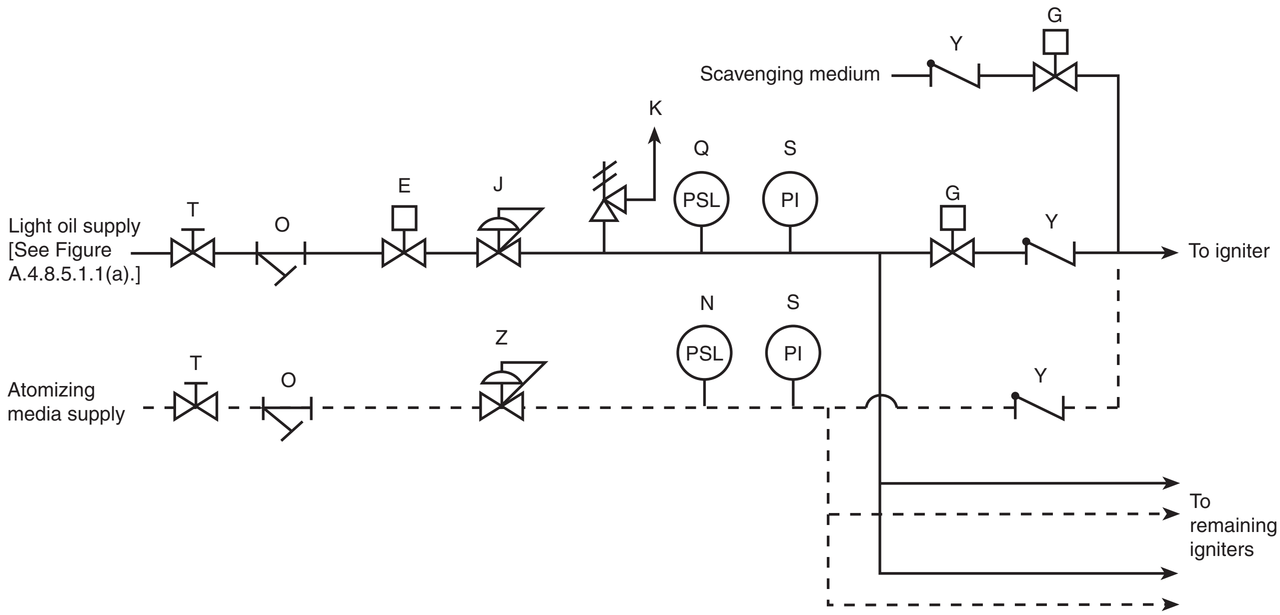


FIGURE A.4.8.5.1.1(d) Typical light oil ignition system — individually controlled steam/air atomized igniters (automatic).

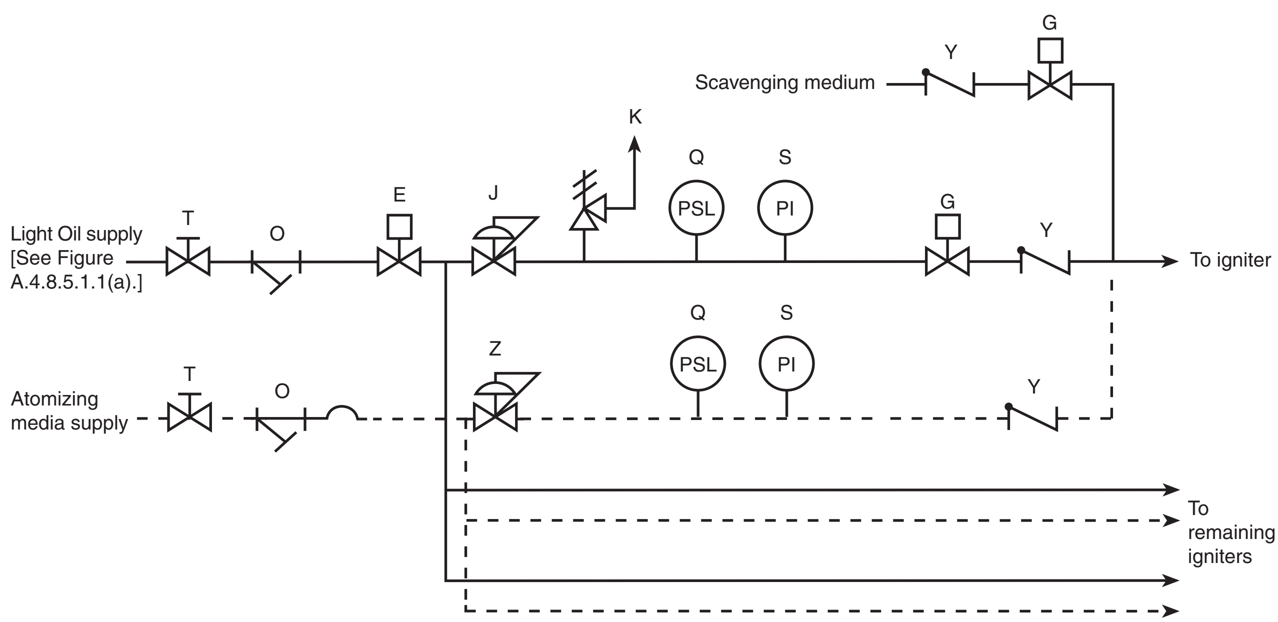


FIGURE A.4.8.5.1.1(e) Typical oil burner/lance system — mechanically atomized master fuel control valve for multiple burners (automatic).

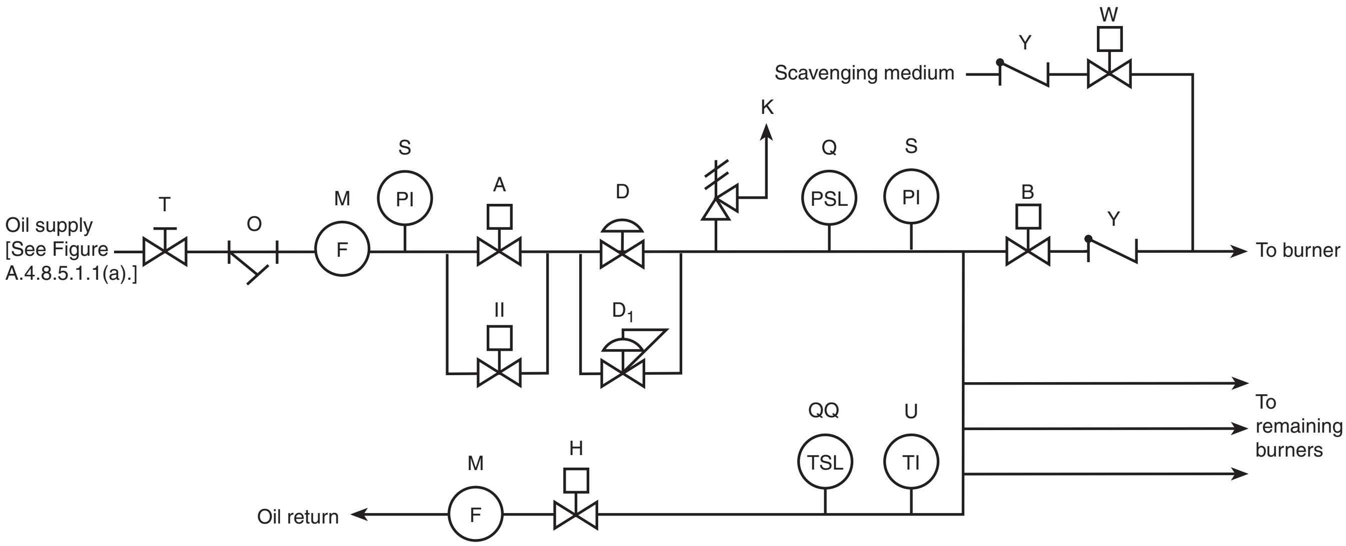


FIGURE A.4.8.5.1.1(f) Typical oil burner/lance system — mechanically atomized individual fuel control valve for multiple burners (automatic).

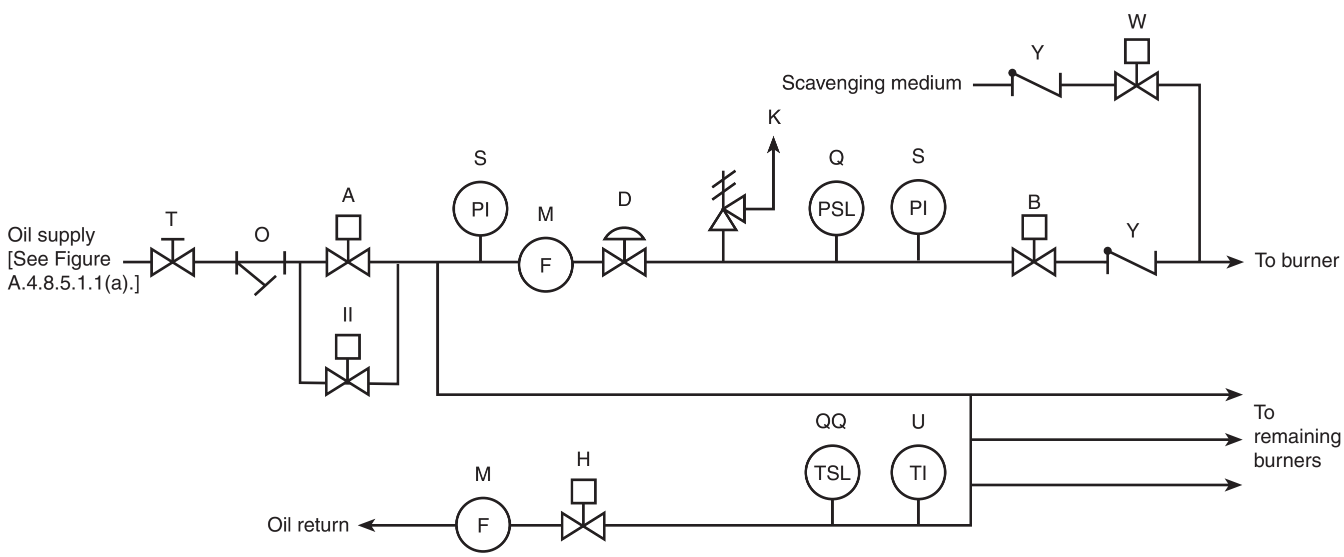


FIGURE A.4.8.5.1.1(g) Typical oil burner/lance system — air/steam atomized master fuel control valve for multiple burners (automatic).

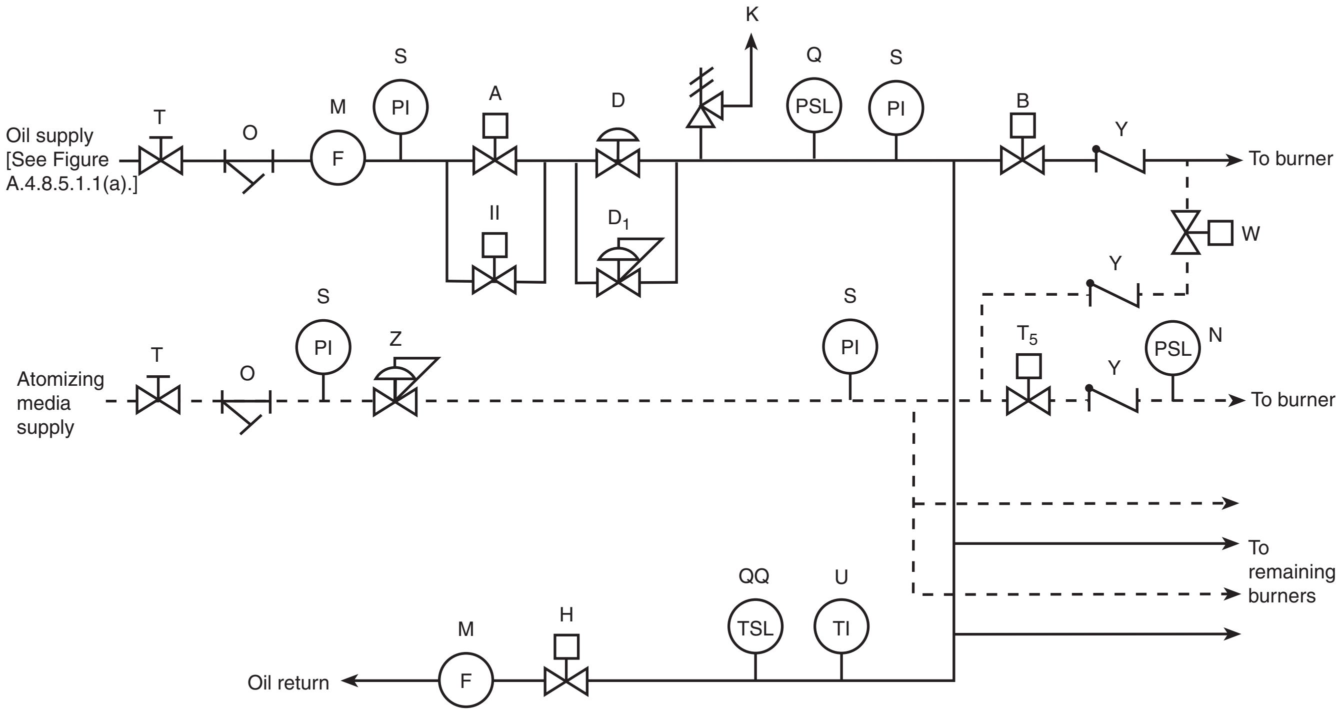
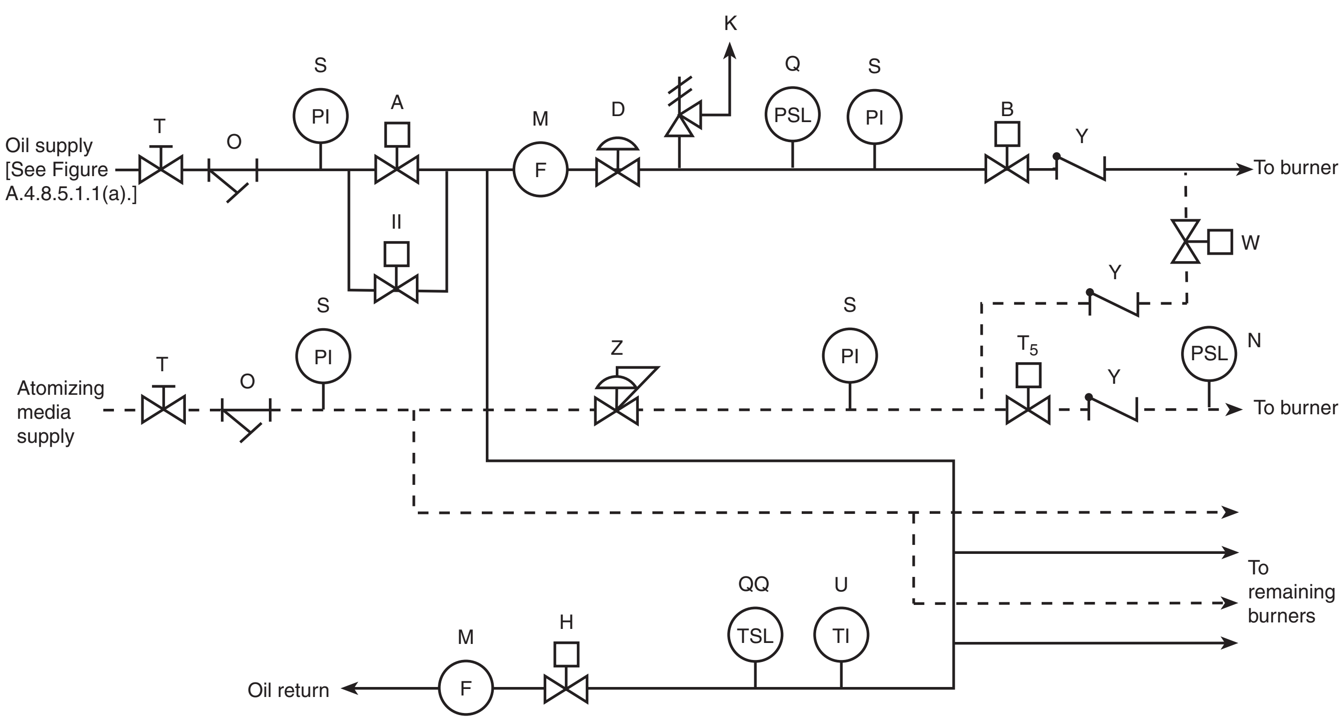


FIGURE A.4.8.5.1.1(h) Typical oil burner/lance system — air/steam atomized individual fuel control valve (automatic).



A.4.9.1.1 The mandatory automatic master fuel trips (MFTs) specified in Table 4.6.2.5.2(a), the main fuel trips specified in 4.6.2.6, and the warm-up burner trips specified in 4.7.5.3 and 4.8.5.3 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, although not mandatory, is recommended.

It is possible to experience conditions conducive to a furnace explosion without detection of such conditions 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.

A.4.9.2.3(i) The mandatory master fuel trip system and circuits should be functionally independent and physically separated from all other control system operations. The intent of this separation should be to ensure that any credible failure in the control system cannot prevent or prohibit any necessary mandatory automatic trip. The intent is that the master fuel trip system function should not be intermixed with other control system functions, although they may be permitted to use the same type of hardware and software. Components such as operator interfaces or annunciation may be permitted to be shared where it is desirable to do so. Information on input status should be dedicated to the mandatory master fuel trip and interlock system to the greatest extent possible. Where signals are shared between the mandatory master fuel trip and interlock systems and other control systems, the signal should be input to the master fuel trip system and retransmitted to any other control system(s).

A.4.9.3.1.5 Bed temperature low and warm-up burner flame not proven are the equivalent of a loss of all flame in a burner-fired boiler.

A.4.9.3.2.3 It is recommended that manual initiation be required before the purge reset of the master fuel trip device is completed.

A.4.9.3.3 Some fuel supply systems for warm-up burners are configured with sensors and interlock logic for monitoring and tripping burners on a per burner basis. Others are configured with sensors and interlocks for monitoring and tripping warm-up burners as a group. Care must be taken to ensure that interlocks are designed for use with the fuel supply piping arrangement used.

A.4.9.3.3.2 Monitoring of header pressure to multiple warm-up burners with individual flow control capability does not satisfy this requirement. With low-pressure gas burners, furnace pressure fluctuations might be more influential on burner gas flow than burner pressure drop.

A.4.10.1 Consideration should be given to the use of an additional annunciator dedicated to high-priority critical alarms.

A.4.10.2.1 Recommended Additional Alarms — General

(a) *Combustible or carbon monoxide high.* An alarm warns the operator of a possible hazardous condition when measurable combustibles are indicated.

(b) *Air/fuel ratio (high and low).* If proper metering is installed, an alarm indicates a potentially hazardous air/fuel ratio.

(c) *Oxygen analyzer trouble.* An alarm warns the operator of a malfunctioning flue gas oxygen analyzer.

A.4.10.2.2 Recommended Additional Alarms — Fuel Gas Burners. In addition to the recommended alarms, the following alarms are recommended to indicate abnormal conditions and, where applicable, to alarm in advance of an emergency shutdown. It is recommended that provision be made in the design for possible future conversion to automatic trips in the interlock system.

(a) *Burner register closed.* This alarm provides control room indication or alarm for the condition that all secondary air burner dampers are closed on an operating burner.

(b) *Change in heating value of the fuel gas.* In the event that the gas supply is subject to heating value fluctuations in excess of 50 Btu/ft^3 (1861 kJ/m^3), a meter in the gas supply or an oxygen meter on the flue gas should be provided.

(c) *Air/fuel ratio (high and low).* If proper metering is installed, this may be permitted to be used to indicate a potentially hazardous air/fuel ratio with an initial alarm indicating approach to a fuel-rich condition and a second alarm indicating approach to a hazardous fuel-rich condition.

(d) *Flame detector trouble.* This alarm warns the operator of a flame detector malfunction.

(e) *Ignition fuel supply pressure (low).* This alarm monitors the ignition fuel supply pressure at a point as far upstream of the control and safety shutoff valves as practicable.

(f) *Any vent valve failed to close.* An alarm warns the operator of vent valve failure to close.

A.4.10.2.3 Recommended Additional Alarms — Fuel Oil. In addition to the required alarms, the following alarms are recommended to indicate abnormal conditions and, where applicable, to alarm in advance of a safety shutdown. It is recommended that provisions be made in the design for possible future conversion to automatic trips in the interlock system.

(a) *Burner register closed.* This alarm provides control room indication or alarm for the condition that all secondary air burner dampers are closed on an operating burner.

(b) *Air/fuel ratio (high and low).* If proper metering is installed, this may be permitted to be used to indicate a potentially hazardous air/fuel ratio with an initial alarm indicating approach to a fuel-rich condition and a second alarm indicating approach to a hazardous fuel-rich condition.

(c) *Ignition fuel supply pressure (low).* This alarm monitors the ignition fuel supply pressure at a point as far upstream of the control and safety shutoff valves as practicable.

(d) *Flame detector trouble.* This alarm warns the operator of a flame detector malfunction.

(e) *Main oil temperature (high).* This alarm is used for heated oils only.

(f) *Main oil viscosity (high).* If the viscosity of the fuel supply is variable, it is recommended that a viscosity meter be used to provide the alarm. Interlocking to trip on high viscosity also shall be considered in such cases.

(g) *Flame detector trouble.* This alarm warns the operator of a flame detector malfunction.

A.5.1.1 It is not possible for this code to encompass the specific hardware applications, nor should it be considered a cookbook for the design of a safe HRSG system. An HRSG is a complex system, often involving numerous components; multiple steam pressure levels; emission control systems; and augmented air or supplementary firing.

The simplest combined cycle plant automatically has certain hazards that are common to all designs. Coupling various designs of heat recovery units with combustion turbines of varying characteristics in different configurations (such as varying damper arrangements) can produce very unique hazards. The potential ineffective use of the combustion turbine as the source of the purge and potential sources of substantial fuel entering the HRSG from normal and false starts are major considerations that need to be addressed.

Other concerns include special provisions such as automatic transfer during transients, multiple stacks that can create reverse flows, internal maintenance of the HRSG with the combustion turbine in operation, multiplicity of cross connections between units to prevent shutdown and/or fitting it into a small space using finned tubes that are more sensitive to temperature and subject to iron fires.

Insufficient failure analysis of arrangements, configurations, and equipment can increase the number of damaging incidents, lost production, and the possibility of personal injury or death. It is vital that the designer of the combustion turbine and any burner safety system(s) be completely familiar with the features, characteristics, and limitations of the specific hardware and also possess a thorough understanding of this standard and its intent.

A.5.2.2 No code can guarantee the elimination of HRSG explosions and implosions. Technology in this area is under constant development and is reflected in revisions to this code.

A.5.3 Due to misoperation, there have been occurrences of fin-metal tube fires in HRSGs, and there is a need to address this potential. See Appendix I.2 for specific articles related to iron fires, which in turn have references to previous literature. Consideration should be given to detecting and alarming fin-metal tube fires.

Iron fires in conventional and marine boilers have also occurred, principally in air preheaters. At a temperature of approximately 1060°F (571°C), carbon steel fins oxidize at an accelerated rate, and with insufficient cooling, an iron fire is inevitable.

A.5.5.3.1 The following list of factors, at minimum, should be considered during the design evaluation:

(1) Single versus multiple steam pressure levels
(2) Allowable combustion turbine exhaust backpressure
(3) Supplementary, auxiliary, or augmented firing
(4) Combustion turbine exhaust bypass system
(5) Corrosiveness and fouling of by-products of combustion (for example, fin-tube versus bare-tube, metallurgy, cold-end metal temperature)
(6) Single or multiple fuels
(7) SCR or other environmental control systems
(8) Heat transfer surface cleaning (during operation and shutdowns) and inspection
(9) Freeze protection
(10) Rapid start, operating and transients, and thermal shock
(11) Dry operation
(12) Protective systems
(13) Degree of automation and complexity of control systems
(14) Operator interface
(15) Overall system performance evaluation, feedback, and iteration (expert system database consideration)
(16) Description of start-up validation test program (reference test cases and simulator data library where available)
(17) Combustion turbine (purge exhaust)
(18) Bypass stack and damper
(19) HRSG and interconnecting ducts
(20) Forced draft fan, induced draft fan, or discharge stack, in any combination
(21) Burner management system logic
(22) Flame monitoring and tripping systems
(23) Combustion control system
(24) Power supplies configuration and codes
(25) Piping system configuration and codes
(26) Operating information
(27) Input/output selection
(28) Information displayed
(29) Data transmission (noise accuracy considerations)
(30) Programmable logic controller software and hardware considerations
(31) Requirements for operation from a remote location
(32) Initial control tuning

A.5.5.3.2 Dynamic simulation, where utilized, should include development of the following:

(1) Configuration and data initialization
(2) Plant behavior knowledge
(3) Preliminary control system design and tuning
(4) Validation of operating requirements (system performance)
(5) Transients and ramps for intended and unintended operation

A.5.5.4 An HRSG is a complex system, often involving numerous components; multiple steam pressure levels; emission control systems; and auxiliary, augmented air, or supplementary firing.

A.5.6.2.1 The volume between the combustion turbine stop valves should be minimized.

A.5.6.2.3 In the event HRSG system conditions deviate beyond alarm set points, the operator or control system should initiate corrective action(s) to prevent reaching the interlock limits. These actions could include those that reduce thermal energy input to the HRSG, such as duct burner runback, duct burner trip, and combustion turbine runback.

Consideration should be given to taking preemergency action automatically in the event tripping parameters deviate beyond alarm levels, in order to minimize thermal stress duty cycles on the combustion turbine. Runback parameters should initiate from the HRSG or other plant subsystems.

A.5.6.3 The operation of the HRSG combustion turbine system differs from a conventional multiple burner boiler. Some of the differences include the following:

(a) The combustion turbine is an internal combustion engine. The engine burns a lean mixture of fuel with compressed air. The hot, pressurized combustion gases expand from the combustor through a series of rotating turbine wheel and blade assemblies, resulting in shaft power output and hot turbine exhaust gas discharge to the HRSG. Turbine exhaust gas is hot and has a reduced oxygen content relative to air.

(b) The design of the HRSG differs from that of a regular steam generator in that, in most cases, the HRSG is designed to utilize the residual heat from the combustion turbine exhaust gas, with some supplementary firing by the duct burner, if necessary.

(c) Because the combustion turbine is a volumetric machine, combustion turbine exhaust gas is discharged within closely prescribed limits, with the oxygen content varying as a function of load.

(d) Separate purge requirements exist prior to combustion turbine light-off and prior to duct burner light-off.

(e) Air/fuel ratios controlled by duct burners are neither possible nor recommended. As vast quantities of turbine exhaust gases that are far in excess of the theoretical air requirements of the fuel are utilized, fuel-rich conditions cannot inherently occur under normal controlled operating conditions.

(f) Many types of burners are available for HRSG systems. The burner can consist of a number of parallel tubes or runners placed in the duct to provide the required heat release. This commonly is used for gaseous fuels and is referred to as a "grid" burner. Alternatively, wall-mounted burner systems with parallel flame holders within the duct can be used for liquid fuels. In-line register-type burners manufactured in Europe also have been used. Ignition systems for these burner types can employ Class 1, Class 2, or Class 3 igniters.

A.5.6.4.1.7 Protection for burner front exposed equipment might justify installation of fire protection as indicated in NFPA 850, *Recommended Practice for Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations.*

A.5.6.4.2.1 Usually this can be accomplished by providing full relieving capacity vented to a safe location.

A.5.6.4.2.2 Atmospheric vent valves located between shutoff valves are intended to relieve any gas pressure that builds up due to failure of the first (upstream) shutoff valve. This minimizes the potential for leakage into an idle HRSG. To perform properly, these valves should be large enough to relieve gas to the atmosphere at a rate equal to the potential leakage rate. In the absence of equivalent protection, vent pipe sizes and vent valve port diameters should conform to Table 1.9.2.4.1. Special precautions should be taken to safely vent heavier-than-air gases.

A.5.6.4.3.7 Special attention should be given to the routes of piping, valve locations, and other such components to minimize exposure to high-temperature or low-temperature sources. Low temperature might increase viscosity, inhibit flow, or precipitate waxy materials. High temperatures might cause carbonization or excessive pressures and leakage due to fluid expansion in "trapped" sections of the system.

A.5.6.4.5.1.5 Variations in burning characteristics of the fuel and the normal variations in fuel-handling and fuel-burning equipment introduce an uncertainty to the lower operating limits of the main fuel subsystem in any given HRSG design. In these circumstances, Class 1 or Class 2 igniters, as demonstrated by test, can be used to maintain stable flame.

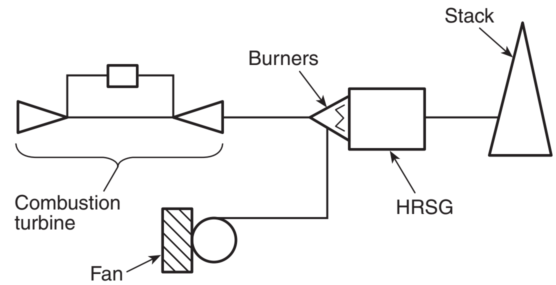
A.5.6.4.5.1.6 Such transients are generated by burner shutoff valves, dampers, and other components that operate at speeds faster than the response speeds of other components in the system.

A.5.6.5 See Figure A.5.6.5 for typical system with augmented air.

A.5.7 Proper design consideration should be given to internal insulation and cover plates so that the following factors are properly addressed:

(1) Insulation thickness and external casing temperature calculations
(2) Internal plate thickness and material
(3) Pin pitch, diameter, and fixing methods
(4) Welding procedures

FIGURE A.5.6.5 HRSG burners with augmented combustion air supply.



A.5.7.1 The external skin temperature and acoustical design of the HRSG, HRSG ducts, and HRSG stack should comply with the requirements of federal, state, and local regulations.

A.5.7.3 Any through-duct penetrations should have proper provision for expansion and sealing. Where pipes, tubes, headers, or drums create a through-duct penetration, calculations should be provided to demonstrate that the differential expansion and the sealing can properly accommodate such expansion.

A.5.7.4 Access should be provided for proper maintenance and repair. This should include personnel access where allowed by ducting. All pressure parts should have access for periodic inspection and for mandatory hydraulic tests.

A.5.7.8.1 Consideration should be given in the design to minimizing pockets that could trap combustible materials.

A.5.7.8.2 Drains should be provided in all ducts or enclosures where fluid accumulation is possible.

A.5.8 Some authorities having jurisdiction require the installation of selective catalytic reduction systems in some HRSG systems to reduce the emissions of NO_x. Because such a system has a narrow range of optimum operating temperatures and is subject to maximum temperature limitations lower than many combustion turbine full-load exhaust temperatures, it usually is installed between heat transfer surfaces within the HRSG.

The chemical process of reduction necessitates the addition of ammonia to reduce NO_x to nitrogen and water in the presence of the catalyst. In addition, if the fuel contains sulfur, a reaction that results in the formation of ammonium bisulfate can occur. This material tends to deposit on both the catalyst and metallic surfaces downstream of the reactor section, primarily at low temperatures. Although troublesome in terms of corrosion, fouling, and material life, ammonium bisulfate does not directly affect flame safety.

It is common practice to use either anhydrous or aqueous ammonia as the reducing agent in a selective catalytic reduction (SCR) system. These chemicals are not interchangeable, and a specific system design is needed, depending on the form to be used at a particular installation. Both forms, on release, are considered a potential health hazard. Ammonia gas is flammable in air at concentrations between 16 percent and 25 percent by volume. Such concentrations usually are not encountered. The system should provide the necessary features to ensure such concentrations cannot occur during abnormal conditions.

Aqueous ammonia usually is stored in a closed vessel to prevent the release of vapor. Such vessels are designed for low [less than a gauge pressure of 50 psi (344.7 kPa)] pressures and only approach the design pressure under high ambient temperature conditions. Due to the corrosive nature of ammonia, material selection is an important consideration.

Anhydrous ammonia is stored in a concentrated liquid–vapor form within closed vessels. Under ambient temperature conditions, pressures higher than those observed with aqueous ammonia can result. Precautions should be taken when selecting a storage area for ammonia, because the pressure in storage vessels can rise significantly when exposed to elevated temperatures. Vessels built in accordance with the ASME *Boiler and Pressure Vessel Code* are required with design gauge pressures of 250 psi (1723.7 kPa) or higher. The following sources provide additional information and requirements for storage and handling of anhydrous ammonia: CGA G-2, *Anhydrous Ammonia; Code of Federal Regulations,* Title 29, Part 1910.111, "Storage and Handling of Anhydrous Ammonia"; and ANSI K61.1, *Safety Requirements for the Storage and Handling of Anhydrous Ammonia.*

A.5.9.4 For guidance in determining area classification, see NFPA 497, *Recommended Practice for the Classification of Flammable Liquids, Gases, or Vapors and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas;* NFPA 499, *Recommended Practice for the Classification of Combustible Dusts and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas;* NFPA 497M, *Manual for Classification of Gases, Vapors, and Dusts for Electrical Equipment in Hazardous (Classified) Locations;* NFPA 70, *National Electrical Code*®, Article 500; and API RP 500A, *Classification of Locations for Electrical Installations in Petroleum Facilities Classified as Class I, Division I, and Division 2.*

A.5.10.1 *(Refer to A.1.9.5.)* Paragraph A.1.9.5 might also apply to burner management systems.

The user is encouraged to use judgment in the application of these guidelines for all process and safety functions contained in the distributed control system. This section is not intended to apply specifically to burner management systems.

(a) Data Transmission.

(1) Every input should be sampled at an interval no longer than 1 second. Every output should be updated at an interval no longer than 1 second.
(2) For protective actions, the system should be able to convert a changed input sensor value to a completed output control action in less than 250 milliseconds.
(3) Changes in displayed data or status should be displayed within 5 seconds.
(4) Data acquisition and transmission systems should be protected from noise pickup and electrical interference.
(5) In redundant systems, the data links should be protected from common mode failures. Where practical, redundant data links should be routed on separate paths to protect against physical damage that disables both data links.

(b) Hardware.

(1) The hardware selected should have adequate processor capacity to perform all the functions required for start-up sequencing, normal operation alarming, monitoring, and shutdown of the controlled equipment. Capacity also should be available for data storage and sorting; this can be permitted to be located in a separate processor.
(2) Selection should take into consideration the requirements for reliability, maintainability, and electrical classification.
(3) The hardware should provide for automatic tracking between auto–manual functions to allow for immediate seamless transfer.
(4) The hardware should be capable of stable dynamic control.
(5) The hardware should be capable of thorough self-diagnosis.
(6) Consideration should be given to all levels and types of electrical interference that can be tolerated by the hardware without compromising its reliability or effectiveness.
(7) Fail-safe operation should be obtained through a thorough and complete analysis of each control loop and by providing for a failure of that loop (i.e., valve/actuator) to cause a fail-safe position.

(c) Software.

(1) The software package should be designed to include all logic to provide a safe and reliable control system. When the software calls for the operation of a field safety device, a feedback signal should be provided to prove that the requested operation has taken place, and an alarm should be actuated if the action is not confirmed in a specified time.
(2) The software package should be checked to ensure that no unintended codes or commands are present (e.g., viruses or test breaks). The software package should be tested and exercised before being loaded into the plant site computers or processors.
(3) The software system should be protected from inadvertent actions from operators and also should be tamperproof.
(4) Written procedures should specify the functions that can and cannot be accessed by the operator and those functions that require additional authorization for access.
(5) The software should be permitted to provide for authorized on-line changes of the timers and set points, provided the safety of the operating equipment is not compromised.
(6) The software should implement and enhance the self-diagnostic hardware that has been provided.

A.5.10.2.3 Consideration should be given to monitoring the following additional HRSG parameters:

(1) Fuel flow
(2) Fuel supply header pressure
(3) Feedwater pressure at each pressure level
(4) Feedwater flow at each pressure level
(5) Economizer inlet water temperature
(6) Economizer outlet water temperature
(7) Steam temperature at each level
(8) Steam flow at each pressure level
(9) Oxygen in flue gas at HRSG outlet

A.5.11.1 The requirements in Chapters 1 and 5 apply to all combustion turbine and HRSG configurations. Configurations not specified might require additional safety considerations and requirements.

Sections 5.1 through 5.11 of this code have been based on a directly coupled combustion turbine and HRSG, either with or without duct burners. Combustion turbine exhaust is the only source of heat to the HRSG where no duct burners are supplied and is the principal source of combustion air for the duct burners where the HRSG system is so equipped. *See Figures A.5.11.1(a) and A.5.11.1(b).*

FIGURE A.5.11.1(a) Combustion turbine with directly coupled unfired HRSG.

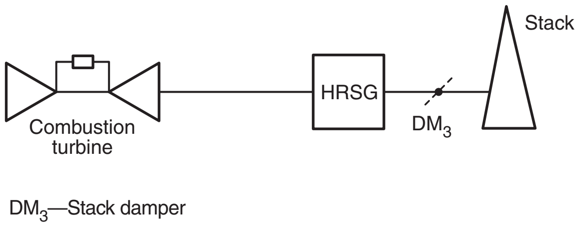
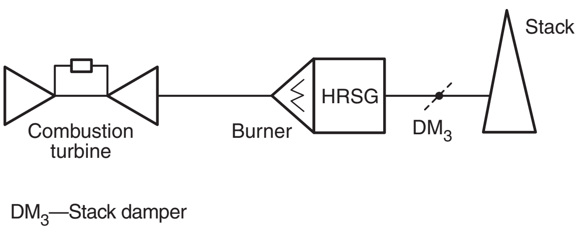


FIGURE A.5.11.1(b) Combustion turbine and directly coupled HRSG with burners.



A.5.11.2.7.2 This sequence provides a continuous airflow or flue gas flow through the HRSG at a rate that is at least the rate that existed during the purge operation. The objective of this practice is to ensure minimum velocities through the unit to prevent hazardous accumulations of unburned fuel.

A.5.11.2.7.3 Automatic start systems can be permitted to establish igniter flame on multiple burner elements simultaneously with proper supervision. Similarly, main burner elements can be permitted to be configured to operate as one with proper supervision.

A.5.11.4.1 The objective of this practice is to remove potential accumulations of hazardous unburned fuel from the volume defined in 5.11.4.2.1 that could be ignited by light-off of the combustion turbine.

A.5.11.4.2.2(2) An engineered model study has shown the capability of accurately depicting the gas flow characteristics within an HRSG enclosure. The greatest experience base for model studies has been physical scale models utilizing a cold airflow. These models are generally accurate if kinematic similitude is maintained by ensuring that the test flow within the model is fully turbulent (Reynolds Number > 3,200). The increasing availability of computational fluid dynamics (CFD) programs offers an alternative to physical modeling. With any model study, the accuracy of the results is dependent on the skill of the modeler, the quality of the modeling tools, and the detail of the model.

Engineered model studies can be used to determine purge effectiveness. For this use, the physical model generally offers the advantage of ease of visualization when identifying areas of high combustible concentrations. It is difficult, however, to quantify purge efficiencies with a physical model. The CFD model, when properly created, is able to define the change in concentration of the combustibles, but in general, is less easily visualized. It is also recognized that it is possible to consolidate the results of many model studies to develop a calculative method of correlating HRSG configurations with specific purge rates.

Physical or computational modeling or other engineering approaches can demonstrate or define a specific purge rate (higher or lower than those specified in 5.11.4.2.2) for HRSGs. However, the parameters vary for each installation and are unique.

As a minimum, consideration should be given, but not be limited to, the following:

(1) Ductwork and stack geometry
(2) HRSG geometry
(3) Fuel characteristics (lower explosive limits, autoignition temperature, density, etc.)
(4) Combustion turbine/HRSG conditions (hot or cold)
(5) Fuel accumulation zones

In general, when using physical or computational modeling, the reproduction of areas where combustible gas can accumulate is of extreme importance.

An example of this would be the steam drum and collection header cavities located on the top of HRSGs. These pockets can be very large and vary in size considerably, depending on the manufacturer and model. Low purge rates might not be able to dissipate the flammable vapors in these locations and could require separate venting or blowers to reduce the flammable vapors.

While not covered by this code at the present time, interconnected multiple combustion turbines and HRSGs are being installed and operated. These configurations require special purge considerations and could require purge rates significantly higher than required by this code.

Follow the principles provided in NFPA 69, *Standard on Explosion Prevention Systems,* to determine the required purge airflow air rate. When applying this method, a k factor consistent with the HRSG design should be established.

A.5.11.5.8 Figures A.5.11.5.8(a) through A.5.11.5.8(j) represent typical fuel supply systems for duct burners.

FIGURE A.5.11.5.8(a) Typical duct burner gaseous fuel ignition system of a single element or multiple elements fired simultaneously (Class 3 igniter monitoring requirements shown).

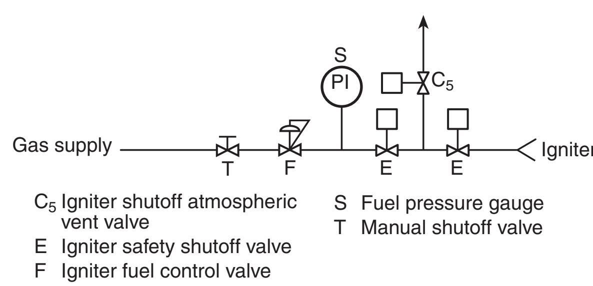


FIGURE A.5.11.5.8(b) Typical duct burner liquid fuel ignition system of a single burner or multiple burners fired simultaneously (Class 3 igniter monitoring requirements shown).

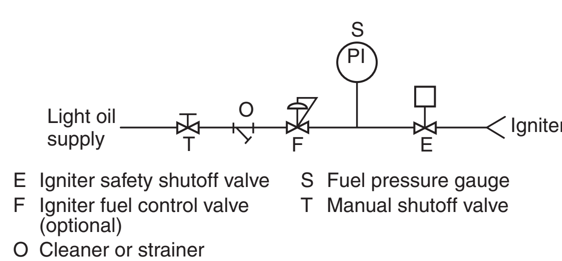
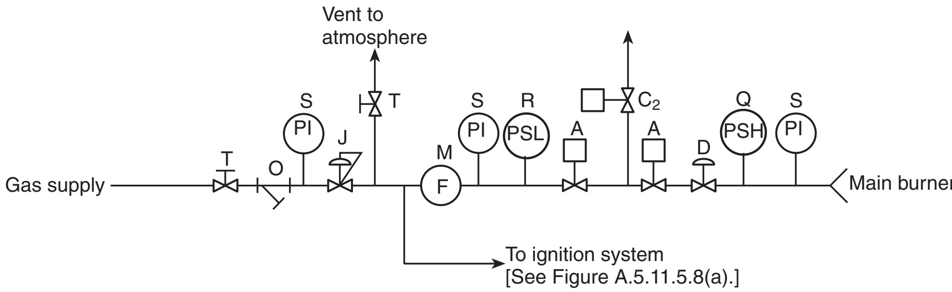
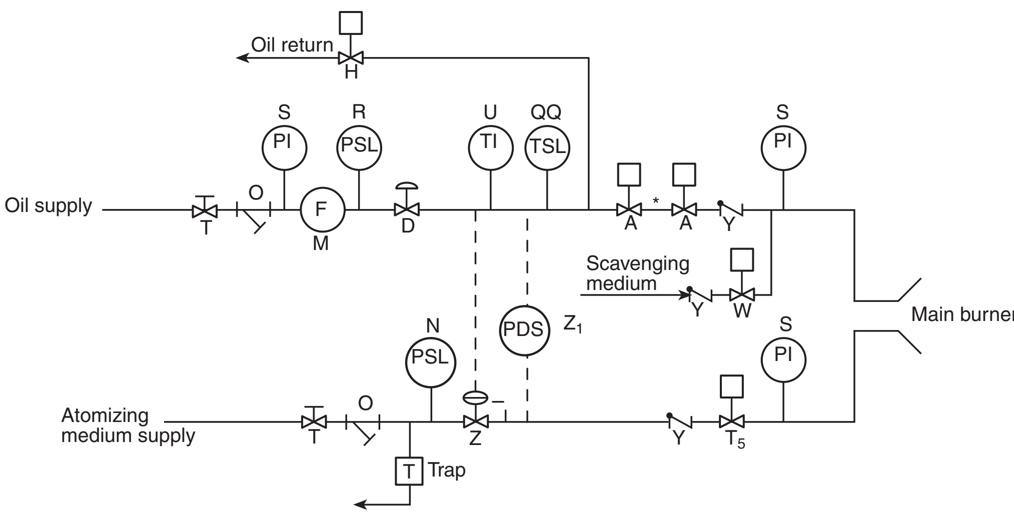


FIGURE A.5.11.5.8(c) Typical main gaseous fuel duct burner system of a single element or multiple elements fired simultaneously.



A Main burner safety shutoff valve
C_2 Main burner shutoff atmospheric vent valve
D Main fuel control valve
J Fuel pressure regulator (optional)
M Flowmeter
O Cleaner or strainer
Q High fuel pressure interlock
R Low fuel pressure interlock
S Fuel pressure gauge
T Manual shutoff valve

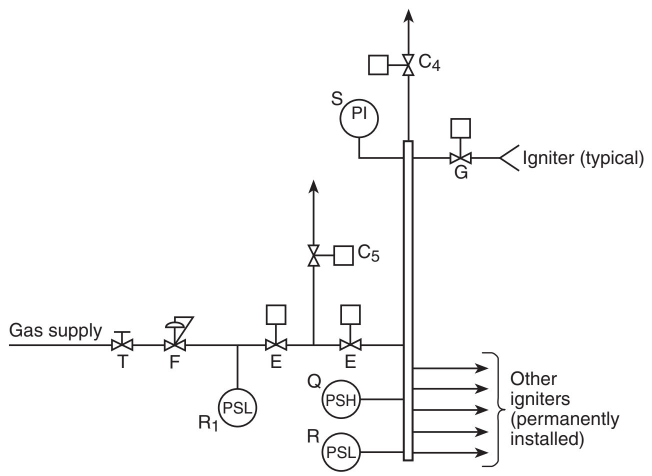
FIGURE A.5.11.5.8(d) Typical steam or air atomizing single main liquid fuel duct burner system.



*Caution: See 5.6.4.3.3.

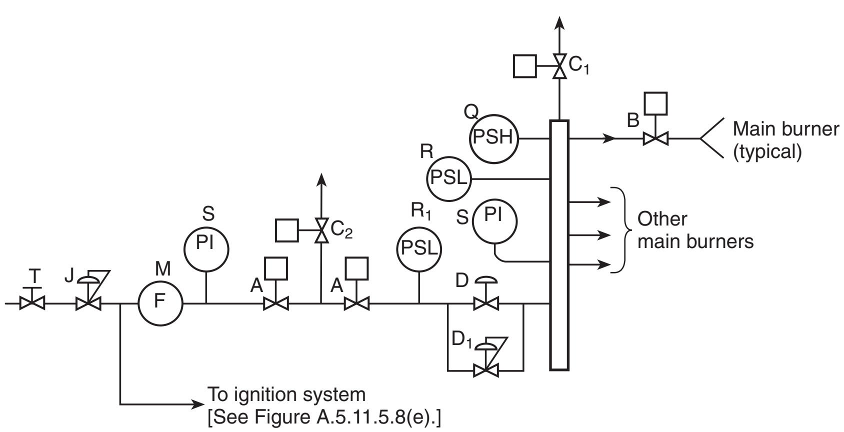
A Main burner safety shutoff valve
D Main fuel control valve
H Recirculating valve (optional for unheated oil)
M Flowmeter
N Low atomizing pressure interlock
O Cleaner or strainer
QQ Low-temperature or high-viscosity alarm (optional for unheated oil)
R Low fuel pressure interlock
S Fuel pressure gauge
T Manual shutoff valve
T_5 Atomizing medium individual burner shutoff valve, automatic
U Temperature gauge (optional for unheated oil)
W Scavenging valve
Y Check valve
Z Differential pressure control valve
Z_1 Differential pressure alarm and trip interlock

FIGURE A.5.11.5.8(e) Typical duct burner gaseous fuel igniter system.



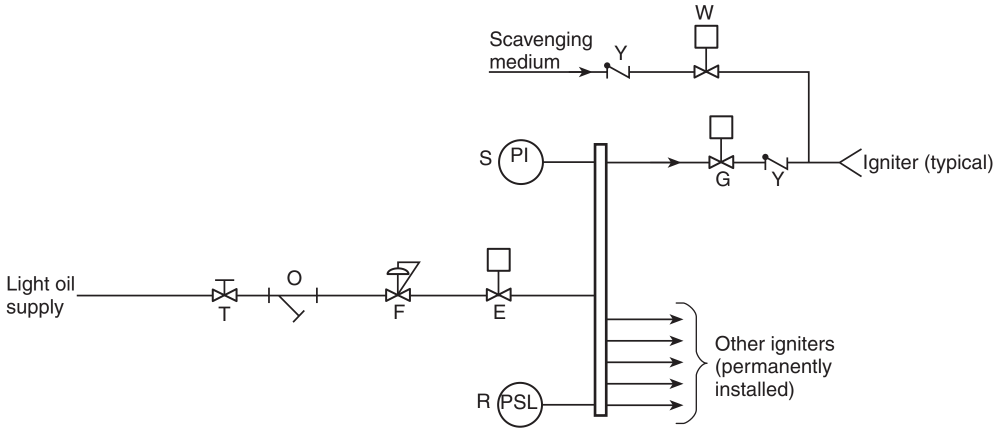
C_4 Igniter header atmospheric vent valve (optional)
C_5 Igniter supply atmospheric vent valve
E Igniter header safety shutoff valve
F Igniter fuel control valve
G Individual igniter safety shutoff valve
Q High fuel pressure interlock
R Low fuel pressure interlock
R_1 Low fuel pressure interlock (alternate location for R)
S Fuel pressure gauge
T Manual shutoff valve

FIGURE A.5.11.5.8(f) Typical main gaseous fuel duct burner system.



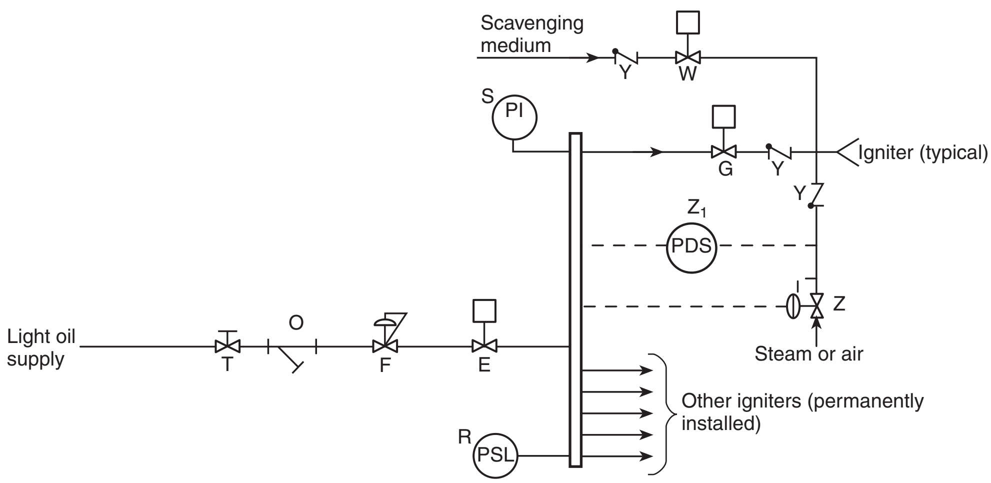
A Main safety shutoff valve
B Individual burner safety shutoff valve
C_1 Main burner header charging atmospheric vent valve (optional)
C_2 Main burner header shutoff atmospheric vent valve
D Main fuel control valve
D_1 Main fuel bypass control valve (optional)
J Fuel pressure regulator (optional)
M Flowmeter
Q Burner header high fuel pressure interlock
R Burner header low fuel pressure interlock
R_1 Burner header low fuel pressure interlock (alternate location for R)
S Fuel pressure gauge
T Manual shutoff valve

FIGURE A.5.11.5.8(g) Typical duct burner mechanical atomizing light liquid fuel igniter system.



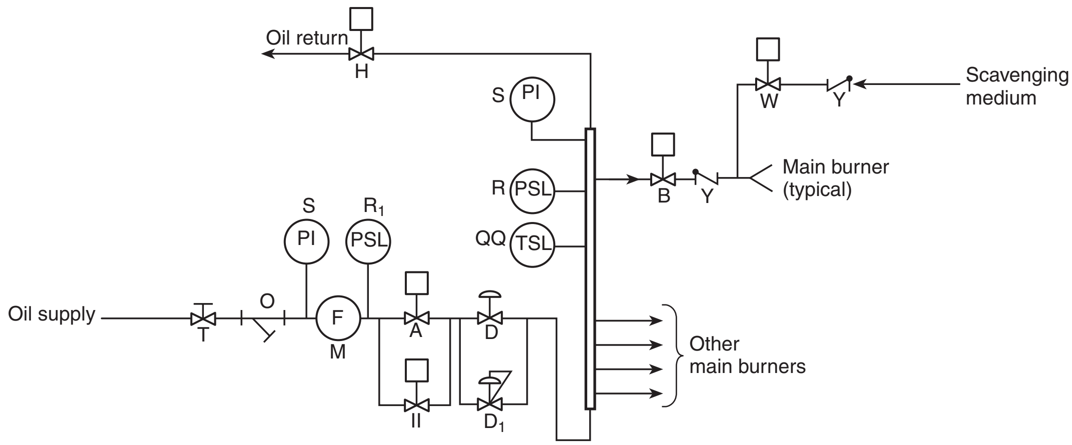
E Igniter safety shutoff valve
F Igniter fuel control valve
G Individual igniter safety shutoff valve
O Cleaner or strainer
R Low fuel pressure interlock
S Fuel pressure gauge
T Manual shutoff valve
W Scavenging valve
Y Check valve

FIGURE A.5.11.5.8(h) Typical duct burner steam or air atomizing light liquid fuel igniter system.



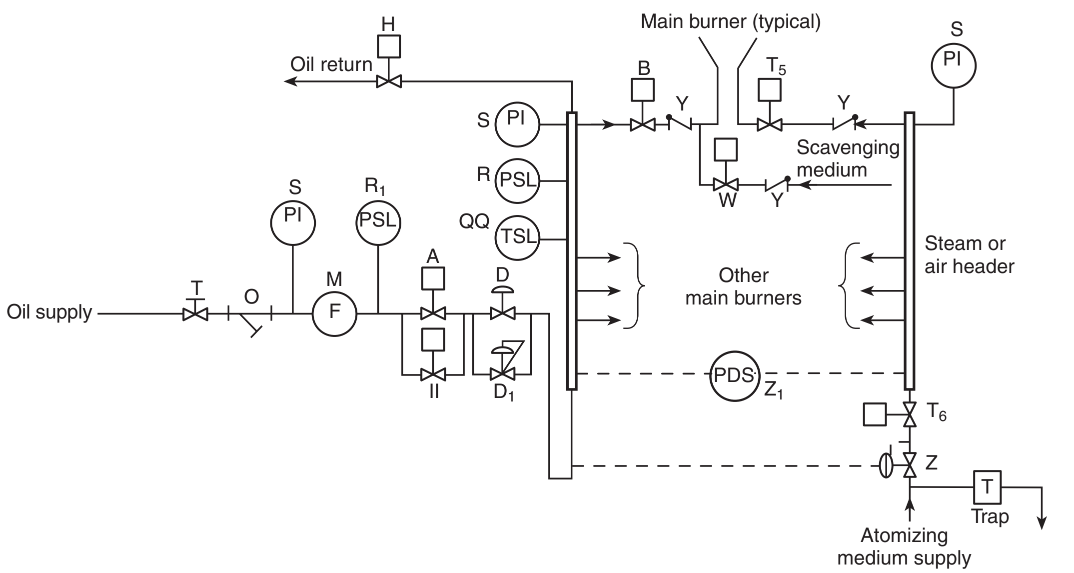
E Igniter safety shutoff valve
F Igniter fuel control valve
G Individual igniter safety shutoff valve
O Cleaner or strainer
R Low fuel pressure interlock
S Fuel pressure gauge
T Manual shutoff valve
W Scavenging valve
Y Check valve
Z Differential pressure control valve
Z_1 Differential pressure alarm and trip interlock

FIGURE A.5.11.5.8(i) Typical mechanical atomizing main liquid fuel duct burner system.



A Main safety shutoff valve
B Individual burner safety shutoff valve
D Main fuel control valve
D_1 Main fuel bypass control valve (optional)
H Recirculating valve (optional for unheated oil)
II Circulating valve (optional for unheated oil)
M Flowmeter
O Cleaner or strainer
QQ Low-temperature or high-viscosity alarm (optional for unheated oil)
R Burner header low fuel pressure interlock
R_1 Low fuel pressure interlock (alternate location for R)
S Fuel pressure gauge
T Manual shutoff valve
W Scavenging valve
Y Check valve

FIGURE A.5.11.5.8(j) Typical steam or air atomizing main liquid fuel duct burner system.



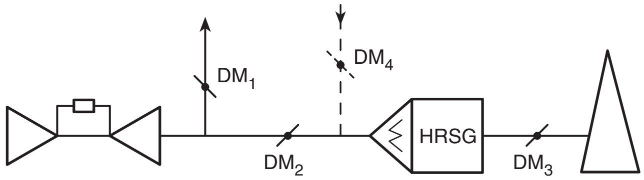
A Main safety shutoff valve
B Individual burner safety shutoff valve
D Main fuel control valve
D_1 Main fuel bypass control valve (optional)
H Recirculating valve (optional for unheated oil)
II Circulating valve (optional for unheated oil)
M Flowmeter
O Cleaner or strainer
QQ Low-temperature or high-viscosity alarm (optional for unheated oil)
R Burner header low fuel pressure interlock
R_1 Low fuel pressure interlock (alternate location for R)
S Fuel pressure gauge
T Manual shutoff valve
T_5 Atomizing medium individual burner shutoff valve, automatic
T_6 Atomizing medium header shutoff valve, automatic (alternate to T_5)
W Scavenging valve
Y Check valve
Z Differential pressure control valve
Z_1 Differential pressure alarm and trip interlock

A.5.11.7.5 After completion of the post-purge in 5.11.7.5, consideration should be given to maintaining airflow through the unit in order to prevent accumulation of combustible gases.

A.5.12.1 Figure A.5.12.1 shows separate dampers for isolating gas flow to the HRSG and allowing gas flow to the bypass stack.

FIGURE A.5.12.1 Damper terminology.

DM_1 allows combustion turbine exhaust gas to bypass the HRSG.
DM_2 blocks combustion turbine exhaust gas from entering the HRSG.
A single unit combination of DM_1 and DM_2 is commonly referred to as a diverter damper.
DM_3 closes the stack to prevent loss of heat during nonoperating conditions.
DM_4 allows ambient air to enter the HRSG



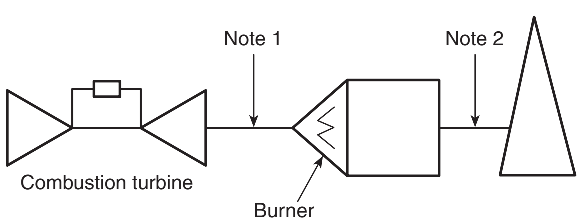
DM_1 Bypass damper
DM_2 HRSG isolation damper
DM_3 Stack damper
DM_4 Air inlet damper

A.5.12.2.2.4 The dew point of the exhaust gases should be determined. Detrimental effects such as corrosion should be minimized when choosing materials of construction.

It may be necessary to take special precautions to protect the superheater or other circuits from excessive temperatures or pressures by ensuring a constant flow of cooling steam through venting.

A.5.13 See Figure A.5.13 for typical combustion turbine and fired HRSG with fresh air firing capability.

FIGURE A.5.13 Combustion turbine and fired HRSG with fresh air firing capability.



Note 1: The fresh air inlet portion can include but is not limited to a bypass damper, an HRSG isolation damper, an air inlet damper, or a forced draft fresh air fan.

Note 2: The outlet duct can include but is not limited to an induced draft fan, an HRSG isolation damper, or a stack damper.

A.5.13.1 The designer should ensure that the proper margin above theoretical air is provided under all operating conditions.

A.6.3.1 *Pulverizing and fuel system component functions.*

(a) *Drying and conveying of fuel.* Pulverizer air is used to continuously convey the pulverized fuel from the pulverizer. Normally, heated pulverizer air evaporates some of the moisture from the raw fuel while it is being pulverized, and it elevates the air/fuel mixture to the desired temperature. The temperature and quantity of pulverizer air that is used is controlled to obtain the desired degree of dryness and pulverizer outlet temperature, depending on the type of fuel being burned.

(b) *Classifying the pulverized fuel.* An essential characteristic of the pulverized product is its fineness. It is desirable that the pulverized fuel system minimize variation in fineness, since pulverizer parts exhibit wear and as fuel properties change over the anticipated range. For this purpose, most pulverizers are equipped with adjustable classifiers or achieve some adjustment of fineness by varying air flow or other means.

(c) *Transporting and distributing the pulverized fuel.* The pulverized fuel should be transported directly to one or more burners, to one or more air/fuel separation devices, or to one or more bins or lock hoppers for intermediate storage.

(d) *Refuse removal.* It is desirable that foreign, hard-to-grind material be removed from the fuel before it is fed to the pulverizers; however, it is advisable that the pulverizers reject or tolerate reasonable amounts of such materials so that damage or interruption of service does not result.

A.6.3.2 *Hazards in pulverized fuel systems.* The design, operation, and maintenance of a pulverized fuel system should recognize certain inherent hazards, as outlined in (a) through (q).

(a) An uninterrupted, controllable, raw fuel supply is essential to minimize fires and explosions within the system. These interruptions and control problems in the fuel supply can be caused by worn equipment, excessive surface moisture, large or unusual fuel sizing, or foreign substances, including iron, wood, rags, excelsior, or rock. Compositions of certain clays (i.e., Bentonitic or mixed layers), which are contained in some coal seams, can cause interruptions in coal flow, which should be guarded against.

(b) The purchaser or the purchaser's designated representative should be aware of the wide range in material-handling characteristics of fuel that are related to differences in moisture, size distribution, and consolidation characteristics. The probable range in these characteristics for the fuels to be used and a determination of time consolidation shear values over these ranges are prerequisites for obtaining a bunker design that provides the desired flow characteristics over the range of fuels to be used. If the fuel is of a nature in which spontaneous combustion in the raw fuel bunker is likely to occur even when equipment is in service, the bunker design should be a mass flow design.

(c) A fire that is ahead of or in the pulverizer usually causes an abnormal increase in temperature of the equipment or of the mixture leaving the pulverizer. Fires are caused by feeding burning fuel from the raw fuel bin, by spontaneous combustion of an accumulation of fuel or foreign material in the pulverizer, piping, or burners, or by operating at abnormally high temperatures.

(d) Fires in burner pipes or other parts of pulverized fuel systems after the pulverizer will generally not be detected by an abnormal increase in pulverizer outlet temperature. Temperature sensors on pipes or in or on other components of the system can be used to detect these fires.

(e) Abnormally hot, smoldering, or burning raw fuel that is ahead of the pulverizer should be considered serious and should be dealt with promptly.

(f) Transport air is used to convey pulverized fuel from the pulverizer through pipes. Malfunction or maloperation introduces several hazards. For example, incorrect procedural steps for removing a burner from service will cause settling of pulverized fuel in the burner pipes. Leakage of pulverized fuel from an operating pulverizer through the burner valve into an idle burner pipe will cause pulverized fuel to settle in the burner pipe. Leakage of gas or air through a burner valve will increase the potential for fire in an idle pulverizer. Procedures are defined in Chapter 3 to prevent such hazards.

(g) Pulverizers that are tripped under load will have fuel remaining in the hot pulverizer, burner piping, and burners. These accumulations increase the potential for spontaneous combustion or explosion of the fuel.

(h) Fuel systems are hazardous when fuel escapes into the surrounding atmosphere or when air enters an inerted system.

(i) Oxidation of fuel has the potential to raise the temperature to a point where auto-combustion or spontaneous combustion occurs. This characteristic constitutes a special hazard with certain fuels and fuel mixtures.

(j) Accumulations of fuel in the pulverizer increase the potential for fires. Causes of fuel accumulation include but are not limited to design, conditions of wear, or insufficient drying, indicated by too low a pulverizer outlet mixture temperature.

(k) Excessive pulverizer outlet mixture temperatures increase the possibility of pulverizer fires and increases the potential for fuel accumulation on burner parts.

(l) Gases are released from freshly crushed fuel. Accumulations of flammable or explosive mixtures occur in bins or other enclosed areas.

(m) Hot air flowing back into the fuel bunker constitutes a hazard.

(n) To ensure compatibility of the type of fuel to be pulverized, a quality definition of the fuel is required. The equipment designer, the agency responsible for procurement of the fuel, and the operating department should use this definition. Volatility, moisture, ash content, maximum size and distribution, grindability, corrosiveness, abrasiveness, and other characteristics should be given close attention.

(o) A pulverized fuel system is designed for a specific range of fuel characteristics. Fuels that differ widely from the design range increase the risk of serious operating difficulties and produce a potential safety hazard. Procedures should be exercised to make sure that all received fuels are within the specific range of the fuel-handling and fuel-burning equipment.

(p) Insufficient personnel training, incomplete maintenance programs, or operation of excessively worn equipment increase the potential for fires and explosions.

(q) Accumulation of pulverized fuel in air ducts or pipes, particularly those shared by a group of pulverizers, is hazardous.

A.6.5.2.2 *Operation with burner(s) out-of-service.* Operation of the pulverizer-burner system with less than the full complement of burners served by a pulverizer, unless the system is designed specifically for such operation, creates the potential for fires and explosion. If not so designed, extra precautions should be used in isolating out-of-service burners.

A.6.5.2.2.3 Some applications utilize auxiliary air dampers to maintain burner line velocities at or above minimum to transport the fuel without settling.

A.7.2 An examination of numerous reports of boiler explosions in stoker fired units utilizing solid fuels indicates that the occurrence of small explosions or furnace puffs has been far more frequent than is usually recognized.

A.7.3 Several areas of stoker-fired boilers, listed in (a) through (h), routinely require maintenance attention.

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

(b) *Fuel feed mechanism.* The fuel feed mechanism must be properly adjusted to provide an even fuel bed. Uneven fuel beds lead to poor combustion, clinker formation, inefficient operation, and potential grate damage.

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

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

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

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

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

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

A.7.3.1.2(b)(3) See NFPA 850, *Recommended Practice for Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations,* for additional information.

A.7.3.1.2(c) Consideration should be given to the potential effects resulting from improper induced draft fan start-up or malfunction of the furnace draft controlling equipment. Consideration also should be given to the use of protective control loops similar to those shown in Chapter 3, modified or simplified in accordance with the manufacturer's recommendations to apply to stoker usage.

A.7.5.8 With multifuel arrangements, it is necessary to measure the airflow to the stoker as well as the auxiliary fuel supply. When the auxiliary fuel is fired through burners and the auxiliary is following boiler demand, the forced draft system should have a controller upstream from the burner control damper that maintains a constant pressure to the supply duct. This will ensure a repeatable supply of air to the stoker. Conversely, it will ensure a repeatable supply of air to the auxiliary burners. Care must be taken to maintain an adequate amount of excess air at all times by continuously observing the flame or the air/fuel ratio or the oxygen indicator, where provided. When firing multiple fuels, care should be taken in interpreting the oxygen analyzer readings, especially with systems having a single point measurement.

A.7.9.1 Use of ash hopper vibrators can minimize problems with bridged fly ash.

Appendix B Multiple Burner Boiler Supervised Manual Systems

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

B.1 General. The following sections provide information on gas- and oil-fired supervised manual systems. These sections do not apply to new construction or to alteration to existing boilers, but are provided for information only.

B.1.1 System Requirements. This section provides minimum requirements for the design, installation, and operation of multiple burner, fuel-fired boilers operated from the boiler front and describes functional requirements for proper operation. No specific degree of automation beyond the minimum specified safeguards is defined or recommended, since this is subject to factors such as the physical size of units, use of central control rooms, degree of reliability desired, and availability of experienced operating personnel. This section defines and specifies the requirements of the operating system that were used under the following conditions:

(a) A trained operator needs to be in constant attendance.

(b) The start-up or normal shutdown of any burner needs to be accomplished by an operator at the burner locations.

(c) The operator needs to have direct visual access to view the furnace.

(d) Suitable equipment needs to be provided to control furnace inputs and their relative rates of change to maintain an air/fuel mixture within the limits necessary for continuous combustion and stable flame throughout the controllable operating range of the unit. See Figures B.1.1(a) and (b) for gas firing, and Figures B.1.1(c), (d), and (e) for oil firing for minimum recommended equipment.

B.1.2 System Description. This operating system is defined as a *supervised manual system.* A supervised manual system is one in which a trained operator has primary responsibility for the proper start-up, operation, and normal shutdown of a boiler with interlocks to ensure that the operation follows established proper procedures. This system includes certain interlocks for preventing improper operator action, certain safety trips and flame supervisions, and an indication of the status of the start-up sequence. The operator(s) of this type of system need to be provided with and operate the system in accordance with a written set of operating instructions for each boiler unit.

B.2 Boiler Front Control — Gas-Fired Units.

B.2.1 Fundamental Principles. The written instructions need to include, but are not limited to, the following:

(a) The airflow needs to be adjusted to the purge rate and a unit purge performed.

(b) The purge airflow rate needs to be maintained continuously from purge initiation through the light-off cycle. If the airflow is not maintained, the prefiring cycle needs to be repeated.

(c) If flame on the first igniter is not established within 10 seconds, the individual igniter safety shutoff valve needs to be closed and the cause of failure to ignite determined and corrected. With airflow maintained at the purge rate, repurge is not needed, but at least 1 minute should elapse before attempting a retrial.

(d) The operator needs to observe the igniter operation continuously while opening the first individual burner supervisory shutoff valve. If the main burner flame is not proven within 10 seconds after the individual burner shutoff valve leaves the closed position, a master fuel trip occurs.

(e) After each stable main burner flame is established, the igniter needs to be shut off unless classified as Class 1 or Class 2. The stability of the main burner flame needs to be verified.

(f) Burner(s) are to be lighted only from their associated igniter(s).

(g) The operator is to observe the main flame stability while making any register or burner damper adjustments. (This is more critical in two-burner boilers.)

(h) After each successive burner light-off, the operator is to verify the flame stability of all operating burners.

(i) If a second or succeeding burner igniter does not light off immediately after its individual igniter safety shutoff valves have been opened, the operator is to close the individual igniter safety shutoff valves and determine and correct the cause of the igniter's failure to light. In all cases, at least 1 minute must elapse before the next light-off is attempted.

(j) If a second or succeeding main burner flame is not established, the operator is to close the individual burner supervisory shutoff valve and the individual igniter safety shutoff valves immediately, open the burner register or damper to firing position, and determine and correct the cause of its failure to ignite. At least 1 minute must elapse before attempting to light this or any other igniter.

(k) Operation at less than 25 percent of load is permitted, provided burners maintain stable flame and airflow is maintained at purge rate regardless of the actual load or fuel input.

(l) Although water side control is not directly related to combustion safety, it is to be given recognition, and low water level in the steam drum monitored and alarmed. Interlock tripping should be considered.

(m) For direct electric (Class 3 Special) igniters, B.2.1(c) and (i) need not apply.

B.2.2 Interlocks, Master Fuel Trip. Any of the following conditions initiates a master fuel trip with first-out annunciation:

(1) High fuel supply pressure
(2) Fuel pressure at the burner below the minimum established by the burner manufacturer or by trial, where measurable; where fuel pressure at the burner is not measurable, provide a low fuel pressure trip upstream of the control valve
(3) Loss of all forced draft fans
(4) Loss of all induced draft fans, if applicable
(5) Operation of the emergency trip switch by the operator
(6) Loss of all flame
(7) Loss of control energy if fuel flow to burners is affected in such an event

B.2.3 Loss of Individual Burner or Igniter Flame.

(1) Loss of flame at an individual igniter causes the igniter individual safety shutoff valve to close and the associated sparks to deenergize.
(2) Loss of flame at an individual burner causes the burner individual safety shutoff valve to close.
(3) The conditions of B.2.3(1) and (2) should be indicated.

FIGURE B.1.1(a) Typical fuel gas ignition system — supervised manual.

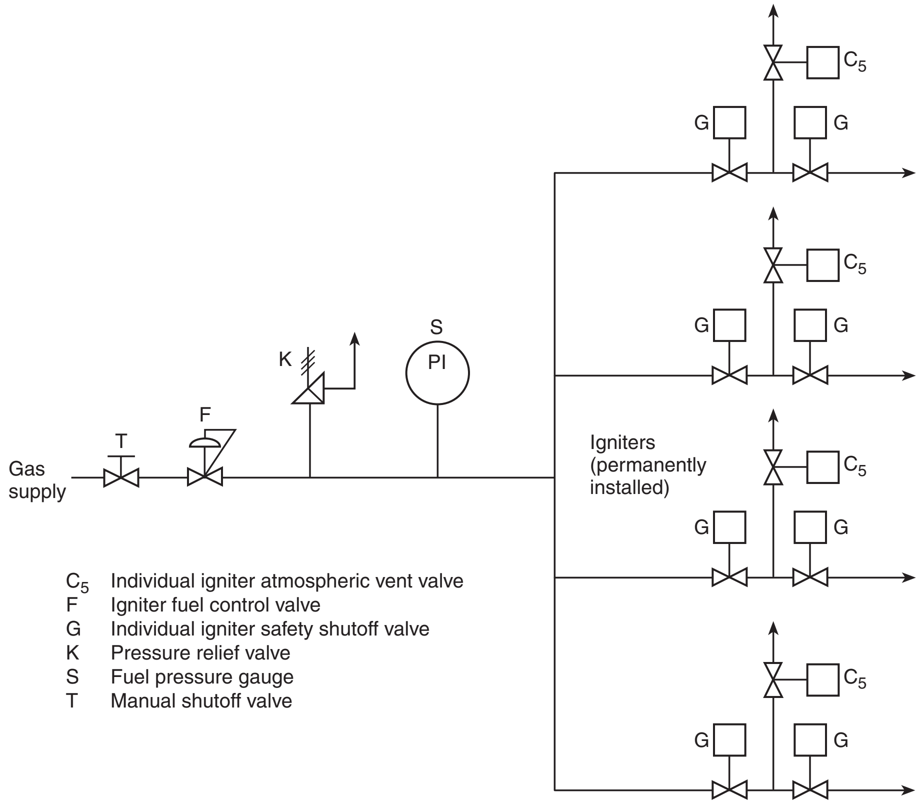


FIGURE B.1.1(b) Typical main burner fuel supply system for fuel gas-fired multiple burner boiler — supervised manual.

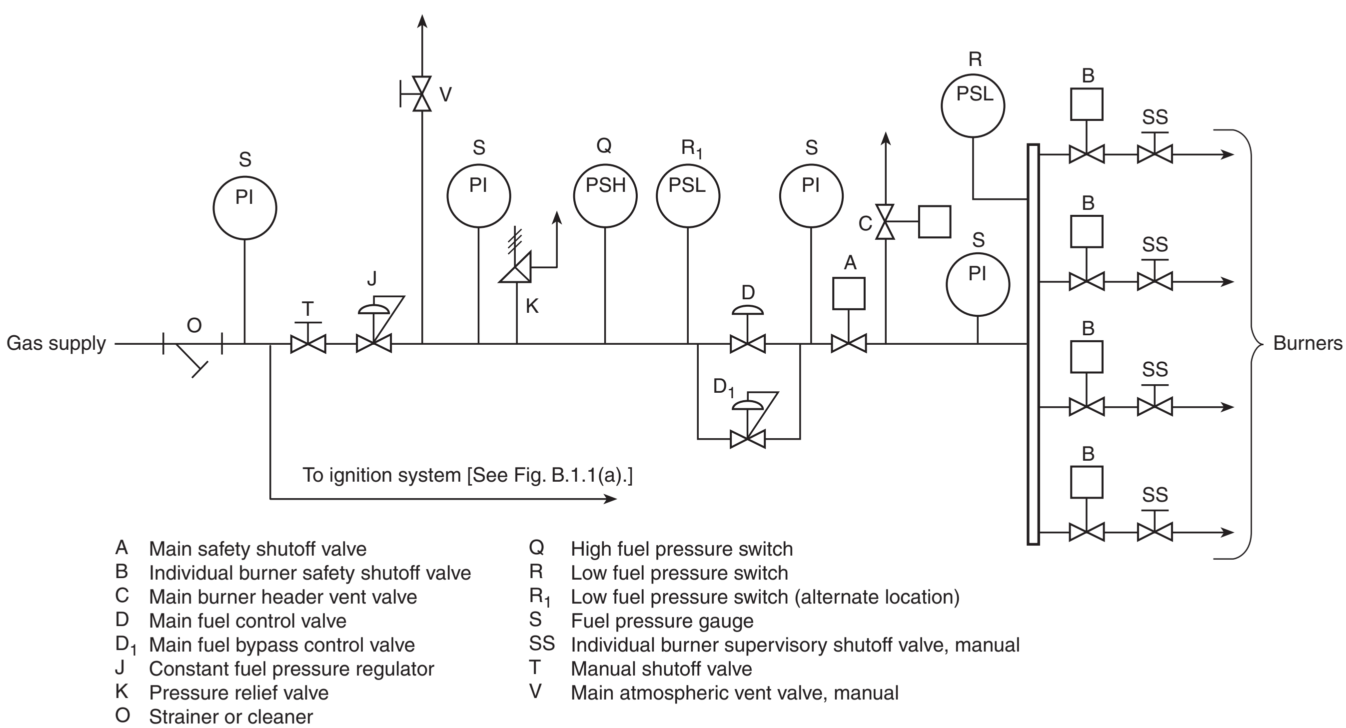


FIGURE B.1.1(c) Typical mechanical atomizing light oil igniter system — supervised manual.

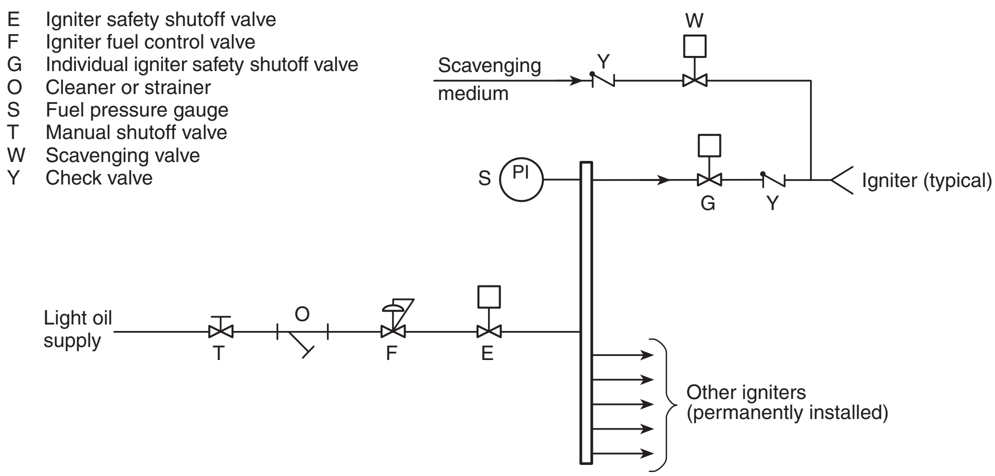


FIGURE B.1.1(d) Typical steam or air atomizing light oil igniter system — supervised manual.

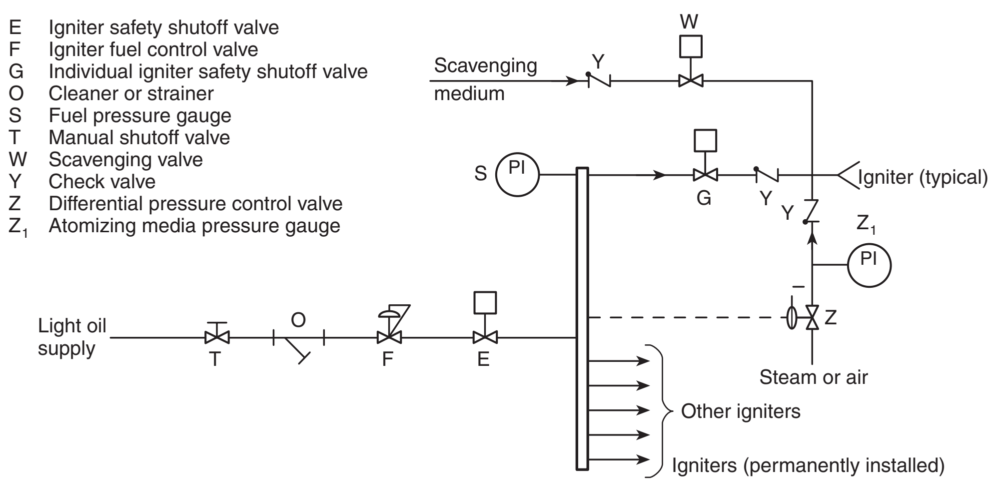
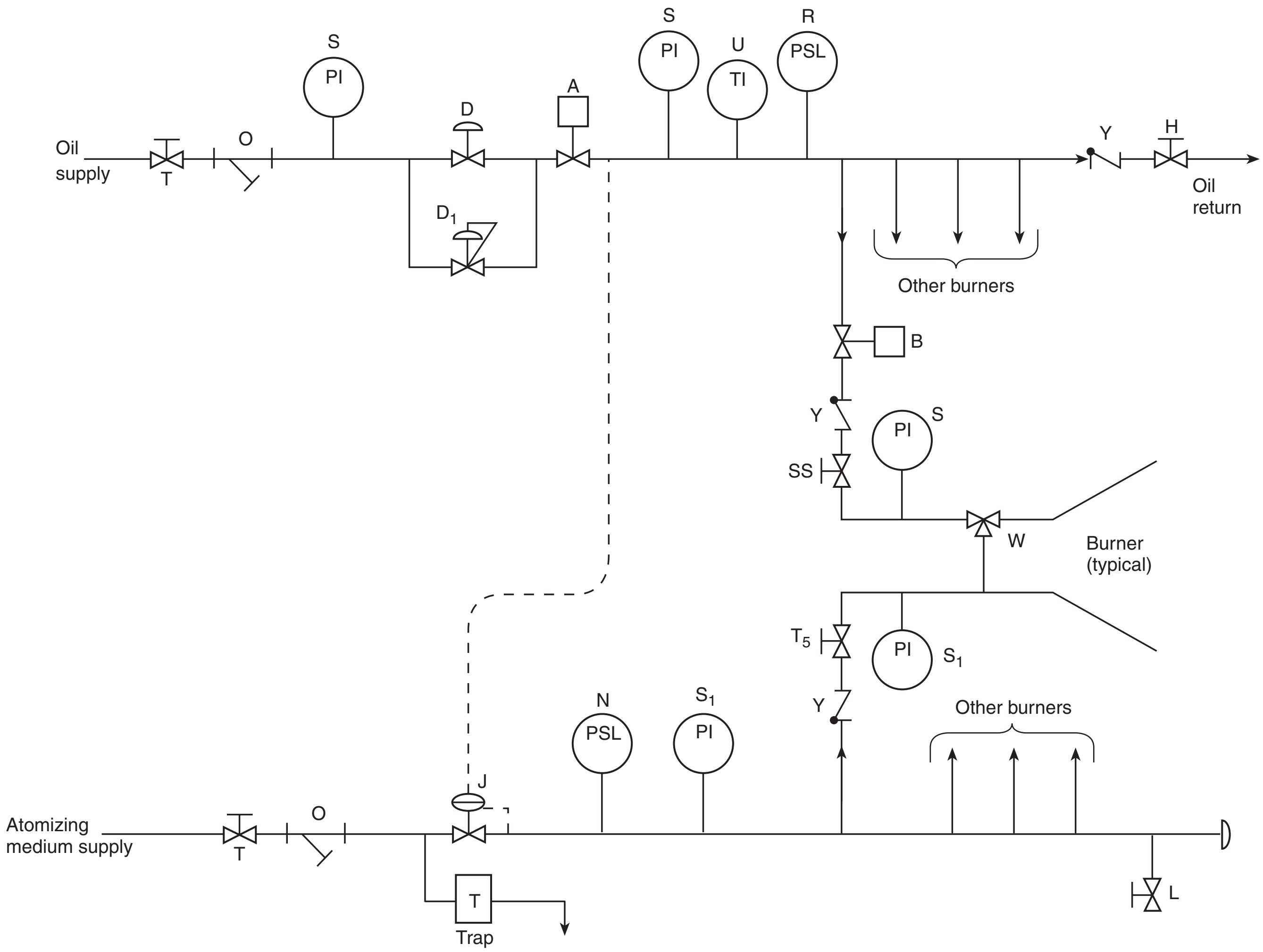


FIGURE B.1.1(e) Typical steam or air atomizing main oil burner system — supervised manual.



A	Main safety shutoff valve	R	Burner header low fuel pressure switch
B	Individual burner safety shutoff valve	S	Fuel pressure gauge
D	Main fuel control valve	S_1	Atomizing medium pressure gauge
D_1	Main fuel bypass control valve	SS	Individual burner supervisory shutoff valve, manual
H	Recirculating valve (optional for unheated oil)	T	Manual shutoff valve
J	Atomizing medium pressure regulator	T_5	Atomizing medium individual burner shutoff valve, manual
L	Bleed valve	U	Thermometer
N	Atomizing medium low pressure switch	W	Scavenging valve
O	Cleaner or strainer	Y	Check valve

B.2.4 Operating Cycle. The following operating sequences are based on a typical system. Certain provisions and sequences do not apply where other systems are used. However, follow the principles outlined in these sequences, and provide all applicable interlocks, trips, alarms, or their equivalents.

B.2.4.1 Prefiring Cycle. The steps listed in Table B.2.4.1 should be taken by the operator when starting a supervised manual unit, and the interlocks satisfied at each step. Establish control system energy, power and water level, and fuel supply. Inspect furnace and gas passages to determine if in good repair. Prior to start-up, determine that the unit and its associated systems are evacuated of all personnel and all access and inspection doors are closed.

Table B.2.4.1 Operator Actions, Prefiring Cycle

Operator Actions[1]	Interlock Functions
(a) Confirm individual burner safety shutoff valves closed.	(a) Proved closed.
(b) Confirm individual burner supervisory shutoff valves closed.	(b) Proved closed.
(c) Confirm main safety shutoff valve closed.	(c) Proved closed.
(d) Confirm main fuel control valve in light-off position.	(d) Proved.
(e) Open all burner registers to purge position.	(e) None.
(f) Start fan(s).	(f) Prove fan(s) operating.
(g) Open main damper(s) to purge positions.	(g) Prove purge airflow rate *[See B.2.1(a) and (b).]*
(h) Start purge timer and perform a unit purge.	(h) None.
(i) Immediately proceed with light-off cycle after completion of purge.	(i) Repurge if airflow rate drops below purge rate prior to initiation of light-off cycle.

Note: See Figures B.1.1(a) and B.1.1(b).
[1]Certain actions are not necessarily performed in the order shown.

B.2.4.2 Light-Off Cycle — First Igniter. This cycle needs to follow prefiring immediately, with all interlocks satisfied. Follow the open register procedure purge during the light-off procedure. The operator is to follow the steps listed in Table B.2.4.2 and satisfy the interlocks at each step.

Table B.2.4.2 Operator Actions, Light-Off Cycle — First Igniter

Operator Actions	Interlock Functions
(a) Maintain purge airflow rate.	(a) Prove that airflow has not dropped below purge rate.
(b) Adjust register of burner to be lighted to light-off position if necessary.	(b) Prove purge airflow.
(c) Confirm manual main atmospheric vent valve is open.	(c) None.
(d) Energize igniter for first burner. For direct electric ignition, omit step (e) and proceed directly to step (d) in Table B.2.4.4.	(d) Prove flame within 10 seconds. If flame is not proved, safety shutoff valves for this igniter should close and spark should be deenergized.
(e) If ignition flame is not established, determine cause and make necessary corrections. Burner register should be opened to purge position for at least 1 minute before repeating light-off cycle.	(e) None.

Note: See Figures B.1.1(a) and B.1.1(b).

B.2.4.3 Light-Off Cycle — Subsequent Igniters. The operator is to follow the steps listed in Table B.2.4.3 and satisfy the interlocks at each step.

Table B.2.4.3 Operator Actions, Light-Off Cycle — Subsequent Igniters

Operator Actions	Interlock Functions
(a) Adjust register of burner to be lighted to light-off position, if necessary.	(a) Prove that airflow has not dropped below purge rate.
(b) Energize igniter. For direct electric igniters, omit step (c) and proceed directly to step (d) in Table B.2.4.4.	(b) Prove flame within 10 seconds. If flame is not proved, safety shutoff valves for this igniter should close and spark should be deenergized.
(c) If igniter flame is not established, determine cause and make necessary corrections. Burner register should be opened to purge position for at least 1 minute before repeating light-off cycle.	(c) None.

B.2.4.4 Light-Off Cycle — First Main Burner. The operator is to follow the steps listed in Table B.2.4.4 and satisfy the interlocks at each step.

Table B.2.4.4 Operator Actions, Light-Off Cycle — First Main Burner

Operator Actions	Interlock Functions
(a) Adjust register of burner to be lighted to light-off position, if necessary.	(a) Prove that airflow has not dropped below purge rate.
(b) Verify that igniter flame is present.	(b) Proved.
(c) Confirm main burner header vent valve is open.	(c) None.
(d) Open main safety shutoff valve. Main burner header vent valve will close.	(d) Individual burner supervisory shutoff valves closed.
(e) Confirm burner gas pressure is being controlled by the main fuel bypass control valve and is at light-off pressure.	(e) None.
(f) Open individual burner safety shutoff valve at burner being lighted.	(f) Igniter flame proved on burner being lighted and individual burner supervisory shutoff valve proved closed.
(g) Slowly open individual burner supervisory shutoff valve until fully open to establish this main burner flame.	(g) Starts main burner trial for ignition. If main burner flame is not proved within 10 seconds after the valve leaves the closed position, a master fuel trip is effected.
(h) If first main burner flame is not established, determine cause and correct conditions. Repeat actions beginning with prefiring cycle. *(See B.2.4.1.)*	(h) Requires repeat of purge cycle.
(i) After main burner flame is established, adjust burner register to firing position, as necessary.	(i) None.
(j) Slowly close manual main atmospheric vent valve while observing header gas pressure.	(j) None.
(k) Unless classified as Class 1 or Class 2, igniter should be removed from service; visually confirm main flame stability.	(k) None.

Note: See Figures B.1.1(a) and B.1.1(b).

B.2.4.5 Light-Off Cycle for Subsequent Main Burners at Light-Off Fuel Pressure. The cycle given in Table B.2.4.5 should be performed after the igniter flame for the burner has been proved and fuel pressure is controlled by the main fuel bypass control valve.

Table B.2.4.5 Operator Actions, Light-Off Cycle for Subsequent Main Burners at Light-Off Fuel Pressure

Operator Actions	Interlock Functions
(a) Adjust register of burner to be lighted to light-off position if necessary.	(a) Prove that airflow has not dropped below purge rate.
(b) If igniter is fuel fired, verify igniter flame is present.	(b) Proved.
(c) Confirm burner fuel pressure is being controlled by the main fuel bypass control valve and is at light-off pressure.	(c) None.
(d) Open individual burner safety shutoff valve at burner being lighted.	(d) Igniter flame proved on burner being lighted and individual burner supervisory shutoff valve proved closed.
(e) Slowly open individual burner supervisory shutoff valve until fully open to establish this main burner flame.	(e) If the main burner flame is not proved within 10 seconds after the valve leaves its closed position, all fuel to this burner and its igniter is shut off.
(f) If this main burner flame is not established, determine cause and correct conditions. Open burner register to firing position; wait 1 minute before attempting to light this or any other burner. Repeat B.2.4.3 and B.2.4.5.	(f) None.
(g) After main burner flame is established, adjust burner register to firing position, as necessary.	(g) None.
(h) Unless classified as Class 1 or Class 2, igniter should be removed from service; visually confirm main flame stability.	(h) None.

Note: See Figures B.1.1(a) and B.1.1(b).

B.2.4.6 Light-Off Cycle for Additional Burner(s) When Fuel Pressure of Operating Burner(s) Is Above Light-Off Pressure. The cycle given in Table B.2.4.6 should be performed. Fuel pressure is controlled by the main fuel control valve.

Table B.2.4.6 Operator Actions, Light-Off Cycle for Additional Burners When Fuel Pressure of Operating Burners Is Above Light-Off Pressure

Operator Actions	Interlock Functions
(a) Place combustion control system on manual; note the value of windbox-to-furnace pressure differential.	(a) None.
(b) Slowly adjust register on burner to be lighted to light-off position while manually adjusting airflow to maintain the windbox-to-furnace differential pressure at the value noted in step (a).	(b) None.
(c) Energize igniter; for direct electric igniters, omit step (d).	(c) Prove flame within 10 seconds. If flame is not proved, safety shutoff valves for this igniter should close and spark should be deenergized.
(d) If igniter flame is not established, determine cause and correct.	(d) None.
(e) Open safety shutoff valve to burner being lighted.	(e) Igniter flame proved and supervisory shutoff valve proved closed.
(f) Slowly open individual supervisory shutoff valve only enough to light burner.	(f) If the main burner flame is not proved within 10 seconds after the valve leaves its closed position, all fuel to this burner and its igniter is shut off.
(g) If the main burner flame is not established, determine cause, correct, wait at least 1 minute, then repeat steps (e) through (h).	(g) None.
(h) With main flame established, open air register to the firing position.	(h) None.
(i) Slowly open supervisory shutoff valve completely but without suddenly dropping header fuel pressure.	(i) None.
(j) Unless classified as Class 1 or Class 2, igniter should be removed from service; visually confirm main flame stability.	(j) None.
(k) Adjust airflow to restore correct fuel/air ratio.	(k) None.
(l) Place combustion control system on automatic, if desired.	(l) None.

Note: See Figures B.1.1(a) and B.1.1(b).

B.2.4.7 Normal Shutdown Cycle. The operator is to follow the steps listed in Table B.2.4.7 and satisfy the interlocks at each step.

Table B.2.4.7 Operator Actions, Normal Shutdown Cycle

Operator Actions	Interlock Functions
(a) Reduce boiler load until main fuel control valve is closed. Main fuel bypass control valve will assume control at light-off gas pressure. Airflow should not be reduced below purge rate.	(a) None.
(b) Close individual supervisory shutoff valve at each burner and associated igniter valve if in operation. Leave burner register at firing position.	(b) As each burner supervisory shutoff valve is closed, loss of flame will cause its associated safety shutoff valve to close. After last burner supervisory shutoff valve is closed, loss of all flame should cause main safety shutoff valve to close. Main atmospheric vent valve should open.
(c) Perform a unit purge.	(c) None.
(d) Shut down fan(s), if desired.	(d) Loss of airflow interlock is actuated.

Note: See Figures B.1.1(a) and B.1.1(b).

B.2.4.8 Emergency Shutdown.

(1) An emergency shutdown initiates a master fuel trip.
(2) For the conditions that initiate an emergency shutdown, see B.2.2.

B.2.4.9 Operator Actions Following an Emergency Shutdown. *[See Figures B.1.1(a) and B.1.1(b).]*

(a) Close all individual burner supervisory shutoff valves. Burner register positions remain unchanged.

(b) The unit should be purged in accordance with the following procedure:

(1) Fans that are operating after the master fuel trip should be continued in service.
(2) Airflow should not be immediately increased by deliberate manual or automatic control action.
(3) If the airflow is above the purge rate, decrease it gradually to this value and purge the unit.
(4) If the airflow is below the purge rate at the time of the trip, continue at the existing rate for 5 minutes and then gradually increase to the purge rate and hold at this value for a unit purge.

(c) Where the master fuel trip is caused by loss of draft fans, or draft fans also have tripped, all dampers in the air and flue gas passages of the unit should be slowly opened to the fully open position in order to create as much natural draft as possible to ventilate the unit. Opening fan dampers should be timed or controlled to avoid excessive positive or negative furnace pressure transients during fan coast-down. Maintain this condition for not less than 15 minutes. At the end of this period, the flow control dampers should be closed and the fan(s) should be started immediately. Airflow should be increased to at least purge rate.

(d) The cause of emergency shutdown should be determined and corrected.

(e) Perform the first igniter light-off cycle *(see B.2.4.2)* if restart of unit is desired.

(f) If it is desired to remove the boiler from service for a period of time, the fans should be shut down upon completion of unit purge and manual shutoff valves should be closed.

B.2.5 Air Heaters. Where provided, regenerative air heaters and gas recirculation fans should be operated in a manner recommended by the boiler manufacturer.

B.3 Boiler Front Control, Oil-Fired Units.

B.3.1 Fundamental Principles. The written instructions should include the following:

(a) The airflow rate should be adjusted to the purge rate, and a unit purge should be performed.

(b) The purge airflow rate should be maintained continuously from purge initiation through the light-off cycle. If the airflow is not maintained, the prefiring cycle should be repeated.

(c) If flame on the first igniter is not established within 10 seconds, the individual igniter safety shutoff valve should be closed and the cause of failure to ignite determined and corrected. With airflow maintained at the purge rate, repurge is not needed, but at least 1 minute should elapse before attempting a retrial.

(d) The operator should observe the igniter operation continuously while opening the first individual burner supervisory shutoff valve. If the main burner flame is not proven within 10 seconds after the individual burner shutoff valve leaves the closed position, a master fuel trip should occur.

(e) After each stable main burner flame is established, the igniter should be shut off unless classified as Class 1 or Class 2. The stability of the main burner flame should be verified.

(f) Burners should be lighted only from their associated igniter(s).

(g) The operator should observe the main flame stability while making any register or burner damper adjustments. (This is more critical in two-burner boilers.)

(h) After each successive burner light-off, the operator should verify the flame stability of all operating burners.

(i) If a second or succeeding burner igniter does not light-off immediately after its individual igniter safety shutoff valves have been opened, the operator should close the individual igniter safety shutoff valves and determine and correct the cause of its failure to light. In all cases, at least 1 minute should elapse before the next light-off is attempted.

(j) If a second or succeeding main burner flame is not established, the operator should close the individual burner supervisory shutoff valve and the individual igniter safety shutoff valves immediately, open the burner register or damper to firing position, and determine and correct the cause of its failure to ignite. At least 1 minute should elapse before attempting to light this or any other igniter.

(k) Operation at less than 25 percent of load is permitted, provided burners maintain stable flame and airflow is maintained at purge rate regardless of the actual load or fuel input.

(l) Although water side control is not directly related to combustion safety, it should be given recognition, and low water level in the steam drum monitored and alarmed. Consider interlock tripping.

(m) For direct electric (Class 3 Special) igniters, B.3.1(c) and (i) need not apply.

B.3.2 Interlocks, Master Fuel Trip. Any of the following conditions should initiate a master fuel trip with first-out annunciation:

(1) Fuel pressure at the burner below the minimum established by the burner manufacturer or by trial
(2) Loss of all forced draft fans
(3) Loss of all induced draft fans, if applicable
(4) Operation of the emergency trip switch by the operator
(5) Loss of atomizing medium to the boiler
(6) Loss of all flame
(7) Loss of control energy if the fuel flow to the burners is affected in such an event

B.3.3 Loss of Individual Burner or Igniter Flame.

(1) Loss of flame at an individual igniter should cause the igniter individual safety shutoff valve to close and the associated sparks to deenergize.
(2) Loss of flame at an individual burner should cause the burner individual safety shutoff valve to close.
(3) The conditions of B.3.3(1) and (2) should be indicated.

B.3.4 Operating Cycle. The following operating sequences are based on a typical system that includes steam-atomized main oil burners. Certain provisions and sequences do not apply where other atomizing media or systems are used. However, the principles outlined in these sequences should be followed, and all applicable interlocks, trips, alarms, or their equivalents should be provided.

B.3.4.1 Prefiring Cycle. The operator should take the steps listed in Table B.3.4.1 when starting a supervised manual unit and satisfy the interlocks at each step. Control system energy, power, water level, fuel supply, and atomizing medium should be established, if used. Furnace and gas passages should be inspected to determine whether they are in good repair. Prior to start-up, it should be determined that the unit and its associated systems are evacuated of all personnel and all access and inspection doors are closed.

B.3.4.2 Light-Off Cycle — First Igniter. This cycle should follow prefiring immediately with all interlocks satisfied. Follow the open register purge airflow rate principle during the light-off procedure. The steps listed in Table B.3.4.2 should be taken by the operator, and the interlocks satisfied at each step.

B.3.4.3 Light-Off Cycle — Subsequent Igniters. The steps in Table B.3.4.3 should be taken by the operator, and the interlocks satisfied at each step.

B.3.4.4 Light-Off Cycle — First Main Burner. The operator is to follow the steps listed in Table B.3.4.4 and satisfy the interlocks at each step.

B.3.4.5 Light-Off Cycle for Subsequent Main Burners at Light-Off Fuel Pressure. This cycle should be performed after the igniter flame for the burner has been proved and fuel pressure is controlled by the main fuel bypass control valve. The steps listed in Table B.3.4.5 should be taken by the operator, and the interlocks satisfied at each step.

Table B.3.4.1 Operator Actions, Prefiring Cycle

Operator Actions[1]	Interlock Functions
(a) Inspect furnace for unburned oil accumulations.	(a) None.
(b) Confirm burner guns have proper tips and sprayer plates.	(b) None.
(c) Confirm individual burner safety shutoff valve closed.	(c) Proved.
(d) Confirm supervisory shut-off valves closed.	(d) Proved.
(e) Confirm burner gun in proper position.	(e) None.
(f) Confirm main fuel control valve in light-off position.	(f) Proved.
(g) Confirm that atomizing medium header has been blown free of condensate and header trap is functioning.	(g) None.
(h) Start fan(s).	(h) Prove fans operating.
(i) Open main safety shutoff valve and recirculation valve to circulate heated oil through main fuel bypass control valve and the burner header.	(i) Prove all interlocks satisfied.
(j) Open main damper(s) to purge position.	(j) Prove purge airflow rate *[See B.3.1(a) and (b).]*
(k) Open all burner registers to purge position.	(k) None.
(l) Start purge timer and purge.	(l) None.
(m) Open atomizing medium individual burner shutoff valve to the burner gun to be lighted. Blow free of condensate. Confirm atomizing pressure has been established.	(m) Prove atomizing medium available.
(n) Immediately proceed with light-off cycle after completion of purge.	(n) Repurge if airflow rate drops below purge rate prior to initiation of light-off cycle.

Note: See Figures B.1.1(c), B.1.1(d), and B.1.1(e).
[1]Certain actions are not necessarily performed in the order shown.

Table B.3.4.2 Operator Actions, Light-Off Cycle — First Igniter

Operator Actions	Interlock Functions
(a) Maintain purge airflow rate.	(a) Prove that airflow has not dropped below purge rate.
(b) Adjust register of burner to be lighted to light-off position, if necessary.	(b) Prove purge airflow rate.
(c) Energize igniter for first burner. For direct electric ignition, omit step (d) and proceed directly to step (c) in Table B.3.4.4.	(c) For fuel-fired igniters, prove flame within 10 seconds. If flame not proved, safety shutoff valves for this igniter should close and spark should be deenergized.
(d) If ignition flame is not established, determine cause and make necessary corrections. Burner register should be opened to purge position for at 1 least minute before repeating light-off cycle.	(d) None.

Note: See Figures B.1.1(c), B.1.1(d), and B.1.1(e).

Table B.3.4.3 Operator Actions, Light-Off Cycle — Subsequent Igniters

Operator Actions	Interlock Functions
(a) Adjust register of burner to be lighted to light-off position, if necessary.	(a) Prove that airflow has not dropped below purge rate.
(b) Energize igniter. For direct electric igniters, omit step (c) in Table B.3.4.2 and proceed directly to step (c) in Table B.3.4.4.	(b) For fuel-fired igniters, prove flame within 10 seconds. If flame is not proven, safety shutoff valves for this igniter should close and spark should be deenergized.
(c) If ignition flame is not established, determine cause and make necessary corrections. Burner register should be opened to purge position for at least 1 minute before repeating light-off cycle.	(c) None.

Note: See Figures B.1.1(c), B.1.1(d), and B.1.1(e).

Table B.3.4.4 Operator Actions, Light-Off Cycle — First Main Burner

Operator Actions	Interlock Functions
(a) Adjust register of burner to be lighted to light-off position, if necessary.	(a) Prove airflow has not dropped below purge rate.
(b) If igniter is fuel fired, verify igniter flame is present.	(b) Proved.
(c) Confirm that burner oil pressure is being controlled by main fuel bypass control valve and is at light-off pressure. If necessary, throttle recirculating valve as needed to maintain light-off oil pressure.	(c) None.
(d) Open individual burner safety shutoff valve at burner being lighted.	(d) Igniter flame proved on burner being lighted and individual burner supervisory shutoff valve proved closed.
(e) Verify atomizing medium flowing from burner gun about to be lighted.	(e) None.
(f) Confirm clearing valve closed.	(f) None.
(g) Slowly open individual burner supervisory shutoff valve until fully open to establish this main burner flame.	(g) Starts main burner trial for ignition. If main burner flame is not proved within 15 seconds after the valve leaves the closed position, a master fuel trip is effected.
(h) If first main burner flame is not established, determine cause and correct conditions. Repeat actions beginning with prefiring cycle. *(See B.3.4.1.)*	(h) Requires repeat of purge cycle.
(i) After main burner flame is established, adjust burner register to firing position, as necessary.	(i) None.
(j) Close recirculating valve.	(j) None.
(k) Unless classified as Class 1 or Class 2, igniter should be removed from service; visually confirm main flame stability.	(k) None.

Note: See Figures B.1.1(c), B.1.1(d), and B.1.1(e).

Table B.3.4.5 Operator Actions, Light-Off of Subsequent Main Burners at Light-Off Fuel Pressure

Operator Actions	Interlock Functions
(a) Adjust register of burner to be lighted to light-off position, if necessary.	(a) Prove that airflow has not dropped below purge rate.
(b) If igniter is fuel fired, verify igniter flame is present.	(b) Proved.
(c) Confirm burner fuel pressure is being controlled by the main fuel bypass control valve and is at light-off pressure.	(c) None.
(d) Open individual burner safety shutoff valve at burner being lighted.	(d) Igniter flame proved on burner being lighted and individual burner supervisory shutoff valve proved closed.
(e) Verify atomizing medium flowing from burner gun about to be lighted.	(e) None.
(f) Confirm clearing valve closed.	(f) None.
(g) Slowly open individual burner supervisory shutoff valve until fully open to establish this main burner flame.	(g) If the main burner flame is not proved within 15 seconds after the valve leaves its closed position, all fuel to this burner and its igniter is shut off.
(h) If the main burner flame is not established, determine cause and correct conditions. Open burner register to firing position; wait 1 minute before attempting to light this or any other burner. Repeat B.3.4.3 and B.3.4.5.	(h) None.
(i) After main burner flame is established, adjust burner register to firing position, as necessary.	(i) None.
(j) Unless classified as Class 1 or Class 2, igniter should be removed from service; visually confirm main flame stability.	(j) None.

Note: See Figures B.1.1(c), B.1.1(d), and B.1.1(e).

B.3.4.6 Light-Off Cycle for Additional Burner(s) When Fuel Pressure of Operating Burner(s) Is Above Light-Off Pressure. Fuel pressure is controlled by the main fuel control valve. The steps listed in Table B.3.4.6 should be taken by the operator, and the interlocks satisfied at each step.

Table B.3.4.6 Operator Actions, Light-Off Cycle for Additional Burners When Fuel Pressure of Operating Burners Is Above Light-Off Pressure

Operator Actions	Interlock Functions
(a) Place combustion control system on manual; note the windbox-to-furnace pressure differential.	(a) None.
(b) Slowly adjust register on burner to be lighted to light-off position while manually adjusting airflow to maintain the windbox-to-furnace differential pressure at the value noted in step (a).	(b) None.
(c) Energize igniter; for direct electric igniters, omit step (d).	(c) Prove flame within 10 seconds. If flame not proved, safety shutoff valves for this igniter should close and spark should be deenergized.
(d) If igniter flame is not established, determine cause and correct.	(d) None.
(e) Open safety shutoff valve to burner being lighted.	(e) Igniter flame proven and supervisory shutoff valve proven closed.
(f) Verify atomizing medium flowing from burner gun about to be lighted.	(f) None.
(g) Confirm clearing valve closed.	(g) None.
(h) Slowly open individual supervisory shutoff valve only enough to light burner.	(h) If the main burner flame is not proved within 15 seconds after the valve leaves its closed position, all fuel to this burner and its igniter should be shut off.
(i) If the main burner flame is not established, determine cause, correct, wait at least 1 minute, then repeat steps (e) through (j).	(i) None.
(j) With main flame established, open air register to the firing position.	(j) None.
(k) Slowly open supervisory shutoff valve completely but without suddenly dropping header fuel pressure.	(k) None.
(l) Unless classified as Class 1 or Class 2, igniter should be removed from service; visually confirm main flame stability.	(l) None.
(m) Adjust airflow to restore correct fuel/air ratio.	(m) None.
(n) Place combustion control system in automatic, if desired.	(n) None.

Note: See Figures B.1.1(c), B.1.1(d), and B.1.1(e).

B.3.4.7 Normal Shutdown Cycle. The steps listed in Table B.3.4.7 should be taken by the operator, and the interlocks satisfied at each step.

Table B.3.4.7 Operator Actions, Normal Shutdown Cycle

Operator Actions	Interlock Functions
(a) Reduce boiler load until main fuel control valve is closed. Main fuel bypass control valve will assume control at light-off oil pressure. Airflow should not be reduced below purge rate.	(a) None.
(b) Each burner should be shut down in the following sequence if the oil gun is to be cleared into the furnace.	(b) None.
1. Establish igniter on the burner to be shut down.	1. None.
2. Close individual burner supervisory shutoff valve.	2. As each burner supervisory shutoff valve is closed, loss of flame will cause its associated safety shutoff valve to close. After last burner supervisory shutoff valve is closed, loss of all flame should cause main safety shutoff valve to close.
3. Open clearing valve to clear the burner.	3. None.
4. Shut off igniter.	4. Igniter safety shutoff valves close, igniter atmospheric vent valve opens (for gas igniters).
5. Leave burner register at firing position.	5. None.
6. Shut off atomizing medium to each burner.	6. None.
7. All burner guns should be removed.	7. None.
(c) If oil guns are not cleared into the furnace, eliminate steps (1), (3), and (4). Remove oil guns and drain oil outside the furnace.	(c) None.
(d) A unit purge should be performed.	(d) None.
(e) Fan(s) should be shut down, if desired.	(e) Loss of airflow interlock is actuated.

Note: See Figures B.1.1(c), B.1.1(d), and B.1.1(e).

B.3.4.8 Emergency Shutdown. An emergency shutdown initiates a master fuel trip. For the conditions that initiate an emergency shutdown, see B.3.2.

B.3.4.9 Operator Actions Following an Emergency Shutdown. *[See Figures B.1.1 (c), (d), and (e).]*

(a) All individual burner supervisory shutoff valves should be closed. Burner register positions should remain unchanged.

(b) Atomizing steam flow to all burners should be shut off.

(c) Oil guns should be removed and drained external to the furnace.

(d) The unit should be purged in accordance with the following procedure:

(1) Fans that are operating after the master fuel trip should be continued in service.
(2) Airflow should not be immediately increased by deliberate manual or automatic control action.
(3) If the airflow is above purge rate, it should be gradually decreased to this value and the unit should be purged.
(4) If the airflow is below purge rate at the time of the trip, it should be continued at the existing rate for 5 minutes and then increased gradually to purge rate and held at this value for a unit purge.

(e) Where the master fuel trip is caused by loss of draft fans, or draft fans also have tripped, all dampers in the air and flue gas passages of the unit should be opened slowly to the fully open position in order to create as much natural draft as possible to ventilate the unit. Opening fan dampers should be timed or controlled to avoid excessive positive or negative furnace pressure transients during fan coast-down. This condition should be maintained for not less than 15 minutes. At the end of this period, the flow control dampers should be closed and the fan(s) should be immediately started. Airflow should be increased gradually to at least purge rate.

(f) The cause of emergency shutdown should be determined and corrected.

(g) The first igniter light-off cycle should be performed *(see B.3.4.2)* if restart of unit is desired.

(h) If it is desired to remove the boiler from service for a period of time, the fans should be shut down on completion of unit purge and manual shutoff valves should be closed.

B.3.5 Air Heaters. Where provided, regenerative air heaters and gas recirculation fans should be operated during all operations of the unit in a manner recommended by the boiler manufacturer.

Appendix C Multiple Burner Boiler Fundamental Principles of a Manual System

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

C.1 Boiler Front Controls — Gas Firing.

C.1.1 Manual System. The manual system is not recommended; however, it is recognized that, in some boiler applications and unusual process requirements, there could be a greater safety hazard from boiler tripping. Under these conditions, the system described in this section should be approved by the authority having local jurisdiction and should be considered as a minimum standard. The system requirements listed in Appendix B, Multiple Burner Boiler Supervised Manual Systems, also should apply.

A manual system is one in which a trained operator has primary responsibility for the proper start-up, operation, and shutdown of a boiler in accordance with the specific operating instructions for each boiler. A key feature of this system is the provision for gas safety shutoff valve assemblies in the main piping and igniter fuel piping supplying the boiler. The system includes interlocks to actuate these assemblies in order to accomplish an emergency shutdown.

C.1.2 Fundamental Principles. The operator should follow written instructions for each specific boiler. These instructions should include the following procedure:

(a) Airflow is adjusted to purge rate, and unit purge is performed.

(b) Purge airflow rate is maintained continuously from purge initiation through the light-off cycle. If airflow is not maintained at purge rate, the prefiring cycle should be repeated.

(c) If the first igniter is not lighted within 5 minutes after the igniter safety shutoff valves have been opened, all fuel valves should be closed and the prefiring cycle should be repeated.

(d) If flame on the first igniter is not established after the igniter supervisory shutoff valve has been opened, all fuel valves should be closed and the prefiring cycle should be repeated.

(e) The operator should observe the igniter flame continuously while opening the first burner supervisory shutoff valve. If main flame is not established or is lost during this operation, all fuel valves should be closed immediately and the prefiring cycle should be repeated.

(f) After each stable main burner flame is established, the igniter should be shut off unless classified as Class 1 or Class 2. The stability of the main burner flame should be verified.

(g) Burners should not be lighted from a previously lighted burner.

(h) The operator should observe main flame stability while making any register or burner damper adjustments. (This is more critical in two-burner boilers.)

(i) After each successive burner light-off, the flame stability of all operating burners should be verified.

(j) If a second or succeeding burner igniter does not light immediately after its igniter supervisory shutoff valve has been opened, the igniter supervisory shutoff valve(s) should be closed and cause for failure to light determined and corrected. At least 1 minute should elapse before the next light-off is attempted.

(k) If a second or succeeding burner flame is not established, the burner and igniter supervisory shutoff valves should be closed immediately, the burner register or damper should be opened to firing position, and cause for failure to ignite should be determined and corrected. At least 1 minute should elapse before attempting to light this or any igniter.

(l) Operation at less than 25 percent load is permitted, provided burners maintain stable flame and airflow is maintained at or above purge rate, regardless of the actual load.

(m) Low water level in the steam drum should be monitored and alarmed. Consideration should be given to interlock tripping.

C.1.3 Equipment. The following equipment should be provided:

(1) Equipment to change the firing rate that simultaneously adjusts the fuel and air supplies to a predetermined air-fuel ratio
(2) A purge timer with proven airflow
(3) Provisions for limiting fuel turndown to prevent reducing fuel input below the point of stable burner operation
(4) Permanently installed igniters

(5) Main and igniter gas supply pressure regulation

(6) Flame failure detection and alarm

C.1.4 Interlocks and Emergency Shutdown — Boiler. An emergency shutdown should be initiated by the following conditions:

(1) High fuel gas pressure

(2) Low igniter gas pressure

(3) Low fuel gas supply pressure

(4) Fuel gas pressure in the burner header below the minimum required for flame stability

(5) Loss of all forced draft fans

(6) Loss of all induced draft fans, if applicable

(7) Operation of the emergency trip switch by the operator

(8) Loss of control energy if fuel flow to burners is affected in such an event

All individual manual burner and igniter supervisory shutoff valves should be in the closed position before the main and igniter safety shutoff valves can be opened.

C.1.5 Operating Cycle.

C.1.5.1 Prefiring Cycle — Gas. The steps in Table C.1.5.1 should be taken by the operator when starting a manual system, and the required interlocks should be satisfied at each step. Control system energy, power and water level, and fuel supply should be established. Prior to start-up, furnace and gas passages should be inspected to determine whether in good repair. It should be determined that the unit and its associated systems are evacuated of all personnel and all access and inspection doors are closed.

Table C.1.5.1 Operator Actions, Prefiring Cycle

Operator Actions[1]	Interlock Functions
(a) Confirm individual burner and igniter supervisory shutoff valves closed.	(a) Prove burner and igniter supervisory shutoff valves closed.
(b) Confirm main and igniter safety shutoff valves closed.	(b) None.
(c) Confirm main fuel control valve closed.	(c) None.
(d) Open all burner registers to firing position.	(d) None.
(e) Start fans.	(e) None.
(f) Open damper(s) to purge position.	(f) Prove purge airflow rate.
(g) Start purge timer and purge boiler per operating instructions.	(g) None.
(h) Immediately proceed with light-off cycle after completion of purge.	(h) None.

Note: See Figures C.1.5.1 and C.1.5.2.
[1]Certain actions are not necessarily performed in the order shown.

C.1.5.2 Light-Off Cycle. The cycle given in Table C.1.5.2 should immediately follow prefiring. Burners are at light-off fuel pressure. The open register purge principle should be followed during the light-off procedure.

C.1.5.3 Normal Shutdown Cycle. The operator is to follow the steps listed in Table C.1.5.3 and satisfy the interlocks at each step.

FIGURE C.1.5.1 Typical ignition system — manual.

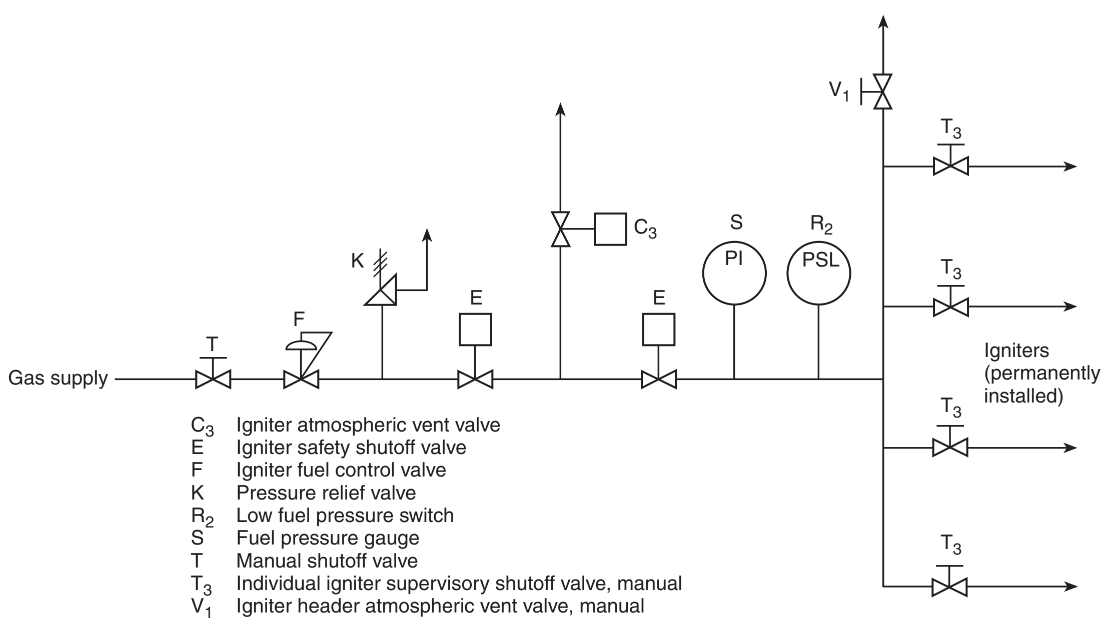


Table C.1.5.2 Operator Actions, Light-Off Cycle

Operator Actions	Interlock Functions
(a) Adjust register of burner to be lighted to light-off position, if necessary. Airflow at purge rate.	(a) None.
(b) Confirm burner header atmospheric vent valve is open.	(b) None.
(c) Open igniter safety shutoff valve(s).	(c) Prove all igniter supervisory shutoff valves closed. Prove low igniter header pressure interlocks satisfied.
(d) Open main safety shutoff valves.	(d) Prove all required interlocks satisfied except burner header low pressure trip switch, which is bypassed by a circuit completed only when burner supervisory shutoff valves are closed.
(e) Confirm that burner gas pressure is being controlled by the main fuel bypass control valve and is at light-off pressure.	(e) None.
(f) Open individual igniter supervisory shutoff valve and establish flame while under visual observation.	(f) Igniter header low fuel pressure trip switch is in effect when igniter safety shutoff valves are open *[see step (c)]*.
(g) While continuously observing igniter flame, slowly open burner supervisory shutoff valve at burner being lighted until fully open to establish burner flame.	(g) Burner header low fuel pressure trip switch is in effect when main safety shutoff valve(s) are open *[see step (d)]*.
(h) Adjust the burner register to firing position, as necessary.	(h) None.
(i) Slowly close manual burner header atmospheric vent valve while observing main fuel pressure gauge.	(i) None.
(j) Unless classified as Class 1 or Class 2, igniter should be removed from service; visually confirm main flame stability.	(j) None.
(k) Repeat steps (a), (e), (f), (g), (h), and (i) for additional burners at light-off pressure, as necessary. After each additional burner is lighted, visually reconfirm the stability of all previously lighted burners.	(k) None.
(l) Above 25 percent load, close registers of all burners not placed in operation.	(l) None.
(m) Adjust firing rate of boiler and fuel/air ratio to meet demand.	(m) None.

Note: See Figures C.1.5.1 and C.1.5.2.

Table C.1.5.3 Operator Actions, Normal Shutdown Cycle

Operator Actions	Interlock Functions
(a) Reduce boiler load until main fuel control valve is closed. Main fuel bypass control valve will assume control at light-off gas pressure. Do not reduce total airflow below purge rate.	(a) None.
(b) Close individual supervisory shutoff valve at each burner and associated igniter valve if in operation. Leave burner register at firing position.	(b) After last burner supervisory shutoff valve is closed, burner header low pressure trip switch is deactivated.
(c) After last burner valve is closed, close main and igniter safety shutoff valves. Main atmospheric valve opens.	(c) None.
(d) Immediately open burner header manual vent valve.	(d) None.
(e) Purge unit.	(e) None.
(f) Shut down fan(s), if necessary.	(f) Combustion air interlocks deactivated.

Note: See Figures C.1.5.1 and C.1.5.2.

C.1.5.4 Emergency Shutdown. When an emergency shutdown occurs, the main safety shutoff valve and igniter safety shutoff valves should close; the atmospheric vent valves should open.

C.1.5.5 Operator Actions Following an Emergency Shutdown.

(a) All main burner and igniter supervisory valves should be closed. Burner register positions remain unchanged.

(b) The atomizing steam flow to all burners should be shut off.

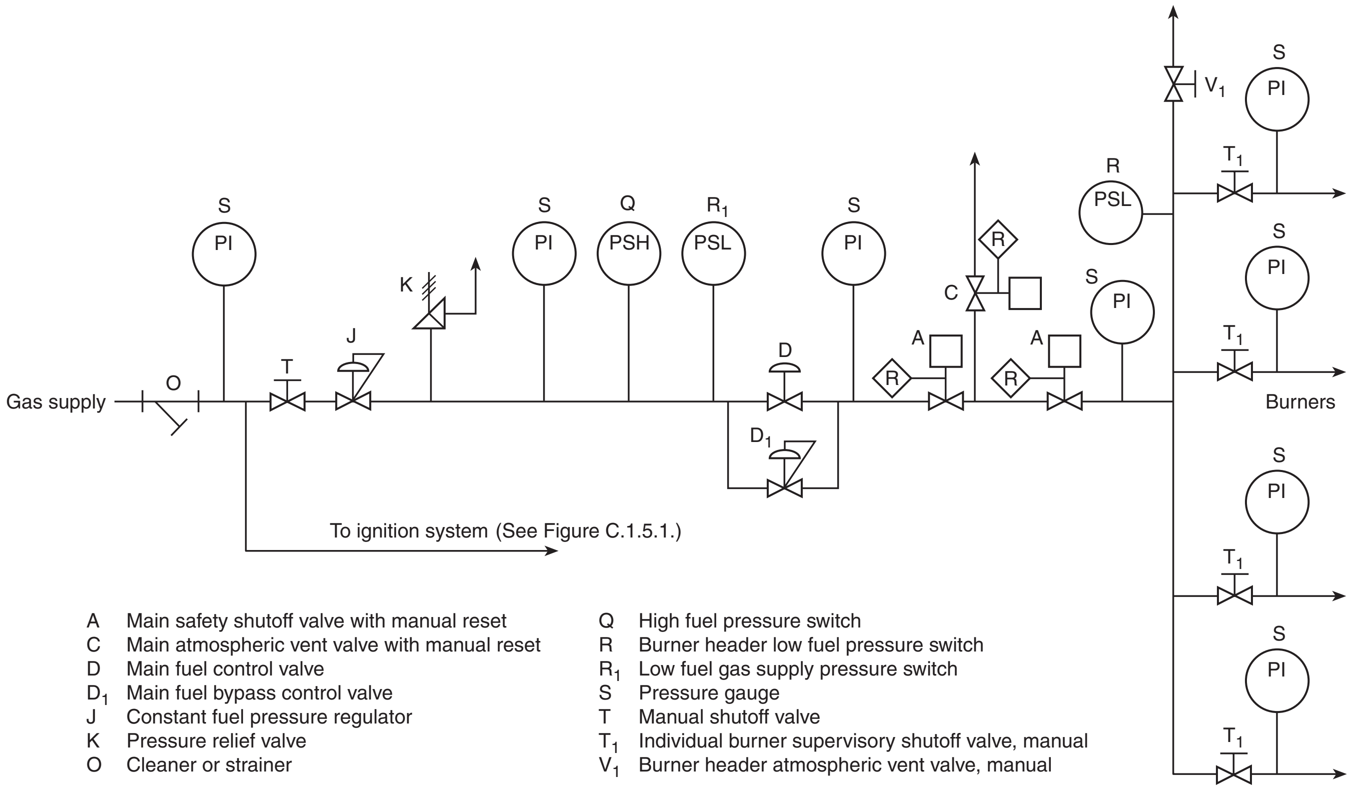
(c) Oil guns external to the furnace should be removed and drained.

(d) The unit should be purged in accordance with the following procedure.

(1) If the fans are operating after the trip, they should be continued in service. Under no circumstances should the airflow be increased immediately. If the airflow is above purge rate, it can be permitted to be decreased gradually to this value for a unit purge. If the airflow is below purge rate at the time of the trip, it should be continued at the existing rate for 5 minutes and then increased gradually to purge rate and held at this value for a unit purge.

(2) If the trip was caused by loss of draft fans, or if draft fans also have tripped, all dampers in the air and flue gas passages of the unit should be opened slowly to the fully open position in order to create as much natural draft as possible to ventilate the unit. This condition should be maintained for not less than 15 minutes. At the end of this period, the flow control dampers should be closed and the fan(s) should be started immediately. The airflow should be increased gradually to at least purge rate.

FIGURE C.1.5.2 Typical fuel supply system for natural gas-fired multiple burner boiler — manual.



(e) The cause of safety shutdown should be determined and corrected.

(f) The light-off cycle then is performed if relight of boiler is desired.

(g) If it is desired to remove the boiler from service for a period of time, the fans should be shut down on completion of purge, and the manual shutoff valves should be closed.

C.2 Boiler Front Controls — Oil Firing.

C.2.1 Manual System. The manual system is not recommended; however, it is recognized that in some boiler applications and unusual process requirements, there could be a greater safety hazard from boiler tripping. Under these conditions, the system described in this section should be approved by the authority having local jurisdiction and should be considered as a minimum standard. The system requirements listed in Appendix B, Multiple Burner Boiler Supervised Manual Systems, also should apply.

A manual system is one in which a trained operator has primary responsibility for the proper start-up, operation, and shutdown of a boiler in accordance with the specific operating instructions for each boiler. A key feature of this system is the provision for oil safety shutoff valve assemblies in the main piping and igniter fuel piping supplying the boiler. The system includes interlocks to actuate these assemblies in order to accomplish an emergency shutdown.

C.2.2 Fundamental Principles. The operator should follow written instructions for each specific boiler. These instructions should include the following procedure:

(a) Airflow is adjusted to the purge rate, and unit purge performed.

(b) Purge airflow rate is maintained continuously from purge initiation through the light-off cycle. If airflow is not maintained at purge rate, the prefiring cycle should be repeated.

(c) If the first igniter is not lighted within 5 minutes after the igniter safety shutoff valves have been opened, all fuel valves should be closed and the prefiring cycle should be repeated.

(d) If flame on the first igniter is not established after the igniter supervisory shutoff valve has been opened, all fuel valves should be closed and the prefiring cycle should be repeated.

(e) The operator should observe the igniter flame continuously while opening the first burner supervisory shutoff valve. If main flame is not established or is lost during this operation, all fuel valves should be closed immediately and the prefiring cycle should be repeated.

(f) After each stable main burner flame is established, the igniter should be shut off unless classified as Class 1 or Class 2. The stability of the main burner flame should be verified.

(g) Burners should not be lighted from a previously lighted burner.

(h) The operator should observe main flame stability while making any register or burner damper adjustments. (This step is more critical in two-burner boilers.)

(i) After each successive burner light-off, the flame stability of all operating burners should be verified.

(j) If a second or succeeding burner igniter does not light immediately after its igniter supervisory shutoff valve has been opened, the igniter supervisory shutoff valve(s) should be closed and cause for failure to light determined and corrected. At least 1 minute should elapse before the next light-off is attempted.

(k) If a second or succeeding main burner flame is not established, the individual burner supervisory and igniter supervisory shutoff valve(s) should be closed immediately, the burner register or damper should be opened to firing position, and cause for failure to ignite should be determined and corrected. At least 1 minute should elapse before attempting to light this or any igniter.

(l) Operation at less than 25 percent load is permitted, provided burners maintain stable flame and airflow is maintained at or above purge rate, regardless of the actual load.

(m) Low water level in the steam drum should be monitored and alarmed. Consideration should be given to interlock tripping.

C.2.3 Equipment. The following equipment should be provided:

(1) Equipment to change the firing rate that simultaneously adjusts the fuel and air supplies to a predetermined air/fuel ratio
(2) A purge timer with proven airflow
(3) Provisions for limiting fuel turndown to prevent reducing fuel input below the point of stable burner operation
(4) Permanently installed igniters
(5) Oil pressure regulation
(6) Oil temperature regulation if heating is required
(7) Flame failure detection and alarm

C.2.4 Interlocks and Emergency Shutdown — Boiler. An emergency shutdown should be initiated by the following conditions:

(1) Low pressure in the oil supply to the control valve
(2) Fuel pressure at the burner below the minimum established by the manufacturer or by trial
(3) Loss of all forced draft fans
(4) Loss of all induced draft fans, if applicable
(5) Operation of the emergency trip switch by the operator
(6) Loss of control energy if fuel flow to burners is affected in such an event
(7) Atomizing medium (if provided) at the burner below the minimum established by the manufacturer or by trial

All individual manual burner and igniter supervisory shutoff valves should be in the closed position before the main and igniter safety shutoff valves can be opened.

C.2.5 Operating Cycle.

C.2.5.1 Prefiring Cycle — Oil (Steam Atomized, Heated Oil). The steps given in Table C.2.5.1 should be taken by the operator when starting a manual system, and the required interlocks should be satisfied at each step. Control system energy, power and water level, fuel supply, and atomizing medium, if used, should be established. Prior to start-up, furnace and gas passages should be inspected to determine whether in good repair. It should be determined that the unit and its associated systems are evacuated by all personnel and all access and inspection doors are closed.

Table C.2.5.1 Operator Actions, Prefiring Cycle

Operator Actions[1]	Interlock Functions
(a) Inspect furnace for unburned oil accumulations.	(a) None.
(b) Confirm burner gun for proper tips or sprayer plates and place gun in proper position.	(b) None.
(c) Confirm individual burner and igniter supervisory shutoff valves closed.	(c) Prove burner and igniter supervisory shutoff valves closed.
(d) Confirm main and igniter safety shutoff valves closed.	(d) None.
(e) Confirm main fuel control valve closed.	(e) None.
(f) Confirm that atomizing steam header has been blown free of condensate and header trap is functioning.	(f) None.
(g) Open all burner registers to firing position.	(g) None.
(h) Start fans.	(h) None.
(i) Open main damper(s) to purge position.	(i) Prove purge airflow rate.
(j) Open main fuel bypass control valve, main safety shutoff valve, and recirculating valve to circulate heated oil through the main fuel bypass control valve and burner header.	(j) Prove all required interlocks satisfied except burner header low fuel pressure switch, which is bypassed by a circuit completed only when all individual burner supervisory valves are closed.
(k) Start purge timer and purge boiler per operating instructions.	(k) None.
(l) Open atomizing medium valve to the burner gun to be lighted. Blow free of condensate. Confirm atomizing pressure has been established.	(l) None.
(m) Immediately proceed with light-off cycle after completion of purge.	(m) None.

Note: See Figures C.2.5.1 through C.2.5.3.
[1]Certain actions are not necessarily performed in the order shown.

C.2.5.2 Light-Off Cycle. This cycle immediately follows prefiring. Burners are at light-off fuel pressure. The open register purge principle should be followed during the light-off procedure. The operator is to follow the steps listed in Table C.2.5.2 and satisfy the interlocks at each step.

C.2.5.3 Normal Shutdown Cycle. The operator is to follow the steps listed in Table C.2.5.3 and satisfy the interlocks at each step.

Table C.2.5.2 Operator Actions, Light-Off Cycle

Operator Actions	Interlock Functions
(a) Adjust register of burner to be lighted to light-off position, if necessary. Airflow at purge rate.	(a) None.
(b) Confirm that burner oil pressure is being controlled by the main fuel bypass control valve and is at light-off pressure. If necessary, throttle oil recirculating valve, as needed, to maintain necessary light-off pressure.	(b) None.
(c) Open igniter header safety shutoff valve(s).	(c) Prove all igniter supervisory shutoff valves closed. Prove low igniter header pressure interlocks satisfied.
(d) Verify atomizing medium flowing from burner gun about to be lighted.	(d) None.
(e) Confirm clearing valve closed.	(e) None.
(f) Open individual igniter supervisory shutoff valve, and establish flame while under visual observation.	(f) Igniter header low fuel pressure trip switch is in effect when igniter safety shutoff valves are open *[see (c) above]*.
(g) While continuously observing igniter flame, slowly open burner supervisory shutoff valve at burner being lighted until fully open to establish burner flame.	(g) Burner header low fuel pressure trip switch is in effect when main safety shutoff valve(s) are open.
(h) Adjust the burner register to firing position, as necessary.	(h) None.
(i) Unless classified as Class 1 or Class 2, igniter should be removed from service; visually confirm main flame stability.	(i) None.
(j) Repeat steps (a), (e), (f), (g), (h), and (i) for additional burners at light-off pressure, as necessary. After each additional burner is lighted, visually reconfirm the stability of all previously lighted burners.	(j) None.
(k) Above 25 percent load, close registers of all burners not placed in operation.	(k) None.
(l) Adjust firing rate of boiler and fuel/air ratio to meet demand.	(l) None.
(m) Close recirculating valve.	(m) None.

Note: See Figures C.2.5.1 through C.2.5.3.

Table C.2.5.3 Operator Actions, Normal Shutdown Cycle

Operator Actions	Interlock Functions
(a) Reduce boiler load until main fuel control valve is closed. Main fuel bypass control valve will assume control at light-off oil pressure. Do not reduce total airflow below purge rate.	(a) None.
(b) Each oil burner should be shut down in the following sequence if oil gun should be cleared into the furnace.	(b) None.
(1) If igniter has been turned off previously, establish igniter flame on the burner to be shut down.	(1) None.
(2) Close individual burner supervisory shutoff valve.	(2) None.
(3) Open clearing valve. The clearing valve should be left open long enough to clear the burner gun thoroughly.	(3) None.
(4) Shut off igniter.	(4) None.
(5) Leave burner register open.	(5) None.
(6) Shut off atomizing medium and remove gun. Note: If oil gun is not cleared into furnace omit steps (1), (3), and (4).	(6) After last burner supervisory shutoff valve closed, burner header low fuel pressure interlock is deactivated.
(c) After the last individual burner supervisory shutoff valve is closed, close main and igniter safety shutoff valves. Igniter atmospheric vent valve opens.	(c) None.
(d) Purge unit.	(d) None.
(e) Shut down fan(s), if necessary.	(e) Combustion air interlocks deactivated.

Note: See Figures C.2.5.1 through C.2.5.3.

FIGURE C.2.5.1 Typical ignition system — manual.

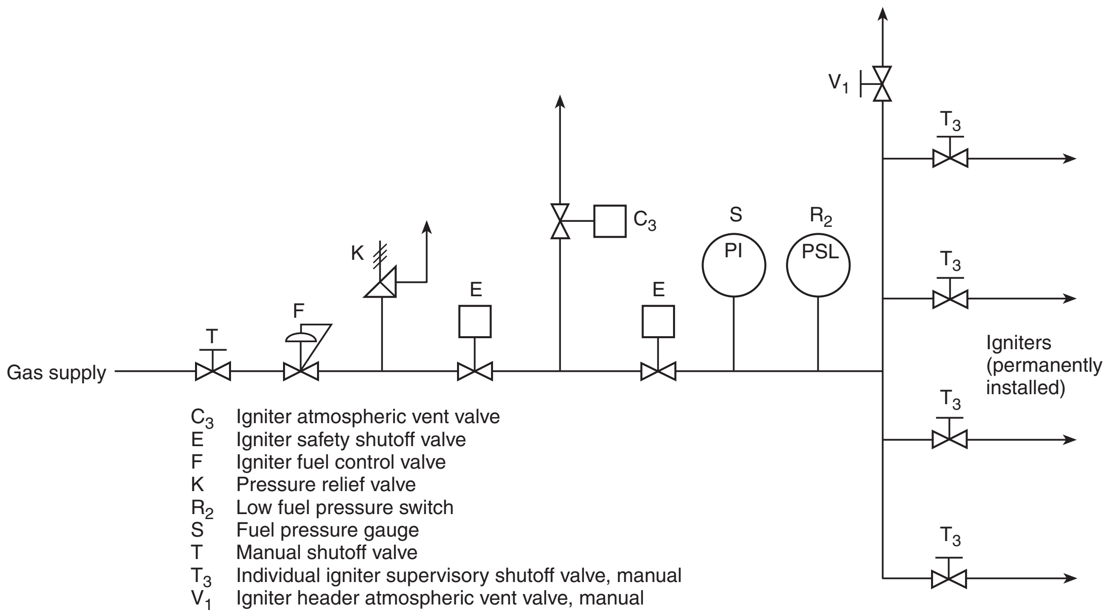


FIGURE C.2.5.2 Typical mechanical atomizing light oil igniter system — manual.

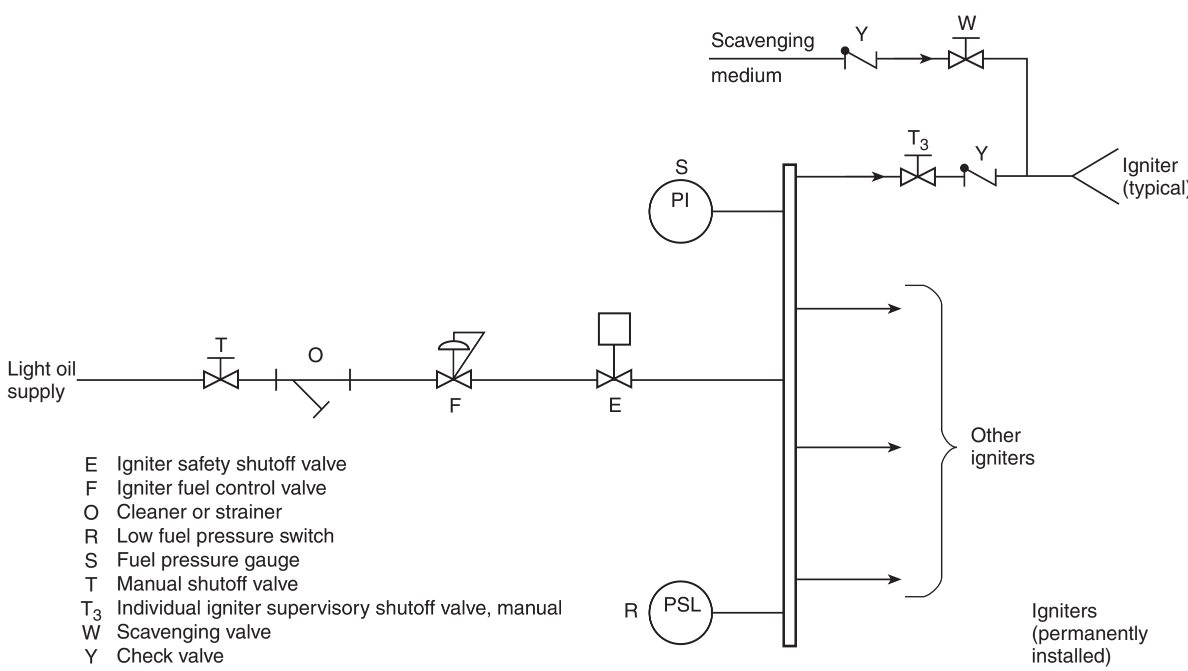
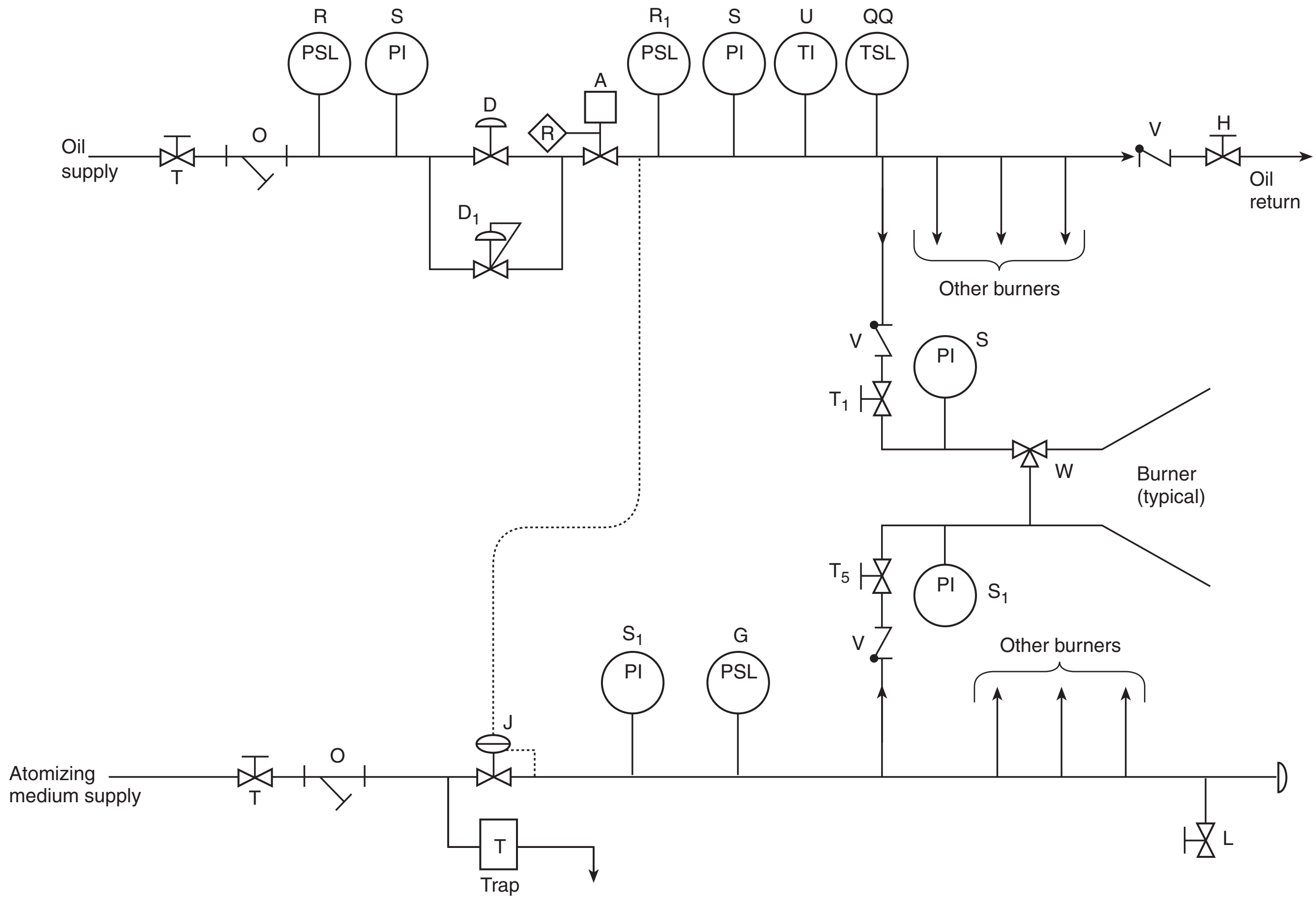


FIGURE C.2.5.3 Typical steam atomizing main oil burner system — manual.



A	Main safety shutoff valve with manual reset
D	Main fuel control valve
D_1	Main fuel bypass control valve
G	Atomizing medium low pressure switch
H	Recirculating valve
J	Atomizing pressure regulator
L	Bleed valve
O	Strainer
QQ	Low temperature or high viscosity alarm switch
R	Low fuel pressure switch
R_1	Burner header low fuel pressure switch
S	Fuel pressure gauge
S_1	Atomizing medium pressure gauge
T	Manual shutoff valve
T_1	Individual burner supervisory shutoff valve, manual
T_5	Atomizing medium individual burner shutoff valve, manual
U	Thermometer
V	Check valve
W	Scavenging valve

C.2.5.4 Emergency Shutdown. When an emergency shutdown occurs, the main safety shutoff valve and igniter safety shutoff valves close; the atmospheric vent valves open.

C.2.5.5 Operator Actions Following an Emergency Shutdown.

(a) All main burner and igniter supervisory valves should be closed. Burner register positions remain unchanged.

(b) The atomizing steam flow to all burners should be shut off.

(c) Oil guns external to furnace should be removed and drained.

(d) The unit is purged in accordance with the following procedure.

(1) If the fans are operating after the trip, they should be continued in service. Under no circumstances should the airflow be increased immediately. If the airflow is above purge rate, it should be decreased gradually to this value for a unit purge. If the airflow is below purge rate at the time of the trip, it should be continued at the existing rate for 5 minutes and then increased gradually to purge rate and held at this value for a unit purge.

(2) If the trip was caused by loss of draft fans, or draft fans also have tripped, all dampers in the air and flue gas passages of the unit should be opened slowly to the fully open position in order to create as much natural draft as possible to ventilate the unit. This condition should be maintained for not less than 15 minutes. At the end of this period, the flow control dampers should be closed and the fan(s) should be started immediately. The airflow should be increased gradually to at least purge rate.

(e) The cause of safety shutdown should be determined and corrected.

(f) The light-off cycle then is performed if relight of boiler is desired.

(g) If it is desired to remove the boiler from service for a period of time, the fans should be shut down on completion of purge, and the manual shutoff valves should be closed.

Appendix D Multiple Burner Boiler Low NO_x Operation — Special Considerations

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

D.1 General Considerations.

D.1.1 Regulations limiting NO_x emissions for both existing and new installations have resulted from the adoption of the Clean Air Act Amendment of 1990. Responses to the regulations have included both technologies and operating techniques that affect the quality of combustion and could have an adverse effect on flame stability. Methods to reduce NO_x, which can affect flame stability, are designed to control fuel and air mixing, distribute heat release over more area, and produce lower flame temperature and longer, less turbulent flames. It is important that the designer recognize these potential hazards and perform tests as specified in 3.6.3.2.2, 3.7.3.2.2, and 3.8.3.3.2 to determine the limits of flame stability under these new operating conditions.

D.1.2 Methods to reduce NO_x could reduce the margins formerly available to prevent or minimize accumulations of unburned fuel in the furnace during combustion upsets. For all methods of NO_x reduction, special considerations are necessary to ensure the stability of the flame envelope. In general, the combustion control system is intended to provide tighter control of fuel and airflows; the windbox design is to be reviewed carefully to ensure proper distribution of flows to the burners; the type of flame detector, its location, and its sighting should be assessed and retested; and distribution, mixing, and injection of recirculated gas into the process should be analyzed carefully. All the methods described tend to increase the possibility of unburned combustibles throughout the unit and ducts. Therefore, the use of flue gas combustibles analyzers is recommended. A number of risks could arise, among them the following:

(1) In-furnace NO_x control technologies could reduce the margins formerly available to prevent or minimize accumulations of unburned fuel in the furnace during combustion upsets.
(2) In-furnace NO_x control technologies could increase the propensity for furnace wall tube corrosion due to very low excess air or even fuel-rich flue gas conditions.
(3) In-furnace NO_x control technologies could result in burner flames that are more difficult to scan and that operate closer to an unstable regime across the load range.
(4) In-furnace NO_x control technologies that utilize staged fuel injection could result in combustion conditions that are not detectable with existing flame scanner technology.

D.1.3 Any change in flame characteristics to reduce NO_x emissions could necessitate changing the type of flame detector, or flame detectors might need to be relocated on existing units.

D.2 Technology Overview.

D.2.1 Low NO_x Burners.

D.2.1.1 For burners having a high air side pressure drop [generally greater than 4 in. (102 mm) water column at full boiler load], one way to indicate proper air/fuel ratio is to compare burner airflow with burner fuel flow as determined by windbox-to-furnace differential and burner header pressure. The ratio thus determined, plus the open register procedure, provides a guide for proper operation of burners under start-up conditions where flows might be out of the range of other meters. Windbox-to-furnace differential taps, where provided, should be located at the burner level.

D.2.2 Overfire Air.

D.2.2.1 Overfire Air Supply.

D.2.2.1.1 The overfire air supply system should be sized and arranged to ensure airflow adequate for all operating requirements of the unit. Consideration should be given to the effects of, or on, the main combustion air system if the overfire air is supplied from any part of the furnace combustion air system. This should include coordination of the main overfire air control damper(s), booster fan (if used), and overfire air port dampers (if used), with the furnace combustion control system. The overfire air supply equipment should be designed with careful consideration of operating environment and ambient conditions. Proper personnel and equipment protection should be utilized when using preheated combustion air for overfire air.

D.2.2.2 Overfire Air Port Cooling.

D.2.2.2.1 Overfire air port cooling should be permitted when the overfire air system is not in service, provided the cooling flow is sufficient to provide a positive flow during all furnace operation and purge procedures. If positive flow overfire air port cooling is not provided, tight shutoff dampers should be provided on the overfire air ports as near as possible to the furnace to prevent furnace gases from entering the out of service overfire air system. All leakage or cooling airflows must be accounted for by the combustion control system.

D.2.3 Reburning.

D.2.3.1 When fuel is injected through reburn injectors without air, there might be no visible combustion taking place at the reburn injectors. Consequently, flame detectors might not provide a useful input to a burner management system in reburn applications. A very rapid chemical reaction does take place, however, due to the elevated temperatures and rapid mixing of the reburn fuel with the products of combustion from the main burner zone, whereby any oxygen in the flue gas from the main burner zone is almost immediately consumed.

D.2.4 Flue Gas Recirculation.

D.2.4.1 Where flue gas recirculation is used, special methods and devices are to be provided to ensure adequate mixing and uniform distribution of recirculated gas and air to the windboxes. Where flue gas recirculation is introduced into the total secondary air to the windboxes, means are to be provided to monitor either the ratio of flue gas to air or the oxygen content of the mixture. Where flue gas recirculation is introduced so that only air, not the mixture, is introduced at the fuel nozzles, adequate means are to be provided to ensure the prescribed distribution of air and the recirculating flue gas/air mixture.

Appendix E Industry Experience (Reserved)

Appendix F Fuels

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

F.1 Coals.

F.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.

F.1.2 Classification.

F.1.2.1 Class I, Anthracite Coal, is divided into three groups:

(1) 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
(2) 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
(3) 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

F.1.2.2 Class II, Bituminous Coal, is subdivided into five groups.

(1) Group 1, Low Volatile Bituminous Coal, has fixed carbon limits greater than 78 percent but less than 86 percent.
(2) Group 2, Medium Volatile Bituminous Coal, has fixed carbon limits greater than 69 percent but less than 78 percent.
(3) Group 3, High Volatile "A" Bituminous Coal, has a fixed carbon quantity of less than 69 percent and greater than 14.0 kBtu/lb (32.564 MJ/kg) calorific value on a moist mineral-matter-free basis.
(4) Group 4, High Volatile "B" Bituminous Coal, has a calorific value equal to or greater than 13.0 kBtu/lb (30.238 MJ/kg) and less than 14.0 kBtu/lb (32.564 MJ/kg). All the bituminous coals in groups (1) through (4) are considered commonly agglomerating.
(5) Group 5, High Volatile "C" Bituminous Coal, has a calorific value equal to or greater than 11.5 kBtu/lb (26.749 MJ/kg) and less than 13.0 kBtu/lb (30.238 MJ/kg) when it is commonly agglomerating and a calorific value limit equal to or greater than 10.5 kBtu/lb (24.423 MJ/kg) but less than 11.5 kBtu/lb (26.749 MJ/kg) when it is always agglomerating.

F.1.2.3 Class III, Sub-Bituminous Coal, is divided into three groups. All three groups are considered nonagglomerating.

(1) Group 1, Sub-Bituminous "A" Coal, has a calorific value equal to or greater than 10.5 kBtu/lb (24.423 MJ/kg) but less than 11.5 kBtu/lb (26.749 MJ/kg).
(2) Group 2, Sub-Bituminous "B" Coal, has a calorific value limit equal to or greater than 9.5 kBtu/lb (22.097 MJ/kg) but less than 10.5 kBtu/lb (24.423 MJ/kg).
(3) Group 3, Sub-Bituminous "C" Coal, has a calorific value equal to or greater than 8.3 kBtu/lb (19.3 MJ/kg) but less than 9.5 kBtu/lb (22.097 MJ/kg).

F.1.2.4 Class IV, Lignite Coal, is divided into two groups. Both are considered nonagglomerating.

(1) Group 1, Lignite A, has a calorific value limit equal to or greater than 6.3 kBtu/lb (14.654 MJ/kg) and less than 8.3 kBtu/lb (19.306 MJ/kg).
(2) Group 2, Lignite B, has a calorific value less than 6.3 kBtu/lb (14.654 MJ/kg).

F.1.3 Sizing. Sizing characteristics vary with stoker type as outlined in the ABMA 202, *Recommended Design Guidelines for Stoker Firing of Bituminous Coal.* Different coals have varying tendencies to break down during mining processes and in handling. Western sub-bituminous coals are considered friable and are generally delivered to the boiler with high percentages of particles less than $^1/_4$ in. (6.35 mm) in size. These can be burned satisfactorily using the correct equipment.

Each plant should carefully analyze the fuel characteristics and associated handling and combustion problems for the best overall operation. Anthracite is generally burned in finer sizes, generally less than $^5/_{16}$ in. (7.94 mm), to expose more surface of the very high fixed carbon fuel to the oxygen in the air.

Sizing in the hopper should be within the two limits as set forth in the ABMA 202, *Recommended Design Guidelines for Stoker Firing of Bituminous Coal.* Means should be provided for the delivery of coal to the stoker hopper without size segregation.

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

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

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

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

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

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

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

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

F.6 Solid Fuel Firing — Special Characteristics.

F.6.1 Solid Fuels.

F.6.1.1 Solid fuels can be burned in three ways: in suspension, in partial suspension with final burnout on a grate, or in mass on a grate. Different types of grates can be used, depending on what kind of system is applicable. Several types of feeders are available. Feeders are specified according to fuel type and method of burning, for example, suspension, in mass, and so forth.

F.6.1.2 Some solid fuels have a high moisture content. For instance, bark has a moisture content of 35 percent to 50 percent; bagasse, 40 percent to 60 percent; and coffee grounds, 60 percent. As a result, these fuels can 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.

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

F.6.2 Finely Divided Solid Fuels.

F.6.2.1 Characteristics of finely divided solid fuel approach those of pulverized fuel. Care should be taken in their handling to prevent accumulations that could ignite spontaneously.

F.6.2.2 These fuels should be handled separately from other solid fuels; therefore, special care should be taken to follow safe design and operating procedures. Recommendations of the equipment manufacturer should be followed.

F.6.3 Specific Fuels.

F.6.3.1 Bagasse.

F.6.3.1.1 Bagasse is the portion of sugar cane remaining after sugar is extracted. It consists of cellulose fibers and fine particles.

F.6.3.1.2 Variations in refining and handling can lead to variations in fuel particle size, which can create firing problems. These variations can cause rapid and severe furnace pulsations, resulting in a dangerous condition as well as inefficient operation.

F.6.3.2 Refuse-Derived Fuel.

F.6.3.2.1 Refuse-derived fuel has many of the same characteristics as wood and bagasse and receives its heating value from the cellulose contained in it. If given proper preparation, RDF can have a heating value as high as lignite. RDF has a high ash but low sulfur content. The heating value of RDF has increased in recent years because of the large amounts of cardboard, plastics, and other synthetic materials used. Typical components of RDF are paper and paper products, plastics, wood, rubber, solvents, oils, paints, and other organic materials.

F.6.3.2.2 Other conventional fuels can be burned in the same furnace along with RDF. Older installations may also be converted to burn RDF.

F.6.3.2.3 A number of complex factors must be considered before attempting conversion to RDF firing. Additional information can be obtained from the boiler manufacturer.

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

Appendix G Stoker Descriptions

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

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

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

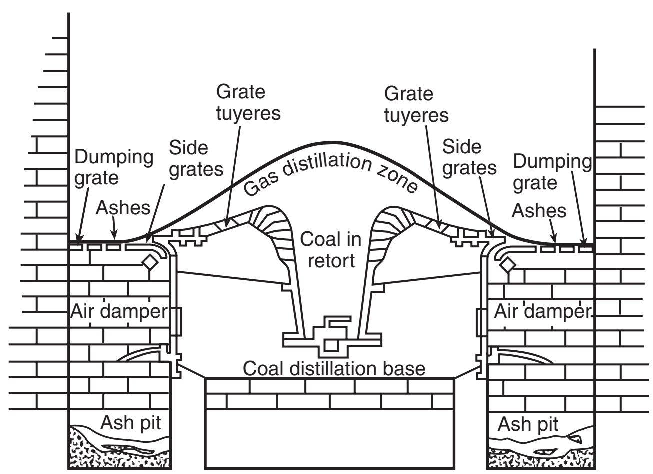
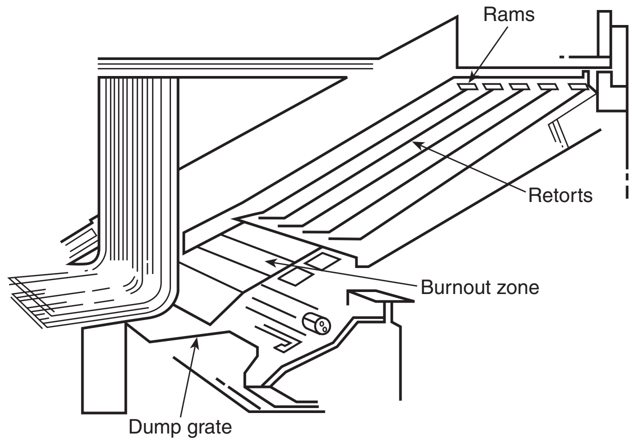


FIGURE G.1(b) Multiple retort underfeed stoker showing components. *(Reprinted with permission of Detroit Stoker Company.)*



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

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

G.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.

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

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

G.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.

G.2.2 The recommended grate heat release should not exceed 450 kBtu/hr per ft^2 (1.420 MW per m^2) of effective air admitting grate area. Maximum grate heat release rates per foot of stoker width should be 9.0 M × 106 Btu/hr per linear foot (8.66 MW/m^2 per linear meter) of stoker width without arches and 10.8 M × 106 Btu/hr per linear foot (10.4 MW/m^2 per linear meter) with arches.

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

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

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

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

G.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.

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

G.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.

G.2.10 Chain and Traveling Grate Stoker. See Figure G.2.10.

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

G.2.10.2 These stokers are mainly used for medium-sized industrial boilers with heat inputs from 40 MBtu/hr (11.72 MW) to 170.0 MBtu/hr (49.8 MW). Coal sizing should be 1 in. (25.4 mm) with approximately 20 percent to 50 percent passing through a $^1/_4$-in. (6.35-mm) round mesh screen. This stoker will handle such fuels as bituminous coals, anthracite coals, coke breeze, sub-bituminous coals, and lignite. This stoker produces low particulate emission.

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

G.2.11 Vibrating Grate Stoker. See Figure G.2.11.

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

FIGURE G.2.10 Side view of chain grate overfeed stoker. *(Reprinted with permission of Detroit Stoker Company.)*

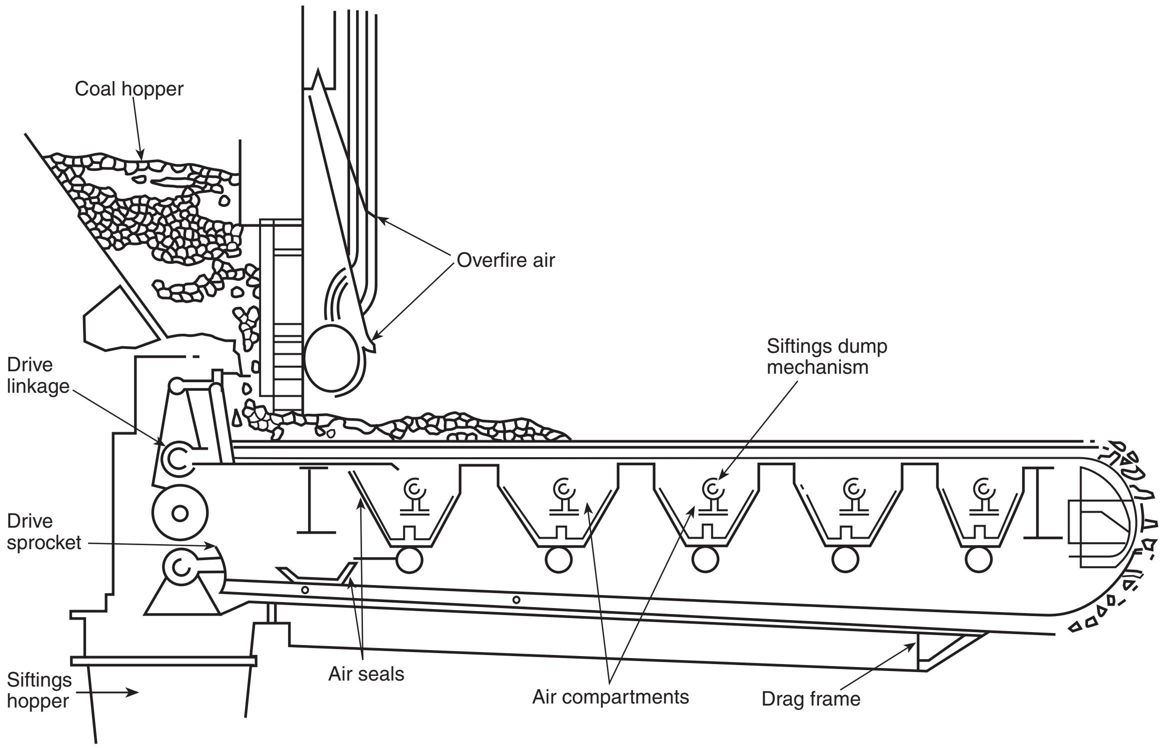
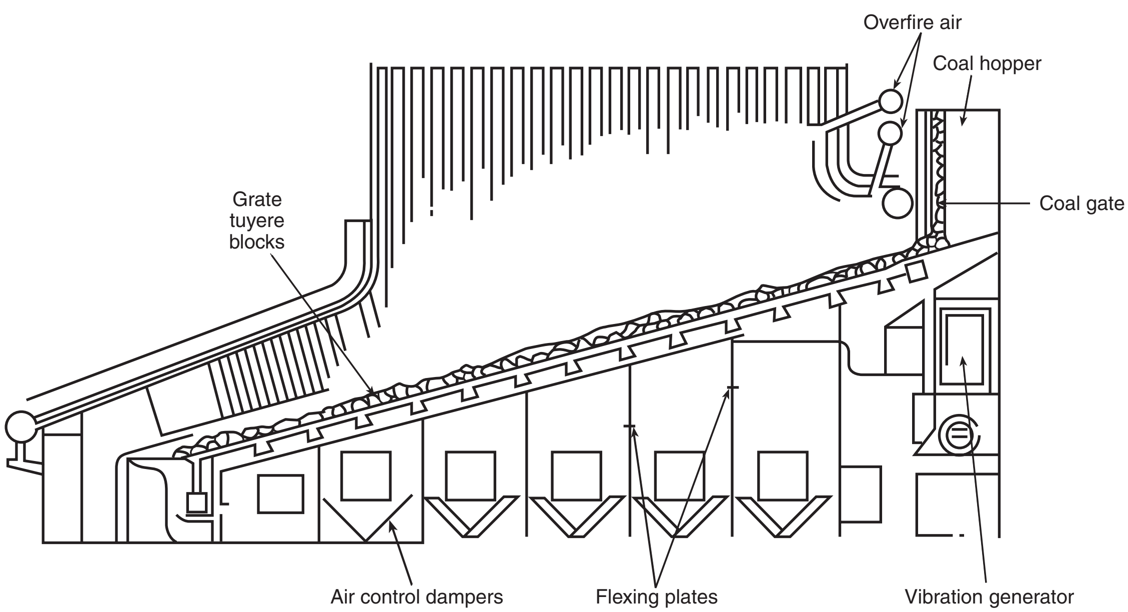


FIGURE G.2.11 Side view of a water-cooled vibrating grate stoker. *(Reprinted with permission of Detroit Stoker Company.)*



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

G.2.11.3 These stokers are mainly used for medium-sized industrial boilers with heat inputs from 70.0 MBtu/hr (20.5 MW) to 140.0 MBtu/hr (41.0 MW). They are designed to burn low-ranking coals. Coal sizing should be 1 in. (25.4 mm) with approximately 20 percent to 50 percent through a $^{1}/_{4}$-in. (6.35-mm) round mesh screen.

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

G.2.12 MSW Stoker. See Figure G.2.12.

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

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

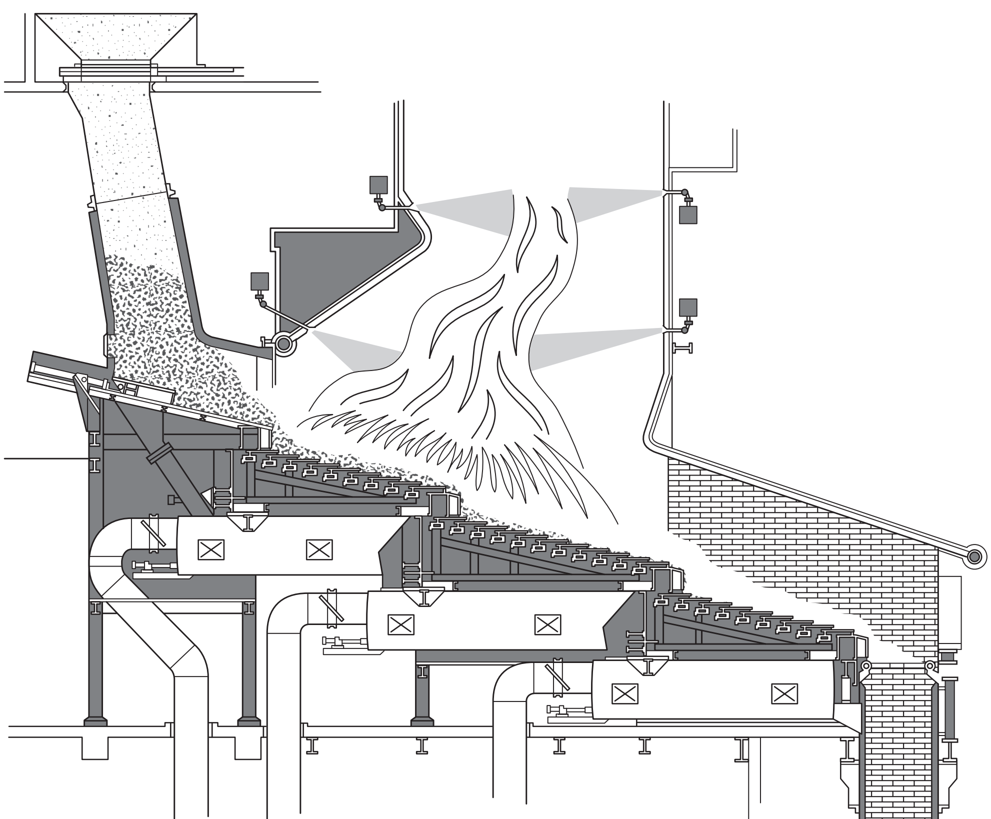
G.2.12.3 Since feed rate is directly proportional to the stoker grate speed, the feed rate must be correlated very closely with the stoker burning rate and, in turn, with combustion air supply and distribution. Since an automatic grate speed control to match actual burning rates is not always practical,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

G.2.12.4 This stoker is currently used for medium-sized boilers with heat inputs from 30.0 MBtu/hr (8.8 MW) to 340.0 MBtu/hr (99.6 MW).

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

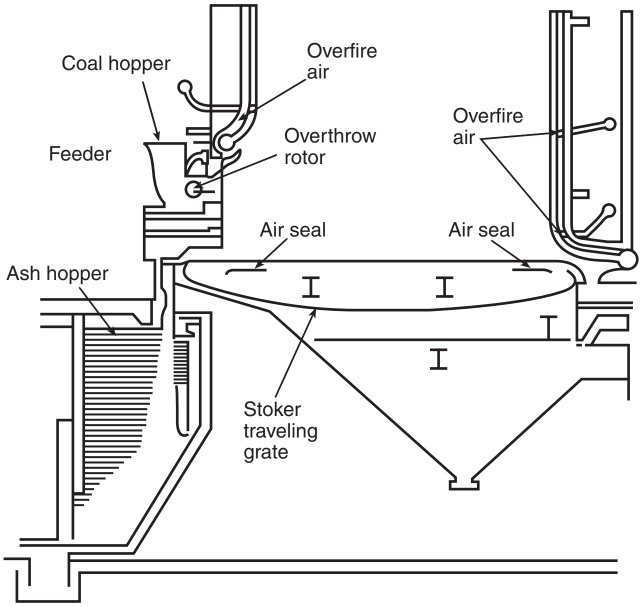
G.2.12.6 This type of stoker is designed to burn unprepared raw municipal waste refuse with most of the combustion occurring on or near the grate surface. Generally, the stoker is sized for the highest anticipated refuse heat value. The heat values for refuse can vary from 3.0 kBtu/lb (6.978 MJ/kg) to 6.0 kBtu/lb (13.956 MJ/kg).

FIGURE G.2.12 Side view of a traveling grate overfeed stoker. *(Reprinted with permission of Detroit Stoker Company.)*



G.3 Spreader Stoker. See Figure G.3.

FIGURE G.3 Side view of a spreader stoker with traveling grate. *(Reprinted with permission of Detroit Stoker Company.)*



G.3.1 General.

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

G.3.1.2 There are five spreader stoker grate types in general use today.

(1) A traveling grate with a continuous forward moving grate in which the return portion is on the underside, within the air plenum chamber. Ashes are conveyed to the front end.
(2) A reciprocating grate, which is a stepped grate having a slow reciprocating action to convey the ashes to the front end.
(3) A vibrating grate, either air-cooled or water-cooled, having an intermittent vibrating action to convey the ashes to the front end.
(4) A dumping grate, which manually intermittently discharges all of the ashes on the grate vertically downward to the ash pit. The dumping grate is seldom supplied today.
(5) A stationary grate, which is typically used for low-ash fuels.

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

G.3.1.4 A spreader stoker system can 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.

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

G.3.1.6 Spreader stokers are utilized on boilers having heat inputs from 30 MBtu/hr (8.8 MW) to 820 MBtu/hr (240.3 MW), depending on the fuel and type of spreader stoker grate. Spreader stokers have a very thin, active fuel bed and thus can respond to load changes quite rapidly.

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

G.3.3 All wood, municipal waste, and other wastes listed in Appendix F 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.

Appendix H Guidelines for Determining the Minimum Permitted Temperature for Feeding a Fuel into a Fluidized Bed

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

H.1 Scope. This method describes a procedure for establishing the minimum fluid bed temperature at which a fuel ignites and sustains controllable combustion. The test approaches described in Sections H.3 and H.4 are typical approaches followed by manufacturers to assist in design activities for this equipment. The test method described in Section H.5 is an important boiler commissioning activity performed on each new unit by the manufacturer and observed by other interested parties.

H.2 General Consideration. The purpose of this recommended procedure is to establish an initial minimum temperature permissive above which fuel can be fed into the fluidized bed. This initial temperature permissive should be verified by tests in the full-scale plant.

This procedure can be used by the fluidized-bed combustor (FBC) supplier to determine the minimum fluidized-bed temperature at which fuel can be fed into the furnace. The FBC supplier can use this temperature for defining the fuel permissive safety system for both start-up and hot restart.

The FBC supplier and operator should be aware of the following concerns and cautions.

(a) Pilot test information can differ from full-scale unit operation. The supplier should be aware of such differences and include a safety margin based on actual experience.

(b) Typically, there is a time delay between fuel feed command and fuel entering the furnace. This is reflected in a decrease in temperature of the fluidized-bed material during the period between bed fluidization and the arrival of the fuel in the bed. Bed cooling during this delay period could cause the temperature to fall below the fuel feed permissive.

(c) The minimum bed temperature at which fuel ignites and causes the bed material and freeboard temperature to increase is likely to be dependent on the air velocities, the air/fuel ratio, and the heat extraction surfaces within the combustion zones. The FBC supplier should consider the effect of these factors for both cold start-up and hot restart operation of the FBC.

(d) During initial plant start-up, the temperature permissive for fuel flow is usually verified in the installation. This test might show that a higher permissive fluidized-bed temperature is necessary to ignite the fuel. The supplier anticipates this possibility by providing the means for heating the bed to a higher temperature than that indicated by the pilot combustion tests.

H.3 Test Setup and Measurements.

H.3.1 Pilot Test Setup and Measurements. The test should use a pilot fluidized-bed combustion system that simulates the supplier's full-scale equipment. As a minimum, the test should include the following.

(a) A fuel feed system with feed rate control and feed rate monitor.

(b) Air controls and measurements of the fluidizing air, fuel transport air, and secondary air as applicable.

(c) Thermocouples to monitor the temperatures of the incoming airstreams, the bed temperature and freeboard temperature, and the temperature of the combustion products exhausting the freeboard.

(d) Recording instruments that provide a record of the fluidized-bed and freeboard temperatures. The printout scale and speed should be adjustable to provide a clear history of time and temperatures.

(e) Bed material that simulates the size distribution and material density projected for the full-scale system.

(f) Solid fuel that is representative of samples of the design fuels. Control should be exercised to ensure that fuel moisture content and size are properly simulated. If dictated by the pilot unit restrictions for maximum fuel size, the oversized fraction of fuel can be removed from the test feedstock, or the maximum fuel size can be reduced by means of additional processing.

(g) Equipment to allow heat extraction from the fluidized bed or furnace freeboard, as appropriate, to simulate the supplier's equipment design.

(h) A pilot test device that is rated at a minimum throughput capacity of 1.0 MBtu/hr (293 kW).

H.3.2 Bench-Scale Flammability Test Setup. An alternate means of establishing an initial minimum ignition temperature by test is through the use of conventional ignition or flammability tests. The intent of these tests is not so much to establish directly a minimum ignition temperature, but rather to allow the manufacturer to extrapolate an ignition temperature based upon the results of a given test and similar tests on fuels fired at other actual installations. The correlation between the ignition temperature (flammability index) yielded by tests of various fuels at an actual plant and the verified minimum ignition temperature established for that plant and the results of the testing performed on the unknown fuel are sufficient to yield an initial set point for the unknown fuel. As a minimum, the following should be used for the test:

(1) A furnace with a controllable heat source
(2) Thermocouples to monitor the temperature of the furnace
(3) Representative samples of the fuel to be fired (The samples should be prepared in accordance with normal procedures for the test setup to be utilized.)

The intent is not to require any specific test, but rather to use the same test on multiple fuel samples in order to establish a relationship between the unknown fuel and its appropriate minimum ignition temperature based on the relationship of other known fuels and their proven ignition temperatures.

H.4 Test Procedure. The proposed test procedure is a repetitive process that incrementally reduces the bed temperature until the system fails the success criteria for fuel ignition and sustained combustion. A fuel might have a very low temperature for ignition and sustained combustion, possibly one that is considerably lower than the operating bed temperature range of interest. Where such fuel is used, the FBC equipment supplier may be permitted to terminate the tests after they demonstrate successful operation at a temperature lower than the proposed minimum ignition temperature.

H.4.1 Test Operation.

H.4.1.1 Pilot Test Operation.

(a) With fans operating, the FBC test unit should be stabilized at 100°F to 200°F (56°C to 111°C) above the minimum bed temperature at which the fuel is known to sustain combustion. Verification of instrument operation and calibration should be made, and operating conditions should be adjusted to the selected air velocity excess air and bed temperature. Fuel flow, airflows, and temperatures should be monitored and recorded.

(b) The fuel should be shut off, and the bed temperature should be allowed to fall. The fuel feed conveying and metering equipment should be kept primed to minimize the fuel delivery delay time at fuel restart. At 50°F (28°C) below the previously demonstrated temperature for sustaining combustion, the fuel flow should be resumed at the rate used in H.4.1.1(a) for a maximum of 90 seconds.

(c) In a successful test, the temperature responses of the bed and freeboard are to be smooth and are to indicate a reversal of the fluidized-bed and freeboard temperature gradients. If the success criteria are met, (a) through (c) should be repeated at successively lower temperatures. If the success criteria are not met, the test should be terminated and a postpurge completed.

H.4.1.2 Minimum Permitted Bed Temperature. The minimum permitted bed temperature for admitting fuel flow into the fluidized bed should be not less than the minimum temperature at which "success" was achieved in H.4.1.1.

H.4.2 Bench-Scale Flammability Test.

H.4.2.1 Test Procedure.

(a) The test furnace should be stabilized at 100°F to 200°F (56°C to 111°C) above the expected ignition temperature of the fuel.

(b) A fuel sample should be admitted.

(c) If the fuel ignites, the test should be repeated after reducing the temperature of the furnace.

(d) If the fuel fails to ignite, the test should be terminated. The ignition temperature of the fuel is the last value that satisfies H.4.2.1(c).

H.4.2.2 Minimum Permitted Bed Temperature. The initial minimum fuel permissive is determined by correlating the results of the tests of the unknown fuel sample with similar tests performed for fuels used in other units of similar design and the corresponding minimum ignition temperatures established for those fuels in the respective units. It should be noted that this procedure, as in the procedure described in H.4.1.1, has a degree of uncertainty, and appropriate safety margins should be implemented until the testing on the actual unit can be completed.

H.5 Verifying Minimum Temperature at Actual Plant. The FBC supplier and the operator should agree to a procedure similar to that described in H.4.1.1 for verifying a minimum bed temperature for fuel flow start in the full-scale plant. A margin of safety should be added to any value derived through test. Where fuel sources change the minimum temperature, the test should be repeated.

Appendix I Referenced Publications

I.1 The following documents or portions thereof are referenced within this code for informational purposes only and are thus not considered part of the requirements of this code unless also listed in Chapter 8. The edition indicated here for each reference is the current edition as of the date of the NFPA issuance of this code.

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

NFPA 850, *Recommended Practice for Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations*, 2000 edition.

I.1.2 Other Publications.

I.1.2.1 ABMA Publication. ABMA 202, *Recommended Design Guidelines for Stoker Firing of Bituminous Coal.*

I.1.2.2 ANSI Publication. American National Standards Institute, Inc., 11 West 42nd Street 13th floor, New York, NY 10018.

ANSI K61.1, *Safety Requirements for the Storage and Handling of Anhydrous Ammonia.*

I.1.2.3 API Publications. American Petroleum Institute, 1220 L Street, NW, Washington, DC 20005.

API 620, *Standard for Design and Construction of Large, Welded, Low-Pressure Storage Tanks*, 1996.

API 650, *Standard for Welded Steel Tanks for Oil Storage*, 1998.

API RP 2003, *Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents*, 1998.

I.1.2.4 ASME Publication. American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016-9990.

ASME *Boiler and Pressure Vessel Code*, 1998.

I.1.2.5 ASTM Publication. American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM D 396, *Standard Specification for Fuel Oils*, 1998.

I.1.2.6 CGA Publication. Compressed Gas Association, 1725 Jefferson Davis Highway, Arlington, VA 22202-4100.

CGA G-2, *Anhydrous Ammonia*, 1995.

I.1.2.7 U.S. Government Publications. U.S. Government Printing Office, Washington, DC 20402.

Title 29, *Code of Federal Regulations*, Part 1910.111, "Storage and Handling of Anhydrous Ammonia."

I.2 Bibliography: Additional HRSG References. The following documents provide additional information on iron fires.

Johnson, A. A., J. A. Von Franuhofer, and E. W. Jannett, "Combustion of Finned Steel Tubing During Stress Relief Heat Treatment," *Journal of Heat Treating*, vol. 4, no. 3, pp. 265–271, June 1986.

McDonald, C. F., "The Potential Danger of Fire in Gas Turbine Heat Exchangers," *ASME* 69-GT-38.

Theoclitus, G., "Heat Exchanger Fires and the Ignition of Solid Metals," *Journal of Engineering for Gas Turbines and Power*, vol. 107, pp. 607–612, July 1985.

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Cross References to Previous Editions

The 2001 edition of NFPA 85 is a consolidation of NFPA 8501, NFPA 8502, NFPA 8503, NFPA 8504, NFPA 8505, and NFPA 8506.

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Note: This matrix is intended only as a guide to assist the user in locating relevant sections of the previous standards. The text of the sections listed for NFPA 85 may or may not have been modified from the original text. No attempt has been made to identify where sections have been modified or where new sections have been added.

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Note: This matrix is intended only as a guide to assist the user in locating relevant sections of the previous standards. The text of the sections listed for NFPA 85 may or may not have been modified from the original text. No attempt has been made to identify where sections have been modified or where new sections have been added.

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Formal Interpretation

NFPA 85

Boiler and Combustion Systems Hazards Code

2001 Edition

Reference: 3.7.5.4.3
F.I. 89-2

Background: On units for which NO_x control at low loads is important, it is desirable to maintain optimal low load burner air/fuel ratio. On some units, even with idle burner registers open, air flows to the operating burners must be reduced to as low as the purge rate air flow in order to reach the optimal ratio. On these units it is desired to drop the purge rate air flow below 25% of "design maximum air flow," to a proposed value of 25% of "maximum operation air flow."

The maximum operating steam flow on these units (limited by turbine-generator rating) is less than maximum boiler design steam flow. The fuel flow and air flow (as measured volumetrically by airfoil differential in the air to the windbox) at this steam flow are optimized for opacity and NO_x control, resulting in an air flow proportionately below design maximum air flow.

Question: Is it the intent of NFPA 8502 to allow purge rate air flow to be 25% of maximum operating air flow as opposed to 25% of design maximum air flow?

Answer: No.
Issue Edition: 1989 of NFPA 85D
Reference: Entire Document
Issue Date: July 16, 1990
Effective Date: August 4, 1990

Formal Interpretation

NFPA 85

Boiler and Combustion Systems Hazards Code

2001 Edition

Reference: 3.7.5.2.3.4
F.I. 89-1

Background: Consider the Chapter 3 definition:

"Class 3 Special (Direct Electric Igniter). A special Class 3 high energy electrical igniter capable of directly igniting the main burner fuel. This type igniter shall not be used unless supervision of the individual main burner flame is provided."

and consider paragraph 3.7.5.4.6:

"3.7.5.4.6 Where cleaning oil passages into the furnace, igniters shall be in service with ignition established."

The situation in question occurs when a Class 3 Special Igniter is monitored by a current sensing relay. With at least one other oil gun in <u>and proven</u> by flame scanners, the subject oil gun is stopped (i.e., its oil trip valve closes) either remotely or locally, by an operator. The normal course of action would be to go into an oil gun purge. The igniter would be first placed in service and proven, and then the purge air (or steam) valve opened for a specified time period until the oil passages are cleared of oil. The length of purge would be proven by test to sufficiently clear the oil passages of oil. Assume that good design of the oil system has been practiced and the oil trip valve is located very close to the burner, thus minimizing the length of oil piping to be cleared.

The above excerpts from 85D have been interpreted by some to mean that the <u>main</u> flame scanner must be proven at all times during the oil gun scavenging. This interpretation, in effect, precludes any scavenging of an oil gun which utilizes a Class 3 special igniter. During the scavenging operation the oil gun flame is unstable and will flame off and back on several times before the oil passages are cleared.

Question: Can a high energy igniter (Class 3 special) be used when "clearing oil passages into the furnace" without proving main flame on?

Answer: Yes.
Issue Edition: 1989 of NFPA 85D
Reference: 5-4.5
Issue Date: November 1, 1989
Effective Date: November 21, 1989

Formal Interpretation

NFPA 85

Boiler and Combustion Systems Hazards Code

2001 Edition

Reference: Appendix B, B.1.1(b)
F.I.

Question: In accordance with Appendix B, does "boiler front control" mean operator start-up from the boiler front with no option for remote control room starting capability?

Answer: The requirement stated in B.1.1(b) for the start-up or normal shutdown of any burner to be accomplished by an operator at the burner location, is controlling. A remotely-controlled light-off or normal shutdown, even with an operator standing by as a passive observer, does not conform with the intent of this section.

It should be noted that this interpretation does not rule out the use of remote burner control systems, but only states that these shall not be considered as conforming to a Boiler Front Control system. Appendix B is intended to be applied to smaller boilers with a limited number of burners, and for which an operator performs the burner light-off function at the boiler front, but with interlocks to prevent improper start-up. For larger units, which are remotely operated, such as those cited in this inquiry, it is the intent of the Committee that other portions of the standard shall apply. Provisions of the other portions of the standard permit and even encourage the application of burner management control systems.

Issue Edition: 1974 of NFPA 85D
Reference: Chapter 8
Date: April 1976

Formal Interpretation

NFPA 85

Boiler and Combustion Systems Hazards Code

2001 Edition

Reference: 6.4.6, Chapter 1
F.I. 78-1

Question 1: Does bench testing to 50 psig steady state, static pressure and retaining pressure integrity for a reasonable time (3 to 5 minutes) prove a component able "to withstand an explosion pressure of 50 psig for containment of possible internal explosions"?

Answer: No. The 50 psig statement is too low to meet the ultimate strength requirements. The Committee believes the inquirer should go to a minimum of 200 psig to meet the intent of the Code.

Question 2: Does this apply to components made of both ductile and non-ductile materials?

Answer: Yes.

Question 3: Does this preclude the need for analytical design justification?

Answer: Yes.

Issue Edition: 1978 of NFPA 85F
Reference: 2-6
Date: January 1982

Formal Interpretation

NFPA 85

Boiler and Combustion Systems Hazards Code

2001 Edition

Reference: 6.4.6, Chapter 1
F.I. 82-3

Question: What static steady state internal design pressure should be used in conunction with the allowable stresses of 6.4.6 when designing equipment per NFPA 8503?

Answer: 50 psig.

Question: Does "Bench Testing" a component of a pulverizer system to 200 psig on the basis of a factor of safety of 4 over the 50 psig required in 6.4.6 comply with the intent of the standard?

Answer: Yes.

Question: Does the standard require that components of a pulverizer system subjected to combined bending and membrane stresses be tested to 200 psig, a safety factor of 4 over the 50 psig required in 2.6.1.1?

Answer: Yes.

Question: Could a component which was permanently deformed as a result of bench testing be repaired and utilized in service?

Answer: No.

Question: Is a component of a pulverizer system which is permanently deformed but remains intact in successfully passing a bench test considered acceptable?

Answer: Yes.

Question: Would a successful bench test conducted on one component qualify, as acceptable, for all indentical components of the same design, material and construction as the component successfully tested?

Answer: Yes.

Question: Must the test requirements for pulverizer system components as specified in 6.4.6 be increased to make allowances for wear encountered in normal service?

Answer: No, but throughout the life of the component it should be capable of withstanding a bench test of 200 psig.

Question: Does the standard allow for the use of standard pressure components such as flanges, pipe fittings, valves, etc., which have non-shock capabilities but do have a static pressure rating of 200 psig or greater?

Answer: Yes.

Question: Would the components such as flanges, pipe fittings, valves, etc., be selected on the basis of a non-shock pressure rating or their hydrostatic test pressure?

Answer: The pressure rating of these components would be 200 psig provided the 200 psig did not exceed the ultimate strength of the material.

Question: What value must be specified for non-shock pressure ratings and hydrostatic pressure ratings for components such as flanges, pipe fittings, valves, etc., in keeping with the requirements of the text?

Answer: 200 psig.

Question: What is the pressure rating of the flanges listed in Table 2.6.3? Are these flanges capable of withstanding a 200 psig bench test?

Answer: Indeterminate.

Question: What is the dimension of the allowance for wear as mentioned in 2.6.3.1 which is included in the thickness of pipe listed in Table 2.6.3?

Answer: The amount of wear resistance varies depending on the pipe size. Also localized wear faces must be analyzed on a case-by-case basis. Analysis and specifications are determined by the manufacturer.

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