8502

NFPA 8502 Standard for the Prevention of Furnace Explosions/Implosions in Multiple Burner Boilers 1995 Edition

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

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Policy Adopted by NFPA Board of Directors on December 3, 1982

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

There is a concern that the growing use of synthetic materials may produce more or additional toxic products of combustion in a fire environment. The Board has, therefore, asked all NFPA technical committees to review the documents for which they are responsible to be sure that the documents respond to this current concern. To assist the committees in meeting this request, the Board has appointed an advisory committee to provide specific guidance to the technical committees on questions relating to assessing the hazards of the products of combustion.

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Errata

NFPA 8502

Furnace Explosions/Implosions in Multiple Burner Boilers

1995 Edition

Reference: 5-4.3(a)2

The Committee on Boiler Combustion System Hazards notes the following error in the 1995 edition of NFPA 8502, *Standard for the Prevention of Furnace Explosions/Implosions in Multiple Burner Boilers.* In an attempt to editorially revise the text in the 1995 edition, the meaning was inadvertently changed. Therefore, the text will be returned to the 1991 edition [formerly 5-4.2.2(a)2].

Revise 5-4.3(a)2 to read as follows:

"Before main fuel firing and following a five-minute period after a master fuel trip (furnace post purge), trip forced draft fans if the furnace pressure exceeds the normal operating pressure by a value recommended by the manufacturer."

Issue Date: March 1, 1996

NFPA 8502

Standard for the Prevention of

Furnace Explosions/Implosions in Multiple Burner Boilers

1995 Edition

This edition of NFPA 8502, *Standard for the Prevention of Furnace Explosions/Implosions in Multiple Burner Boilers*, was prepared by the Technical Committee on Multiple Burner Boilers, released by the Technical Correlating Committee on Boiler Combustion System Hazards, and acted on by the National Fire Protection Association, Inc., at its Annual Meeting held May 22-25, 1995, in Denver, CO. It was issued by the Standards Council on July 21, 1995, with an effective date of August 11, 1995, and supersedes all previous editions.

This edition of NFPA 8502 was approved as an American National Standard on August 11, 1995.

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

Origin and Development of NFPA 8502

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

NFPA 85B, *Standard for the Prevention of Furnace Explosions in Natural Gas-Fired Multiple Burner Boiler-Furnaces*

NFPA 85D, *Standard for the Prevention of Furnace Explosions in Fuel Oil-Fired Multiple Burner Boiler-Furnaces*

NFPA 85E, *Standard for the Prevention of Furnace Explosions in Pulverized Coal-Fired Multiple Burner Boiler-Furnaces*

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

In 1964, NFPA 85B was prepared by what was then the Sectional Committee on Public Utility Units and was tentatively adopted. In the following year and a half, the tentative standard was subjected to intensive study by the electric utility industry, boiler manufacturers, insurers, consultants, and others. The first official edition of NFPA 85B, adopted in 1966, incorporated the revisions that resulted from this study.

During this same period, NFPA 85D was prepared and was tentatively adopted in 1966. Revisions were adopted in 1967, but the status of the standard remained tentative.

NFPA 85E was prepared and eventually adopted as a tentative standard in May 1968. Amendments were adopted in 1969 to strengthen the standard and to provide more uniformity among NFPA 85B, NFPA 85D, and NFPA 85E, but its status remained tentative. Amendments also were made to NFPA 85B and NFPA 85D in 1969, and NFPA 85D was officially adopted that year.

NFPA 85B and NFPA 85D were revised again in 1970. NFPA 85B, NFPA 85D, and NFPA 85E were amended in 1971, and NFPA 85E was officially adopted. In 1972, provisions were

added to NFPA 85D to cover crude oil firing, and amendments were made to all three documents in 1973 and 1974. A new section covering boilers with a small number of burners and a new Appendix B were added to NFPA 85B and NFPA 85D in 1976.

The increased size of furnaces in utility boilers, along with changes in technology, introduced the problem of excessive negative pressure excursion development within the furnace setting. In 1976, a task group was appointed to investigate this problem. As a result of the task group investigation, it was concluded that a new standard for the prevention of furnace implosions was needed, and the development of NFPA 85G was initiated. NFPA 85G was published first in 1978. The official adoption of NFPA 85G in 1978 was accompanied by amendments to NFPA 85B, NFPA 85D, and NFPA 85E.

NFPA 85E and NFPA 85G were revised in 1980, followed by amendments to NFPA 85G in 1982. NFPA 85B and NFPA 85D were both revised in 1984. The most current of these four standards were the 1989 editions of NFPA 85B and NFPA 85D, the 1985 edition of NFPA 85E, and the 1987 edition of NFPA 85G.

In late 1988, the subcommittee responsible for these four documents was assigned the task of combining them into a single document for consistency and ease of management. The 1991 edition of NFPA 85C was the result of this effort.

In 1993, the technical committee responsible for NFPA 85C was assigned the task of revising this document and for redesignating it as NFPA 8502, *Standard for the Prevention of Furnace Explosions/Implosions in Multiple Burner Boilers*. The purpose of this redesignation is consistency with other NFPA 8500 series documents on boilers, furnaces, and related equipment. The 1995 edition of NFPA 8502 is the result of this effort.

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

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

Committee Scope: This Committee shall have primary responsibility for documents on the reduction of combustion system hazards in commercial, industrial, and utility boilers with a heat input rate of 12,500,000 Btu/hr and above. This includes all fuels or heat inputs except nuclear. Also responsible for documents on the reduction of hazards in pulverized fuel systems and stoker-fired boilers with a heat input rate of 400,000 Btu/hr and above.

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

Committee Scope: This Committee shall have primary responsibility for documents 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 andabove. This includes all fuels.

Contents

NFPA 8502

Standard for the Prevention of

Furnace Explosions/Implosions in Multiple Burner Boilers

1995 Edition

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

Information on referenced publications can be found in Chapter 10 and Appendix B.

Foreword

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 standard 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 standard and its intent.

It is not possible for this standard to encompass all specific hardware applications, nor should this standard 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.

This document is to be used for the design, installation, operation, and maintenance of multiple burner boilers and their burner management and combustion control systems. The standard is organized as follows:

1. The introduction and those sections that apply to all fuels covered in this standard (Chapters 1–5 and Chapter 9).

2. Detailed sections that specifically apply to the particular fuel fired. Chapter 6 applies to fuel gas systems. Chapter 7 applies to fuel oil systems. Chapter 8 applies to pulverized coal systems.

When using this standard, the sections that apply to all fuels covered should be used in conjunction with those covering the specific fuel utilized. The appendices include additional useful information but are not mandatory.

Chapter 1 Introduction

1-1 Scope.

1-1.1 This standard shall apply to boilers with a fuel input rating of 12,500,000 Btu/hr (3663 kW) or greater. This standard applies only to boilers using multiple burners firing the following:

(a) Fuel gas only, as defined in Chapter 3

(b) Fuel oil only, as defined in Chapter 3

(c) Pulverized coal as defined in Chapter 3.

1-1.2 This standard does not cover simultaneous firing of more than one fuel. Where simultaneous firing is planned, additional interlocks and other provisions shall be required but are not covered by this standard.

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

1-1.4 Furnaces such as those of process heaters used in chemical and petroleum manufacture, wherein steam generation is incidental to the operation of a processing system, are not covered by this standard.

1-1.5 Since this standard is based on the current state of the art, its application to existing installations is not mandatory. Nevertheless, operating companies are encouraged to adopt those features of this standard that are considered applicable and reasonable for existing installations.

1-1.6 Chapter 5 prescribes methods for minimizing the risk of negative furnace draft in excess of furnace structural capability.

1-1.7 Chapter 6 includes requirements for burner management, combustion control systems, and operating procedures for boilers utilizing fuel gas as defined in Chapter 3.

1-1.8 Chapter 7 includes requirements for burner management, combustion control systems, and operating procedures for boilers utilizing fuel oils as defined in Chapter 3.

1-1.9 Chapter 8 includes requirements for burner management, combustion control systems, and operating procedures for boilers utilizing pulverized coal as defined in Chapter 3.

1-2 Purpose.

1-2.1 The purpose of this document is to contribute to operating safety and to prevent furnace explosions and implosions. It establishes minimum standards for the design, installation, operation, and maintenance of boilers and their fuel-burning, air supply, and combustion products removal systems. The standard requires the coordination of operating procedures, control systems, interlocks, and structural design.

1-2.2* No standard can guarantee the elimination of furnace explosions and implosions in boilers. Technology in this area is evolving constantly, and this is reflected in revisions to this standard. The user of this standard needs to recognize the complexity of firing fuel with regard to the type of equipment and the characteristics of the fuel. Therefore, the designer is cautioned that the standard is not a design handbook. The standard does not eliminate the need for the engineer or for competent engineering judgment. It is intended that a designer capable of applying more complete and rigorous analysis to special or unusual problems is to be given latitude in the development of such designs. In such cases, the designer is responsible for demonstrating the validity of the proposed design.

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

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

Chapter 2 General

2-1 Furnace Explosions.

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

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

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

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

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

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

(d) The accumulation of an explosive mixture of fuel and air as a result of loss of flame or incomplete combustion at one or more burners in the presence of other burners operating normally or during lighting of additional burners;

(e) The accumulation of an explosive mixture of fuel and air as a result of a complete furnace flameout and the ignition of the accumulation by a spark or other ignition source, such as could occur where attempting to light a burner(s);

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

2-1.4 The conditions favorable to a furnace explosion described in 2-1.3 are typical examples, and an examination of numerous reports of furnace explosions suggests that the occurrence of small explosions, furnace 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 furnace explosions.

2-1.5 In a boiler, 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 reestablished. Dead pockets might exist in the boiler enclosure or other parts of the unit, where combustible mixtures can accumulate under upset furnace conditions. These accumulations could ignite with explosive force in the presence of an ignition source.

2-2 Furnace Implosions.

2-2.1 A furnace implosion is the result of the occurrence of excessively low gas side pressure, which causes equipment damage.

2-2.2 Two conditions that have caused furnace implosions include:

(a) A maloperation of the equipment regulating the boiler gas flow, including air supply and flue gas removal, resulting in furnace exposure to excessive induced draft fan head capability.

(b) The rapid decay of furnace gas temperatures and pressure resulting from either a rapid reduction in fuel input or a master fuel trip.

2-2.3 A combination of the two conditions indicated in 2-2.2 has resulted in the most severe furnace implosion incidents.

2-3 Manufacture, Design, and Engineering.

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

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

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

2-3.4 This standard necessitates a minimum degree of automation (*see Section 5-4, 6-6.1.1, 7-6.1.1, or 8-6.1.1*). The trend toward more complex plants or increased automation shall require additional provisions for:

(a) Information regarding significant operating events that allow the operator to make a rapid evaluation of the operating situation. The operator shall be provided with continuous and usable displays of variables that allow the operator to avoid unsafe conditions.

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

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

2-3.5 The burner front piping and equipment shall be designed and constructed to prevent the formation of hazardous concentrations of combustible gases that exist under normal operating conditions.

2-3.6 On the basis of reported incidents and field tests, the maximum negative furnace pressure is determined primarily by the maximum head characteristic of the induced draft fan; a major objective of the final design shall be to limit the maximum head capacity of draft equipment to that necessary for satisfactory operation. Special consideration shall be given to fan selection and arrangement of duct work to limit the effect of negative head.

2-3.7 With scrubbers or other high draft loss equipment for removing flue gas contaminants, a booster fan might be necessary. A bypass or other appropriate means shall be provided to counteract the potentially excessive negative pressure conditions resulting from combining the suction heads of both the induced draft fan and booster fan.

2-4 Installation.

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

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

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

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

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

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

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

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

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

2-5.2 Furnace explosions have occurred as a result of unfavorable functional design. The investigation frequently has revealed human error and has 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 shall be integrated. Consideration shall be given to the existing ergonomics that can affect operation of the system.

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

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

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

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

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

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

2-7* Basic Operating Objectives.

2-7.1 Basic operating objectives shall include the following:

(a) Establishment of operating procedures that result in a minimum number of manual operations.

(b) Standardization of all operating procedures. The use of interlocks is essential to minimize improper operating sequences and to interrupt sequences when conditions are not proper for continuation. It is particularly important that purge and start-up procedures with necessary interlocks be established and rigidly enforced. Sections 5-3, 6-5, 7-5, and 8-5 describe operating sequences that have proven effective.

(c)* Maintenance of airflow at or above purge rate during all operations of the boiler using the open register light-off procedure. (*See 6-5.1.5, 7-5.1.5, or 8-5.1.5.*)

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

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

Chapter 3 Definitions

3-1 Definitions. The following definitions shall apply for the purposes of this standard.

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

Air, Furnace Purge. See Purge.

Air, Primary (Transport Air, Pulverizer Air). The air or flue gas introduced into the pulverizer to dry the fuel and convey the pulverized fuel to the burners.

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

Air, Secondary. The air for combustion supplied to the burners by the forced draft fan.

Air, Tempering. Air at a lower temperature added to the hot primary air or gas to modify its temperature.

Air, Tertiary. The air supplied to certain types of burners for cooling the burner metal or to improve the combustion process.

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

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

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

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

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

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

Approved. Acceptable to the authority having jurisdiction.

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

Atomizer. A device in a burner that emits liquid fuel in a finely divided state.

Atomizer, Mechanical. A device in an oil burner that emits liquid fuel in a finely divided state without using an atomizing medium.

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

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

NOTE: The phrase "authority having jurisdiction" is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, 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.

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.

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

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

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

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

Burner Management System. The control system dedicated to boiler furnace 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. The burner management system includes the following functions specified in this standard: interlock system, fuel trip system, master fuel trip system, master fuel trip relay, flame monitoring and tripping systems, ignition subsystem, and main burner subsystem.

Burner, Warm-Up (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.

Coal. The general name for the natural, rock-like, brown-to-black derivative of forest-type plant material. By subsequent underground geological processes, this organic material is compressed and indurated over time, ultimately becoming graphite and graphite-like material. Coal contains carbon, hydrogen, oxygen, nitrogen, and sulphur, as well as inorganic constituents that form ash after burning. There is no fixed standard for coal, but there is an endless variety with respect to character and composition. The basic classifications for coal are lignite, subbituminous, bituminous, and anthracite. (*See ASTM D388, Standard Classification of Coals by Rank.*)

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

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

Damper, Primary Air Control. A controllable damper for regulating the flow of primary air or pulverizer air.

Damper, Primary Air Shutoff. A tight-seating damper that usually is located upstream from the primary air regulating damper to prevent flow.

Damper, Tempering Air (Cold Air Damper). A damper used to control tempering air.

Damper, Tight Shutoff. A close-fitting damper to minimize leakage of air or flue gas into any system component.

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

Directional Blocking. An interlock that, upon detection of significant error in furnace pressure, acts to inhibit the movement of all appropriate final control elements in the direction that increases the error.

Drip Leg. A chamber of ample volume, with suitable clean-out and drain connections, into which gas is discharged so that liquids and solids are trapped.

Exhauster, Pulverizer. See Fan, Exhauster.

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

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

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

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

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

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

Feeder, Raw Fuel. A device for supplying a controllable amount of raw fuel to the pulverizer.

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

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

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

Flame Detector, Self-Checking. A flame detector that automatically, and at regular intervals, tests the entire sensing and signal processing system of the flame detector. This ensures that the failure of any single component cannot result in a false indication of flame.

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

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

Fuel Gas. See LP-Gas and Natural Gas.

Fuel Oil. Grades 2, 4, 5, and 6 fuel oils as defined in ASTM D396, *Standard Specification for Fuel Oils*.

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

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

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

Furnace Purge. See Purge.

Gas. See LP-Gas and Natural Gas.

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

Grindability. The characteristic of solid fuel that indicates its relative ease of pulverization (*see ASTM D409, Standard Test Method for Grindability of Coal by the Hardgrove-Machine Method*). On the Hardgrove grindability scale, larger values (e.g., 100) represent coals that are easier to pulverize; smaller values (e.g., 40) represent coals that are more difficult to pulverize.

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

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

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

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

Igniter, Class 1. An igniter 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 provides 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. Class 1 igniters also shall be permitted to operate as Class 2 or Class 3 igniters.

Igniter, Class 2. An igniter applied to ignite the fuel input through the burner under prescribed light-off conditions. The range of capacity of such igniters generally is 4 percent to 10 percent of full-load burner fuel input.

Igniter, Class 3. 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.

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

Inerting. The dilution of the oxygen content of an air/fuel mixture through the addition of an inert gas or vapor to a point where it is no longer explosive.

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

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

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

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

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

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

(b) *Microprocessor-based Systems.*

1. Computer hardware, power supplies, I/O devices, and the interconnections among them.
2. Operating system and logic software.

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

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

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

Low Water Cutout. A device arranged to effect a master fuel trip when the water level in the steam drum falls to a predetermined low level.

LP-Gas. A material composed predominantly of any of the following hydrocarbons or their mixtures: propane, propylene, normal butane, isobutane, and butylenes.

Master Fuel Trip. An event resulting in the rapid shutoff of all fuel, including igniters.

Master Fuel Trip Relay. An electromechanical relay(s) utilized to trip all required equipment simultaneously.

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

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

Oil. See Fuel Oil.

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

Open Register. A procedure for purging and lighting-off a boiler under specified, controlled conditions. (*See 6-5.1.5, 7-5.1.5, or 8-5.1.5.*)

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

Outlet Draft. The flue gas pressure at the outlet of the last convection pass of the boiler.

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

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.

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

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

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

Purge Rate, Coal. A constant flow of not less than 25 percent nor more than 40 percent of the full-load mass airflow.

Purge Rate, Gas/Oil. A constant flow of not less than 25 percent of the full-load mass airflow.

Register. A set of dampers for a burner or air supply system to a particular burner used to distribute the combustion air admitted to the furnace. It also might control the direction and velocity of the airstream for efficient mixing with the incoming fuel.

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

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

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.

Separator, Filter, Scrubber. A device incorporated in the main fuel supply line that effectively separates foreign liquids or solids from the fuel.

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

Shall. Indicates a mandatory requirement.

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

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

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

Start-Up Combustion Control System. A control system used to regulate and maintain 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.

Supervise. To sense a condition needing attention and automatically initiate corrective action.

Supervised Manual System. A system 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 procedures.

Unit. The confined spaces of the furnace and the associated boiler passes, ducts, and fans that convey the gases of combustion to the stack.

Unit Purge. Air at purge rate that is flowed through the unit from the forced draft (FD) fan through the stack for (1) a period of not less than 5 minutes, or (2) five changes in volume of the boiler enclosure, whichever is longer.

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

Valve, Charging. A small valve bypassing the main safety shutoff valve used for purging and charging the fuel headers and piping and for testing for leaks.

Valve, Check. A valve used to prevent reverse flow.

Valve, Dusttight. A tight-seating valve installed in the fuel supply pipe to the burner to allow or stop flow.

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

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

Valve, Supervisory Shutoff. A manually operated shutoff valve with a means to provide a "valve closed" position signal.

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

Chapter 4 Equipment Requirements

4-1 Furnace Structural Design.

4-1.1* The furnace shall be capable of withstanding a transient design pressure without permanent deformation due to yield or buckling of any support member. (*See Section 5-1.*)

4-1.1.1 The positive transient design pressure shall be at least, but shall not be required to exceed, (+) 35 in. (+8.7 kPa) of water.

Exception: If the test block capability of the forced draft fan at ambient temperature is less positive than (+) 35 in. (+8.7 kPa) of water, 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.

4-1.1.2 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. (-8.7 kPa) of water [e.g., (-) 27 in. (-6.72 kPa) of water], 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.

4-1.2 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. (-8.7 kPa) of water, consideration shall be given to an increased negative design pressure.

4-1.3 Combustion Products Removal Subsystem. The transient internal design pressure defined in 4-1.1 shall be taken into consideration in the design of the air and gas flow path from the FD fan discharge through the stack.

4-2 Functional Requirements of Fuel-Burning System.

4-2.1 The fuel-burning system shall function to convert continuously any ignitable furnace input into unreactive products of combustion at the same rate that the fuel and air reactants enter the furnace.

4-2.2 The fuel-burning system shall be sized properly, adequate to meet the operating requirements of the unit, compatible with other boiler component systems, and capable of being controlled for the full operating range of the unit.

4-2.3 System Requirements.

4-2.3.1 The fuel-burning system shall provide means for proper start-up, operation, and shutdown of the combustion process. This shall include appropriate openings and configurations in the component assemblies to allow suitable observation, measurement, and control of the combustion process.

4-2.3.2 The fuel-burning system consists of the boiler enclosure and the following subsystems: air supply, raw coal, pulverizer, fuel supply, main burner, atomizing, ignition, and combustion products removal. Each shall be sized and interconnected to satisfy the following requirements:

(a) *Boiler Enclosure.*

1. The boiler enclosure shall be sized and arranged with respect to the main burner subsystem so that fuel can be fired to maintain stable flame.

2. The boiler enclosure shall be free from "dead pockets" where prescribed purge procedures are followed.

3. Observation ports shall be provided to allow inspection of the furnace and burners.

(b) *Air Supply Subsystem.*

1. The air supply equipment shall be sized and arranged to ensure a continuous airflow adequate for all operating conditions on the unit.

2. The arrangement of air inlets, duct work, and air preheaters shall minimize contamination of the air supply by such materials as flue gas, water, and fuel. Appropriate drain and access openings shall be provided.

3. The air supply equipment shall be capable of continuing the proper airflow during anticipated furnace pressure pulsations.

(c) *Raw Coal, Pulverizer, Fuel Supply, Main Burner, and Atomizing Subsystems.* See Sections 6-3, 7-3, and 8-3 for information on these subjects.

(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 Chapter 3 and as verified by test. Many factors affect the classification of the igniters, including the characteristics of the main fuel, the furnace and the burner design, and the igniter capacity and location relative to the main fuel burner.

2. Class 1 igniters also shall be permitted to be used as Class 2 or Class 3 igniters. Class 2 igniters also 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 to the furnace 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 turned off as a part of the burner light-off procedure when the time trial for ignition of the main burner has expired. This practice ensures 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 6-3.2.2, 7-3.2.2, and 8-3.3.2 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 available where 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. (*See also 6-3.2.2, 7-3.2.2, and 8-3.3.2.*)

10. Igniters shall be permanently installed. They shall be individually supervised to verify that the requirements of 4-2.3.2(d)1 and 4-2.3.2(d)2 are met. This supervision shall include the igniter flame and capacity.

11. The ignition equipment shall be located in an appropriate environment with convenient access for maintenance.

12. All igniter safety shutoff valves shall be located as close as practicable to igniters 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 furnace 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. Convenient access and drain openings shall be provided.

3. The flue gas ducts shall be designed so that they do not contribute to furnace pulsations.

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

4-3 Burner Management System Logic. The intent of this section is to provide guidance in the use of logic systems in burner management.

4-3.1 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.

4-3.2* Specific Requirements. As a minimum, the requirements of 4-3.2.1 through 4-3.2.4 shall be included in the design to ensure that a logic system for burner management meets the intent of these standards.

4-3.2.1 Failure Effects. The logic system designer shall evaluate the failure modes of components where considering the design application of the system. As a minimum, the following failures shall be evaluated and addressed:

(a) Interruptions, excursions, dips, recoveries, transients, and partial losses of power;
(b) Memory corruption and losses;
(c) Information transfer corruption and losses;
(d) Inputs and outputs (fail-on, fail-off);
(e) Signals that are unreadable or not being read;
(f) Failure to address errors;
(g) Processor faults;
(h) Relay coil failure;
(i) Relay contact failure (fail-on, fail-off); and
(j) Timer failure.

4-3.2.2 Design.

(a) Diagnostics shall be included in the design to monitor processor logic function.

(b) Logic system failure shall not preclude proper operator intervention.

(c) Logic shall be protected from unauthorized changes.

(d) Logic shall not be changed while the associated equipment is in operation.

(e) System response time (throughput) shall be sufficiently short to prevent negative effects on the application.

(f) Protection from the effects of noise shall be adequate to prevent false operation.

(g) Any single component failure within the logic system shall not prevent a mandatory master fuel trip. (*See also 6-5.2.5, 7-5.2.5, or 8-5.2.5.*)

(h) The operator shall be provided with a dedicated manual switch(es) that shall actuate the master fuel trip relay independently and directly.

4-3.2.3 Requirement for Independence.

4-3.2.3.1 The logic system performing the safety functions for burner management shall not be combined with any other logic system.

4-3.2.3.2 These burner management safety functions shall include, but shall not be limited to, proper purge interlocks and timing, mandatory safety shutdowns, trial timing for ignition, and flame monitoring.

4-3.2.3.3 The logic system shall be limited to one boiler only.

4-3.2.3.4 The burner management system shall be provided with independent logic, independent input/output systems, and independent power supplies and shall be functionally and physically separate from other logic systems (e.g., boiler control system).

4-3.2.3.5 The same hardware type used for burner management systems shall be permitted to be used for other logic systems.

4-3.2.3.6 Data highway communications between the burner management system and other systems shall be permitted. Signals that initiate mandatory master fuel trips shall be hardwired.

4-3.2.4 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.

4-4 Flame Monitoring and Tripping Systems. See Sections 6-4, 7-4, and 8-4 for additional requirements concerning flame detection associated with a specific fuel.

4-4.1 Functional Requirements. The basic requirements of any flame monitoring and tripping system shall be as follows:

(a) Combustion instability situations shall be brought to the attention of the operator for remedial action.

(b) An emergency shutdown of the involved equipment shall be automatically initiated upon detection of serious combustion problems likely to lead to the accumulation of unburned fuel.

4-4.2 Flame Detection.

4-4.2.1 Flame Detector Sighting. The use of flame detector sighting shall be considered in the initial furnace 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.

4-4.2.2 Clean Air Supply. Clean air, where necessary, shall be supplied in order to minimize problems with dirty detector lenses.

4-4.2.3 Self-Checking of Flame Detectors. Where flame-sensing detectors can fail in the flame-proven mode, self-checking features shall be provided.

4-4.2.4 Reduced Emissions Control Effects. Methods and equipment used to reduce the emission of air pollutants can affect the burner flame, selection of the flame detector, and location/sighting of the flame detector. (*See A-6-5.2.1.3.*)

4-4.3 System Objectives. System objectives shall be developed with due consideration given to those requirements that are specifically related to the combustion conditions that are typical for particular furnace configurations, burner systems, and fuel characteristics. Such objectives shall be consistent with the individual manufacturer's design philosophy.

4-5 Combustion Control System.

4-5.1 Functional Requirements.

4-5.1.1 The combustion control system shall maintain furnace fuel and air input in accordance with demand.

4-5.1.2 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 flame for the full operating range of the boiler.

4-5.2 System Requirements.

(a) For start-up conditions, airflow shall be maintained at the purge rate while fuel is controlled to satisfy start-up rates within the limits established as compatible with airflow at each burner. Equipment shall be provided and operating procedures established to preclude the possibility of an improper air/fuel ratio condition at each burner.

(b) Provisions shall be made for setting minimum and maximum limits on the fuel and air control subsystems to prevent fuel and airflows beyond the stable flame limits of the fuel-burning system. These minimum and maximum limits shall be defined by the burner manufacturer and verified by operating tests. (*See 6-3.2.2, 7-3.2.2, or 8-3.3.2.*)

(c) Where changing the rate of furnace input, the airflow and fuel flow shall be changed simultaneously to maintain proper 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. Placing fuel flow control on automatic without the airflow control on automatic shall be prohibited.

(d) The control system design shall prevent the need for a fuel-rich mixture. Control action to increase fuel and decrease air shall be blocked when the air/fuel ratio falls below a preset value.

(e) When the air/fuel ratio falls below a preset value, control actions to decrease fuel or increase air, or both, shall be taken. (*See 6-5.3.2, 7-5.3.2, or 8-5.4.2.*)

(f) On balanced draft furnaces, the furnace draft shall be maintained at the set point.

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

(h) Provisions for calibration and testing of combustion control and associated interlock equipment shall be furnished.

(i) Consideration shall be given to providing oxygen and combustibles meters for use as operating guides.

(j) Gas flow meters shall be operated at constant pressure conditions or shall be pressure compensated where pressure variations introduce significant error.

(k) Oil flow meters shall be compensated where variations in temperature or viscosity introduce significant error.

(l) Consideration shall be given to providing coal flow devices on each pulverizer as a part of the combustion control and burner control systems to provide indices of total fuel flow versus total airflow and for use as an operating guide.

(m) Means shall be provided to control the pulverizer coal-air temperature within the required limits.

(n) Means shall be provided to ensure adequate primary air for transport of the required pulverized coal input.

4-6 Power Supplies. All reasonable precautions shall be taken to ensure the availability of a failure-free power supply (electric or pneumatic) to all control and safety devices.

4-7 Operating Information. As a minimum, continuous trend display of boiler output, feed water flow rate, total fuel flow rate, and total airflow rate as a percentage of the maximum unit load plus drum level, final steam temperature, main steam pressure, and furnace draft shall be provided simultaneously at the operating location. (*See 2-3.4, 2-5.2, and 2-5.4.*)

Chapter 5 Furnace Implosion Protection

5-1* General. This chapter prescribes methods for minimizing the risks of negative furnace draft in excess of furnace structural capability. Consideration shall be given to one or both of the following methods:

(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 Section 5-2, and furnace design shall be in accordance with Section 4-1.

5-2 Furnace Pressure Control Systems (Implosion Protection).

5-2.1 Functional Requirements. The furnace pressure control system shall control the furnace pressure at the desired set point in the combustion chamber.

5-2.2 System Requirements. See Figure 5-2.2.

5.2.2.1 The furnace pressure control subsystem (A), as shown in Figure 5-2.2, shall position the draft regulating equipment to maintain furnace pressure at the desired set point.

5-2.2.2 The control system, as shown in Figure 5-2.2, shall include the following features and functions:

(a) 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.

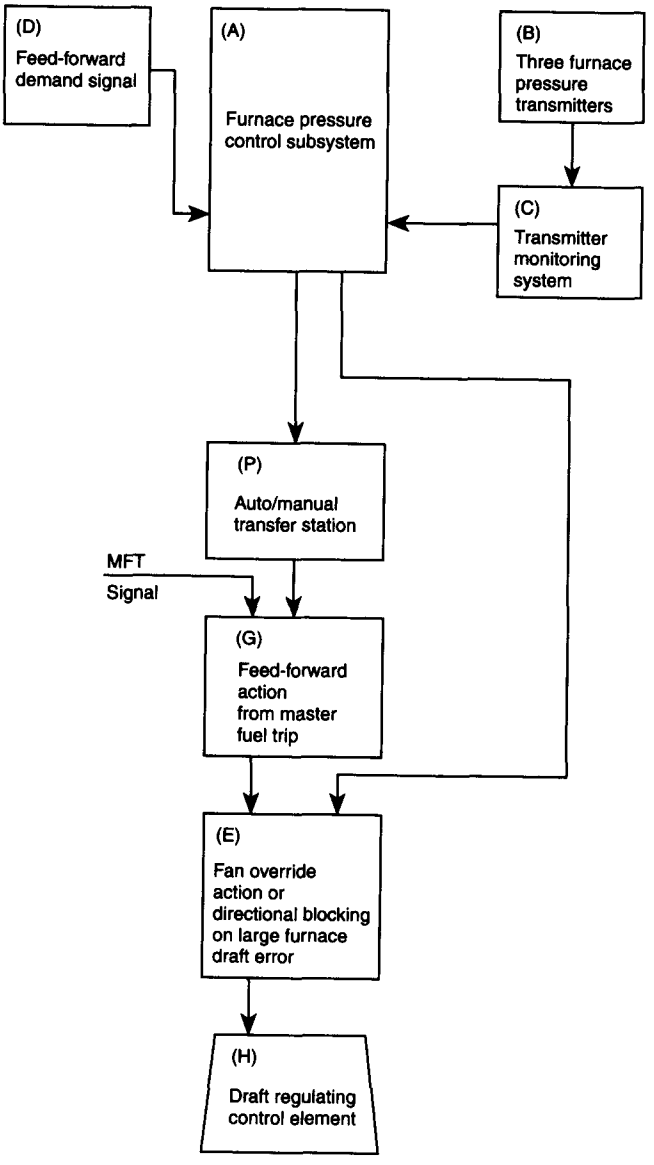


Figure 5-2.2 System requirements.

(b) 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 suitable index of demand but shall not be a measured airflow signal.

(c) An override action or directional blocking (E) on large furnace draft errors introduced after the auto/manual transfer station (P).

(d) A feed-forward action (G) initiated by a master fuel trip to minimize the pressure excursions, introduced after the auto/manual transfer station (P).

(e) Axial fans, where used, shall be operated in such a manner as to avoid a stall condition in order to prevent uncontrolled changes in airflow or flue gas flow.

5-2.3 Component Requirements. The furnace pressure control element(s) (*see H in Figure 5-2.2*) (draft fan inlet damper drive, blade pitch control, speed control) shall meet the following criteria:

(a) The operating speed shall not exceed the control system's sensing and positioning capabilities in order to avoid undesirable hunting and overshooting of automatic control. Excessive speed can create damaging negative pressure transients downstream. Excessive speed also might be unsuitable for manual control.

(b) The operating speed of the draft control equipment shall not be less than that of the airflow control equipment.

(c) Special consideration shall be given to the design of the furnace draft control system to ensure a satisfactory rate of response with variable speed and axial fans.

5-3 Sequence of Operations Requirements.

5-3.1 The purpose of sequencing requirements is to ensure that the operating events occur in the proper order and is not to provide fan operating procedures. The proper 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 chapter and in the related chapters applicable to the fuel being fired as follows:

(a) Gas-fired systems, Chapter 6

(b) Oil-fired systems, Chapter 7

(c) Pulverized coal-fired systems, Chapter 8.

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, sufficient isolating dampers, windbox dampers, air registers, and other control dampers shall be opened 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 ensures acceptable 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 manufacturers' 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.

5-3.3 The sequence for starting and stopping fans under all conditions shall be as follows:

(a) 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 5-3.4.

(b) Shutdown procedures shall be the reverse of those specified in 5-3.3(a).

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.

5-3.5 Following shutdown of the last fan due to any cause, the opening of fan dampers shall be delayed or controlled to avoid excessive positive or negative furnace pressure transients during fan coast-down.

5-4 Interlock System Functional Requirements. The functional requirements for interlock systems specified in the chapter for the fuel being fired shall be as follows:

(a) Gas-fired systems, Chapter 6

(b) Oil-fired systems, Chapter 7

(c) Pulverized coal-fired systems, Chapter 8.

5-4.1 System Requirements.

5-4.2 It is possible to achieve conditions conducive to a furnace implosion that cannot be detected by any of the mandatory automatic-trip devices, even though such devices are properly adjusted and maintained; therefore, operating personnel shall be made aware of the limitations of the automatic protection system.

5-4.3 The following interlocks shall be provided:

(a) *High Furnace Pressure.*

1. The master fuel trip shall be activated when the furnace pressure exceeds the normal operating pressure by a 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.

2. Before the main fuel firing and for a 5-minute period following a master fuel trip (furnace post purge),

forced draft fans shall be tripped, if the furnace pressure exceeds the normal operating pressure, by a value recommended by the manufacturer.

(b) *High Furnace Draft (Balanced-Draft Units).*

1.* The master fuel trip (not necessarily automatic) shall be activated when the furnace negative pressure exceeds the normal operating pressure by a 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.

2. Before the main fuel firing and following a master fuel trip, all induced draft fans shall be tripped if furnace negative pressure exceeds the normal operating pressure by a 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 5-4.3(b)1.

(c) *Loss of Forced Draft Fans.*

1. 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 appropriate loss of forced draft fan interlocks. Variable speed and axial flow fans might require special provisions.

2. Associated 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 induced draft fan shall remain in controlled operation, and the dampers associated with the forced draft fan shall remain open.

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 avoid 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 each induced draft fan is running and capable of providing the required flow shall be provided. Loss of such proofs shall initiate appropriate loss of induced draft fan interlocks. Variable speed and axial flow fans might require special provisions.

2. Associated damper(s) shall be closed on loss of an individual induced draft fan, unless it is 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, 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.

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 avoid high draft during fan coast-down. Dampers shall remain open and fans shall be started in accordance with 5-3.2 through 5-3.4. Gas recirculation fan system dampers shall be closed.

(e) *Multiple and Variable Speed Fans.* 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).

5-5 Alarm System.

5-5.1 Functional Requirements. The functional requirements for alarm systems specified in the chapter for the fuel being fired shall be as follows:

(a) Gas-fired systems, Chapter 6

(b) Oil-fired systems, Chapter 7

(c) Pulverized coal-fired systems, Chapter 8.

5-5.2 System Requirements. In addition to the alarms required in 5-5.1, the following separately annunciated alarms shall be provided:

(a) Initiation of directional blocking or override action;

(b) Redundant transmitter malfunctions within the furnace pressure control system;

(c) Axial flow fan, if used, nearing stall line.

Chapter 6 Fuel Gas Systems

6-1 General. This chapter contains the additional requirements to be followed where burning fuel gas.

6-2 Gas Firing—Special Problems. Common hazards are involved in the combustion of solid, liquid, and gaseous fuels. Each of these fuels has special hazards related to its physical characteristics. The following factors shall be considered in the design of the firing systems:

(a) Gas is colorless; therefore, a leak usually cannot be detected visually. In addition, detection of a gas leak by means of odor is unreliable.

(b) Potentially hazardous conditions are most likely to occur within buildings, 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 proper 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, shall be considered potentially hazardous. This also shall apply to manual firing without the above-mentioned interlocks or alarms. (*See Sections 6-3, 6-4, and 6-5 for requirements to avoid such hazards.*)

(d) Natural gas can be either "wet" or "dry." A wet gas usually implies the presence of distillate, which can 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 a furnace explosion. Therefore, special precautions shall be taken with wet gas supply systems. (*See NFPA 54, National Fuel Gas Code.*)

(e) Widely different characteristics of gas from either a single source or multiple sources could result in a significant change in Btu input rate to the burners without an equivalent change in airflow.

(f) Discharges from relief valves or from any other form of atmospheric vents can become hazardous unless special precautions are taken.

(g) Maintenance and repair of gas piping can be hazardous unless proper methods are used for purging and recharging the line before and after making repairs. (*See NFPA 54, National Fuel Gas Code.*)

(h) Where firing oil, the operation of air heater sootblowers shall be in accordance with the recommendations of the air heater manufacturer. Initial firing of fuel oil in a cold boiler can create a special hazard by causing fires in air heaters.

6-3 System Requirements.

6-3.1 Fuel Supply Subsystem, Fuel Gas. See Figures A-6-5.1.2(a) and (b).

6-3.1.1 The fuel supply equipment shall be sized and arranged to ensure a continuous fuel flow adequate 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 might result in exceeding burner limits for stable flame as a result of placing burners in service or taking them out of service.

6-3.1.2 The portion of the fuel supply system outside of the boiler room [*see Figure A-6-5.1.2(b)*] 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 usually can be accomplished by providing full relieving capacity that is vented to a safe location. Where full relieving capacity is not installed, a high gas pressure trip shall be provided.

6-3.1.3 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.

6-3.1.4 The fuel supply equipment shall be capable of continuing the proper fuel flow during anticipated furnace pressure pulsations.

6-3.1.5 The fuel supply equipment shall be designed with careful consideration of operating environment and ambient conditions. The piping might be required to withstand severe external conditions such as fire or mechanical damage.

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.

6-3.1.7 Periodic tightness tests of the main safety shutoff valves, individual burner safety shutoff valves, and associated vent valves shall be performed. Provisions shall be made in the gas piping to allow for permanent and ready means for making easy, accurate leak tests and subsequent repairs.

6-3.1.8 The discharge from atmospheric vents 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 sufficiently above the boiler and adjacent structures so that gaseous discharge does not present a fire hazard.

6-3.1.9* Manifolding of Vents. 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.

6-3.1.10 Gas piping materials and system design shall be in accordance with ANSI B31.1, *Power Piping.*

6-3.2 Main Burner Subsystem.

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. 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. In these circumstances, Class 1 or Class 2 igniters, as demonstrated by test, shall be permitted to be used to maintain stable flame. [*See 4-2.3.2(d)1 and 6-3.2.2.*]

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. 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. These tests shall include the expected range of available fuels.

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 anticipated furnace pulsations and maintain stable combustion.

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.

6-3.2.5 The burner equipment shall be located in an appropriate environment with convenient access for maintenance. Special recognition shall be given to the fire hazards imposed by leakage or rupture of piping near the burner. The requirements of good housekeeping shall be followed.

6-3.2.6 All burner safety shutoff valves shall be located as close to the burner as practicable to minimize the volume of fuel left downstream of the burner valves in the burner lines.

6-4 Flame Monitoring and Tripping System.

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.

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.

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.

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.

6-4.2 Upon detection of loss of all flame in the furnace or partial loss of flame to the extent that hazardous conditions could develop, a master fuel trip shall be automatically initiated. [*See 6-6.3.1.1(d)6.*]

6-4.3 It is recognized that any fuel input that does not ignite and burn on a continuous basis creates 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 potential hazard.

6-4.4 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 similar size and arrangement, including burners/nozzles of substantially the same capacity using similar fuels. These tests shall not be used to replace acceptance tests relating to proof of design, function, and components.

6-5 Sequence of Operations. For supervised manual systems, see Section 6-8.

6-5.1 General.

6-5.1.1 Sequencing shall be required to ensure that operating events occur in the proper order. Sequencing shall provide procedures that allow properly prepared fuel to be admitted to the burners only when there is sufficient ignition energy and proper airflow to ignite the fuel as it enters the furnace. Sequencing also shall be utilized where removing burners from operation.

6-5.1.2* Sequences of operation are based on the typical fuel supply system shown in Figures A-6-5.1.2(a) and (b). These sequences shall be followed whether the unit is operated manually or certain functions are accomplished by interlocks or automatic controls. Different arrangements shall be permitted if they provide equivalent protection and meet the intent of the operating sequences specified in this chapter.

6-5.1.3 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 is to ensure an air-rich furnace atmosphere during start-up. It also establishes minimum velocities through the furnace to prevent hazardous accumulations of unburned fuel.

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 that ensure proper light-off.

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:

(a) Raise the boiler pressure or temperature.
(b) Carry the initial load on the unit.

6-5.1.4.2 If some registers have been maintained in the closed position, these 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.

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 is based upon the concept that the following basic operating conditions significantly improve the margin of operating safety, particularly during start-up. These conditions include:

(a) Use of minimum number of required equipment manipulations, thereby minimizing exposure to operating errors or equipment malfunction;

(b) The desired fuel-rich condition at individual burners during light-off;

(c) 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.

6-5.1.5.1 This procedure shall incorporate the following operating objectives:

(a) All or most of the registers shall be placed in a predetermined open position.

(b) A unit purge shall be completed with the burner air registers in the position specified in 6-5.1.5.1(a).

(c) 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 into service, whichever is longer.

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

(e) The first burner or group of burners shall be lighted without any change in the airflow setting or in the burner air register position.

6-5.1.5.2 Each boiler shall be tested during initial start-up to determine whether any modifications to the procedure specified in 6-5.1.5 are required in order to obtain satisfactory ignition or to satisfy other design limitations during light-off and warm-up. For example, some boilers are purged with the registers in the normal operating position. In this instance, it might be necessary to close the registers of the burner being lighted momentarily to establish ignition. However, unnecessary modifications in the basic procedure shall be avoided, particularly that of 6-5.1.5(a), thereby satisfying the basic objectives in 6-5.1.5.1.

6-5.1.6 Modification to the mode of operation resulting from improper water, steam, and flue gas temperatures in the economizers and superheaters shall be made only after it has been determined to be necessary by operating experience.

6-5.2 Functional Requirements.

6-5.2.1 Cold Start.

6-5.2.1.1 Preparation for starting shall include a thorough inspection that shall verify the following:

(a) The furnace and gas passages are in good repair and free of foreign material.

(b) The bottom of the furnace is free of accumulations of solid or liquid fuel, gases, or vapors. Such an inspection is particularly important for a cold start where the fuel burned prior to shutdown contained or could generate volatile vapors heavier than air. The possibility of such accumulations shall be considered 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 normally adjustable individual burner dampers or registers have been operated through their full range to check the operating mechanism.

(f) All safety shutoff valves are closed. All sparks are deenergized.

(g) For oil ignition systems, see Chapter 7.

(h) The fuel system vents are open and venting to atmosphere outside the boiler room. Lines are drained and cleared of materials such as condensate.

(i) 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.

(j) The burner elements and igniters are positioned in accordance with the manufacturer's specification.

(k) Energy is supplied to control systems and to safety interlocks.

(l) The meters or gauges indicate fuel header pressure to the unit.

(m) The oxygen and combustibles analyzer(s), if provided, are operating satisfactorily and a sample has been obtained. Combustibles indication is at zero and oxygen indication is at maximum.

(n) A complete functional check of the safety interlocks has been made after an overhaul or other significant maintenance.

(o) A complete periodic operational test of each igniter has been made. The frequency of testing depends on the design and operation history of each individual boiler and ignition system. As a minimum, the test shall be made during each start-up following an overhaul or other significant maintenance. The test shall be integrated into the starting sequence and shall follow the purge and precede the admission of any main fuel.

(p) 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 normal start-up or light-off position.

(q) Units with a history of igniter unreliability shall require additional test routines to verify the continuing operating ability of igniters and ignition system components. The importance of reliable igniters and ignition systems cannot be overstressed.

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.

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, where appropriate, 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 5-3, as necessary, to achieve purge flow rate.

(c) An operational leak test of the fuel header piping system shall be performed in accordance with established procedures while maintaining purge rate airflow. Successful completion of the leak test shall be part of a completed unit purge. [*See Figure A-6-5.1.2(b).*]

(d) Dampers and burner registers shall be opened to the purge position in accordance with the open register purge method objectives outlined in 6-5.1.5.

(e) The airflow shall be adjusted to purge airflow rate and a unit purge shall be performed. Special provisions might be necessary to prevent the hazardous accumulation of volatile vapors that are heavier than air or to detect and purge accumulations in the furnace bottom.

(f) The main fuel control valve shall be closed and the main safety shutoff valve(s) shall be opened. (*See Section 6-6 for permissive conditions in the furnace purge system that shall be satisfied before this can be accomplished.*)

(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 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 can function to regulate and maintain the correct pressure for burner light-off. The main fuel control valve shall be opened when necessary.

CAUTION: The time needed to vent for control of header pressure after header charging shall be evaluated and minimized.

(h) The igniter safety shutoff valve shall be opened and it shall be determined that the igniter fuel control valve is holding the recommended fuel pressure for proper igniter 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 can function to regulate and maintain the correct pressure for lighting the igniters.

CAUTION: The time needed to vent for control of header pressure after header charging shall be evaluated and minimized.

(i) The air register or damper on the burner selected for light-off shall be adjusted to the position recommended by the manufacturer. (*See 6-5.1.5.2.*)

(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 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.

(k) Where Class 3 special electric igniters are used, the procedures described in 6-5-2.1.3(a) through (g), (i), and (l) through (o) 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 appropriate 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 satisfactory 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 for proper 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 normal 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 [*see 6-5.2.1.3(l)*]. 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 proper associated interlocks.

(o) 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 6-5.2.1.3(c). The main fuel bypass control valve will automatically control the burner header gas pressure.

(p) The same procedures in 6-5.2.1.3(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. Automatic control of burner fuel flow and burner airflow during the lighting and start-up sequence is recommended [*see 6-5.2.1.3(r)*]. 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.

CAUTION: 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. It might be necessary to vary fuel header pressure to avoid excessive lighting-off and shutting down of burners. Such variations shall be limited to a predetermined range. This range is a function of the incremental fuel input that is added by the lighting of a single burner or gang of burners.

(q) In accordance with the requirements of 6-5.1, it is preferable to commit the maximum number of burners consistent with the anticipated continuous load and with the range of fuel header pressures specified in 6-5.2.1.3(p).

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

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 suitable 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.

6-5.2.2 Normal Operation.

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 normal 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.

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.

6-5.2.2.2 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.

6-5.2.2.3 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.

6-5.2.2.4 The burner fuel and airflow shall be maintained within a range between the maximum and minimum limits specified by the boiler manufacturer or, preferably, as determined by trial. These trials shall test for minimum load and for stable flame as follows:

(a) With all burners in service and combustion control on automatic; and

(b) With different combinations of burners in service and combustion control on automatic.

Where changes occur to the minimum and maximum limits because of various burner combinations and fuel conditions, retesting shall be required.

6-5.2.2.5 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.

6-5.2.2.6 Total airflow shall not be reduced below the purge rate.

6-5.2.3 Normal Shutdown.

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.

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 start-up practices.

Exception: Where designed for start-up and shutdown procedures, the metering combustion control shall not be required to be taken out of service.

6-5.2.3.3 The reverse procedure of that used during start-up shall be followed for normal shutdown. As the load is reduced, a sequential shutdown of the burners shall be accomplished by closing the individual burner safety shutoff valves and opening the vent valves.

6-5.2.3.4 The last burner or group of burners shall be taken out of service by tripping the main safety shutoff valve.

6-5.2.3.5 All atmospheric vent valves shall be opened to minimize the possibility of gas leaking into the boiler enclosure.

6-5.2.3.6 When all burners and igniters have been removed from service, the purge rate airflow shall be verified and a unit purge shall be performed.

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, consideration shall be given to maintaining airflow through the unit to prevent accumulation of combustible gases. Leakage of main or igniter fuel into the furnace or windbox shall be prevented.

6-5.2.4 Normal Hot Restart.

6-5.2.4.1 When restarting a hot unit, the requirements of 6-5.2.1.1(f) through (m) for a cold start shall be met.

6-5.2.4.2 The starting sequence in 6-5.2.1.3 shall be followed.

6-5.2.5 Emergency Shutdown—Master Fuel Trip.

6-5.2.5.1 An emergency shutdown shall initiate a master fuel trip.

6-5.2.5.2 A master fuel trip that results from any of the emergency conditions tabulated in Tables 6-5.2.5.2(a) and (b) shall stop all fuel flow to the furnace 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 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.

Table 6-5.2.5.2(a) Mandatory Automatic Master Fuel Trips
(See Sections 5-4 and 6-6)

A master fuel trip shall result from any of the following conditions:

(a) Fuel pressure at the burner below the minimum established by the manufacturer or by trial; where fuel pressure at the burner is not measurable, a low gas pressure trip shall be provided upstream of the control valve;

(b) Total airflow drops below the purge rate by 5 percent full-load airflow;

(c) Loss of either all induced draft fans or all forced draft fans;

(d) Loss of all flame;

(e) Partial loss of flame sufficient to introduce a hazardous accumulation of unburned fuel [*see 6-6.3.1.1(d)6*];

(f) Furnace pressure exceeds the normal operating pressure by a value specified by the manufacturer;

(g) Last individual burner safety shutoff valve closed;

(h) High fuel gas pressure.

Table 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:

(a) Loss of energy supply for boiler control, burner management, or interlock systems;

(b) Furnace negative pressure exceeds the value specified by the manufacturer. (*See also Chapter 5.*)

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 above the purge rate, it shall be permitted to be decreased gradually to the purge rate for a post-firing 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 post-firing unit purge.

6-5.2.5.4 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 avoid excessive positive or negative furnace pressure transients 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 Chapter 5. The airflow shall be increased gradually to the purge rate and a post-firing unit purge shall be completed.

6-5.2.5.5 Action following the purge after an emergency shutdown (*see 6-5.2.5.3 and 6-5.2.5.4*) shall be in accordance with the following:

(a) The unit shall be shut down in accordance with 6-5.2.3.7; or

(b) If the purge following an emergency shutdown is performed at the purge rate and the conditions of 6-5.2.1.1(f) through (m) and 6-5.2.1.3(c) and (d) are satisfied, a relight in accordance with 6-5.2.1.3(f) through (t) shall be permitted.

6-5.3 Emergency Conditions Not Requiring Shutdown or Trip.

6-5.3.1 Many unit installations include multiple induced draft fans or forced draft fans, or both. In the event of a loss of a fan or fans, the control system shall be capable of reducing the fuel flow to match the available airflow; otherwise, tripping of the unit is mandatory.

6-5.3.2 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; or, if fuel flow cannot be reduced, the airflow shall be increased slowly until the proper air/fuel ratio has been restored.

NOTE: 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.

6-5.4 General Operating Requirements—All Conditions.

6-5.4.1 Prior to starting a unit, action shall be taken to prevent fuel from entering the furnace.

6-5.4.2 The unit shall be purged prior to starting a fire in the furnace.

6-5.4.3 The igniter for the burner always shall be used. Burners shall not be lighted using a previously lighted burner or from hot refractory.

6-5.4.4 Where operating at low capacity, the burner fuel pressure shall be maintained above minimum by reducing the number of burners in service as necessary.

6-5.4.5 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 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 airflow is maintained, nor does it preclude the use of air heater sootblowers during start-up.

6-5.4.6 Before maintenance is performed on the gas header, the header shall be purged. [*See Section 6-2(g).*]

6-6 Interlock System.

6-6.1 General. The basic requirement of an interlock system for a unit is that it protect personnel from injury and also protect the equipment from damage. The interlock system functions to protect against improper boiler operation by limiting actions to a prescribed operating sequence or by initiating trip devices when approaching an undesirable or unstable operating condition. The interlock system shall comply with Section 4-3.

6-6.1.1 The mandatory automatic trips specified in 6-6.3.1 represent that portion of automatic trips for which sufficient experience has been accumulated to demonstrate a high probability of successful application for all units. The use of additional automatic trips, while not mandatory, is recommended. (*Also see 2-3.3 and A-2-3.3.*)

6-6.1.2 It is possible to achieve 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 interlock system.

6-6.2 Functional Requirements.

6-6.2.1 The operation of any interlock that causes a trip shall be annunciated.

6-6.2.2 An interlock system shall be of sound design and shall be properly installed, adjusted, and tested to confirm design function and proper timing. Periodic testing and maintenance shall be performed to keep the interlock system functioning properly.

6-6.2.3 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 proper sequence when the safety of personnel or equipment is jeopardized.

(c) The initiating cause of the trip shall be indicated and no portion of the process shall be started until proper conditions are established.

(d) The necessary trip devices shall be coordinated into an integrated system.

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

(f) The design shall retain as much flexibility with respect to alternate modes of operation as is consistent with good operating practice.

(g) Proper preventive maintenance shall be provided.

(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. Other means shall be substituted to supervise this interlock function.

(i) 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:

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

(b) Tripping set points are protected from unauthorized changes; and

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

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

6-6.2.4 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 suitable adjustment, each path and the complete system shall be tested to demonstrate the adequacy of adjustment for that furnace.

6-6.3 System Requirements.

6-6.3.1 Interlocks. See Figure 6-6.3.1.1.

6-6.3.1.1 Figure 6-6.3.1.1 shows the required system of interlocks that provides the basic furnace protection for a natural gas-fired multiple burner boiler operated in accordance with this standard.

(a) Block 1 shows loss of an individual igniter flame, which shall be interlocked to accomplish the following:

1. Close the individual igniter safety shutoff valve(s) and deenergize the spark(s);

2. Open the vent valve;

3. Signal the main flame protection system that the igniter flame has been lost.

(b) Block 2 represents conditions caused by improper igniter fuel header pressure, which shall be interlocked to initiate the tripping of the igniter header and individual igniter safety shutoff valves and to deenergize sparks. Where gas is used for ignition fuel, both high and low pressure shall be interlocked. Where oil is used, low pressure shall be interlocked.

(c) 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.

(d) Blocks 3 through 14 represent conditions that initiate the tripping of both the main and ignition fuel supply through a master fuel trip relay. The master fuel trip relay shall be of the type that stays tripped until the furnace purge system allows it to be reset, as shown at the bottom of Figure 6-6.3.1.1. Whenever the fuel trip relay is operated, it trips all safety shutoff valves and deenergizes sparks. The interlocks are as follows:

1. Blocks 3 through 7 represent protection against loss of large quantities of combustion air. The loss of all induced draft fans or all forced draft fans shall operate the master fuel trip relay. The loss of one induced draft fan or forced draft fan or other large loss of air shall reduce the fuel in order to maintain the proper air/fuel ratio. This function shall be permitted to be interlocked or made a part of the combustion control system. (*See Chapter 5 and 6-5.3.*)

2. Block 8 represents low combustion airflow below the permitted limits and is interlocked to activate the master fuel trip relay.

3. Excess furnace pressure (Block 9) also is interlocked with the master fuel trip relay to protect against abnormal furnace conditions, such as those resulting from a tube rupture or damper failure.

4. When the main burner header fuel pressure (Blocks 10a and 10b) is above the maximum or below the minimum for a stable flame, the master fuel trip relay shall be actuated. [*See Table 6-5.2.5.2(a), items (a) and (h).*]

5. Block 11 represents loss of all flame in the furnace and is interlocked to activate the master fuel trip relay.

6. Block 12 represents a partial loss of flame to the extent that hazardous conditions could develop irrespective of, or due to the failure of, other protective interlocks. It is potentially more hazardous at lower load levels. The decision regarding specific requirements or implementation of this trip shall 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 to activate the master fuel trip.

7. Block 13 represents an interlock operation when all fuel inputs to the furnace are shut off following a shutdown of the boiler for any reason. This necessitates the use of the purge sequence before the fuel supply can 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." (*See Figure 6-6.3.1.1.*)

8. Block 14 represents a manual switch that can be used by the operator in an emergency to actuate the master fuel trip relay. The manual trip switch shall actuate the master fuel trip relay directly.

(e) Block 15 represents loss of flame at an individual burner with one or more additional burners operating with stable flames but does not introduce a serious enough condition to warrant a master fuel trip as called for in 6-6.3.1.1(d)6 (Block 12). This trip is interlocked to 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, see 6-5.2.1.3(s).*]

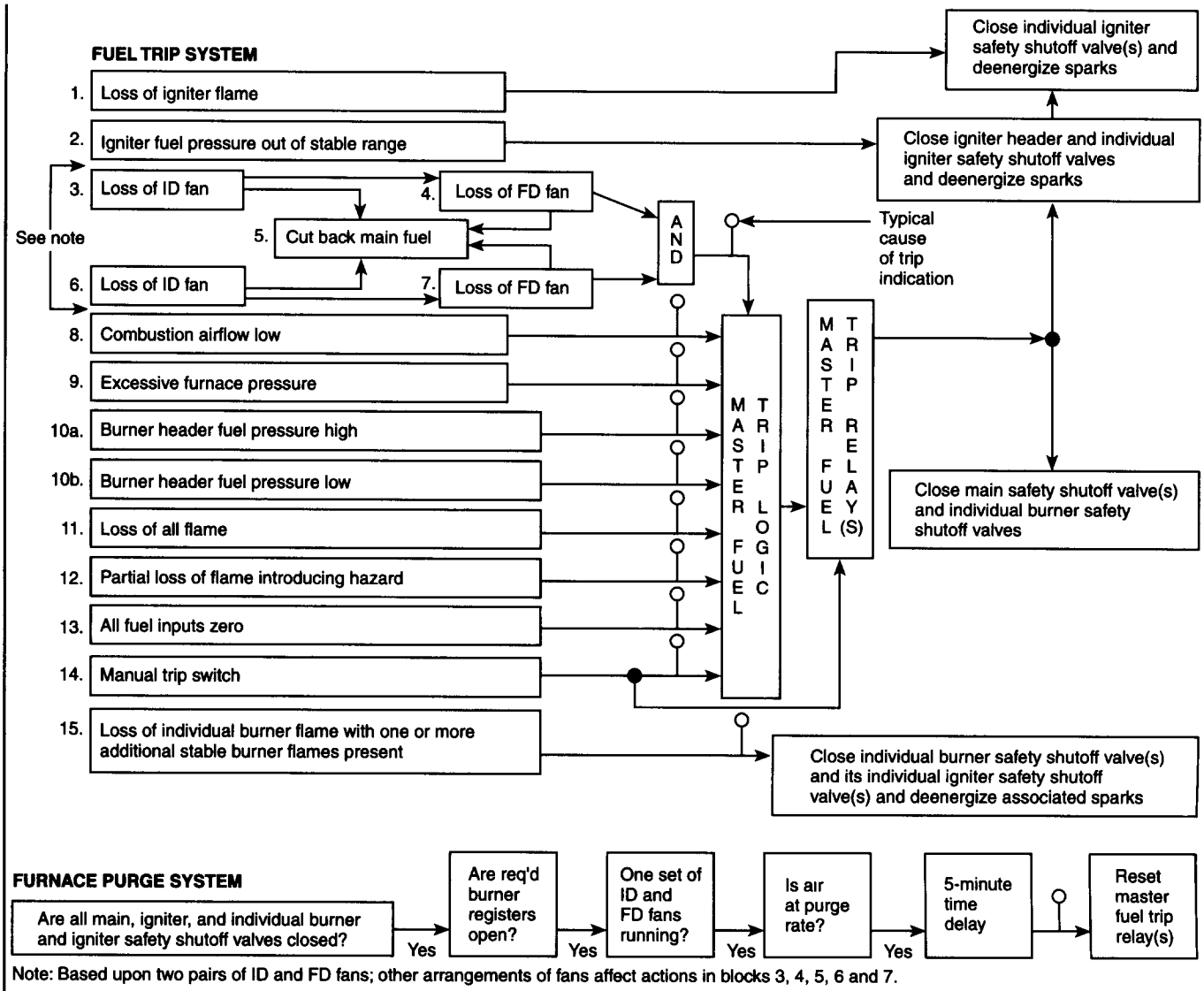


Figure 6-6.3.1.1 Interlock system for natural gas-fired multiple burner boiler.

6-6.3.1.2 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.

6-6.3.1.3 The proper starting sequence shall be supervised by a series of permissive interlocks shown in Figure 6-6.3.1.1 as the furnace purge system. All requirements of this system shall be satisfied before the ignition system can be energized by resetting the master fuel trip relay. This ensures that a unit purge has been completed with all required burner registers in purge position and all safety shutoff valves closed before the master fuel trip relay can be reset and the light-off sequence can be started. Completion of the purge shall be indicated.

6-6.3.1.4 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.

6-7 Alarm System.

6-7.1 Functional Requirements.

6-7.1.1 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 abnormal conditions that pose a threat of impending or immediate hazards.

6-7.1.2 Alarm systems shall be designed so that, for the required alarms in 6-7.2, the operator receives audible and visual indication of the abnormal condition. Means shall be permitted to silence the audible alarm after actuation, but the visual indication shall continue until the condition has been returned to normal.

6-7.1.3 The design shall make it difficult to manually defeat the alarm, and, where equipment malfunction makes defeat

necessary, it shall be performed by authorized personnel and the alarm shall be tagged as inoperative.

6-7.2* Required Alarms. In addition to the trip alarms in the interlock system shown in Figure 6-6.3.1.1, the separately annunciated alarms in 6-7.2(a) through (n) shall be provided.

(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, main fuel control, and main safety shutoff valves as practicable. This shall warn the operator of unusual pressure conditions that might result in damage to equipment or indicate a complete loss of gas supply.

(b) *Fuel Gas Burner Header Pressure (High and Low).* The burner header gas pressure shall be monitored as close to the burners as practicable in order to warn the operator of abnormal fuel pressures in advance of trip conditions.

(c) *Fuel Gas Meter Pressure (High and Low).* The fuel gas meter pressure shall be monitored at the upstream tap if the fuel gas flow meter is part of the combustion control system and is not pressure compensated. This shall warn the operator that significant error is present in the flow signal to the control system.

(d) *Ignition Fuel Header Pressure (High and Low).* The ignition fuel header pressure shall be monitored as close to the burners as practicable in order to warn the operator of high or low pressure in advance of conditions that lead to a trip.

(e) *Furnace Pressure (High).* This shall be measured near the normal furnace pressure tap location. It shall warn the operator of a pressure in excess of normal operation and of an approach to trip conditions.

(f) *Furnace Draft (High).* This applies to balanced draft furnace operation. It shall be measured near the normal furnace draft tap location. It shall warn the operator of a draft in excess of normal operation and of an approach to trip conditions.

(g) *Loss of Operating FD Fan.* This shall be sensed and alarmed only when the fan is not operating when expected.

(h) *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.

(i) *Furnace Airflow (Low).* This shall be sensed and alarmed when total airflow falls below purge rate.

(j) *Loss of Interlock Power.* This shall be sensed and alarmed and shall include all sources of power necessary to complete interlock functions. For example, if both a 125-volt DC electric circuit and a compressed air circuit are needed for an interlock scheme, loss of either circuit shall be annunciated separately.

(k) *Loss of Control Power.* This shall be sensed and alarmed to include any sources of power for the control systems.

(l) *Loss of Flame.* A partial or total loss of flame envelope still receiving fuel shall be monitored and alarmed so that it can be determined if a hazardous condition exists in the furnace.

(m) *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.

(n) *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 safe operating point. (*See A-6-7.2 for recommended alarms and monitors in addition to those that are required.*)

6-8 Boiler Front Control (Supervised Manual).

6-8.1 General. Section 6-8 shall not apply to new construction. Section 6-8 shall apply only to existing boilers with boiler front control and to the alteration of manual boilers.

6-8.1.1* 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 shall be required, as this is subject to factors such as the physical size of units, use of central control rooms, degree of reliability required, and availability of experienced operating personnel. All devices shown in Figures A-6-8.1.1(a) and (b) and discussed in the text shall be required.

This section defines and specifies the requirements of the operating system that shall be used under the following conditions:

(a) A trained operator shall be in constant attendance.

(b) The start-up or normal shutdown of any burner shall be accomplished by an operator at the burner locations.

(c) The operator shall have direct visual access to view the furnace.

(d) Suitable equipment shall 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 A-6-8.1.1(a) and (b) for minimum recommended equipment.*]

6-8.1.2 System Description. This operating system is defined as "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 shall be provided with and shall operate the system in accordance with a written set of operating instructions for each boiler unit.

6-8.1.3 Fundamental Principles. The written instructions shall include, but shall not be limited to, the following:

(a) The airflow rate shall be adjusted to purge the airflow and purge the unit.

(b) The purge airflow rate shall be maintained continuously from purge initiation through the light-off cycle. If the airflow is not maintained, the prefiring cycle shall be repeated.

(c) If flame on the first igniter is not established within 10 seconds, the individual igniter safety shutoff valve shall be closed and the cause of failure to ignite shall be determined and corrected. With airflow maintained at the purge rate, repurge shall not be required, but at least 1 minute shall elapse before attempting a retrial.

(d) The operator shall 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 shall occur.

(e) After each stable main burner flame is established, the igniter shall be shut off unless classified as Class 1 or Class 2. The stability of the main burner flame shall be verified.

(f) Burner(s) shall be lighted only from their associated igniter(s).

(g) The operator shall 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 shall 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 shall 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 shall elapse before the next light-off is attempted.

(j) If a second or succeeding main burner flame is not established, the operator shall 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 shall elapse before attempting to light this or any other igniter.

(k) Operation at less than 25 percent of load shall be 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 shall be given recognition, and low water level in the steam drum shall be monitored and alarmed. Consideration shall be given to interlock tripping.

Exception: For direct electric (Class 3 Special) igniters, 6-8.1.3(c) and (i) shall not apply.

6-8.1.4 Interlocks, Master Fuel Trip. Any of the following conditions shall initiate a master fuel trip with first-out annunciation (*see 6-6.2.3*):

(a) High fuel supply pressure;

(b) 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, a low fuel pressure trip shall be provided upstream of the control valve;

(c) Loss of all forced draft fans;

(d) Loss of all induced draft fans, if applicable;

(e) Operation of the emergency trip switch by the operator;

(f) Loss of all flame;

(g) Loss of control energy if fuel flow to burners is affected in such an event.

6-8.1.5 Loss of Individual Burner or Igniter Flame.

(a) Loss of flame at an individual igniter shall cause the igniter individual safety shutoff valve to close and the associated sparks to deenergize.

(b) Loss of flame at an individual burner shall cause the burner individual safety shutoff valve to close.

(c) The conditions of 6-8.1.5(a) and (b) shall be indicated.

(*See A-6-7.2 for recommended alarms in addition to those that are required.*)

6-8.2 Operating Cycle. The following operating sequences are based on a typical system. Certain provisions and sequences shall not apply where other systems are used. However, the principles outlined in these sequences shall be followed, and all applicable interlocks, trips, alarms, or their equivalents shall be provided.

6-8.2.1 Prefiring Cycle. The following steps shall be taken by the operator when starting a supervised manual unit, and the required interlocks shall be satisfied at each step. Control system energy, power and water level, and fuel supply shall be established. Furnace and gas passages shall be inspected to determine if in good repair. Prior to start-up, it shall be determined that the unit and its associated systems are evacuated of all personnel and all access and inspection doors are closed.

Operator Actions[1] [*See Figures A-6-5.1.2(a) and (b).*]	**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 6-8.1.3 (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 required if airflow rate drops below purge rate prior to initiation of light-off cycle.

[1] Certain actions are not necessarily performed in the order shown.

6-8.2.2 Light-Off Cycle—First Igniter. This cycle shall follow prefiring immediately, with all required interlocks satisfied. The open register procedure purge shall be followed during the light-off procedure. (*See 6-5.1.3, 6-5.1.4, and 6-5.1.5.*)

Operator Actions [*See Figures A-6-5.1.2(a) and (b).*]	**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) Confirm manual main atmospheric vent valve is open;	(c) None;

(d) Energize igniter for first burner. For direct electric ignition, omit 6-8.2.2(e) and proceed directly to 6-8.2.4(d);	(d) Prove flame within 10 seconds. If flame is not proved, safety shutoff valves for this igniter shall close and spark shall be deenergized;
(e) If ignition flame is not established, determine cause and make necessary corrections. Burner register shall be opened to purge position for at least 1 minute before repeating light-off cycle.	(e) None.

6-8.2.3 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 6-8.2.3(c) and proceed directly to 6-8.2.4(d);	(b) Prove flame within 10 seconds. If flame is not proved, safety shutoff valves for this igniter shall close and spark shall be deenergized;
(c) If igniter flame is not established, determine cause and make necessary corrections. Burner register shall be opened to purge position for at least 1 minute before repeating light-off cycle.	(c) None.

6-8.2.4 Light-Off Cycle—First Main Burner.

Operator Actions [*See Figures A-6-5.1.2(a) and (b).*]	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 6-8.2.1*);	(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 shall be removed from service; visually confirm main flame stability.	(k) None.

6-8.2.5 Light-Off Cycle for Subsequent Main Burners at Light-Off Fuel Pressure. This cycle shall be performed after the igniter flame for the burner has been proved and fuel pressure is controlled by the main fuel bypass control valve.

Operator Actions [*See Figures A-6-5.1.2(a) and (b).*]	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 6-8.2.3 and 6-8.2.5;	(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 shall be removed from service; visually confirm main flame stability.	(h) None.

6-8.2.6 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.

Operator Actions [*See Figures A-6-5.1.2(a) and (b).*]	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 6-8.2.6(a);	(b) None;
(c) Energize igniter; for direct electric igniters, omit 6-8.2.6(d);	(c) Prove flame within 10 seconds. If flame is not proved, safety shutoff valves for this igniter shall close and spark shall 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 6-8.2.6(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 shall 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.

6-8.2.7 Normal Shutdown Cycle.

Operator Actions [*See Figures A-6-5.1.2(a) and (b).*]	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 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) 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 shall cause main safety shutoff valve to close. Main atmospheric vent valve shall open;
(c) Perform a unit purge;	(c) None;
(d) Shut down fan(s), if required.	(d) Loss of airflow interlock is actuated.

6-8.2.8 Emergency Shutdown.

(a) An emergency shutdown shall initiate a master fuel trip.

(b) For the conditions that shall initiate an emergency shutdown, see 6-8.1.4.

6-8.2.9 Operator Actions Following an Emergency Shutdown. [*See Figures A-6-5.1.2(a) and (b).*]

(a) All individual burner supervisory shutoff valves shall be closed. Burner register positions shall remain unchanged.

(b) The unit shall be purged in accordance with the following procedure:

1. Fans that are operating after the master fuel trip shall be continued in service.

2. Airflow shall not be increased immediately by deliberate manual or automatic control action.

3. If the airflow is above purge rate, it shall be permitted to be decreased gradually to this value and a post-firing unit purge shall be performed.

4. If the airflow is below purge rate at the time of the trip, it shall be continued at the existing rate for 5 minutes and then increased gradually to purge rate and held at this value for a post-firing 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 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 avoid excessive positive or negative furnace pressure transients during fan coast-down. This condition shall be maintained for not less than 15 minutes. At the end of this period, the flow control dampers shall be closed and the fan(s) shall be started immediately. Airflow shall be increased gradually to at least purge rate.

(d) The cause of emergency shutdown shall be determined and corrected.

(e) The first igniter light-off cycle (*see 6-8.2.2*) shall be performed if restart of unit is required.

(f) If it is desired to remove the boiler from service for a period of time, fans shall be shut down on completion of unit purge and manual shutoff valves shall be closed.

6-8.2.10 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.

6-9 Two-Burner Systems—Single Fuel Flow Control.

6-9.1 Fundamental Principles.

6-9.1.1 This section provides special design and operating requirements for 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. These boilers are subject to hazardous air/fuel ratio upsets at either burner during light-off, fuel transfer, and when one of the two burners automatically trips during operation.

6-9.1.2 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.

6-9.1.3 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. [*See NFPA 8501, Standard for Single Burner Boiler Operation, and 6-5.2.1.3(s).*]

6-9.2 System Requirements.

6-9.2.1 The following control system design options shall be provided in order to maintain a proper air/fuel ratio on one burner in the event of an automatic trip of the other burner.

6-9.2.1.1 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. The result of this operation is that the remaining operating burner maintains the proper air/fuel ratio after the fuel is shut off to the failed 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 maximum firing rate or the air/fuel ratio limits of the burner.

6-9.2.1.2 The automatic recycling mode of operation shall be prohibited.

6-9.2.2 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) It might be necessary to operate a boiler on one burner with the air supply closed off to the other burner. If it then becomes necessary to light the second burner, care shall be used to avoid creating a hazardous air/fuel ratio at the first operating burner. The following general procedures shall be followed to avoid 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 of 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, proper 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, 6-9.2.2(e) shall not apply. Total boiler airflow shall be maintained so that the operating burner has the proper air/fuel ratio.

6-9.3 Fuel Transfer Procedure. An operating procedure, either manual or automatic, shall be followed that prevents a hazardous air/fuel ratio at either burner when making a fuel transfer. The following procedure shall be followed:

Total fuel and airflow shall be reduced to within the 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 6-9.2.2(e).

Chapter 7 Fuel Oil Systems

7-1* General. This chapter contains additional requirements to be followed where burning fuel oil.

7-2* Oil Firing—Special Problems. Common hazards are involved in the combustion of solid, liquid, and gaseous fuels. Each of these fuels has special hazards related to its physical characteristics. The following factors shall be considered in the design of the firing systems:

(a) Fuel oils have high volumetric heats of combustion; therefore, even small leaks can create potential fire hazards.

(b) Where firing oils that need preheating, the viscosity of oil flowing to the burners shall be held within limits to maintain proper atomization.

(c) Water or sludge in fuel oil storage tanks or improperly located suction takeoffs from the storage tank could result in hazardous interruptions or pulsations of the fuel supply to the burners. A flameout, either immediately or later, could result due to plugged strainers or burner tips.

(d) Widely different characteristics of fuel oil from either a single source or multiple sources could result in a significant change in Btu 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 as described in A-7-1 and A-7-2.

(e) On installations designed to fire both heated and unheated fuel oils, consideration shall be given to the design of the burner control system to ensure proper interlocks are activated for the selected fuel oil. Similar consideration shall 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.

(f) There is the ever-present hazard of inserting an oil gun in the burner assembly without a tip, new gaskets, or sprayer plate. This can result in an unsafe operating condition.

(g) 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. Very close attention shall be given to the design and operation of viscosity control systems for each fuel where the source or properties are variable.

(h) Clear distillate fuels have low conductivities 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, Recommended Practice for Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents.*)

(i) The incompressibility of fuel oil can create very rapid transients in oil flow through operating burners under the following conditions:

1. The rapid operation of an oil supply valve;
2. The rapid operation of individual burner shutoff valves;
3. The rapid operation of a regulating valve in the return oil line from the burner header (on systems using this type of control).

(j) Operation of air heater sootblowers shall 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.

7-3 System Requirements.

7-3.1 Fuel Supply Subsystem, Fuel Oil. See Figures A-7-5.1.2(a) and (d).

7-3.1.1 The fuel supply equipment shall be sized and arranged to ensure a continuous fuel flow adequate 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 prevent fuel pressure transients that might result in exceeding burner limits for stable flame as a result of placing burners in or taking them out of service.

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 shall be provided. Adequate drains shall be provided.

7-3.1.3 Fill and recirculation lines to storage tanks shall discharge below the liquid level to avoid free fall, which might generate static electrical charges as well as increase vaporization.

7-3.1.4 Adequate strainers, filters, traps, sumps, and other such items shall be provided to remove harmful contaminants where practicable; compensation for those materials not removed shall be provided by special operating and maintenance procedures. 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.

7-3.1.5* The fuel supply equipment shall be designed with careful consideration of operating environment and ambient conditions including severe external conditions such as fire or mechanical damage. Special attention shall be given to such factors as routes of piping and valve locations to minimize exposure to possible explosion hazard or to high temperature or low temperature sources.

7-3.1.6 As much of the fuel supply subsystem as practicable shall be located outside of the boiler house. A manual emergency shutoff valve shall be provided that is accessible in the event of fire in the boiler area.

7-3.1.7 Means shall be provided to prevent or relieve excess pressure from expansion of entrapped oil in the fuel system. This is especially important for crude oil.

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. This piping might need to be heat traced.

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*, and ANSI B31.1, *Power Piping*.

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 proper temperature. The use of interface fluids or sealing diaphragms might be necessary with this instrumentation.

7-3.1.11 Positive means to prevent leakage of oil into an idle furnace shall be provided.

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 and ready means for making easy, accurate periodic tightness tests of the main safety shutoff valves and individual burner safety shutoff valves.

7-3.1.13 Fuel oil shall be delivered to the burners at the proper temperature and pressure as recommended by the burner manufacturer to ensure that the oil is at the viscosity necessary for proper atomization.

7-3.1.14 If heating of oil is necessary, it shall be accomplished without contamination or coking.

7-3.1.15 Adequate 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.

7-3.1.16 Positive means shall be provided to prevent fuel oil entering the burner header system through recirculating valves, particularly from the fuel supply system of another boiler [*see also 7-6.3.1.1(e)*]. Check valves for this function have not proven dependable in heavy oil service.

7-3.1.17 Provisions shall be included for clearing (scavenging) the passages of an atomizer that leads into the furnace. (*See 7-5.2.3.3, 7-5.2.5.7, and 7-5.4.5.*)

7-3.2 Main Burner Subsystem.

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. 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. In these circumstances, Class 1 or Class 2 igniters, as demonstrated by test, shall be permitted to be used to maintain stable flame. (*See 7-3.2.2 and 7-3.2.3.*)

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. 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. These tests shall include the expected range of available fuels.

7-3.2.3 Where Class 1 and Class 2 igniters are used, the tests described in 4-2.3.2(d)1, 4-2.3.2(d)2, and 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 available where Class 1 igniters are in service and flames proved.

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.

7-3.2.5 Provisions shall be made for cleaning of the burner nozzle and tip.

7-3.2.6 The burner equipment shall be located in an appropriate environment with convenient access for maintenance. Special recognition shall be given to the fire hazards imposed by leakage or rupture of piping near the burner. Particular attention shall be given to the integrity of flexible hoses or swivel joints. The requirements of good housekeeping shall be followed.

7-3.2.7 All burner safety shutoff valves shall be located as close to the burner as practicable to minimize the volume of oil left downstream of the burner valves in the burner lines or that flow by gravity into the furnace on an emergency trip or burner shutdown.

7-3.3 Atomizing Subsystem.

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, adequate insulation and traps shall be included to ensure dry atomizing steam to the burners.

7-3.3.2 The atomizing medium shall be provided and maintained at the pressure necessary for proper operation.

7-3.3.3 Provisions shall be made to ensure that fuel cannot enter the atomizing medium line during or after operation.

7-3.3.4 The atomizing subsystem shall be designed for convenient cleaning and maintenance.

7-4 Flame Monitoring and Tripping System.

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.

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.

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.

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.

7-4.2 Upon detection of loss of all flame in the furnace or partial loss of flame to the extent that hazardous conditions could develop, a master fuel trip shall be automatically initiated. [*See 7-6.3.1.1(e)9.*]

7-4.3 It is recognized that any fuel input that does not ignite and burn on a continuous basis creates 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 potential hazard.

7-4.4 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 similar size and arrangement, including burners/nozzles of substantially the same capacity using similar fuels. These tests shall not be used to replace acceptance tests relating to proof of design, function, and components.

7-5 Sequence of Operations. For supervised manual systems, see Section 7-8.

7-5.1 General.

7-5.1.1 Sequencing shall be required to ensure that operating events occur in the proper order. Sequencing shall provide procedures that allow properly prepared fuel to be admitted to the burners only when there is sufficient ignition energy and proper airflow to ignite the fuel as it enters the furnace. Sequencing also shall be utilized where removing burners from operation.

7-5.1.2* Sequences of operation are based on the typical fuel supply system shown in Figures A-7-5.1.2(a) through (d). These sequences shall be followed whether the unit is operated manually or certain functions are accomplished by interlocks or automatic controls. Different arrangements shall be permitted if they provide equivalent protection and meet the intent of the operating sequences specified in this chapter.

7-5.1.3 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 is to ensure an air-rich furnace atmosphere during start-up. It also establishes minimum velocities through the furnace to prevent hazardous accumulations of unburned fuel.

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 that ensure proper light-off.

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:

(a) Raise the boiler pressure and temperature.

(b) Carry the initial load on the unit.

7-5.1.4.2 If some registers have been maintained in the closed position, these 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.

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 is based upon the concept that the following basic operating conditions significantly improve the margin of operating safety, particularly during start-up. These conditions include:

(a) Use of a minimum number of required equipment manipulations, thereby minimizing exposure to operating errors or equipment malfunction;

(b) The desired fuel-rich condition at individual burners during light-off;

(c) 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.

7-5.1.5.1 This procedure shall incorporate the following operating objectives:

(a) All or most of the registers shall be placed in a predetermined open position.

(b) A unit purge shall be completed with the burner air registers in the position specified in 7-5.1.5.1(a).

(c) 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 into service, whichever is longer.

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

(e) The first burner or group of burners shall be lighted without any change in the airflow setting or in the burner air register position.

7-5.1.5.2 Each boiler shall be tested during initial start-up to determine whether any modifications to the procedure specified in 7-5.1.5 are required in order to obtain satisfactory ignition or to satisfy other design limitations during light-off and warm-up. For example, some boilers are purged with the registers in the normal operating position. In this instance, it might be necessary to close the registers of the burner being lighted momentarily to establish ignition. However, unnecessary modifications in the basic procedure shall be avoided, particularly that of 7-5.1.5(a), thereby satisfying the basic objectives in 7-5.1.5.1.

7-5.1.6 Modification to the mode of operation resulting from improper water, steam, and flue gas temperatures in the economizers and superheaters shall be made only after it has been determined to be necessary by operating experience.

7-5.2 Functional Requirements.

7-5.2.1 Cold Start.

7-5.2.1.1 Preparation for starting shall include a thorough inspection that shall verify the following:

(a) The furnace and gas passages are in good repair and free of foreign material.

(b) The bottom of the furnace, including ash hopper, is free of accumulations of liquid fuel, gases, or vapors. Such an inspection is particularly important for a cold start where the fuel burned prior to shutdown contained volatile vapors heavier than air. The possibility of such accumulations shall be considered prior to each start-up.

(c) All personnel are evacuated from unit and associated equipment and all access and inspection doors are closed.

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

(f) All safety shutoff valves are closed. All sparks are deenergized.

(g) For gas ignition systems, see Chapter 6.

(h) The circulating valves are open to provide and maintain hot oil in the burner headers.

(i) 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.

(j) The burner guns are checked for proper tips or sprayer plates. [*See Section 7-2(f).*]

(k) The burner elements and igniters are positioned in accordance with the manufacturer's specification.

(l) Energy is supplied to control system and to safety interlocks.

(m) The meters or gauges indicate fuel header pressure to the unit.

(n) The oxygen analyzer(s) and combustibles analyzer(s), if provided, are operating satisfactorily and a sample has been obtained. Combustibles indication is at zero and oxygen indication is at maximum.

(o) A complete functional check of the safety interlocks has been made after an overhaul or other significant maintenance.

(p) A complete, periodic, operational test of each igniter has been made. The frequency of testing depends on the design and operating history of each individual boiler and ignition system. As a minimum, the test shall be made during each start-up following an overhaul or other significant maintenance. The test shall be integrated into the starting sequence and shall follow the purge and precede the admission of any main fuel.

(q) 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 normal start-up or light-off position.

(r) Units with a history of igniter unreliability shall require additional test routines to verify the continuing operating ability of igniters and ignition system components. The importance of reliable igniters and ignition systems cannot be overemphasized.

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.

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, where appropriate, 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 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 7-5.1.5.

(d) The airflow shall be adjusted to purge airflow rate and a unit purge shall be performed. Special provisions might be 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 proper for good atomization. The circulating valve and throttle recirculating valve, if necessary, shall be closed to allow establishment of proper burner header pressure as specified in 7-5.2.1.3(g).

(f) The main fuel control valve shall be closed and the main safety shutoff valve(s) shall be opened. (*See Section 7-6 for permissive conditions in the furnace purge system that shall be satisfied before this can be accomplished.*)

(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 recommended fuel pressure for proper igniter capacity.

(i) The air register or damper on the burner selected for light-off shall be adjusted to the position recommended by the manufacturer. (*See 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 any 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 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 appropriate 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 satisfactory 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 for proper 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 normal 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 [*see 7-5.2.1.3(l)*]. 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 proper associated interlocks.

(o) The procedures of 7-5.2.1.3(i) through (n) shall be followed where placing additional burners with open registers into service, as necessary, to raise 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 [*see 7-5.2.1.3(r)*]. The fuel flow to each burner 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.

CAUTION: 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. It might be necessary to vary fuel header pressure to avoid 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 suitable 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) In accordance with the requirements of 7-5.1, it is preferable to commit the maximum number of burners consistent with the anticipated continuous load and with the range of fuel header pressures specified in 7-5.2.1.3(o).

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

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 suitable 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.

7-5.2.2 Normal Operation.

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 normal air/fuel ratio 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.

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.

7-5.2.2.3 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.

7-5.2.2.4 The burner fuel and airflow shall be maintained within a range between the maximum and minimum limits specified by the boiler manufacturer or, preferably, as determined by trial. These trials shall test for minimum load and for stable flame as follows:

(a) With all burners in service and combustion control on automatic; and

(b) With different combinations of burners in service and combustion control on automatic.

Where changes occur to the minimum and maximum limits because of various burner combinations and fuel conditions, retesting shall be required.

7-5.2.2.5 On loss of an individual burner flame, that individual burner's safety shutoff valve shall be automatically closed. The burner register shall be closed if it interferes with the air/fuel ratio supplied to any other individual burner flame.

7-5.2.2.6 Total airflow shall not be reduced below the purge rate.

7-5.2.3 Normal Shutdown.

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.

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 start-up practices.

Exception: Where designed for start-up and shutdown procedures, the metering combustion control shall not be required to be taken out of service.

7-5.2.3.3 The shutdown procedures shall be the reverse of the start-up procedures and shall be accomplished by shutting down the burners sequentially as load is reduced. Each burner shall be shut down in the following sequence:

(a) The igniter shall be placed into service on the particular burner to be shut down.

(b) With the igniter in service, the burner safety shutoff valve shall be closed and the steam (or air) clearing valves shall be opened.

(c) The clearing steam (or clearing air) shall be left in service a sufficient length of time to remove all oil that could carbonize and plug the burner tip.

(d) The igniter shall be removed from service, and the oil gun shall be removed or retracted unless cooling is provided.

(e) 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.

7-5.2.3.4 As the load is reduced, the remaining burners shall be shut down sequentially as described in 7-5.2.3.3. The last burner shall not be scavenged.

Exception: Where associated Class I igniters are in use, the last burner shall be permitted to be scavenged.

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.

7-5.2.3.6 Where all burners and igniters have been removed from service, the purge rate airflow shall be verified and a unit purge shall be performed.

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, consideration shall be given to maintaining airflow through the unit to prevent accumulation of combustible gases. Leakage of main or igniter fuel into the furnace or windbox shall be prevented.

7-5.2.3.8 If fuel recirculation in the burner header is to be established, the following shall be completed:

(a) Confirmation that individual burner safety shutoff valves are closed and that flame is out on each burner;

(b) Confirmation that main safety shutoff valve is closed;

(c) Opening of circulating valve and recirculating valve.

7-5.2.4 Normal Hot Restart.

7-5.2.4.1 When restarting a hot unit, the requirements of 7-5.2.1.1(f) through (n) for a cold start shall be met.

7-5.2.4.2 The starting sequence in 7-5.2.1.3 shall be followed.

7-5.2.5 Emergency Shutdown—Master Fuel Trip.

7-5.2.5.1 An emergency shutdown shall initiate a master fuel trip.

7-5.2.5.2 A master fuel trip that results from any of the emergency conditions tabulated in Tables 7-5.2.5.2(a) and (b) shall stop all fuel flow to the furnace 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 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.

7-5.2.5.3 Clearing of oil passages into the furnace immediately following an emergency trip shall not be permitted.

7-5.2.5.4 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 post-firing 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 post-firing unit purge.

Table 7-5.2.5.2(a) Mandatory Automatic Master Fuel Trips (*see Sections 5-4 and 7-6*)

A master fuel trip shall result from any of the following conditions:

(a) Fuel and atomizing medium (if provided) to the burners outside operating limits necessary to accomplish proper atomization as established by trial or by the burner manufacturer.

(b) Total airflow drops below the purge rate by 5 percent full-load air-flow;

(c) Loss of either all induced draft; or all forced draft fans;

(d) Loss of all flame;

(e) Partial loss of flame sufficient to introduce a hazardous accumulation of unburned fuel; [*see 7-6.3.1.1(e)9*]

(f) Furnace pressure exceeds the normal operating pressure by a value specified by the manufacturer;

(g) Last individual burner safety shutoff valve closed.

Table 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:

(a) Loss of energy supply for boiler control, burner management, or interlock systems;

(b) Furnace negative pressure exceeds the value specified by the manufacturer. (*See also Chapter 5.*)

7-5.2.5.5 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 avoid excessive positive or negative furnace pressure transients 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 Chapter 5. The airflow shall be increased gradually to the purge rate and a post-firing unit purge shall be completed.

7-5.2.5.6 Action following the purge after an emergency shutdown (*see 7-5.2.5.4 and 7-5.2.5.5*) shall be in accordance with the following:

(a) The unit shall be shut down in accordance with 7-5.2.3.7, 7-5.2.3.8, and 7-5.2.5.6; or

(b) If the purge following an emergency shutdown is performed at the purge rate and the conditions of 7-5.2.1.1(f) through (n) and 7-5.2.1.3(c) and (e) are satisfied, a relight in accordance with 7-5.2.1.3(f) through (s) shall be permitted.

7-5.2.5.7 One burner (or group of burners) at a time shall be placed in service in a manner specified in 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.

7-5.3 Emergency Conditions Not Requiring Shutdown or Trip.

7-5.3.1 Many unit installations include multiple induced draft fans or forced draft fans, or both. In the event of a loss of a fan or fans, the control system shall be capable of reducing the fuel flow to match the available airflow; otherwise, tripping of the unit is mandatory.

7-5.3.2 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; or, if fuel flow cannot be reduced, the airflow shall be increased slowly until the proper air/fuel ratio has been restored.

NOTE: 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.

7-5.3.3 Burners with poor atomization shall be shut down. If a sufficient number are so affected as to introduce a hazardous condition, all fuel shall be tripped.

7-5.4 General Operating Requirements—All Conditions.

7-5.4.1 Prior to starting a unit, action shall be taken to prevent fuel from entering the furnace.

7-5.4.2 The unit shall be purged prior to starting a fire in the furnace.

7-5.4.3 The igniter for the burner always shall be used. Burners shall not be lighted using a previously lighted burner or from hot refractory.

7-5.4.4 Where operating at low capacity, the burner fuel pressure shall be maintained above minimum by reducing the number of burners in service as necessary.

7-5.4.5 Where clearing oil passages into the furnace, igniters shall be in service, with ignition established.

7-5.4.6* 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 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 airflow is maintained, nor does it preclude the use of air heater sootblowers during start-up.

7-5.4.7 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 defined limits, the individual burner safety valves shall be considered to be free of leaks. Leaks can develop in the oil valves due to temperature changes.

7-6 Interlock System.

7-6.1 General. The basic requirement of an interlock system for a unit is that it protect the personnel from injury and also protect the equipment from damage. The interlock system functions to protect against boiler operation by limiting actions to a prescribed operating sequence or by initiating trip devices when approaching an undesirable or unstable operating condition. The interlock system shall comply with Section 4-3.

7-6.1.1 The mandatory automatic trips specified in 7-6.3.1 represent that portion of automatic trips for which sufficient experience has been accumulated to demonstrate a high probability of successful application for all units. The use of additional automatic trips, while not mandatory, is recommended. (*Also see 2-3.3 and A-2-3.3.*)

7-6.1.2 It is possible to achieve 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 interlock system.

7-6.2 Functional Requirements.

7-6.2.1 The operation of any interlock that causes a trip shall be annunciated.

7-6.2.2 An interlock system shall be of sound design and shall be properly installed, adjusted, and tested to confirm design function and proper timing. Periodic testing and maintenance shall be performed to keep the interlock system functioning properly.

7-6.2.3 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 proper sequence when the safety of personnel or equipment is jeopardized.

(c) The initiating cause of the trip shall be indicated and no portion of the process shall be started until proper conditions are established.

(d) The necessary trip devices shall be coordinated into an integrated system.

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

(f) The design shall retain as much flexibility with respect to alternate modes of operation as is consistent with good operating practice.

(g) Proper preventive maintenance shall be provided.

(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. Other means shall be substituted to supervise this interlock function.

(i) 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:

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

(b) Tripping set points are protected from unauthorized changes; and

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

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

7-6.2.4 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 suitable adjustment, each path and the complete system shall be tested to demonstrate the adequacy of adjustment for that furnace.

7-6.3 System Requirements.

7-6.3.1 Interlocks. See Figure 7-6.3.1.1.

7-6.3.1.1 Figure 7-6.3.1.1 shows the required system of interlocks that provides the basic furnace protection for an oil-fired multiple burner boiler operated in accordance with this standard.

(a) Block 1 shows loss of an individual igniter flame, which shall be interlocked to accomplish the following:

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.

(b) Block 2 represents conditions caused by improper igniter fuel header pressure that shall be interlocked to initiate the tripping of the igniter header and individual igniter safety shutoff valves and to deenergize sparks. Where gas is used for ignition fuel, both high and low pressure shall be interlocked. Where oil is used, low pressure shall be interlocked.

(c) Where oil is used for ignition fuel with air or steam atomization, improper atomization of an igniter fuel is a condition that shall trip the igniter and individual igniter safety shutoff valves and deenergize sparks as indicated by Block 3.

(d) Where direct electric igniters are used, Blocks 1 through 3 shall not apply. However, the master fuel trip system shall deenergize sparks and prevent reenergizing until all conditions for light-off have been reestablished.

(e) Blocks 4 through 16 represent conditions that initiate the tripping of both the main and ignition fuel supply through a master fuel trip relay. The master fuel trip relay shall be of the type that stays tripped until the furnace purge system allows it to be reset, as shown at the bottom of Figure 7-6.3.1.1. Whenever the fuel trip relay is operated, it trips all safety shutoff valves, the circulating valve, and the recirculating valve and deenergizes sparks and all ignition devices within the unit and flue gas path. If the design of the fuel 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 interlocks are as follows:

1. Blocks 4 through 8 represent protection against loss of large quantities of combustion air. The loss of all induced draft fans or all forced draft fans shall operate the fuel trip relay. The loss of one induced draft fan or forced draft fan or other large loss of air shall reduce the fuel in order to maintain the proper air/fuel ratio. This function shall be permitted to be interlocked or made a part of the combustion control system. (*See Chapter 5 and 7-5.3.*)

2. Block 9 represents low combustion airflow below the permitted limits and is interlocked to activate the master fuel trip relay.

3. Excess furnace pressure (Block 10) also is interlocked with the master fuel trip relay to protect against abnormal furnace conditions such as those resulting from a tube rupture or damper failure.

4. Block 11 represents an interlock operation when all fuel inputs to the furnace are shut off following a shutdown of the boiler for any reason. This necessitates the use of the purge sequence before the fuel supply can 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." (*See Figure 7-6.3.1.1.*)

5. When the main burner header fuel pressure (Block 12) is below the minimum for a stable flame, the master fuel trip relay shall be actuated. [*See Table 7-5.2.5.2(a), item (a).*]

6. Block 13 represents operation of the master fuel trip relay to prevent an unsafe condition developing from improper atomization of the oil.

7. Block 14 represents a manual switch that can be used by the operator in an emergency to actuate the master fuel trip relay. The manual trip switch shall actuate the master fuel trip relay directly.

8. Block 15 represents loss of all flame in the furnace and is interlocked to activate the master fuel trip relay.

9. Block 16 represents a partial loss of flame to the extent that hazardous conditions could develop irrespective of, or due to the failure of, other protective interlocks. It is potentially more hazardous at lower load levels. The decision regarding specific requirements or the implementation of this trip shall 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.

(f) Block 17 represents loss of flame at an individual burner with one or more additional burners operating with stable flames but does not introduce a serious enough condition to warrant a master fuel trip as called for in 7-6.3.1.1(e)9 (Block 16). This trip is interlocked to 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, see 7-5.2.1.3(s).*]

7-6.3.1.2 Each source of operation of the master fuel trip relay shall actuate a "cause of trip" indication that informs the operator of the initiating cause of the tripping impulse.

7-6.3.1.3 The 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.

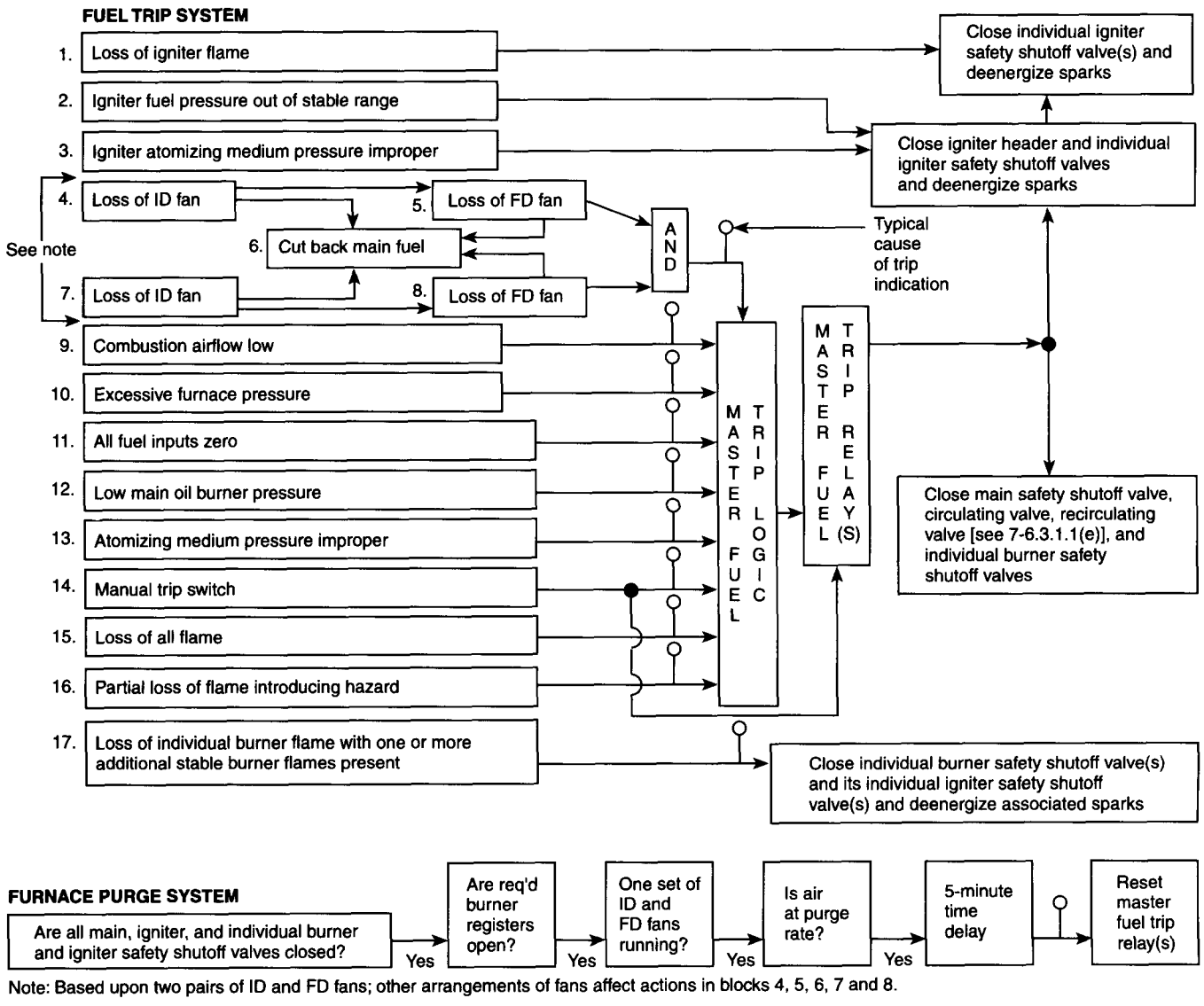


Figure 7-6.3.1.1 Interlock system for oil-fired multiple burner boiler.

7-6.3.1.4 The proper starting sequence shall be supervised by a series of permissive interlocks shown in Figure 7-6.3.1.1 as the furnace purge system. All requirements of this system shall be satisfied before the ignition system can be energized by resetting the master fuel trip relay. This ensures that a unit purge has been completed with all required burner registers in purge position and all safety shutoff valves closed before the master fuel trip relay can be reset and the light-off sequence can be started. Completion of the purge shall be indicated.

7-6.3.1.5 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.

7-7 Alarm System.

7-7.1 Functional Requirements.

7-7.1.1 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 abnormal conditions that pose a threat of impending or immediate hazards.

7-7.1.2 Alarm systems shall be designed so that, for the required alarms in 7-7.2, the operator receives audible and visual indication of the abnormal condition. Means shall be permitted to silence the audible alarm after actuation, but the visual indication shall continue until the condition has been returned to normal.

7-7.1.3 The design shall make it difficult to manually defeat the alarm, and, where equipment malfunction makes defeat necessary, it shall be performed by authorized personnel and the alarm shall be tagged as inoperative.

7-7.2* Required Alarms. In addition to the trip alarms in the interlock system shown in Figure 7-6.3.1.1, the separately annunciated alarms in 7-7.2(a) through (p) shall be provided.

(a) *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. The purpose is to warn the operator of unusual pressure conditions that might result in damage to equipment or to indicate a complete loss of supply.

(b) *Fuel Oil Burner Header Pressure (Low).* The burner header oil pressure shall be monitored as close to the burners as practicable in order to warn the operator of low pressure in advance of trip conditions.

(c) *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 could result. 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.

(d) *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 could result.

(e) *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 could result.

(f) *Ignition Fuel Header Pressure (High and Low).* The ignition fuel header pressure shall be monitored as close to the burners as practicable in order to warn the operator of high or low pressure in advance of conditions that lead to a trip.

Exception: For oil-fired igniters, only low ignition fuel header pressure shall be required be monitored.

(g) *Furnace Pressure (High).* This shall be measured near the normal furnace pressure tap location. It shall warn the operator of a pressure in excess of normal operation and of an approach to trip conditions.

(h) *Furnace Draft (High).* This shall apply to balanced draft furnace operation. It shall be measured near the normal furnace draft tap location. It shall warn the operator of a draft in excess of normal operation and of an approach to trip conditions.

(i) *Loss of Operating FD Fan.* This shall be sensed and alarmed only when the fan is not operating when expected.

(j) *Loss of Operating ID Fan.* This shall apply to balanced draft furnace operation. It shall be sensed and alarmed only when the fan is not operating when expected.

(k) *Furnace Airflow (Low).* This shall be sensed and alarmed when total airflow falls below purge rate.

(l) *Loss of Interlock Power.* This shall be sensed and alarmed and shall include all sources of power necessary to complete interlock functions. For example, if both a 125-volt DC electric circuit and a compressed air circuit are needed for an interlock scheme, loss of either circuit shall be annunciated separately.

(m) *Loss of Control Power.* This shall be sensed and alarmed to include any sources of power for the control systems.

(n) *Loss of Flame.* A partial or total loss of flame envelope still receiving fuel shall be monitored and alarmed so that it can be determined if a hazardous condition exists in the furnace.

(o) *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.

(p) *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 safe operating point. (*See A-7-7.2 for recommended alarms and monitors in addition to those that are required.*)

7-8* Boiler Front Control (Supervised Manual).

7-8.1 General. Section 7-8 shall not apply to new construction. Section 7-8 shall apply only to existing boilers with boiler front control and to the alteration of manual boilers.

7-8.1.1* 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 shall be required, as this is subject to factors such as the physical size of units, use of central control rooms, degree of reliability required, and availability of experienced operating personnel. All devices shown on the diagrams and discussed in the text shall be required.

This section defines and specifies the requirements of the operating system that shall be used under the following conditions:

(a) A trained operator shall be in constant attendance.

(b) The start-up or normal shutdown of any burner shall be accomplished by an operator at the burner locations.

(c) The operator shall have direct visual access to view the furnace.

(d) Suitable equipment shall 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 A-7-5.1.2(a), (b), and (c) for minimum recommended requirements.*]

7-8.1.2 System Description. This operating system is defined as "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 shall be provided with and shall operate the system in accordance with a written set of operating instructions for each boiler unit.

7-8.1.3 Fundamental Principles. The written instructions shall include, but shall not be limited to, the following:

(a) The airflow rate shall be adjusted to purge the airflow and purge the unit.

(b) The purge airflow rate shall be maintained continuously from purge initiation through the light-off cycle. If the airflow is not maintained, the prefiring cycle shall be repeated.

(c) If flame on the first igniter is not established within 10 seconds, the individual igniter safety shutoff valve shall be closed and the cause of failure to ignite shall be determined and corrected. With airflow maintained at the purge rate, repurge shall not be required, but at least 1 minute shall elapse before attempting a retrial.

(d) The operator shall 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 shall occur.

(e) After each stable main burner flame is established, the igniter shall be shut off unless classified as Class 1 or Class 2. The stability of the main burner flame shall be verified.

(f) Burners shall be lighted only from their associated igniter(s).

(g) The operator shall 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 shall 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 shall 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 shall elapse before the next light-off is attempted.

(j) If a second or succeeding main burner flame is not established, the operator shall 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 shall elapse before attempting to light this or any other igniter.

(k) Operation at less than 25 percent of load shall be 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 shall be given recognition, and low water level in the steam drum shall be monitored and alarmed. Consideration shall be given to interlock tripping.

Exception: For direct electric (Class 3 Special) igniters, 7-8.1.3 (c) and (i) shall not apply.

7-8.1.4 Interlocks, Master Fuel Trip. Any of the following conditions shall initiate a master fuel trip with first-out annunciation (*see 7-6.2.3*):

(a) Fuel pressure at the burner below the minimum established by the burner manufacturer or by trial;

(b) Loss of all forced draft fans;

(c) Loss of all induced draft fans, if applicable;

(d) Operation of the emergency trip switch by the operator;

(e) Loss of atomizing medium to boiler;

(f) Loss of all flame;

(g) Loss of control energy if fuel flow to burners is affected in such an event.

7-8.1.5 Loss of Individual Burner or Igniter Flame.

(a) Loss of flame at an individual igniter shall cause the igniter individual safety shutoff valve to close and the associated sparks to deenergize.

(b) Loss of flame at an individual burner shall cause the burner individual safety shutoff valve to close.

(c) The conditions of 7-8.1.5(a) and (b) shall be indicated.

(*See A-7-7.2 for recommended alarms in addition to those that are required.*)

7-8.2 Operating Cycle. The following operating sequences are based on a typical system that includes steam-atomized main oil burners. Certain provisions and sequences shall not apply where other atomizing media or systems are used. However, the principles outlined in these sequences shall be followed, and all applicable interlocks, trips, alarms, or their equivalents shall be provided.

7-8.2.1 Prefiring Cycle. The following steps shall be taken by the operator when starting a supervised manual unit, and the required interlocks shall be satisfied at each step. Control system energy, power, water level, fuel supply, and atomizing medium, if used, shall be established. Furnace and gas passages shall be inspected to determine if in good repair. Prior to start-up, it shall be determined that the unit and its associated systems are evacuated of all personnel and all access and inspection doors are closed.

Operator Actions[1] [*See Figures A-7-5.1.2(a) and (d).*]	**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 shutoff 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 required interlocks satisfied;
(j) Open main damper(s) to purge position;	(j) Prove purge airflow rate [*see 7-8.1.3(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 required if airflow rate drops below purge rate prior to initiation of light-off cycle.

[1] Certain actions are not necessarily performed in the order shown.

7-8.2.2 Light-Off Cycle—First Igniter. This cycle shall follow prefiring immediately with all required interlocks satisfied. The open register purge airflow rate principle shall be followed during the light-off procedure. (*See 7-5.1.3, 7-5.1.4, and 7-5.1.5.*)

Operator Actions [*See Figures A-7-5.1.2(a) and (d).*]	**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 7-8.2.2(d) and proceed directly to 7-8.2.4(c);	(c) For fuel-fired igniters, prove flame within 10 seconds. If flame not proved, safety shutoff valves for this igniter shall close and spark shall be deenergized;
(d) If ignition flame is not established, determine cause and make necessary corrections. Burner register shall be opened to purge position for at least 1 minute before repeating light-off cycle.	(d) None.

7-8.2.3 Light-Off Cycle—Subsequent Igniters.

Operator Actions [*See Figures A-7-5.1.2(a) and (d).*]	**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 7-8.2.2(c) and proceed directly to 7-8.2.4(c);	(b) For fuel-fired igniters, prove flame within 10 seconds. If flame is not proven, safety shutoff valves for this igniter shall close and spark shall be deenergized;
(c) If ignition flame is not established, determine cause and make necessary corrections. Burner register shall be opened to purge position for at least 1 minute before repeating light-off cycle.	(c) None.

7-8.2.4 Light-Off Cycle—First Main Burner.

Operator Actions [*See Figures A-7-5.1.2(a) and (d).*]	**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 7-8.2.1*);	(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 shall be removed from service; visually confirm main flame stability.	(k) None.

7-8.2.5 Light-Off Cycle for Subsequent Main Burners at Light-Off Fuel Pressure. This cycle shall be performed after the igniter flame for the burner has been proved and fuel pressure is controlled by the main fuel bypass control valve.

Operator Actions [*See Figures A-7-5.1.2(a) and (d).*]	**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 7-8.2.3 and 7-8.2.5;	(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 shall be removed from service; visually confirm main flame stability.	(j) None.

7-8.2.6 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.

Operator Actions [*See Figures A-7-5.1.2(a) and (d).*]	**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 7-8.2.6(a);	(b) None;
(c) Energize igniter; for direct electric igniters, omit 7-8.2.6(d);	(c) Prove flame within 10 seconds. If flame not proved, safety shutoff valves for this igniter shall close and spark shall 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 is shut off;
(i) If the main burner flame is not established, determine cause, correct, wait at least 1 minute, then repeat 7-8.2.6(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 shall 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.

7-8.2.7 Normal Shutdown Cycle.

Operator Actions [*See Figures A-7-5.1.2(a) and (d).*]	**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 airflow below purge rate;	(a) None;
(b) Each burner shall 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 shall 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 shall be removed;	7. None;
(c)	If oil guns are not cleared into the furnace, eliminate steps 1, 3, and 4 above. Remove oil guns and drain oil outside the furnace;	(c) None;
(d)	Perform a unit purge;	(d) None;
(e)	Shut down fan(s), if necessary.	(e) Loss of airflow interlock is actuated.

7-8.2.8 Emergency Shutdown.

(a) An emergency shutdown shall initiate a master fuel trip.

(b) For the conditions that shall initiate an emergency shutdown, see 7-8.1.4.

7-8.2.9 Operator Actions Following an Emergency Shutdown. [*See Figures A-7-5.1.2(a) and (d).*]

(a) All individual burner supervisory shutoff valves shall be closed. Burner register positions shall remain unchanged.

(b) Atomizing steam flow to all burners shall be shut off.

(c) Oil guns external to the furnace shall be removed and drained.

(d) The unit shall be purged in accordance with the following procedure:

1. Fans that are operating after the master fuel trip shall be continued in service.

2. Airflow shall not be increased immediately by deliberate manual or automatic control action.

3. If the airflow is above purge rate, it shall be permitted to be decreased gradually to this value and a post-firing unit purge shall be performed.

4. If the airflow is below purge rate at the time of the trip, it shall be continued at the existing rate for 5 minutes and then increased gradually to purge rate and held at this value for a post-firing 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 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 avoid excessive positive or negative furnace pressure transients during fan coast-down. This condition shall be maintained for not less than 15 minutes. At the end of this period, the flow control dampers shall be closed and the fan(s) shall be started immediately. Airflow shall be increased gradually to at least purge rate.

(f) The cause of emergency shutdown shall be determined and corrected.

(g) The first igniter light-off cycle (*see 7-8.2.2*) shall be performed if restart of unit is required.

(h) If it is desired to remove the boiler from service for a period of time, fans shall be shut down on completion of unit purge and manual shutoff valves shall be closed.

7-8.2.10 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.

7-9 Two-Burner Systems—Single Fuel Flow Control.

7-9.1 Fundamental Principles.

7-9.1.1 This section provides special design and operating requirements for 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. These boilers are subject to hazardous air/fuel ratio upsets at either burner during light-off, fuel transfer, and when one of the two burners automatically trips during operation.

7-9.1.2 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 that provide independent burner operation.

7-9.1.3 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. [*See NFPA 8501, Standard for Single Burner Boiler Operation, and 7-5.2.1.3(s).*]

7-9.2 System Requirements.

7-9.2.1 The following control system design options shall be provided in order to maintain a proper air/fuel ratio on one burner in the event of an automatic trip of the other burner.

7-9.2.1.1 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. The result of this operation is that the remaining operating burner maintains the proper air/fuel ratio after the fuel is shut off to the other 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 maximum firing rate or the air/fuel ratio limits of the burner.

7-9.2.1.2 The automatic recycling mode of operation shall be prohibited.

7-9.2.2 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) It might be necessary to operate a boiler on one burner with the air supply closed off to the other burner. If it then becomes necessary to light the second burner, extreme care shall be used to avoid creating a hazardous air/fuel ratio at the first operating burner. The following general procedures shall be followed to avoid 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, proper 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, 7-9.2.2(e) shall not apply. Total boiler airflow shall be maintained so that the operating burner has the proper air/fuel ratio.

7-9.3 Fuel Transfer Procedure. An operating procedure, either manual or automatic, shall be followed that prevents a hazardous air/fuel ratio at either burner when making a fuel transfer. The following procedure shall be followed:

Total fuel and airflow shall be reduced to within the 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 7-9.2.2(e).

Chapter 8 Pulverized Coal Systems

8-1 General.

8-1.1 This chapter contains additional requirements to be followed where burning pulverized coal.

8-1.2 Pulverized coal systems shall be in accordance with NFPA 8503, *Standard for Pulverized Fuel Systems.*

8-1.3 Although the pulverized coal section of this standard emphasizes direct-fired systems, it also generally is applicable to bin systems.

8-2* Coal Firing—Special Problems.

8-2.1 Common hazards are involved in the combustion of solid, liquid, and gaseous fuels. Each of these fuels has special hazards related to its physical characteristics. The following factors shall be considered in the design of the firing systems:

(a) It can take 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. Since a larger boiler burns 100lb (45.4 kg) or more of coal per second, the safe burning of pulverized coal necessitates strict adherence to carefully planned operating sequences. (*See Section 8-5.*)

(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.

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

(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 hangup in the raw coal supply system. Wide variations in the size of raw coal can result in coal feeding that is erratic or uncontrollable.

(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:

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; and

3. Leakage of gas or air through a burner valve, thereby causing a fire in an idle pulverizer.

Section 8-5 provides precautions to minimize such hazards.

(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 shall be made in the design of the system to prevent these occurrences and to allow periodic inspections.

(g) The burning of pulverized coal necessitates close integration of the pulverizer system. Commonly, 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. Precautions shall be taken to prevent ignition of the pulverized coal in the burner pipe. This is accomplished principally by preventing the velocity of the transport air from falling below a predetermined value during operation [transport air shall not be maintained during an emergency trip condition (*see 8-5.3*)] 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 could cause a furnace explosion 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 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 as appropriate shall be performed to verify that individual pipe velocities are adequate. A velocity in a burner pipe that is too low could cause coking of coal at the burner tip, resulting in a pipe fire.

(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. The coal-air mixture temperature leaving the pulverizer shall be maintained within limits. 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. The pulverizer outlet temperature shall be adjusted for the type of coal being burned. Maintaining a controlled outlet temperature also aids in controlling the relationship between the fuel and the primary air.

(j) In order 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 (*see 8-5.3.5*). Where a pulverizer is shut down with a significant amount of coal remaining in the pulverizer, this coal is subject to spontaneous combustion if it is not kept below its critical temperature. If the pulverizer is tripped under load, the clearing procedure outlined in 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. Most meters and associated sampling systems measure only gaseous combustibles. Therefore, the lack of meter indication of combustibles shall not be considered proof that unburned coal particles or other combustibles are not present.

(l) Where firing oil, operation of air heater sootblowers shall 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.

8-2.2 Coal Burner Turndown Ratio.

8-2.2.1 In addition to the criteria that determines the range of burner operation for stable flame shown in 8-3.3.2, other factors involving proper burner operation are described in 8-2.2.2 and 8-2.2.3.

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 shall be avoided.

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. To avoid this condition, the turndown ratio for extended reduced load operation shall be determined for the full range of coals to be fired.

8-2.3 Effect of Turndown Ratio on Open Register Light-Off.

8-2.3.1 The restrictions described in 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 standard are somewhat different than for oil or gas.

8-2.3.2 Wide variation in coal quality (*see 8-2.2.2*) 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.

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.

8-2.3.4 The low turndown ratio and other restrictions described in 8-2.3.1 through 8-2.3.3 might require variations in light-off procedures. However, the basic objectives of an open register light-off as set forth in 8-5.1.5 shall be met.

8-3 System Requirements.

8-3.1 Raw Coal Supply Subsystem.

8-3.1.1 The raw coal supply subsystem shall be sized properly and arranged to ensure a continuous, steady fuel flow adequate for all operating requirements of the unit.

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.

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.

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 satisfactory coal fineness over a specified range of coal analyses and characteristics. Pulverizer systems shall be designed and operated in accordance with NFPA 8503, *Standard for Pulverized Fuel Systems.*

8-3.3 Main Burner Subsystem.

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. 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. In these circumstances, Class 1 or Class 2 igniters, as demonstrated by test, shall be permitted to be used to maintain stable flame. (*See 8-3.3.2 and 8-3.3.3.*)

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. 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. These tests shall include the expected range of available fuels.

8-3.3.3 Where Class 1 and Class 2 igniters are used, the tests described in 4-2.3.2(d)1, 4-2.3.2(d)2, and 8-3.3.2 shall be performed to determine the limits of stable flame with the igniters in service. The resulting extended turndown range shall be available where Class 1 igniters are in service and flame is proved.

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.

8-3.3.5 Provisions shall be made for the cleaning of the burner nozzle and tip.

8-3.3.6 The burner equipment shall be located in an appropriate environment with convenient access for maintenance. Special recognition shall be given to the fire hazards imposed by leakage or rupture of piping near the burner. The requirements of good housekeeping shall be followed.

8-4 Flame Monitoring and Tripping System.

8-4.1 Tripping Philosophy.

8-4.1.1 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.

8-4.1.2 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.

8-4.2 It is recognized that any fuel input that does not ignite and burn on a continuous basis creates 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 potential hazard.

8-4.3 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 similar size and arrangement, including burner/nozzles of substantially the same capacity using similar fuels. These tests shall not be used to replace acceptance tests relating to proof of design, function, and components.

8-4.4 Basic Furnace Configurations.

8-4.4.1 The three principal furnace configurations are as follows:

(a) Wall-fired configuration;
(b) Angular downshot-fired configuration;
(c) Tangentially-fired configuration.

8-4.4.2 The applicability of the tripping philosophies described in 8-4.4.3(a) through (c) generally is specific to only one or two of the three furnace configurations. No single philosophy is necessarily applicable to all three furnace configurations.

8-4.4.3 Upon detection of loss of flame on a burner, a pulverizer/burner group, or the furnace as a whole, an automatic trip of the appropriate equipment shall be initiated as follows:

(a) *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 pulverizer and feeder, shall be tripped when a predetermined number or arrangement of burners served by that pulverizer have tripped. 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.

(b) *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 if burner or pulverizer operation can be continued safely. 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 after considering the spatial arrangement of burners and unit load. Under circumstances of operation where adequate support between the operating burners cannot be shown, 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.

(c) *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, proper main fuel combustion in one zone shall provide adequate sustaining energy to adjacent zones if each zone is not self-sustaining.

3. Under circumstances of operation where adequate support between each zone receiving fuel cannot be shown, ignition support shall be provided, or, upon loss of flame in a zone or in the entire furnace, the master fuel trip shall be automatically initiated.

8-5 Sequence of Operations.

8-5.1 General.

8-5.1.1 Sequencing shall be required to ensure that operating events occur in the proper order. Sequencing shall provide procedures that allow properly prepared fuel to be admitted to the burners only when there is sufficient ignition energy and proper airflow to ignite the fuel as it enters the furnace. Sequencing also shall be utilized where removing burners from operation.

8-5.1.2* Sequences of operation are based on the typical fuel supply systems shown in Figures A-8-5.1.2(a) through (c). These sequences shall be followed whether the unit is operated manually or certain functions are accomplished by interlocks or automatic controls. Different arrangements shall be permitted if they provide equivalent protection and meet the intent of the operating sequences specified in this chapter.

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 is to ensure an air-rich furnace atmosphere during start-up. It also establishes minimum velocities through the furnace to prevent hazardous accumulations of unburned fuel.

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 that ensure proper light-off.

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 stop of either a mechanical or control setting type 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) While light-off of all burners associated with a pulverizer is recommended, it might be 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 sufficiently high to maintain stable flame without the aid of igniters (as determined by test), the igniters shall be permitted to be removed from service.

8-5.1.4.2 If some registers have been maintained in the closed position, these 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.

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 is based upon the concept that the following basic operating conditions significantly improve the margin of operating safety, particularly during start-up. These conditions include:

(a) Use of a minimum number of required equipment manipulations, thereby minimizing exposure to operating errors or equipment malfunction.

(b) The desired fuel-rich condition at individual burners during light-off.

(c) 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.

(d) Minimizing the hazard of dead pockets in the gas passes and the accumulation of combustibles by continuously diluting the furnace with large quantities of air.

8-5.1.5.1 This procedure shall incorporate the following operating objectives:

(a) All or most of the registers shall be placed in a predetermined open position.

(b) A unit purge shall be completed with the burner air registers in the position specified in 8-5.1.5.1(a).

CAUTION: See 2-1.3(f) and definition of "purge rate, coal" for special hazards where purging a coal-fired boiler.

(c) 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 into service, whichever is longer.

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

(e) The first burner or group of burners shall be lighted without any change in the airflow setting or in the burner air register position.

8-5.1.5.2 Each boiler shall be tested during initial start-up to determine whether any modifications to the procedures specified in 8-5.1.5 are required in order to obtain satisfactory ignition or to satisfy other design limitations during light-off and warm-up. For example, some boilers are purged with the registers in the normal operating position. In this event, it might be necessary to close the registers of the burner being lighted momentarily to establish ignition. However, unnecessary modifications in the basic procedure shall be avoided, particularly that of 8-5.1.5(a), thereby satisfying the basic objectives in 8-5.1.5.1.

8-5.1.6 Modification to the mode of operation resulting from improper water, steam, and flue gas temperatures in the economizers and superheaters shall be made only after it has been determined to be necessary by operating experience.

8-5.2 Functional Requirements.

8-5.2.1 Cold Start.

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 in good repair and free of foreign material.

(b) The bottom of the furnace, including ash hopper, is free of accumulations of solid or liquid fuel, gases, or vapors. Such an inspection is particularly important for a cold start where the fuel burned prior to shutdown contained volatile vapors heavier than air. The possibility of such accumulations shall be considered prior to each start-up.

(c) All personnel are evacuated from 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 normally adjustable individual burner dampers or registers have been operated through their full range to check the operating mechanism.

(f) The igniter safety shutoff valves are closed and sparks are deenergized [*see Figures A-8-5.1.2(a) through (c)*]. For gas ignition systems, see Chapter 6; for oil ignition systems, see Chapter 7.

(g) The pulverizing equipment is isolated effectively to prevent inadvertent or uncontrolled leakage of coal into the furnace.

(h) 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.

(i) The pulverizers, feeders, and associated equipment are in good condition and adjusted properly to be ready for service. All pulverizer and feeder sensor lines are clean prior to starting.

(j) Energy is supplied to control system and to safety interlocks.

(k) The oxygen analyzer(s) and combustibles analyzer(s), if provided, are operating satisfactorily and a sample has been obtained. Combustibles indication is at zero and oxygen indication is at maximum.

(l) A complete functional check of the safety interlocks has been made after an overhaul or other significant maintenance.

(m) A complete, periodic, operational test of each igniter has been made. The frequency of testing depends on the design and operating history of each individual boiler and ignition system. As a minimum, the test shall be made during each start-up following an overhaul or other significant maintenance. The test shall be integrated into the starting sequence and shall follow the 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 normal start-up or light-off position.

(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. The importance of reliable igniters and ignition systems cannot be overemphasized.

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.

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, where appropriate, 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 Chapter 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 8-5.1.5.

(d) The airflow shall be adjusted to purge airflow rate and a unit purge shall be performed. Special provisions might be 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 recommended fuel pressure for proper igniter capacity.

(f) The air register or damper on the burners selected for light-off shall be adjusted to the position recommended by the manufacturer. (*See 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 any 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 adequate 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, can 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. Satisfactory ignition shall be obtained within 10 seconds following the specific time delay described in 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 conditions for proper 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 for proper 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 normal 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, it is desirable to start another pulverizer with all burners in service and to shut down the pulverizer with idle burners and empty it, rather than to start the idle burners. Idle burners shall be permitted to be started on the first pulverizer without shutting it down if precautions are taken to prevent the following conditions (*see also 8-5.5.4*):

1. Accumulation of coal in idle burner lines;

2. Hot burner nozzles and diffusers that could cause coking and fires when coal is introduced; and

3. Excessive disturbance of the air-fuel ratio of the operating burners.

(q) The procedures of 8-5.2.1.3(f) through (p) shall be followed where placing an additional pulverizer into service.

CAUTION: When fuel is being admitted to the furnace, igniters shall never be placed into service for any burner without proof that there is a normal fire in the furnace. Furnace explosions commonly are caused by placing igniters into service where there has been a flameout of an operating burner.

(r) Igniters shall be permitted to be shut off after exceeding a predetermined minimum main fuel input (*see 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 normal on-line metering combustion control (unless designed specifically for start-up procedures) shall not be placed into service until:

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 suitable 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 8-5.2.1.3(f) through (p).

8-5.2.2 Normal Operation.

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 normal air/fuel ratio continuously at all firing rates. This shall not eliminate requirements for air lead and lag during changes in the fuel firing rate.

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.

8-5.2.2.3 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.

8-5.2.2.4 The burner fuel and airflow shall be maintained within a range of the maximum and minimum limits specified by the boiler manufacturer or, preferably, as determined by trial. These trials shall test for minimum load and for stable flame as follows:

(a) With all burners in service and combustion control on automatic; and

(b) With different combinations of burners in service and combustion control on automatic.

Where changes occur to the maximum and minimum limits because of various burner combinations and fuel conditions, retesting shall be required.

8-5.2.2.5 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 take into consideration the transient stability factors described in 8-3.3.2.

8-5.2.2.6 The ignition system shall be tested for stable operation at the various conditions described in 8-5.2.2.5.

8-5.2.2.7 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 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. (*See 8-5.3 for hazards and NFPA 8503, Standard for Pulverized Fuel Systems, for procedures for clearing pulverizers tripped while full of coal.*)

8-5.2.2.8 Total airflow shall not be reduced below the purge rate.

8-5.2.3 Normal Shutdown.

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 reverse procedure of that used during start-up.

8-5.2.3.2 A pulverized fuel system shall be shut down in the following sequence:

(a) Combustion controls shall be switched from automatic to manual control unless controls are designed and tuned to bring boiler down to shutdown conditions.

(b) Fuel input, airflow, and register positions shall be adjusted to values established for start-up.

(c) The presence of flame at the burners of the pulverizer to be shut down shall be determined, and the igniters then shall be placed into service at these burners.

(d) The hot primary air shall be shut off and the cold primary air shall be opened to cool down the pulverizer. (*See NFPA 8503, Standard for Pulverized Fuel Systems, for detailed information on pulverizer cooling.*)

(e) The feeder shall be stopped when the pulverizer has cooled. Operation of the pulverizer shall be continued with sufficient airflow to empty out the pulverizer and associated burner lines.

(f) The inerting medium shall be introduced into the pulverizer as dictated by the coal characteristics.

(g) The pulverizer subsystem shall be shut down when burner fires are out and the pulverizer is empty and cool.

(h) All individual burner line shutoff valves shall be closed.

Exception: Where otherwise directed by the manufacturer's instructions.

(i) Igniters shall be removed from service.

8-5.2.3.3 As the boiler load is reduced, the following procedures shall be followed:

(a) The remaining pulverizers shall be shut down consecutively following the procedures of 8-5.2.3.2(c) through (i).

(b) In cases where the next pulverizer being removed could result in flame instability, igniters shall be placed into service on burners that are still being fired.

8-5.2.3.4 When all pulverizers and igniters have been removed from service, the purge rate airflow shall be verified and a unit purge shall be performed.

8-5.2.3.5 After completion of the unit purge, closing the burner air registers and shutdown of forced draft fans and induced draft fans shall be permitted to be optional. However, consideration shall be given to maintaining airflow through the unit to prevent accumulation of combustible gases. Leakage of main or igniter fuels into the unit shall be prevented.

8-5.2.4 Normal Hot Restart.

8-5.2.4.1 When restarting a hot unit, the requirements of 8-5.2.1.1(f) through (k) for a cold start shall be met.

8-5.2.4.2 The starting sequence in 8-5.2.1.3(a) through (q) shall be followed.

8-5.2.5 Emergency Shutdown—Master Fuel Trip.

8-5.2.5.1 An emergency shutdown shall initiate a master fuel trip.

8-5.2.5.2 A master fuel trip that results from any of the emergency conditions tabulated in Tables 8-5.2.5.2(a) and (b) shall stop all coal flow to the furnace from all pulverizer subsystems by tripping the burner safety shutoff valves or equivalent. 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.

Table 8-5.2.5.2(a) Mandatory Automatic Master Fuel Trips
(See Section 8-6 and Chapter 5)

A master fuel trip shall result from any of the following conditions:

(a) Loss of either all forced draft fans or all induced draft fans;

(b) Total airflow drops below the purge rate by 5 percent of full-load airflow;

(c) Furnace pressure exceeds the normal operating pressure by a value recommended by the manufacturer;

(d) All fuel inputs are shut off [*see 8-6.3.1.1(d)4*]. (*See 8-6.3.1 for required interlocks and trips for individual pulverizer subsystems*);

(e) Loss of all flame;

(f) Partial loss of flame sufficient to introduce a hazardous accumulation of unburned fuel. [*See 8-6.3.1.1(d)*].

Table 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:

(a) Failure of the first pulverizer subsystem to operate successfully under the conditions specified in 8-5.2.1.3(k) and 8-6.3;

(b) Loss of energy supply for combustion control, burner control, or interlock systems;

(c) Furnace negative pressure exceeds the value specified by the manufacturer. (*See Chapter 5.*)

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 post-firing 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 post-firing unit purge.

8-5.2.5.4 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 avoid excessive positive or negative furnace pressure transients 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 Chapter 5. The airflow shall be increased gradually to the purge rate and a post-firing unit purge shall be completed.

8-5.2.5.5 Action following the purge after an emergency shutdown (*see 8-5.2.5.3 and 8-5.2.5.4*) shall be in accordance with the following:

(a) The unit shall be shut down in accordance with 8-5.2.3.5; or

(b) If the purge following an emergency shutdown is performed at purge rate and the conditions of 8-5.2.1.1(f) through (k) and 8-5.2.1.3(d), (e) and (f) are satisfied, a relight in accordance with 8-5.2.1.3(g) through (t) shall be permitted.

8-5.2.5.6 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.

8-5.3 Hazards of Residual Coal Charges in Pulverizers and Clearing after Shutdown.

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 is likely to be sufficient to change light-off conditions, and the start-up procedure shall be in accordance with NFPA 8503, *Standard for Pulverized Fuel Systems*. If there is doubt regarding whether a pulverizer is charged with coal, the procedure of NFPA 8503 shall be used.

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 NFPA 8503, *Standard for Pulverized Fuel Systems*.

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 NFPA 8503, *Standard for 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.

8-5.3.4 If there is a significant delay before firing can be 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 NFPA 8503, *Standard for Pulverized Fuel Systems*.

8-5.3.5 If firing cannot 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. There is danger of an explosion where opening and cleaning any pulverizer, and caution shall be used. (*See NFPA 8503, Standard for Pulverized Fuel Systems.*)

8-5.4 Emergency Conditions Not Requiring Shutdown or Trip.

8-5.4.1 Many unit installations include multiple induced draft fans or forced draft fans, or both. In the event of a loss of a fan or fans, the control system shall be capable of reducing the fuel flow to match the available airflow; otherwise, tripping of the unit is mandatory.

8-5.4.2 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; or, if fuel flow cannot be reduced, the airflow shall be increased slowly until the proper air/fuel ratio has been restored.

NOTE: 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.

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 can be restored or adequate ignition energy can be supplied 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. (*See 8-4.4.3.*)

8-5.5 General Operating Requirements—All Conditions.

8-5.5.1 Prior to starting a unit, action shall be taken to prevent fuel from entering the furnace.

8-5.5.2 The unit shall be purged prior to starting a fire in the furnace.

8-5.5.3 The igniter for the burner always shall be used. Burners shall not be lighted using a previously lighted burner or from the hot refractory.

8-5.5.4 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 can result from operation under such conditions.

8-5.5.5 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 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 airflow is maintained, nor does it preclude the use of air heater sootblowers during start-up.

Exception: Sootblowers shall not be operated at low-load and high excess air conditions. This does not preclude use of wall sootblowers and high temperature superheater and reheater sootblowers for cleaning during outage periods if a unit purge has been completed and purge airflow maintained.

8-5.5.6 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.

8-5.5.7 Where the pulverizer and burner piping is being cleared into a furnace, the procedures of 8-5.3 shall apply.

8-5.5.8 The procedures of NFPA 8503, *Standard for Pulverized Fuel Systems*, shall apply where dealing with pulverizer equipment fires.

8-6 Interlock System.

8-6.1 General. The basic requirement of an interlock system for a unit is that it protect personnel from injury and also protect the equipment from damage. The interlock system functions to protect against improper boiler operation by limiting actions to a prescribed operating sequence or by initiating trip devices when approaching an undesirable or unstable operating condition. The interlock system shall comply with Section 4-3.

8-6.1.1 The mandatory automatic trips specified in 8-6.3.1 represent those automatic trips for which sufficient experience has been accumulated to demonstrate a high probability of successful application for all boilers. The use of additional automatic trips, while not mandatory, is recommended. (*Also see 2-3.3 and A-2-3.3.*)

8-6.1.2 It is possible to achieve 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 burner interlock system.

8-6.2 Functional Requirements.

8-6.2.1 The operation of any interlock that causes a trip shall be annunciated.

8-6.2.2 An interlock system shall be of sound design and shall be properly installed, adjusted, and tested to confirm design, function, and proper timing. Periodic testing and maintenance shall be performed to keep the interlock system functioning properly.

8-6.2.3 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 proper sequence when the safety of personnel or equipment is jeopardized.

(c) The initiating cause of the trip shall be indicated and no portion of the process shall be started until proper conditions are established.

(d) The necessary trip devices shall be coordinated into an integrated system.

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

(f) The design shall be provided as much flexibility with respect to alternate modes of operation as is consistent with good operating practice.

(g) Proper preventive maintenance shall be provided.

(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. Other means shall be substituted to supervise this interlock function.

(i) 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:

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

(b) Tripping set points are protected from unauthorized changes; and

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

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

8-6.2.4 The actuation values and time of action of the initiating devices shall be tuned to the furnace and equipment on which they are installed. After adjustment, each path and the complete system shall be tested to demonstrate the adequacy of adjustment for that furnace.

8-6.3 System Requirements.

8-6.3.1 Interlocks. See Figure 8-6.3.1.1.

8-6.3.1.1 Figure 8-6.3.1.1 shows the required system of interlocks that provides the basic furnace protection for a pulverized coal multiple burner boiler operated in accordance with this standard.

(a) Block 1 shows loss of an individual igniter flame, which shall be interlocked to accomplish the following:

1. Close the individual igniter safety shutoff valve(s) and deenergize the spark(s).

2. With the main flame proven at individual burners, signal the main flame protection system that the igniter flame has been lost. (*See 8-4.3.*)

(b) Block 2 represents conditions caused by improper igniter fuel header pressure, which shall be interlocked to initiate the tripping of the igniter header and individual igniter safety shutoff valves and deenergize sparks. Where gas is used for ignition fuel, both high and low pressure shall be interlocked. Where oil is used, low pressure shall be interlocked.

(c) Where oil is used for ignition fuel with air or steam atomization, improper atomization of an igniter fuel is a condition that shall trip the igniter and individual igniter safety shutoff valves and deenergize sparks as indicated by Block 3.

(d) Blocks 4 through 14 represent conditions that initiate the tripping of both the main and ignition fuel supplies through a master fuel trip relay. The master fuel trip relay shall be of the type that stays tripped until the furnace purge system allows it to be reset, as shown at the bottom of Figure 8-6.3.1.1. Whenever the master fuel trip relay is operated, it trips all coal burner line shutoff valves or equivalent functional action to stop coal delivery to burners, primary air fans or exhausters, and coal feeders and deenergizes all sparks and all ignition sources within the unit and flue gas path. The interlocks are as follows:

1. Blocks 4 through 8 represent protection against loss of large quantities of combustion air. The loss of all induced draft fans or all forced draft fans shall operate the master fuel trip relay. The loss of one induced draft fan or forced draft fan or other large loss of air shall reduce the fuel in order to maintain the proper air/fuel ratio. This function shall be permitted to be interlocked or made a part of the combustion control system. (*See Chapter 5 and 8-5.4.*)

2. Block 9 represents low combustion airflow below the permitted limits and is interlocked to activate the master fuel trip relay.

3. Excess furnace pressure (Block 10) also is interlocked with the master fuel trip relay to protect against abnormal furnace conditions such as those resulting from a tube rupture or damper failure.

4. Block 11 represents an interlock operation when all fuel inputs to the furnace are shut off following a shutdown of the boiler for any reason. This necessitates the use of the purge sequence before the fuel supply can be established. This is a trip function in addition to the permissive function for verification that all individual safety shutoff valves are closed as shown in the "Furnace Purge System." (*See Figure 8-6.3.1.1.*)

5. Block 12 represents a manual switch that can be used by the operator in an emergency to actuate the master fuel trip relay. The manual trip switch shall actuate the master fuel trip relay directly.

6. Block 13 shows loss of all flame in the furnace and is interlocked to activate the master fuel trip relay.

7. Block 14 represents a partial loss of flame to the extent that hazardous conditions could develop irrespective of, or due to the failure of, other protective interlocks. It is potentially more hazardous at lower load levels. The decision regarding specific requirements or implementation of this trip shall 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.

(e) Block 15 indicates that, on loss of main burner flame, the tripping strategy of 8-4.4.2 shall be followed.

8-6.3.1.2 Each source of operation of the master fuel trip relay shall actuate a "cause of trip" indication that informs the operator of the initiating cause of the tripping impulse.

8-6.3.1.3 The proper starting sequence shall be supervised by a series of permissive interlocks shown in Figure 8-6.3.1.1 as the purge system. All requirements of this system shall be satisfied before the ignition system can be energized by resetting the master fuel trip relay. This ensures that the unit purge has been completed with all required burner registers in purge position and all fuel and ignition input sources shut off before the master fuel trip relay can be reset and the light-off sequence can be started. Completion of the purge shall be indicated.

8-6.3.1.4 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 into operation, whichever is longer. Completion of the purge shall be indicated.

8-6.4 Trips and Interlocks for Individual Pulverizer Subsystem on Direct-Fired Furnaces.

8-6.4.1 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.

8-6.4.2 Mandatory Pulverizer Subsystem Trips—Not Necessarily Automatically Initiated.

(a) Loss of igniters or adequate ignition energy 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. (*See 8-5.2.2.7.*)

(c) Loss of coal feed to the burners of a pulverizer subsystem shall trip the feeder. Feeder tripping shall not be

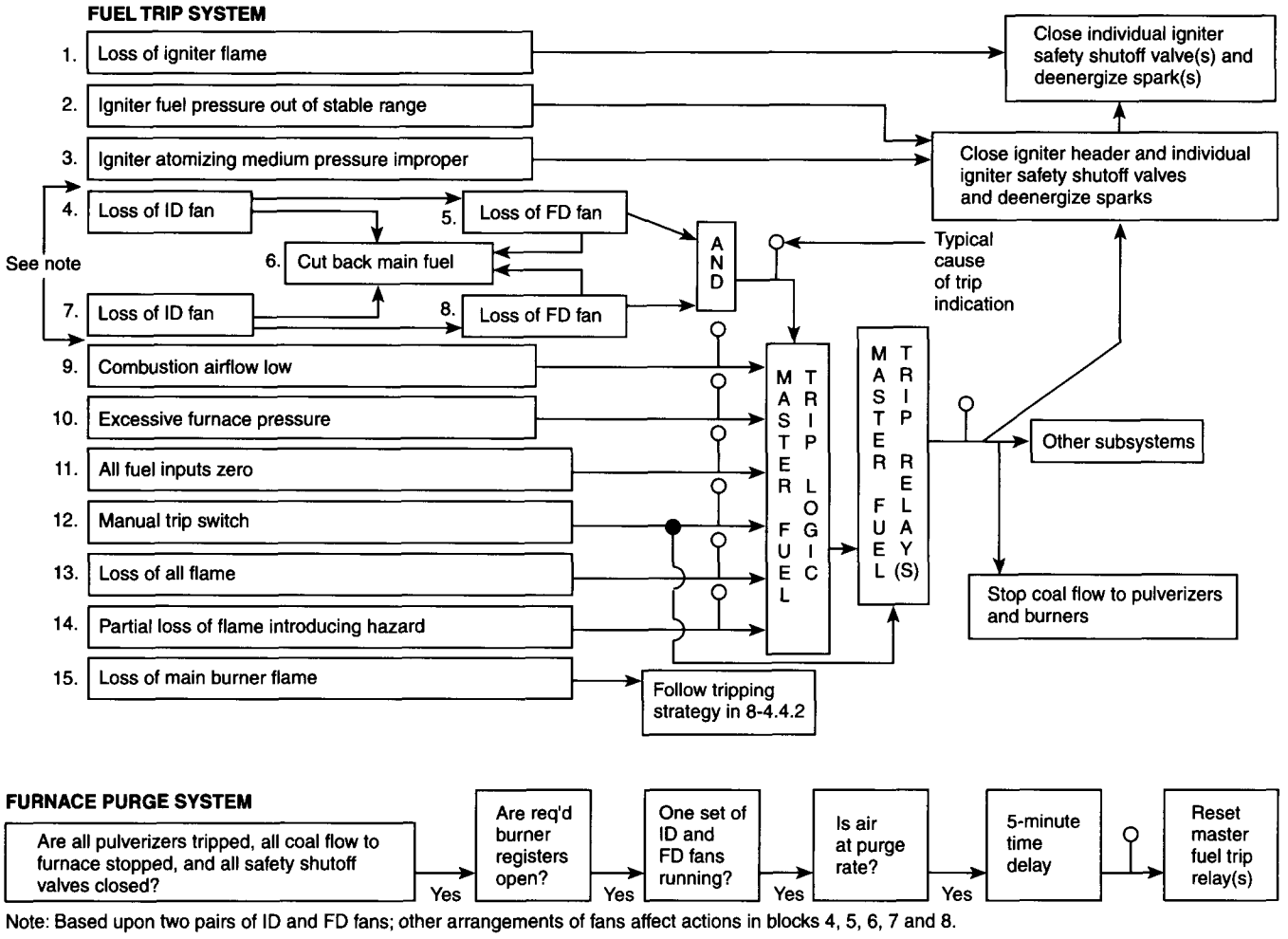


Figure 8-6.3.1.1 Master fuel trip system. Block diagram for furnace interlocks for a pulverized coal-fired multiple burner boiler (see 8-6.3.1).

required if the associated Class 1 igniters are in operation. 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, shall be used to indicate loss of coal.

NOTE: The conditions under which the igniters are to ignite the input should be established before restarting the feeder. (*See 8-5.4.3.*)

8-6.4.3 Mandatory Sequential Starting Interlocks. Permissive sequential interlocking shall be arranged so that the pulverizer subsystem can be started only in the following sequence:

(a) Igniters for all burners served by the pulverizer are in service and proven;

(b) Primary air fan or exhauster is started;

(c) Pulverizer is started;

(d) Raw coal feeder is started.

8-7 Alarm System.

8-7.1 Functional Requirements.

8-7.1.1 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.

8-7.1.2 Alarm systems shall be designed so that for the required alarms in 8-7.2, the operator receives audible and visual indication of the condition. Means shall be permitted to silence the audible alarm after actuation, but the visual indication shall continue until the condition has been returned to normal.

8-7.1.3 The design shall make it difficult to manually defeat the alarm, and, where equipment malfunction makes defeat necessary, it shall be performed by authorized personnel and the alarm shall be tagged as inoperative.

8-7.2* Required Alarms. In addition to the trip alarms in the interlock system shown in Figure 8-6.3.1.1, the separately annunciated alarms in 8-7.2(a) through (n) shall be provided.

(a) *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 could result.

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

Exception: For oil-fired igniters, only low ignition fuel header pressure shall be required to be monitored.

(c) *Pulverizer Tripped.* An alarm shall indicate when the pulverizer is tripped (not normal shutdown).

(d) *Primary Air Fan Tripped.* An alarm shall indicate when the primary air fan is tripped (not normal shutdown).

(e) *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 trips (not normal shutdown).

(f) *Coal-Air High Temperature.* An alarm shall indicate when coal-air temperature within or at the pulverizer outlet exceeds normal operating limits. (*See NFPA 8503, Standard for Pulverized Fuel Systems.*)

(g) *Furnace Pressure (High).* This shall be measured near the normal furnace pressure tap location. It shall warn the operator of a pressure in excess of normal operation and an approach to trip conditions.

(h) *Furnace Draft (High).* This shall apply to balanced draft furnace operation. It shall be measured near the normal furnace draft tap location. It shall warn the operator of a draft in excess of normal operation and of an approach to trip condition.

(i) *Loss of Operating FD Fan.* This shall be sensed and alarmed only when the fan is not operating when expected.

(j) *Loss of Operating ID Fan.* This shall apply to balanced draft furnace operation. It shall be sensed and alarmed only when the fan is not operating when expected.

(k) *Furnace Airflow (Low).* This shall be sensed and alarmed when total airflow falls below purge rate.

(l) *Loss of Interlock Power.* This shall be sensed and alarmed and shall include all sources of power necessary to complete interlock functions. For example, if both a 125-volt DC electric circuit and a compressed air circuit are needed for an interlock scheme, circuit loss of either shall be annunciated separately.

(m) *Loss of Control Power.* This shall be sensed and alarmed to include all sources of power for the control systems.

(n) *Loss of Flame.* A partial or total loss of a flame envelope still receiving fuel shall be monitored and alarmed so that it can be determined if a hazardous condition exists in the furnace.

(o) *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 safe operating point. (*See A-8-7.2 for recommended alarms and monitors in addition to those that are required.*)

Chapter 9 Maintenance, Inspection, Training, and Safety

9-1 Maintenance and Equipment Inspection.

9-1.1 The objective of a maintenance program is to identify and correct conditions that adversely affect the safety, continued reliable operation, and efficient performance of equipment. A program shall be provided for maintenance of equipment at intervals consistent with the type of equipment used, service requirements, and manufacturers' recommendations.

9-1.2 As a minimum, the maintenance program shall include the following:

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

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

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

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

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

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

9-1.3* An inspection and maintenance schedule shall be established and followed.

9-1.4 Operation, set points, and adjustments shall be verified by periodic testing, and the results shall be documented.

9-1.5 Defects shall be reported and corrected, and the repairs shall be documented.

9-1.6 System configuration, including logic, set points, and sensing hardware, shall not be changed without evaluation and approval of the effect.

9-1.7 Inspections, adjustments, and repairs shall be performed by trained personnel, using tools and instruments suitable for the work. Maintenance and repairs shall be performed in accordance with the manufacturer's recommendations and applicable standards and codes.

9-2 Training.

9-2.1 Operator Training.

9-2.1.1 A formal training program shall be established to prepare personnel to operate equipment safely and effectively. This program can consist of a review of operating manuals and videotapes, programmed instruction, testing, use of simulators, and field training, among others. The training program shall be consistent with the type of equipment and hazards involved.

9-2.1.2 Operating procedures shall be established that cover normal and emergency conditions. Start-up and shutdown procedures, normal operating conditions, and lockout procedures shall be covered in detail.

9-2.1.3 Operating procedures shall be directly applicable to the equipment involved and consistent with safety requirements and the manufacturer's recommendations.

9-2.1.4 Operating procedures shall be reviewed periodically to keep them current with changes in equipment and personnel.

9-2.2 Maintenance Training.

9-2.2.1 A formal maintenance training program shall be established to prepare personnel to perform any required maintenance tasks safely and effectively. This program can consist of a review of maintenance manuals and videotapes, programmed instruction, testing, field training, and equipment manufacturer training, among others. The training program shall be specific to the equipment and potential hazards involved.

9-2.2.2 Maintenance procedures shall be established to cover routine and special techniques. Any potential environmental factors such as temperature limitations, dusts, contaminated or oxygen-deficient atmospheres, internal pressures, and limited access or confined space restrictions shall be included.

9-2.2.3 Procedures shall be consistent with safety requirements and the manufacturer's recommendations.

9-2.2.4 Procedures shall be reviewed periodically to keep them current with changes in equipment and personnel.

Chapter 10 Referenced Publications

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

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

NFPA 31, *Standard for the Installation of Oil-Burning Equipment*, 1992 edition.

NFPA 8503, *Standard for Pulverized Fuel Systems*, 1992 edition.

10-1.2 Other Publications.

10-1.2.1 AISC Publication. American Institute of Steel Construction, 400 N. Michigan Avenue, Chicago, IL 60611.

AISC *Manual of Steel Construction.*

10-1.2.2 ANSI Publication. American National Standards Institute, 1430 Broadway, New York, NY 10018.

ANSI B31.1, *Power Piping*, 1992.

10-1.2.3 ASTM Publication. American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM D396, *Standard Specification for Fuel Oils*, 1992.

Appendix A Explanatory Material

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

A-1-1.3 In existing units, it is not always practical to apply the provisions of this standard strictly. 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 boiler combustion system hazard should be mitigated by application of appropriate safeguards. Modification of conditions that do not represent a significant threat, even if such conditions are not in strict conformance with the requirements of this standard, are not required.

A-1-2.2 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 standard to meet these limits is not recommended. There are insufficient data and operating experience to justify changes to this standard.

A-2-3.3 The maximum number of automatic trip features does not necessarily provide for maximum overall safety. Some trip actions result in additional operations that increase exposure to hazards.

A-2-5.1 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.

A. 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.

B. Welding and Flame Cutting. (*See also NFPA 51, Standard for the Design and Installation of Oxygen-Fuel Gas Systems for Welding, Cutting, and Allied Processes, and NFPA 51B, Standard for Fire Prevention in Use of Cutting and Welding Processes. For work on pulverized fuel systems, see NFPA 8503, Standard for Pulverized Fuel Systems.*)

(a) Fire-resistant blankets or other approved methods should be used in a manner 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.

C. 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®*.

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

E. 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. A confined space is any work location or enclosure in which any of the following could possibly exist:

(a) 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.

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

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

B. Specific procedures that provide the following should be developed for and used by personnel entering a confined space:

(a) Positive prevention of inadvertent introduction of fuel, hot air, steam, or gas;

(b) Positive prevention of inadvertent starting or moving of mechanical equipment or fans;

(c) Prevention of the accidental closing of access doors or hatches;

(d) Inclusion of tags, permits, or locks to cover confined space entry;

(e) 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.

(f) 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.

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

A-2-7 Housekeeping.

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

II. Creation of dust clouds should be minimized during cleaning. Compressed air should not be used to dislodge coal dust accumulations; washing with water or vacuum cleaning methods are recommended.

A-2-7.1(c) The minimum airflow value (25 percent) is based on historical experience in reducing the occurrence of furnace 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:

(a) Removal of combustibles and products of combustion;

(b) Cooling requirements for burners out of service;

(c) Accuracy of total burner airflow, individual burner airflow, and other airflow measurements;

(d) Accuracy of burner air and fuel distribution;

(e) Effect of thermal and pressure transients within the furnace on the air and fuel flows;

(f) Impact of air leakage;

(g) Wear and deterioration of the unit and equipment; and

(h) Operational and control margins.

A-3-1 Air, Excess. This is not equivalent to "Air-rich" as defined in Section 1-3.

A-4-1.1 Examples: If the test block capability of the forced draft fan at ambient temperature is +25 in. (+6.2 kPa) of water, then the minimum positive design pressure is +25 in. (+6.2 kPa) of water.

If the test block capability of the induced draft fan at ambient temperature is -15 in. (-3.7 kPa) of water, then the minimum negative design pressure is -15 in. (-3.7 kPa) of water.

If the test block capability of the forced draft fan at ambient temperature is +40 in. (+9.9 kPa) of water, then the minimum positive design pressure is +35 in. (+8.7 kPa) of water.

If the test block capability of the induced draft fan at ambient temperature is -40 in. (-9.9 kPa) of water, then the minimum negative design pressure is -35 in. (-8.7 kPa) of water.

A-4-3.2 Some items are not applicable to specific types of logic systems (e.g., relay).

A-5-1 Furnace Implosion Protection. No standard can guarantee the elimination of furnace implosions. Chapter 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 Chapter 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 or special duct arrangements or special instrumentation or control.

A-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 may be permitted to be closed.

A-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 may be permitted to be closed.

A-5-4.3(b)1 For the trips specified in 5-4.3(a)1, (a)2, and (b)1, a short time delay might be necessary to prevent tripping on rapid transients that do not present a hazard.

A-6-2(c) Fundamental Principles of a Manual System.

I. Boiler Front Controls (Gas Firing).

A. 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 requirements of 6-8.1.1 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.

B. Fundamental Principles. The operator is to follow written instructions for each specific boiler. These instructions include, but are not limited to, purging of the boiler as accomplished by 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 is to 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 are to be closed and the prefiring cycle is to be repeated.

(d) If flame on the first igniter is not established after the igniter supervisory shutoff valve has been opened, all fuel valves are to be closed and the prefiring cycle is to be repeated.

(e) The operator is to 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 are to be closed immediately and the prefiring cycle is to be repeated.

(f) After each stable main burner flame is established, the igniter is to be shut off unless classified as Class 1 or Class 2. The stability of the main burner flame is to be verified.

(g) Burners are not to be lighted from a previously lighted burner.

(h) The operator is to 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 is to 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) is to be closed and cause for failure to light determined and corrected. At least 1 minute is to 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 are to be closed immediately, the burner register or damper is to be opened to firing position, and cause for failure to ignite is to be determined and corrected. At least 1 minute is to elapse before attempting to light this or any igniter.

(l) Operation at less than 25 percent load may be 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. Equipment. The following equipment should be provided:

(a) Equipment to change the firing rate that simultaneously adjusts the fuel and air supplies to a predetermined air/fuel ratio;

(b) A purge timer with proven airflow;

(c) Provisions for limiting fuel turndown to prevent reducing fuel input below the point of stable burner operation;

(d) Permanently installed igniters;

(e) Main and igniter gas supply pressure regulation;

(f) Flame failure detection and alarm.

D. Interlocks and Emergency Shutdown (Boiler). An emergency shutdown is to be initiated by the following conditions:

(a) High fuel gas pressure;

(b) Low igniter gas pressure;

(c) Low fuel gas supply pressure;

(d) Fuel gas pressure in the burner header below the minimum required for flame stability;

(e) Loss of all forced draft fans;

(f) Loss of all induced draft fans, if applicable;

(g) Operation of the emergency trip switch by the operator;

(h) Loss of control energy if fuel flow to burners is affected in such an event.

All individual manual burner and igniter supervisory shutoff valves are to be in the closed position before the main and igniter safety shutoff valves can be opened.

II. Operating Cycle.

A. Prefiring Cycle—Gas. The following steps are to be taken by the operator when starting a manual system, and the required interlocks are to be satisfied at each step. Control system energy, power and water level, and fuel supply are to be established. Prior to start-up, furnace and gas passages are to be inspected to determine if in good repair. It is to be determined that the unit and its associated systems are evacuated of all personnel and all access and inspection doors are closed.

Operator Actions[1] [*See Figures A-6-2(c)I and A-6-2(c)II.*]	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 [*see A-6-2(c)IB*];	(g) None;
(h) Immediately proceed with light-off cycle after completion of purge.	(h) None.

[1] Certain actions are not necessarily performed in the order shown.

B. Light-Off Cycle. This cycle immediately follows prefiring. Burners are at light-off fuel pressure. The open register purge principle is to be followed during the light-off procedure. (*See 6-5.1.3, 6-5.1.4, and 6-5.1.5.*)

Operator Actions [*See Figures A-6-2(c)I and A-6-2(c)II.*]	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 (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 [*see (d) above*];
(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 is to be removed from service; visually confirm main flame stability;	(j) None;
(k) Repeat steps (a), (e), (f), (g), (h), and (i) above 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% 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.

C. Normal Shutdown Cycle.

Operator Actions [*See Figures A-6-2(c)I and A-6-2(c)II.*]	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.

D. Emergency Shutdown. When an emergency shutdown occurs, the main safety shutoff valve and igniter safety shutoff valves close; the main and igniter atmospheric vent valves open. [*See A-6-2(c)ID.*]

E. Operator Actions Following an Emergency Shutdown.

(a) All burner and igniter supervisory shutoff valves are to be closed. Burner register positions remain unchanged;

(b) Header manual vent valve is opened;

(c) Unit is purged in accordance with the following procedure:

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 may be permitted to be decreased gradually to this value for the post-firing purge for a minimum of 5 minutes. 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 post-firing purge of 5 minutes duration.

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 are to be opened slowly to the fully open position in order to create as much natural draft as possible to ventilate the unit. This condition is to be maintained for not less than 15 minutes. At the end of this period, the flow control dampers are to be closed and the fan(s) is to be started immediately. The airflow is to be increased gradually to at least purge rate.

(d) The cause of safety shutdown is to be determined and corrected;

(e) The light-off cycle [*see A-6-2(c)IIB*] then is performed if relight of boiler is necessary;

(f) If it is desired to remove the boiler from service for a period of time, the fans are to be shut down on completion of purge, and the manual shutoff valves are to be closed.

A-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 atmosphere at a rate equal to the potential leakage rate. In the absence of other justification, vent pipe sizes and vent valve port diameters should conform to Table A-6-3.1.6.

A-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-6-3.2.1 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, or 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 Sections 6-9 and 7-9. 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-6-5.2.1.3 Low NO_x Operation—Special Problems.

I. General Considerations.

A. Air pollution 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 using outdated operating procedures. In addition, air quality regulations in some local areas require a reduction of NO_x emissions from existing boilers.

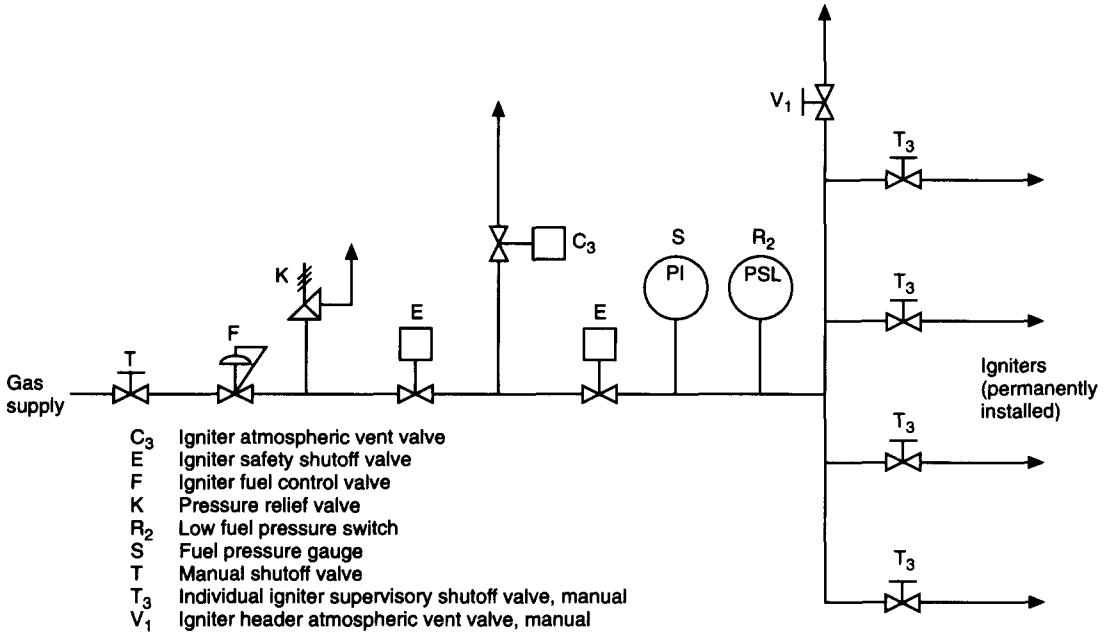
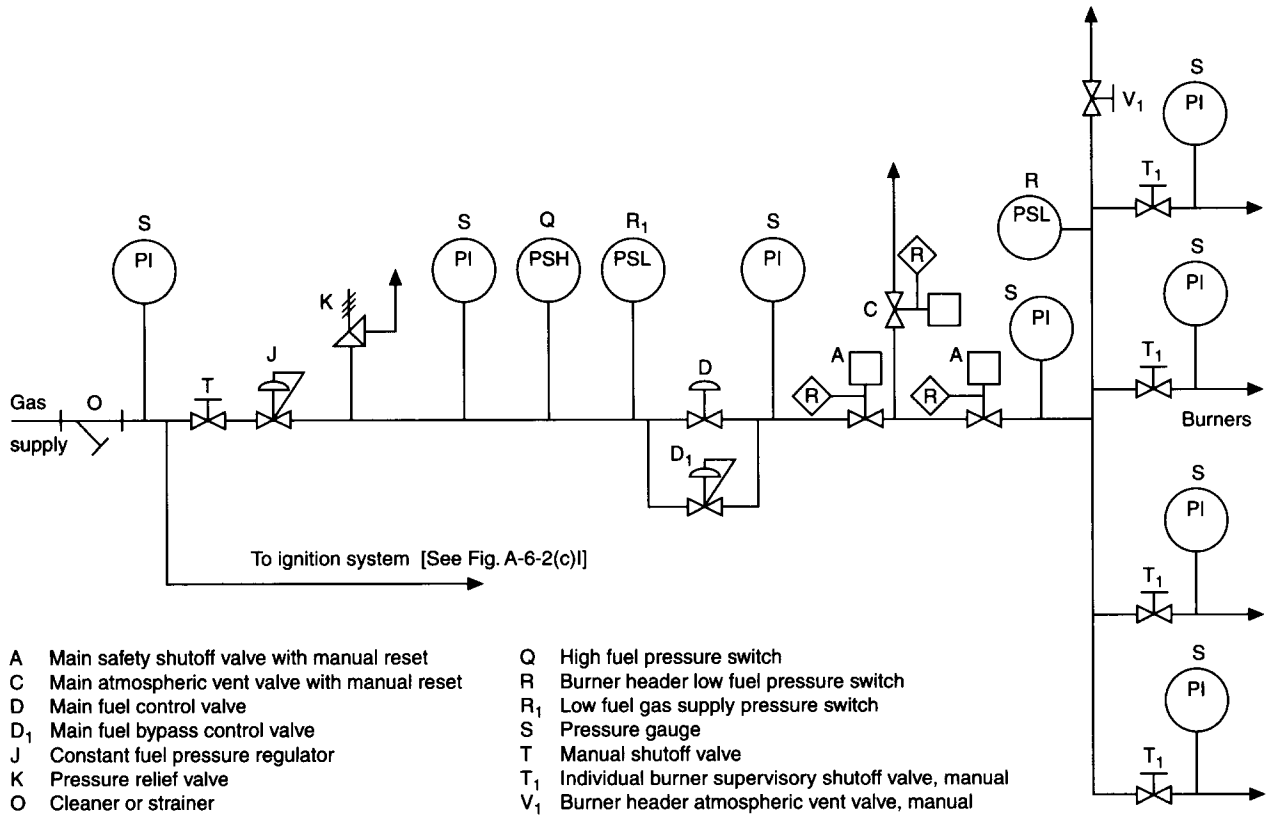


Figure A-6-2(c)I Typical ignition system (diagram)—manual.



A Main safety shutoff valve with manual reset
C Main atmospheric vent valve with manual reset
D Main fuel control valve
D_1 Main fuel bypass control valve
J Constant fuel pressure regulator
K Pressure relief valve
O Cleaner or strainer
Q High fuel pressure switch
R Burner header low fuel pressure switch
R_1 Low fuel gas supply pressure switch
S Pressure gauge
T Manual shutoff valve
T_1 Individual burner supervisory shutoff valve, manual
V_1 Burner header atmospheric vent valve, manual

Figure A-6-2(c)II Typical fuel supply system for natural gas-fired multiple burner boiler (diagram)—manual.

Table A-6-3.1.6 Vent Line Sizes

Gas Supply Line Size (in.)	Gas Supply Line Size (mm)	Shutoff System Vent Port Size (in.)	Shutoff System Vent Port Size (mm)
≤ 1½	≤ 38	¾	19
2	50.8	1	25.4
2½ to 3	64 to 76	1¼	31.8
3½	89	1½	38
4 to 5	102 to 127	2	50.8
5½ to 6	139.7 to 152.4	2½	64
8	203	3½	89
> 8	> 203	15% of supply line cross-sectional area	

B. In order to achieve these mandated NO_x reductions at higher loads, a number of methods may be permitted to be used singly or in combination. These methods could have an adverse effect on flame stability. It is important that the designer recognize these potential hazards and perform tests as specified in 6-3.2.2, 7-3.2.2, and 8-3.3.2 to determine the limits of flame stability under these new operating conditions.

C. Methods to reduce NO_x, which can affect flame stability, are designed to produce lower flame temperatures and longer, less turbulent flames.

D. For all methods of NO_x reduction, special considerations are necessary to ensure the stability of the flame envelope. It is beyond the scope of this document to detail these considerations. 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.

II. Hazards of Low NO_x Firing Methods.

A. The various methods of NO_x reduction can have important implications with regard to furnace safety, particularly for existing units, and can introduce unacceptable risks if precautions are not taken.

(a) 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.

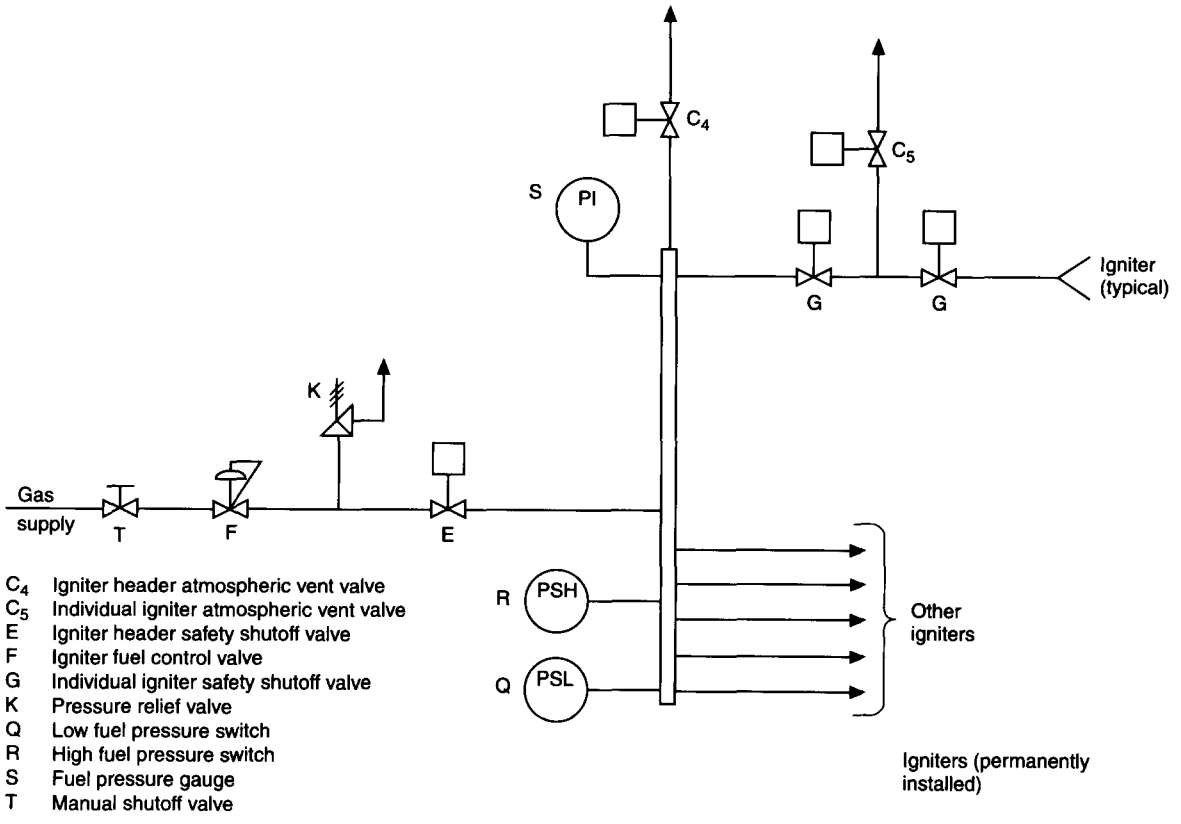


Figure A-6-5.1.2(a) Typical gas igniter system (diagram).

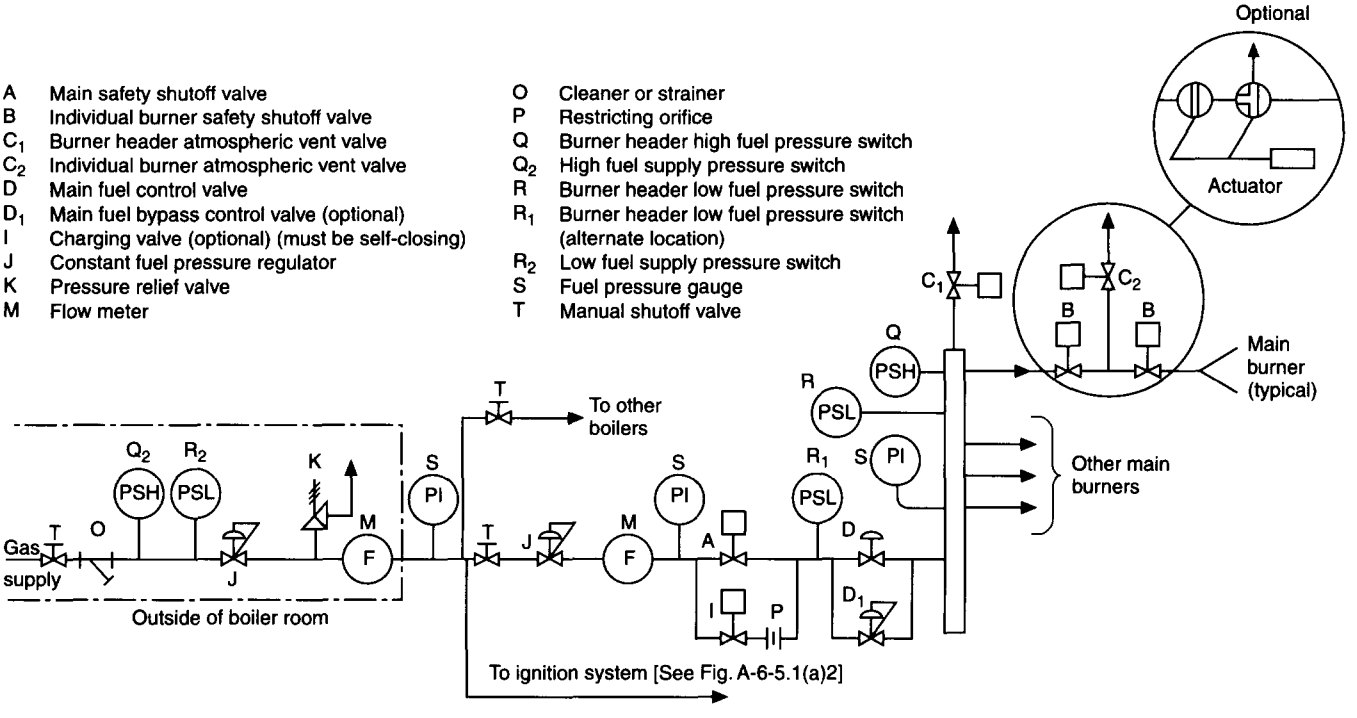


Figure A-6-5.1.2(b) Typical main burner fuel supply system for fuel gas-fired multiple burner boiler (diagram).

(b) 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, and 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.

(c) All the methods described tend to increase the possibility of unburned combustibles throughout the unit and ducts. Therefore, the use of flue gas CO analyzers is recommended.

B. 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.

A-6-5.2.2.1 High Air Pressure Drop Burners. 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.

A-6-7.2 Recommended Additional Alarms (Fuel Gas).

I. All Systems Except Supervised Manual (Sections 6-5 through 6-7).

A. 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 Btu Content of the Fuel Gas.* In the event that the gas supply is subject to Btu 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.

B. 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.

III. Supervised Manual System (Section 6-8).

A. 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:

(a) High fuel supply pressure;
(b) Low fuel supply pressure;
(c) High furnace pressure;
(d) High furnace draft;
(e) Low combustion airflow;
(f) Loss of interlock energy;
(g) Loss of control system energy;
(h) Failure of burner safety shutoff valve to close;
(i) Flame detector trouble.

A-7-1 Fuel Oil—General Considerations.

I. 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 was 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.

II. The more important characteristics of fuel oils are defined in ASTM standards. It is relatively simple to identify oils that need special provisions for such functions as storing, heating, pumping, and atomizing. Generally, fuel oil grades 2 and 4 have lower viscosities and less water and sediment than grades 5 or 6 and so necessitate 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 needed in the design and operation of fuel oil systems supplied with grade 6 oil than with other ASTM grades to avoid flameouts caused by interruptions or pulsation of the fuel supply or plugging of strainers or burner tips.

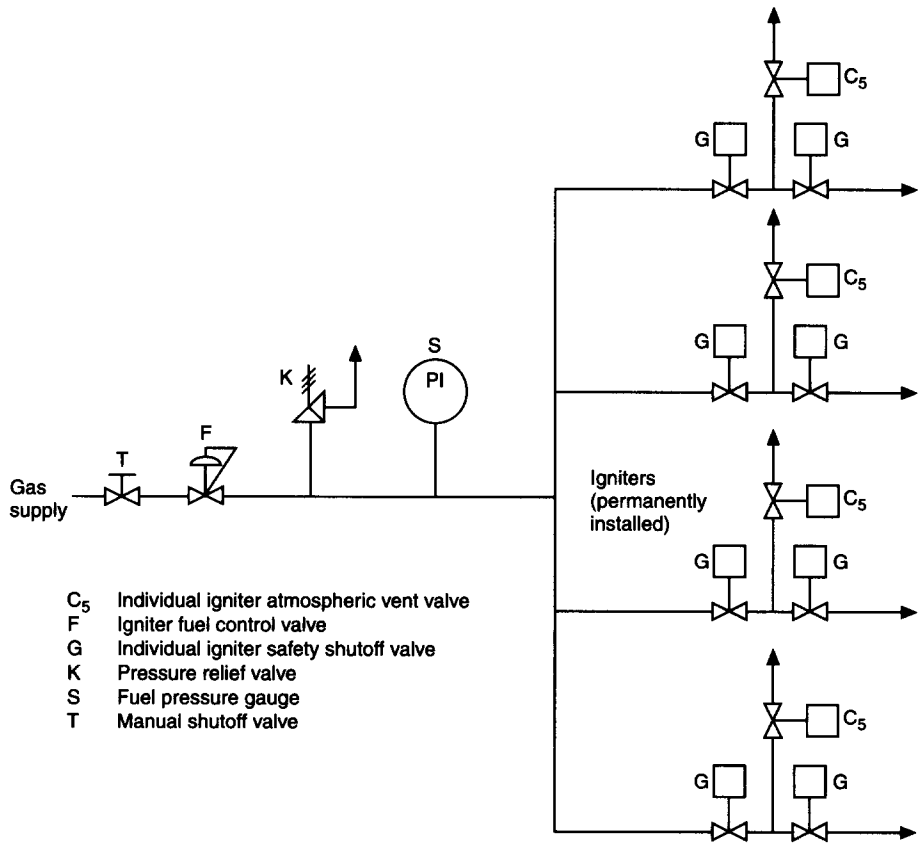


Figure A-6-8.1.1(a) Typical fuel gas ignition system (diagram)—supervised manual.

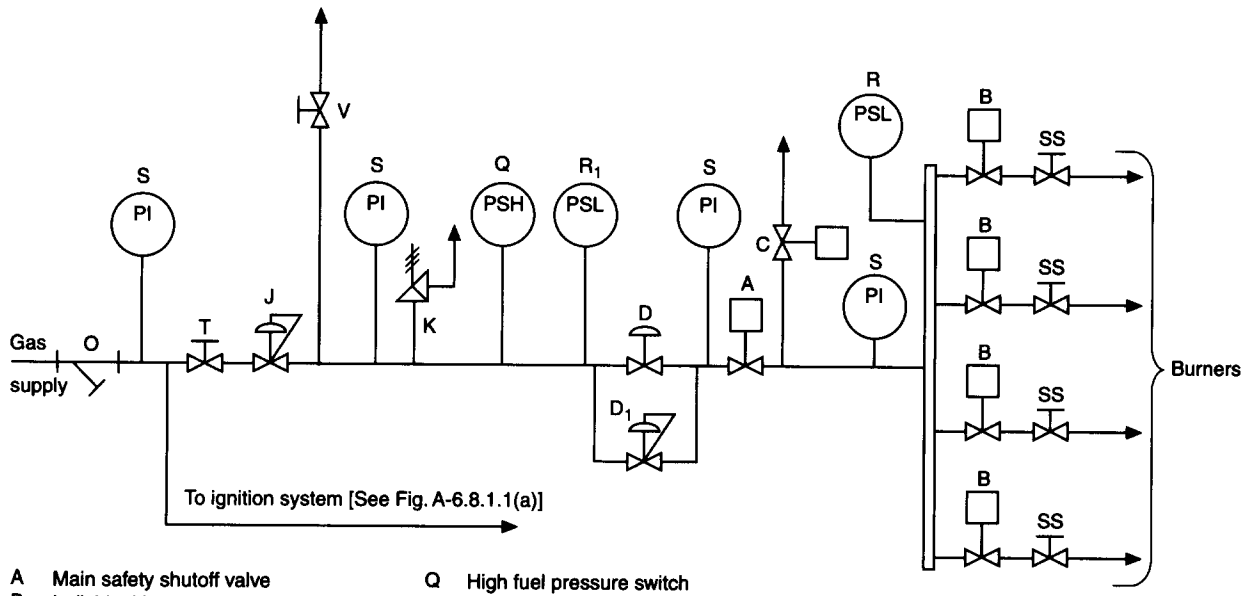


Figure A-6-8.1.1(b) Typical main burner fuel supply system for fuel gas-fired multiple burner boiler (diagram)—supervised manual.

III. The following characteristics could influence the proper and safe burning of fuel oils:

(a) Fuel oil is a complex mixture of hydrocarbons of differing molecular weights and boiling and freezing points. When subjected to sufficiently high temperature, accumulations of fuel partially decompose and volatilize, thus creating new liquid, gaseous, and solid fuels with unpredictable properties.

(b) Fuel oil should be introduced into the furnace as an extremely fine mist to mix intimately with the combustion air in order to burn quickly and completely. In boilers, this is accomplished by spraying 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 the characteristics of the oil that indicate ease of atomization.

(c) Viscosity affects ease of pumping and atomization. Temperature significantly affects viscosity.

(d) Flash point is an indicator of volatility and, thus, of the potential for combustible vapors.

(e) Some fuel oils contain constituents that, when overheated, might decompose to form solids or might solidify when exposed to low ambient temperatures. The presence of such solids in the fuel could cause interruptions.

A-7-2 Hazards Peculiar to Crude Oil Firing.

I. 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 D396, *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 can 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 D396, *Standard Specification for Fuel Oils*. Some of these volatile hydrocarbons, such as propane, butane, and pentane, can volatilize crude oil to the atmosphere; since it is heavier than air, this vaporized material can travel for considerable distances and accumulate as a hazardous concentration.

II. Storage and Handling of Crude Oils. Extensive treatment of storage and handling of crude oils is beyond the scope of this standard. However, the safety aspects are so broad that some clarification is essential. Additional general background information can be found in A-7-1.

A. 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*; or

API 650, *Standard for Welded Steel Tanks for Oil Storage*.

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 might 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*, Section 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.

(c) 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.

(d) Consideration should be given to agitation or other means to prevent settling of sludge in crude oil storage tanks.

(e) 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.

(f) 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.

(g) Ignition sources should be minimized. All piping should be bonded and grounded in accordance with NFPA 77, *Recommended Practice on Static Electricity*.

(h) Consideration should be given to detecting and monitoring combustible gases in areas where they are likely to accumulate.

(i) 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 in Use of Cutting and Welding Processes*. Each area is to be checked with a portable combustible gas tester before starting work that could involve possible flames or ignition sources.

(j) 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-7-3.1.5 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.

A-7-5.4.6 Air Heater.

I. Operation of air heater sootblowers shall be in accordance with the recommendations of the air heater manufacturer. The initial firing of oil fuel in a cold boiler can create a special hazard by causing fires in air heaters.

A-7-7.2 Recommended Additional Alarms (Fuel Oil).

I. All Systems Except Supervised Manual (Sections 7-5 through 7-7).

A. 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 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 also 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) *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.

(f) *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.

(g) *Flame Detector Trouble.* This warns the operator of a flame detector malfunction.

(h) *Main Oil Temperature (High).* This is used for heated oils only.

B. Furnace Conditions.

(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.

II. Supervised Manual Systems (Section 7-8).

A. 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:

(a) Low fuel oil supply pressure;

(b) Low atomizing medium pressure or atomizing medium oil pressure differential;

(c) High furnace pressure;

(d) High furnace draft;

(e) Low combustion airflow;

(f) Loss of interlock energy;

(g) Loss of control system energy;

(h) Failure of burner safety shutoff valve to close;

(i) Low oil temperature;

(j) High oil temperature;

(k) Flame detector trouble.

A-7-8 Fundamental Principles of a Manual System.

I. Boiler Front Controls (Oil Firing).

A. 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 requirements of 7-8.1.1 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.