Report of Committee on Boiler-Furnace Explosions

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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.


This Report has been submitted to letter ballot of the Technical Committee on Boiler-Furnace Explosions which consists of 21 voting members; of whom 17 voted affirmatively, and 4 ballots were not returned (Messrs. Broadhurst, Conaway, Hammon, Lake).
NFPA 85E

BSE-1 - (Entire Standard): Accept
SUBMITTER: Technical Committee on Boiler-Furnace Explosions
RECOMMENDATION: Revise the entire NFPA 85E, Standard for Prevention of Furnace Explosions in Pulverized Coal-Fired Multiple Burner Boiler-Furnaces.
SUBSTANTIATION: The purpose of this revision is:
1. To change the scope of the standard so that it applies to boiler-furnaces with a fuel input of 12,500,000 Btuh in keeping with other of the NFPA 85 series.
2. To refine and expand the definition section.
3. To reorganize the text so that boiler-furnace operational functions are presented in a more orderly manner and in keeping with the NFPA Manual of Style.
4. To provide additional cautionary statements regarding operational conditions.
5. To provide more precise information regarding required interlocks and interlock function for pulverizers and igniters for furnace protection. The changes are shown in Block Diagram I and accompanying text.
6. To provide for consistency in valve nomenclature in various illustrations and throughout the entire text.
COMMITTEE ACTION: Accept.

Standard for Prevention of Furnace Explosions in Pulverized Coal-Fired Multiple Burner Boiler-Furnaces
NFPA 85E-1985

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

Foreword

The Committee on Boiler-Furnace Explosions was organized in 1960 at the request of the American Boiler Manufacturers Association, American Society of Mechanical Engineers, Edison Electric Institute and others, because of concern over the growing hazard to personnel and economic loss from fuel explosions in industrial and utility boiler-furnaces.

The Committee on Boiler-Furnace Explosions functioned until 1970 with two Sectional Committees. The Sectional Committee on Industrial Units was concerned with watertube boilers with a single burner having a capacity of 12,500,000 Btuh and up and was responsible for NFPA 85A. The Sectional Committee on Public Utility Units was concerned with large multiple burner boiler-furnaces and was responsible for NFPA 85B, NFPA 85D and NFPA 85E.

In 1970 the Sectional Committees were disbanded and replaced by Subcommittee 1, which is concerned with multiple burner boiler-furnaces; Subcommittee 2 is concerned with single burner boiler-furnaces. No standard can be promulgated which will guarantee the elimination of furnace explosions. Technology in this area is under constant development which will be reflected in revisions to this standard. The user of this standard must recognize the complexity of fuel firing, both as to types of equipment and the characteristics of the fuel. Therefore, the designer is cautioned that the standard is not a design handbook. Nevertheless, operating companies are encouraged to adopt those features of this standard which are considered applicable and reasonable for existing installations.

1. Purpose.

1-2 Purpose.

1-2.1 The purpose of this standard is to establish minimum standards for the design, installation, operation and maintenance of boiler-furnaces, their fuel burning systems, and related systems, to contribute to operating safety and, in particular, the prevention of furnace explosions.

1-2.2 No standard can be promulgated which will guarantee the elimination of pulverized coal-fired explosions. Technology in this area is under constant development which will be reflected in revisions to this standard. The user of this standard must recognize the complexity of pulverized coal firing as 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 do away with the need for the engineer or competent engineering judgment. It is intended that a designer capable of applying more complete and rigorous analysis to special or unusual problems shall have latitude in the development of such designs. In such cases, the designer is responsible for demonstrating the validity of his approach.

1-2.3 This standard is applicable to new installations and to modifications or extensions of existing equipment for the preparation and burning of fuel in pulverized form contracted for subsequent to June 1, 1985. The standard is not retroactive.

1-2.4 Since this standard is based upon the present state of the art, its application to existing installations is not mandatory. Nevertheless, operating companies are encouraged to adopt those features of this standard which are considered applicable and reasonable for existing installations.

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

Chapter 2 General

2-1 Basic Cause of Furnace Explosions.

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

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

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

(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 attempting to light burner(s).

(f) Purging with too high an air flow which stirs up combustibles shoveling in hoppers.
2-1.4 The conditions favorable to a boiler-furnace explosion described in 2-1.3 are typical examples, and an examination of numerous reports of boiler-furnace explosions suggests that the occurrence of low-fuel explosions, furnace puffs or near-misses has been far more frequent than is usually recognized. It is believed that improved instrumentation, safety interlocks and protective devices, proper operating sequences and a clearer understanding of the problem by both designers and operators can greatly reduce the risks and actual incidence of furnace explosions.

2-1.5 In a boiler-furnace, upset conditions or control malfunction may lead to an air/fuel mixture which may result in a flammable condition after combustion as air/fuel ratio has been re-established. There may exist, in certain parts of the boiler-furnace enclosure or other parts of the unit, dead pockets susceptible to the accumulation of combustibles. These accumulations may ignite with explosive force in the presence of an ignition source.

2-2 Manufacture, Design and Engineering.

2-2.1 The purchaser or his agent shall, in cooperation with the manufacturer, assure that the unit is not deficient in apparatus that is required for proper operation. So far as practical, with respect to pressure parts, fuel burning equipment, air and fuel metering, and safe lighting and maintenance of stable flame.

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

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

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

2-2.4 Although this standard requires a minimum degree of automation (6-1.2) the trend toward more complex plants with increased automation requires added provision for:

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

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

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

2-2.5 The burner front piping and equipment shall be designed and constructed to prevent the formation of hazardous concentrations of combustible gases that may exist under normal operating conditions.

2-3 Installation.

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

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

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

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

2-4 Coordination of Design, Construction and Operation.

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

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

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

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

2-4.2 Furnace explosions have occurred as a result of unfavorable functional design. Frequently, the investigation has revealed human error, and has completely overlooked the contributing causes which resulted in the operating error. Therefore, the design, installation, and functional objectives of the overall system of components and their controls shall be integrated. Consideration shall be given to the man-machine relationships which will exist during the operating life of the system.

2-4.3 In the planning and the engineering phases of plant construction, design shall be coordinated with operating personnel.

2-4.4 The proper integration of the various components consisting of boiler, burner, fuel and air supply equipment, combustion controls, interlocks and safety devices, operator functions, operator communication and training shall be the responsibility of the operating company, and shall be accomplished by:

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

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

2-5 Maintenance Organization.

2-5.1 A program shall be provided for maintenance of equipment at intervals consistent with type of equipment, service requirements and the manufacturers' recommendations.

2-6 Basic Operating Objectives.

2-6.1 Basic operating objectives shall include the following:

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

(b) Standardize all operating procedures. The use of interlocks is essential to minimize improper operating sequences and to stop sequences when conditions are not proper for continuation. It is particularly important that purge and start-up procedures with necessary interlocks be established and rigidly enforced. Chapter 5 describes operating sequences which have proved to be effective in unit operation.

(c) Maintain volumetric air flow at or above purge rate during all operations of the boiler using the open register lightoff procedure (see 5-1.5).

2-6.2 Written operation procedures and detailed checklists for operator guidance shall be provided for achieving these basic operating objectives. All manual and automatic functions shall be described.

2-7 Coal Firing -- Special Problems.

2-7.1 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 items shall be considered in the design of the firing systems:

(a) It may take as little as three pounds of pulverized coal in 1,000 cu ft (.05 oz per cu ft) (.05 kg/m³) of air to form an explosive mixture. Since a larger boiler burns 100 lb (45.4 kg) or more of coal per second, the burning of pulverized coal safely requires close adherence to carefully planned operating sequences. (See Chapter 5.)

(b) Coal requires considerable processing in several independent subsystems which must 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 may accumulate in enclosed spaces.

(d) The raw coal delivered to the plant may contain foreign substances: scrap iron, wood shoring, rags, excelsior, rock, etc. Much of this foreign material can interrupt coal feed, damage or jam equipment, or become a source of ignition within a pulverizer. The presence of foreign material may constitute a hazard by interrupting coal flow. This may cause a total or partial flameout and possible reignition by a dangerous furnace puff or explosion. Wet coal can cause a coal hango in the in-plant coal supply system. Wide variations in the size of raw coal may cause erratic or uncontrollable coal feeding.
(e) Pulverized coal is conveyed through pipes from the pulverizer to the burner as a mixture of finely divided coal in transport air. Improper operation may introduce several hazards. For example, improper removal of a burner from service may introduce: (1) settling out of pulverized coal in the burner pipes to inoperative burners which, on restarting 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. Under Sequence of Operations, Chapter 5, necessary precautions are set up to avoid such hazards.

(f) Pulverizer system explosions have resulted from accumulation of pulverized coal in the hot air, tempering air and coal pipe seal air supply system which are shared by a group of pulverizers. Provisions shall be made in the design of this system to prevent these occurrences and to permit periodic inspections.

(g) The burning of pulverized coal requires close integration of the pulverizer system. Commonly, the pulverizer and the burner systems function as a unit so that starting of the pulverizer is coordinated with the light-off of all burners associated with it. Precautions shall be taken to prevent preignition 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 and by purging the pipes with at least this air flow during the shutdown procedure. Also by operating above these minimum velocities, settling of coal in the burner pipe is prevented associated with this settling is that the accumulated coal may cause a furnace explosion as the flow in that pipe is increased. Means shall be provided to prevent 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 introduces an additional need to maintain minimum transport air velocity, as described in paragraph (g) above. Possible means must be provided for maintaining minimum individual pipe velocity, or the minimum safe pipe velocity must be based on the lowest velocity pipe associated with a particular pulverizer. This requires testing during initial start-up and periodically thereafter. Too low a velocity in a burner pipe may cause coking of coal at the burner tip, resulting in damaging burner pipe fires.

(i) It is necessary to dry the coal for proper pulverizer operation and combustion. This is usually accomplished by supplying hot air to the pulverizer. Temperature control is normally 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. Too low an outlet temperature impedes pulverization. Too high an outlet temperature 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 fuel and 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 2-7.3). When 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, follow the clearing procedure outlined in 5-3 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. Thus, the lack of meter indication of combustibles does not prove that unburned coal particles or other combustibles are not present.

2-7.3 Coal Burner Turndown Ratio.

2-7.3.1 In addition to the criteria determining the range of burner operation for stable flame shown in 4-1.2.2(2)(e)(h) other factors involving proper burner operation are described in 2-7.3.2 and 2-7.3.3, inclusive.

2-7.3.2 Coal is subject to wide variations in analysis and characteristics. The change in percent of volatile constituents affects the ignition characteristics of the coal and may affect the safe 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 safe minimum firing rate may increase significantly. Pulverized coal fitness may also affect the safe turndown ratio. Therefore, it is necessary to establish minimum firing rates for the range of volatile and fitness expected. Too low a firing rate may result in gradual buildup of coke or slags on the burner tip or on the furnace floor, and shall be avoided.
Control and/or shut off tempering air.

Coal, but an almost endless variety as to character and constituents which form ash after burning. There is no standard pressure parts and the combustion process.

Pulverized and delivered in suspension directly to the burner(s).

Gas passing into any system component.

Regulating the flow of primary air or pulverizer air.

The other basic classifications are subbituminous, bituminous and composition. Starting with lignite (brown coal) at one extreme, and stored in bins from which it is withdrawn through feeders as required for burning.

The application of heat from combustible fuels, in a boiler.

The physical boundary for all boiler and combustion process.

One in which the fuel is pulverized and stored in bins from which it is withdrawn through feeders as required for burning.

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

A characteristic of coal representing its relative ease of pulverization measured on an arbitrary scale. The larger values, such as 40, represent coals easier to pulverize. The smaller values, such as 4, represent coals more difficult to pulverize.

A pressure actuated device arranged to stop the fuel input when the air/fuel ratio is less than a prescribed value.

A device which provides proven ignition energy to immediately light-off the main burner.

An igniter applied to ignite the fuel input through the burner and to support ignition under any burnout light-off or operation. Its capacity and capacity are such that it will provide sufficient ignition energy (generally in excess of 10 percent of full load burner input) at its associated burner to raise any credible combination of burner inputs of both fuel and air above the minimum ignition temperature.

An igniter applied to ignite the fuel input through the burner under prescribed light-off conditions. It is also used to support ignition under low load of certain adverse operating conditions. The range of capacity of such igniters is generally 4 percent to 10 percent of full load burner fuel input. It shall not be used to ignite main fuel under uncontrolled or abnormal conditions. The burner shall be operated under controlled conditions to limit the potential for abnormal operation, as well as to limit the charge of fuel to the furnace in the event that ignition does not occur during light-off. Class 2 igniters may be operated as Class 3 igniters.

An igniter applied particularly to gas and oil burners to ignite the fuel input under prescribed light-off conditions. The capacity of such igniters generally does not exceed 4 percent of the full load burner fuel input. As a part of the burner light-off procedure the igniter is turned off when the timed trial for ignition of the main burner has expired. This is to ensure that the main flame is self-supporting, is stable and is not dependent upon ignition support from the igniter. The use of such ignition or to extend the burner control range shall be prohibited.

A special Class 3 high energy electrical igniter capable of directly igniting the main burner fuel. This type igniter shall not be used unless supervision of the individual main burner flame is provided.

The process of rendering a combustible mixture noncombustible through the addition of an inert gas or steam.

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

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

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 Water Cutout. A device arranged to effect a master fuel trip when 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 mixtures of them: propane, propylene, normal butane, isobutane and butylenes.

Master Fuel Trip. An event resulting in the rapid automatic shut-off of all fuel, including igniters.

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

Natural Gas. A gaseous fuel occurring in nature consisting mostly of a mixture of organic compounds (normally methanenormal butane, propane and ethane). The Btu value of natural gas varies between 700 and 1500 Btu per cu ft (26.1 and 55.2 MJ/m^3), the majority averaging 1000 Btu per cu ft (37.3 MJ/m^3).

Oil. See Fuel Oil.

Open Register. A procedure for purging and lighting-off a boiler-furnace under specified, controlled conditions. (See Section 5–1.5.)

Operating Range. The region between the maximum fuel input and minimum fuel input in which the burner flame can be maintained, continuous and stable.

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

Partial Loss of Flame. Loss of flame at one or more separate flame envelopes or burners of a furnace while stable flame is maintained at one or more 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 will burn in suspension.

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

Purge Rate. A constant flow of not less than 25 percent or more than 40 percent of the full load volumetric air flow at the point of measurement.

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 may also control the direction and velocity of the air stream for efficient mixing with the incoming fuel.

Safety Shut-off Valve (Safety Trip Valve). A fast-closing valve which automatically and completely shuts off the fuel supply to main burners or igniters in response to the master fuel trip or other actuating devices.

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.

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

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

Unit. The confined space of the furnace and the associated boiler component systems and capable of being controlled over the full operating range of the unit.

Unit Purge. A flow of air (at purge rate) through the unit from the FD fan to the stack for the greater of either: (1) a period of not less than 5 minutes; or (2) 5 changes in volume of the boiler-furnace enclosure.

Valve. Barrier Valve. A valve, not necessarily dust-tight, to prevent furnace gases from travelling back into any system component opened for inspection or maintenance.

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

Dust-Tight Valve. A tight-seating valve installed in the fuel supply pipe to the burner to permit or stop flow.

Flow Control Valve. A device capable of regulating quantity of throughput to a controlled range.

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

Warm-up Burner (Warm-up Gun). A burner, usually smaller than the main burner, which 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.

Chapter 4 Equipment Requirements

4–1 Fuel Burning System.

4–1.1 Functional Requirements.

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

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

4–1.2 System Requirements.

4–1.2.1 The fuel burning system shall provide means for proper startup, operation and shutdown of the combustion process. This shall include appropriate openings and configurations in the component assemblies to permit suitable observation, measurement and control of the combustion process.

4–1.2.2 The fuel burning system consists of the boiler-furnace enclosure and the following subsystems: air supply, raw coal supply, pulverizer, main burner, ignition, and combustion products removal. Each shall be sized and interconnected to satisfy the following requirements.

(a) Boiler-Furnace Enclosure.

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

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

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

(b) Air Supply Subsystem.

1. The air supply subsystem shall be sized and arranged to ensure a continuous air flow 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 fuel gas, water, and fuel. Appropriate drain and access openings shall be provided.

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

(c) Raw Coal Supply Subsystem.

1. The raw coal supply subsystem shall be properly sized and arranged to ensure a continuous, steady fuel flow adequate for all operating requirements of the unit.
2. The raw coal unloading, storage, transfer and preparation facilities 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 includes the installation of breakers, cleaning screens and magnetic separators where necessary.

3. Raw coal feeders shall be designed with a capacity range to allow for variations in size, quality and moisture content of the fuel as specified by the purchaser. Raw coal piping to the burners 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.

(d) Pulverizer Subsystem.

Coal pulverizing equipment shall be designed to provide a range of capacity which will minimize starting and stopping of pulverizers during boiler load changes. It shall produce satisfactory coal fineness over a specified range of fuel analyses and characteristics. Pulverizer systems shall be designed and operated in accordance with NFPA 85E, Standard for the Installation and Operation of Pulverized Fuel Systems.

(e) Main Burner Subsystem.

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 burning characteristics of the fuel, and the normal variations in fuel handling and fuel burning equipment introduce an uncertainty to the lower operating limits of the main fuel subsystem in an given furnace design. In these circumstances Class 1 or Class 2 igniters shall be provided by test may be used to maintain stable flame (see 4-1.2.2(e)(2), and 4-1.2.2(e)(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 adversely affect the burners in operation. Such transients are generated by burner shutoff valves, dampers, etc., that operate at speeds faster than the speed of response of other components in the system. These tests shall include the expected range of available fuel.

3. When Class 1 and Class 2 igniters are used, tests to determine limits of stable flame shall be repeated with the igniters in service. The resulting extended turndown range shall be available when the igniters are proven in service.

4. Provisions shall be made for visual observation of conditions at the ignition zone. Additional provision shall be made for flame detection equipment.

5. Provision shall be made for the cleaning of the burner nozzle and tip.

6. The burner equipment shall be located in an appropriate environment with convenient access for maintenance. Special cognizance shall be taken of the fire hazards imposed by leakage or rupture of piping near the burner. Requirements of good housekeeping shall be recognized.

(f) Ignition Subsystem.

1. The ignition subsystem shall be sized and arranged to ignite the main burner input within the limits 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 are designated by use as Class 1 or Class 2 as defined in Chapter 3. Many factors affect the classification of the igniters, among which are: 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. Tests shall be performed to verify that transients in the ignition air and fuel supply or the main air and fuel supply do not extinguish the igniter flame, reduce the igniter's ability to perform its intended function, or adversely affect other burners and igniters in operation.

3. Permanently installed igniters are required. They shall be individually supervised to verify that 4-1.2.2(e)(1) and (3) are complied with. This supervision shall include igniter flame and capacity.

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

5. All individual igniter safety shutoff valves shall be located as close as practical to igniters so as to minimize the volume of fuel left in the igniter fuel lines.

(g) 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 that 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 as not to contribute to furnace pulsations.

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

4-2 Combustion Control System.

4-2.1 Functional Requirements.

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

4-2.1.2 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 throughout the operating range of the boiler.

4-2.2 System Requirements.

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

(b) The air/fuel ratio shall be maintained within the limits of the boiler output range as established by test.

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

(d) Capability shall be provided for setting minimum and maximum limits on the fuel and air control subsystems to prevent fuel and air flows 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 4-1.2.2(e)(3)).

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

(f) Means shall be provided to assure adequate primary air for transport of the required fuel input.

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

(h) The control system design shall prevent demanding a fuel-rich mixture. Control action toward more fuel and less air shall be blocked when air/fuel ratio decreases below a preset value.

(i) When the air/fuel ratio decreases below a preset value, control action toward less fuel, or more air, or both, shall be taken (see 5-4.2).

(j) On balanced draft furnaces, combustion chamber furnace draft shall be maintained at the desired set point.

(k) Equipment shall be designed and procedures established to permit as much on-line maintenance of combustion control equipment as practical.

(i) Capability for calibration and check testing of combustion control and associated interlock equipment shall be provided.

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

(n) 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 vs. total air flow and for use as an operating guide.

4-3 Flame Monitoring and Tripping Systems.

4-3.1 Functional Requirements.

4-3.1.1 The basic requirements of any flame monitoring and tripping system shall be:

(a) To bring combustion instability situations to the attention of the operator for remedial action.

(b) Upon detection of serious combustion problems likely to lead to accumulation of unburned fuel, to automatically initiate an emergency shutdown of the involved equipment.

4-3.2 System Objectives.
4-3.2.1 Influence of Furnace Configuration. System objectives shall be developed with due consideration given to those requirements which are specifically related to the combustion conditions that are typical for a particular furnace configuration, burner system, and fuel characteristics. Such objectives shall be consistent with the particular manufacturer's design philosophy.

4-3.2.2 Tripping Philosophy. It is not always possible with coal firing to maintain a consistently detectable flame at each flame "envelope" (or burner) even when combustion is maintained. Several factors contribute to development of a realistic tripping philosophy.

Flame stability of each individual burner is normally comparable to that at all other burners associated with a single pulverizer. Where ignition energy and detection is proven for a number of burners there is less concern for random or intermittent indications of loss of flame by individual detectors associated with that pulverizer.

4-3.2.3 It is recognized that any fuel input which does not ignite and burn on a continuous basis will create a hazard. Regardless of the number or pattern of flame loss indications used for tripping, any one of an operating system of flame "envelope" shall initiate an alarm, warning the operator of potential hazard.

4-3.2.4 Field testing is required to validate basic flame tripping concepts. These tests shall be performed on representative units. The results of these tests may be applied to other units of similar size and arrangement, including burners/nozzles of substantially the same capacity using similar fuels. These tests are not intended to replace acceptance tests relating to proof of design function and components.

4-3.2.5 Basic Furnace Configurations. The three principal furnace configurations are: wall-fired, angular downshot-fired, and tangentially-fired.

The applicability of the following tripping philosophies will generally be specific to only one or two of the three furnace configurations. Each philosophy of 4-3.2.5 (a), (b), and (c) is not necessarily applicable to all three furnace configurations.

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 pulverizer shall be tripped when a predetermined number of burners per pulverizer have tripped. The purpose of this interlock is to prevent operating a pulverizer/burner system with an insufficient number of burners per 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 predefined 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 an operator shall visually inspect flame conditions to determine if burner or flame "envelope" shall initiate an alarm, warning the operator of potential hazard.

(c) Furnace Tripping. In furnace configurations where individual pulverizer/burner sets are not selectively tripped: [1] detectors shall be located and restricted to monitor the fuel and air ignited at each zone or burner and [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. 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 the entire furnace, the master fuel trip shall be initiated automatically.

4-3.2.6 Miscellaneous Considerations.

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

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

5-1 General.

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

5-1.2 The sequences are based on the typical fuel supply systems shown in figures D-1 through D-6 (see Appendix D). These sequences shall be developed by the boiler unit manufacturer. Each philosophy of burners/nozzles of substantially the same capacity using similar fuels. These tests are not intended to replace acceptance tests relating to proof of design function and components.

5-1.3 The starting and shutdown sequence outlined herein shall be followed because it describes the recommended practice of maintaining a continuous air flow through the unit throughout the start-up and initial load-carrying period of operation at the rate which existed during the purge operation until such time as more fuel and air are required for load. This means that the same number of burner registers or burner dampers required for purging the boiler are left open throughout the starting sequence as set forth below. This operating practice will maintain an air-rich atmosphere while starting and to establish minimum velocities through the furnace to prevent hazardous accumulations of unburned fuel.

5-1.4 Burners shall not be placed in service or removed in a random pattern but in sequence defined by operating instructions and verified by actual experience with the unit in order to minimize lancing or stratification of fuel or combustion products. Pulverizers and burners are placed in service as required, with fuel flows and individual register or damper settings which will ensure proper light-off.

5-1.4.1 The pulverizer loading and primary air flow may be used as a guide in maintaining the required fuel flow per burner and shall be maintained within prescribed limits.

(a) A minimum stop, either mechanical or by control setting, shall be provided for the primary air through the pulverizer and line. The pulverizer and line cannot be reduced below a minimum flow that is found by test to prevent settling in the burner lines. These minimum settings shall not prevent isolation of the pulverizing equipment.

(b) Because of the relatively high fuel input at minimum permissible 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 which will permit continuous firing.

(c) While it is preferable to light-off all burners associated with a pulverizer, it may 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 burners are not complete to maintain stable flame without the aid of igniters.

5-1.4.2 If some registers have been maintained in the closed position, these shall not be opened without either readjusting the total air flow to maintain the same burner air flow, or the same air flow to the area excluded by closure. Isolation of registers on idle burners. During startup the total furnace air throughput shall not be reduced below the purge flow rate.

5-1.5 The open register light-off and purge procedure shall be used to maintain air flow at or above purges rate during all operation of the open register light-off system. The following purge procedure is based upon the concept that the following basic operating conditions will significantly improve the margin of operating safety, particularly during start-up.

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

(b) Means for establishing the desired fuel-rich condition at individual burners during light-off.

(c) An air-rich furnace atmosphere during the light-off and warm-up by maintaining total furnace air flow at the same rate as that required for the unit purge.
NFPA 85E

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

(a) All or most of the burner air registers are placed in a predetermined open position.

(b) Complete a unit purge with the burner air registers in the position specified in item (a). (Caution: See 2-1.3(f).)

(c) Components (e.g. precipitators, fired reheaters) containing sources of ignition energy shall be purged for the greater of either: (1) a period of less than five minutes or (2) 5 volume changes of that component, prior to being placed into operation.

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

(e) Light the first burner or group of burners without any change in air flow setting or in burner air register position.

5-1.5.2 Each boiler shall be tested during initial start-up to determine whether any modifications to the procedures specified in 5-1.5.1 are required in order to obtain satisfactory ignition or to satisfy other design limitations during light-off and warm-up. For example, some boilers will be purged with the registers in the normal operating position. In this event it may be necessary to momentarily close the registers of the burners being lighted to establish ignition. However, unnecessary modifications in the basic procedure shall be avoided, thereby satisfying the basic objectives set forth in 5-1.5, particularly that of keeping the number of equipment manipulations to a minimum.

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

5-2 Functional Requirements.

5-2.1 Cold Start.

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

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

(b) The bottom of the furnace, including ash hopper, 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 every startup.

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

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

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

(f) Igniter safety shutoff valves closed and spark de-energized. (See Appendix D.) For gas ignition systems, see NFPA 85B; for oil ignition systems, see NFPA 85E.

(g) Pulverizing equipment effectively isolated to prevent inadvertent or uncontrolled leakage of coal into the furnace.

(h) Proper drum water level established in drum-type boilers, and circulating flow established in forced circulation boilers or minimum water flow established in once-through boilers.

(i) Pulverizers, feeders, and associated equipment in good condition and adjusted properly ready for service. All pulverizer and feeder sensor times clean prior to starting.

(j) Igniter safety shutoff valve is operational.

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

(l) Oxygen and combustibles analyzer(s), if provided, operating satisfactorily and obtaining a sample. Combustibles indication at zero and oxygen indication at maximum.

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

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

Individual igniters or groups of igniters may also be tested while the unit is in service. Such tests shall be made with no main fuel present at its associated burner and the burner air register in its normal start-up or light-off position.

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

5-2.1.2 Starting Sequence.

The starting sequence shall be performed in the following order:

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

(b) Start an induced draft fan if provided; then start a forced draft fan. Start additional induced draft or forced draft fans in accordance with NFPA 85B as required to achieve purge flow rate.

(c) When provided, start regenerative type air heaters and gas recirculation fans in the manner recommended by the boiler manufacturer.

(d) Open dampers and burner registers to purge position in accordance with open register purge method objectives outlined in 5-1.5.

(e) Adjust air flow to purge flow rate, and perform a unit purge. Special provisions may be necessary to prevent hazardous accumulation of volatile vapors which may be heavier than air, or to detect and purge accumulations in the furnace ash pit.

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

(g) For gas or oil-fired igniters, open the igniter safety shutoff supply valve and determine that the igniter fuel control valve is holding the recommended fuel pressure for proper igniter capacity.

(h) Adjust the air register or damper on the burners selected for light-off to the position recommended by the manufacturer. (see 5-1.5.2).

(i) Initiate the spark or other source of ignition for the igniter on the burners to be lit. Open the individual igniter safety shutoff valves. If flame on first igniter is not established within 10 seconds, close the igniter safety shutoff valve, determine and correct the cause of failure to ignite. With air flow maintained at purge rate, repurge is not necessary, but a waiting period of at least one minute shall elapse before attempting a retiral. Repeated retrials of igniters without investigating and correcting the cause of the malfunction is particularly hazardous.

(j) With the coal feeder off, open all gates between the coal bunker and pulverizer feeder and make sure coal is available to the feeder.

(k) Make sure that the igniters are established and are providing adequate ignition energy for the main burners. Start the pulverizing equipment following the equipment manufacturer's instruction.

If necessary, readjust furnace air flow after conditions stabilize, but air flow shall not be reduced below the purge rate.

(l) Start the feeder at a predetermined setting with the feeder delivering coal to pulverizer. Pulverized coal will be delivered to the burners after the specific time delay required to build up storage in the pulverizer and transport the fuel to the burner. This time delay, which is determined by test, may be a few seconds with some types of equipment or as much as several minutes with others.

(m) Ensure that the main burner fuel admitted to the furnace is ignited. Satisfactory ignition shall be obtained within ten seconds following the specific time delay described in (l).

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 unless the cause of failure to ignite or loss of ignition is known to be loss of coal in the pulverizer subsystem. In the latter event, initiation of the master fuel trip may be omitted but all conditions for proper light-off shall exist before restoring coal feed.
For the next and all subsequent pulverizers placed in operation, failure to provide for loss of ignition for any reason on any burner shall cause the stopping of fuel flow to that burner in accordance with manufacturer's recommendations. All conditions for proper light-off shall exist before restarting the burner.

(n) After stable flame is established, slowly adjust the air registers (for air) to its normal operating position, making sure that ignition is not lost in the process.

(g) The loading on the operating pulverizer shall be at a level that will prevent its load being reduced below operating limits when an additional pulverizer is placed in operation.

If an operating pulverizer does not have all of its burners in service it is desirable to start another pulverizer with all burners and shut down the pulverizer with idle burners and empty it rather than start its idle burners. If ample precautions are taken to prevent (1) accumulation of coal in idle burner lines, (2) not burners, (3) and diffusers which may cause coking and fires when coal is introduced, and (3) excessive disturbance of air/fuel ratio of the operating burners, idle burners may be started on the first pulverizer without shutting it down. (See also 5-5.4.)

(p) Follow the same procedure (i) through (n) when placing an additional pulverizer into service. CAUTION: When fuel is being admitted to the furnace, never place ignitors in service for any burner without proof that there is a normal fire in the furnace. A common cause of furnace explosions is the placing of ignitors in service where there has been a flameout of an operating burner.

(q) Igniters may be shut off after exceeding predetermined minimum main fuel input (see 4-1.2.2(e)(2)). The burners should then 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 permit 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 undetected flameout of main burners.

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

1. A predetermined minimum main fuel input has been exceeded;
2. All registers on non-operating burners are closed, unless compensated for by the control system;
3. Burner fuel and air flow are adjusted as necessary;
4. Stable flame and suitable furnace conditions have been established.

(s) Place additional pulverizers in service as required by the boiler load following procedures prescribed in (i) through (r).

5-2-2 Normal Operation

5-2.2.1 The firing rate shall be regulated by increasing or decreasing fuel and air supply simultaneously to all operating burners, maintaining normal air/fuel ratio continuously at all firing rates. This does not prohibit provisions for air lead and lag of the fuel during changes in firing rate.

5-2.2.2 The firing rate shall not be regulated by varying the fuel to individual burners by means of the individual burner valves. The individual burner shutoff valves shall be wide open or completely closed (do not use at intermediate settings).

5-2.2.3 Air registers shall be set at the firing positions as determined by tests.

EXCEPTION: This does not apply to systems provided with metering of air and fuel to each burner and designed specifically for individual burners modulating control.

5-2.2.4 The burner fuel and air flow shall be maintained between the maximum and minimum limits specified by the boiler manufacturer or, preferably, as determined by trial. These trials shall be conducted as for minimum fuel and for stable flame: (i) with all burners in service and combustion control on automatic; and (2) with different combinations of burners in service and combustion control on automatic. Where changes are made in the maximum and minimum limits because of various burner combinations and different fuel conditions, retesting shall be required.

5-2.2.5 If lower minimum loads are required, remove pulverizer(s) and associated burners from service and operate the remaining pulverizers at the fuel rate above load 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 most restrictive condition that will prevent its load being reduced below operating limits when an additional pulverizer is placed in operation.

5-2.2.6 The ignition system shall be tested for stable operation at the various conditions described in 5-2.2.5.

5-2.2.7 On loss of an individual burner flame, the flow of fuel to all burners of the pulverizer subsystems shall be stopped unless furnace configuration and tests have determined that one of the three automatic tripping philosophies described in 4-3.2.5 is applicable. Registers of shutdown burners shall be closed if interference with air/fuel ratio at other burner flame envelopes occurs. See 5-3 for hazards and NFPA 85E for procedures for clearing pulverizers tripped while full of coal.

5-2.2.8 Total air flow shall not be reduced below 25 percent of full load volumetric air flow.

5-2.3 Normal Shutdown

5-2.3.1 When taking the unit out of service, the boiler shall be brought down to a load resulting in purge rate air flow the reverse of that used during startup. Burner registers are left in startup position, maintaining purge air flow rate until all burners are removed from service.

5-2.3.2 A pulverized fuel system shall be shutdown in the following sequence:

(a) Switch combustion controls from "automatic" to "manual" control unless controls are designed and tuned to bring boiler down to shutdown conditions.

(b) Adjust fuel input, air flow and register positions to values established for startup.

(c) Determine presence of flame at burners of pulverizer to be shut down, then place the igniters in service at these burners.

(d) Shut off the hot air and open cold air to cool down pulverizer. See 85F, Pulverized Fuel Systems, for detailed information on pulverizer cooling, etc.

(e) Stop the feeder when pulverizer has cooled. Continue operation of the pulverizer with sufficient air flow to empty out pulverizer and associated burner lines.

(f) Introduce inerting medium into pulverizer as required by coal characteristics.

(g) Shut down the pulverizer subsystem when burner fires are out, and the pulverizer is empty and cool.

(h) Close all individual burner line shutoff valves unless otherwise directed by manufacturer's instructions.

(i) Remove igniters from service.

5-2.3.3 As the boiler load is reduced:

a. Shut down remaining pulverizers consecutively following procedures 5-2.3.2 (c) through (l).

b. When the next pulverizer being removed may result in flame instability, place igniters in service on burners still being fired.

5-2.3.4 When all pulverizers and igniters have been removed from service, verify air flow at purge rate and perform a unit purge.

5-2.3.5 After completion of unit purge, closing the burner air registers and shutdown of FD and ID fans is optional. However, maintaining air flow through the unit is recommended to prevent accumulation of combustible gases. Leakage of main or igniter fuels into the unit shall be prevented.

5-2.4 Normal Hot Restart

5-2.4.1 When restarting a unit after it has been tripped or after it has been boiled up under pressure, the requirements for Cold Start, 5-2.1.2(d) through (l), shall be satisfied before proceeding.

5-2.4.2 Following Starting Sequence, 5-2.1.2(a) through (s).

5-2.5 Emergency Shutdown -- Master Fuel Trip

5-2.5.1 With the initiation of a master fuel trip from any of the emergency conditions tabulated in 5-2.5.1.1 and 5-2.5.1.2, all coal flow to the furnace from all pulverizer subsystems shall be stopped by tripping burner shutoff valves or equivalent. The igniter safety shutoff valve, individual igniter safety shutoff valves, primary air fans or exhausts, recirculating fans, and coal feeders shall be tripped and igniter sparks de-energized. If a furnace igniting system is installed, the igniting system shall be operated simultaneously with the master fuel trip.

Electrostatic precipitators, fired reheaters or other ignition sources shall be tripped.
Master fuel trips shall operate in a manner to stop all fuel flow into the furnace within a period that will not permit a dangerous accumulation of fuel in the furnace. A master fuel trip shall not initiate an ID or FD fan trip.

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

(a) Loss of all induced or all forced draft fans (see NFPA 85E).

(b) Furnace pressure exceeds the normal operating pressure by a value recommended by the manufacturer.

(c) All fuel inputs zero (see 6-2.3.2[c]). See 6-3.1 for required interlocks and trips for individual pulverizer subsystems.

(d) Loss of all flame.

(e) Partial loss of flame sufficient to introduce hazardous accumulation of unburned fuel.

5-2.5.1.2 Mandatory Master Fuel Trips with Alarms -- Not Necessarily Automatic.

(a) Failure of the first pulverizer subsystem to operate successfully under the conditions specified in 5-2.1.2(m) and Section 6-3.

(b) Loss of energy supply for combustion control, burner control, or interlock systems.

(c) Furnace negative pressure exceeds normal operating pressure by a value recommended by the manufacturer (see NFPA 85E).

5-2.5.2 Procedure for Purging After an Emergency Shutdown Fans that are operating after the master fuel trip (MFT) shall be continued in service. Do not immediately increase the air flow by deliberate manual or automatic control action. If the air flow is above purge rate, it may gradually be deceased to this value for a post-firing purge. If the air flow is below purge rate at the time of the trip, it shall be continued at the existing rate for five minutes and then gradually increased to purge rate air flow and held at this value for a post-firing purge.

5-2.5.3 When the emergency shutdown was caused by loss of draft fans, or draft fans have also tripped, close gas recirculating fan dampers and slowly open all dampers in the air and flue gas passages of the unit to the wide 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. Maintain this condition for a period of not less than fifteen minutes. At the end of this period, start the fan(s) in accordance with NFPA 85E. Gradually change air flow to purge rate and complete post firing purge.

5-2.5.4 If it is impossible to restart for some extended period of time, a flow of air through the unit to prevent accumulations of combustible gases shall be maintained.

5-3 Hazards of Residual Coal Charges in Pulverizers and Clearing After Shutdown.

5-3.1 Pulverizers will, on tripping, have a residual charge distributed primarily in the pulverizer, but also in burner piping and nozzles. This accumulation in a hot pulverizer will generate volatiles that are combustible and explosive. The charge will likely be sufficient to change light-off conditions and the start-up procedure described in NFPA 85F shall be followed. If there is doubt whether a pulverizer is charged with coal, use the procedure of NFPA BSF.

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 required by the load in accordance with the procedure described in NFPA BSF.

5-3.3 If a delay in load demand is expected or undetermined, but boiler conditions, including completion of purging, will permit firing, the pulverizers shall be started and cleared in sequence per NFPA BSF. 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 flames, one of the pulverizers and its feeder shall be placed in service to help burn the coal being injected from the remaining pulverizers being cleared.

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 will depend on the 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 BSF.

5-3.5 If firing cannot be initiated for an extended time period, 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 when opening and cleaning any pulverizer and caution is necessary (see NFPA BSF).

5-4 Emergency Conditions Not Requiring Shutdown or Trip.

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 air flow or else tripping of the unit is mandatory.

5-4.2 If an air deficiency should develop while flame is maintained at the burners, reduce the fuel until the proper air/fuel ratio has been restored. If fuel flow cannot be reduced, slowly increase air flow until proper air/fuel ratio has been restored.

5-4.3 Common emergencies that may arise when firing pulverized coal include:

(a) Raw coal hangups ahead of feeder causing unstable or intermittent firing.

(b) Wet coal or changing coal quality causing flame instability.

These conditions are particularly hazardous. When these conditions are encountered, igniters shall be placed in service immediately on all operating burners in order to support ignition. If coal feed to a malfunctioning pulverizer subsystem can be restored or adequate ignition energy can be supplied before main burner ignition is lost, the subsystem may be continued in service provided the flame is stable. However, if the main burner flame on any burner of any pulverizer subsystem is extinguished and Class I igniters are not in operation, then that burner or subsystem shall be shut down in a way that will prevent coal being reintroduced to the furnace in a random manner. Start-up conditions shall be established before coal feed is restored.

5-5 General Operating Requirements -- All Conditions.

5-5.1 Prior to entering a unit, action shall be taken to prevent fuel from entering the furnace.

5-5.2 The unit shall be purged prior to starting a fire in the furnace.

5-5.3 The igniter for the burner shall always be used. Burners shall not be lighted one from another or from the hot refractory.

5-5.4 When operating at low capacity, operate with a reduced number of pulverizers, as specified by the manufacturer. 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 voltage to capacitors there is a high probability that coking or serious fires would result from operating under such conditions.

5-5.5 Sootblowers (except for air heater sootblowers) shall be operated only when heat input to the furnace is at a rate high enough to prevent a flameout during the sootblower operation and not be operated at low load and high excess air conditions. This does not preclude use of wall and superheater and reheater sootblowers for cleaning during outage periods if a purge has been completed and purge air flow maintained.

5-5.6 When performing pulverizer or burner line maintenance with the boiler in service, positive means to isolate the pulverizer or burner line from the furnace shall be used.

5-5.7 When clearing the pulverizer and burner piping into a furnace, the procedures outlined in 5-3 shall be followed.

5-5.8 Pulverizer Equipment Fires. The procedures of NFPA BSF shall be followed when dealing with pulverizer equipment fires.

Chapter 6 Interlock System

6-1 General.

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

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

6-1.2.1 It is possible to achieve conditions conducive to a furnace explosion which will not be detected by any of the mandatory automatic trip devices, even though they are properly adjusted and maintained. Therefore, operating personnel shall be made aware of the limitations of the automatic protection system.
6-2 Functional Requirements.

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

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

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

(a) Supervise starting procedure and operation to ensure proper operating practices and sequences.

(b) Trip the minimum amount of equipment in the proper sequence when the safety of personnel or equipment is jeopardized.

(c) Indicate the initiating cause of the trip and prevent starting any portion of the system until proper conditions are established.

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

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

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

(g) Provide for proper preventive maintenance.

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

EXCEPTION: Individual burner flame failure elements may be used for initiating master fuel trip systems.

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

6-3 System Requirements.

6-3.1 Interlocks (see Figure 1).

6-3.1.1 Figure 1 shows the required system of interlocks which will provide the basic furnace protection for a pulverized coal multiple burner boiler-furnace operated in accordance with this standard. The Fuel Trip System is shown in block form.

(a) Block No. 1 shows loss of an individual igniter flame which shall be interlocked as follows:

1. Close the individual igniter safety shutoff valve, and de-energize the spark.

2. With main flame proven at individual burners, signal main flame protection system that igniter flame has been lost (see 4-3).

(b) Block No. 2 represents conditions caused by improper igniter fuel header pressure which shall be interlocked so as to initiate the tripping of the igniter and individual igniter safety shutoff valves, and de-energize sparks. When gas is used for igniter fuel both high and low pressure shall be interlocked. When oil is used, low pressure shall be interlocked.

(c) When oil is used for ignition fuel with air or steam atomization, improper atomization of an igniter fuel is a condition which shall trip the igniter and individual igniter safety shutoff valves, and de-energize sparks as indicated by Block No. 3.

6-3.1.2 Blocks No. 4 through 13 represent conditions which initiate the tripping of both the main and ignition fuel supplies through a master fuel trip element. The master fuel trip element shall be of the type which stays "tripped" until the furnace purge system allows it to be reset as shown at the bottom of Figure 1. Whenever the fuel trip element 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, coal feeders, and de-energizes all sparks, and all ignition sources within the unit and flue gas path. These interlocks are as follows:

FUEL TRIP SYSTEM

1. LOSS OF IGNITOR FLAME (AFTER TRIAL TIME)

2. IGNITOR FUEL PRESSURE OUT OF STABLE RANGE

3. IGNITOR ATOMIZING MEDIUM PRESSURE IMPROPER

4. LOSS OF I.D. FAN

5. LOSS OF F.D. FAN

6. CUT BACK MAIN FUEL

7. LOSS OF I.D. FAN

8. LOSS OF F.D. FAN

9. EXCESSIVE FURNACE PRESSURE

10. ALL FUEL INPUTS ZERO

11. MANUAL TRIP SWITCH

12. LOSS OF ALL FLAME

13. PARTIAL LOSS OF FLAME INTRODUCING HAZARD

14. LOSS OF MAIN BURNER FLAME

CLOSE INDIVIDUAL IGNITOR SAFETY SHUTOFF VALVE AND DE-ENERGIZE SPARK

CLOSE MAIN AND INDIVIDUAL IGNITOR SAFETY SHUTOFF VALVES AND DE-ENERGIZE SPARKS

TYPICAL CAUSE OF TRIP INDICATOR

OTHER SUB-SYSTEMS

STOP COAL FLOW TO PULVERIZERS AND BURNERS

FURNACE PURGE SYSTEM

ARE ALL PULVERIZERS TRIPPED AND ALL SAFETY SHUTOFF VALVES CLOSED

ARE REQUIRED BURNER SAFETY SHUTOFF REGISTERS OPEN

ONE SET OF I.D. AND F.D. FANS RUNNING

IS THERE AT LEAST 5 MIN. AIR FLOW

5 MIN. DELAY

RESET MASTER FUEL TRIP SYSTEM

NOTE:

BASED UPON 2 PAIR OF I.D. AND F.D. FANS; OTHER ARRANGEMENTS OF FANS WILL AFFECT ACTIONS IN BLOCKS 4, 6, 7, AND 8

Figure 1 Block Diagram for Furnace Interlocks for a Pulverized Coal Multiple Burner Boiler-Furnace (6-3.1)
NFPA 85E

(a) Blocks No. 4 through 8 represent protection against loss of large quantities of combustion air. The loss of all ID or all FD fans shall operate the master fuel trip element. The loss of one ID or FD fan or other large loss of air shall shut back the fuel in order to maintain the proper air/fuel ratio. This may be interlocked or made a part of the combustion control system. (See 5-4 and NFPA 85E.)

(b) Excess furnace pressure (Block No. 9) is also interlocked with the master fuel trip element to protect against abnormal furnace conditions such as that resulting from a tube rupture, damper failure, etc.

(c) Block No. 10 represents an interlock operational 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 "pulverizer tripped and all igniter safety shutoff valves closed" function in the furnace purge system at the bottom of Figure 1.

(d) Block No. 11 represents a manual switch which can be used by the operator in an emergency to trip the main and ignition fuel supply.

(e) Block No. 12 shows loss of all flame in the furnace and is interlocked to activate the master fuel trip element.

(f) Block No. 13 represents a partial loss of flame in the furnace with some burners still operating to the extent that hazardous conditions could develop irrespective of, or due to failure of, other protective interlocks. It is potentially more hazardous at low load levels. The decision as to specific requirements for implementation of this trip shall be a design decision based on furnace configuration, total number of burners, number of burners affected, interlock system, and load level.

(g) Block No. 14 indicates that, on loss of main burner flame, the tripping strategy of Section 4-3 shall be followed.

6-3.1.3 Each source of operation of the master fuel trip element shall actuate a "cause of trip" indication which will tell the operator the initiating cause of the tripping impulse.

6-2.1.4 The proper starting sequence shall be checked by a series of permissive interlocks shown on Figure 1 as the purge system, all conditions or evidence shall be satisfied before the ignition system can be energized after resetting of the master fuel trip element. This will assure 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 fuel trip element can be reset and the light-off sequence started. Components (e.g., precipitators, fired reheat) containing sources of ignition energy shall be purged for the greater of either: (1) a period of not less than 5 minutes; or (2) 5 volume changes of that component, prior to being placed into operation.

6-4 Trips and Interlocks for Individual Pulverizer Subsystem on Direct Fired Furnaces.

6-4.1 Mandatory Automatic Pulverizer Subsystem Trips. A direct-fired pulverized coal system shall be interlocked so that:

(a) Failure of primary air fan or exhaust fan trips coal burner shutoff valves and feeder.

(b) Failure of pulverizer trips feeder.

(c) Failure of feeder shall initiate an alarm; restarting is blocked until feeder start-up conditions are re-established.

6-4.2 Mandatory Pulverizer Subsystem Trips — Not Necessarily Automatic.

(a) Loss of igniters or adequate ignition energy during the start-up of a pulverizer trips that pulverizer subsystem.

(b) Loss of individual coal burner flame trips that burner or its pulverizer subsystem (see 5-2.6.7).

(c) Loss of coal feed to the burners of a pulverizer subsystem trips the feeder unless the associated Class 1 igniters are in operation. Before restarting the feeder, establish the conditions under which the igniters will ignite the input. (See 5-4.3.)

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 must preferably a combination shall be used to indicate loss of coal.

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 of the burners served by the pulverizer in service and proven.

(b) Start primary air fan or exhaust.

(c) Start pulverizer.

(d) Start raw coal feeder.

Chapter 7 Alarm System

7-1 Functional Requirements.

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

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

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

7-2 System Requirements.

7-2.1 Required Alarms. In addition to the safety features of the interlock system, the separately annunciated alarms in 7-2.1(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 and air pressure is outside of operating range and that poor oil atomization may result.

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

(c) Pulverizer Tripped. Alarm when pulverizer is tripped (not normal shutdown).

(d) Primary Air Fan Tripped. Alarm when primary air fan is tripped (not normal shutdown).

(e) Coal Stoppage to Pulverizer. Alarm when the feeder is running and the coal detecting device indicates no coal flowing or when the feeder trips (not normal shutdown).

(f) Coal-Air High Temperature. Alarm when coal-air temperature within or at the pulverizer outlet exceeds normal operating limits.

(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). For balanced draft furnace operation. This shall be measured near the normal furnace draft tap location. It warns the operator of a draft, in excess of normal operation, and an approach to trip condition.

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

(j) Loss of Operating ID Fan. For balanced draft furnace operation. This shall be sensed and alarmed only when the fan is supposed to be running and is not.

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

(l) Loss of Interlock Power. This shall be sensed and alarmed and shall include all sources of power required to complete interlock functions. For example, if both a 125 VDC electric circuit and a compressed air circuit are required for an interlock function, then 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 combustion control system.

(n) Loss of Flame. Partial or total loss of a flame "envelope" still receiving fuel shall be monitored and alarmed so that an evaluation can be made as to whether or not a hazardous condition exists in the furnace.

Chapter 8 Mandatory Referenced Publications

8-1 This chapter lists publications referenced within this document which, in whole or in part, are part of the requirements of this document.


A-1.2 Furnace Conditions

 malfunction.

A-I Recommended Additional Alarms and Monitors.

Appendix A

Recommended Additional Alarms

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

A-1.1 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 desirable that provisions be made in the design for possible future conversion to automatic trips in the interlock system.

The alarms and monitors (a) through (k) are recommended but not required.

(a) Ignition Fuel Supply Pressure (Low). Monitor the ignition fuel supply pressure at a point as far upstream of the control and safety trip valve as practical.

(b) Combustibles. This device warns the operator of a possible hazardous condition by alarming when any measurable combustibles are indicated and by providing a second alarm when combustibles reach a dangerous level.

(c) Oxygen (High and Low). This also warns the operator of a possible hazardous condition.

(d) Flue Gas Analyzer Failed. This warns the operator that the analyzer is not functioning properly.

(e) Air/Fuel Ratio (High and Low). If proper metering is installed, this can be used to indicate a potentially hazardous air/fuel ratio.

(f) Flue Gas Analyzer Failed. This warns the operator that the analyzer is not functioning properly.

(g) No Load on Pulverizer. Alarm when the pulverizer indicated coal load substantially below normal and the feeder is running.

(h) Pulverizer Overload. Alarm when the pulverizer indicators over-load.

(i) Burner Register Closed. Provide control room indication and/or alarm for the conditions of all secondary air burner dampers closed on an operating burner.

(j) Flame Detector Trouble. Warn operator of a flame detector malfunction.

A-1.2 Furnace Conditions

(a) Furnace Television. Properly designed and installed furnace television may be of significant value as a supplementary indication of flame or 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 but not a substitute for visual inspection.

(b) Flame Detector Indication. Provide facility for operator observation of flame detector output signal strength.

Appendix B

Coal Firing -- Special Problems

This Appendix is not a part of the requirements of this NFPA document but is included for information purposes only.
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(e) On new units, the equipment manufacturers may also introduce new burner and furnace designs such as wider spacing of burners.

The effect of all of these methods is generally to produce lower flame temperatures and longer, less turbulent flames, which result in lower NOX.

C-1.1.3 NOX emissions on start-up and very low loads are inherently low, well within regulatory limits. Thus, the open-register light-off and purge rate procedure specified in this standard for start-up and low load is not in any way affected and is not to be compromised.

C-1.2 Hazards of Low NOX Firing Methods.

C-1.2.1 The methods discussed in this section may have important implications with regard to furnace safety, particularly for existing units, and may introduce unacceptable risks if precautions are not taken:

(a) Low excess air and multistage air admission tend to reduce the margins formerly available to prevent or minimize accumulations of unburned fuel in the furnace during combustion upsets or flame-outs. Thus, it is important to trip fuel to individual burners or the total furnace flame envelope on loss of flame (See 5-2.5 and 6-4.1).

(b) The methods of C-1.2.1 may narrow the limits of stable flames produced by burner subsystems. The tests specified in 4-1.2.2(e)(2) are to be repeated on existing units when any of these methods are introduced.

(c) When flue gas recirculation is used, special methods and devices are to be provided to assure adequate mixing and uniform distribution of recirculated gas and air to the windboxes. When 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. When flue gas recirculation is introduced so that only air and not the mixture is introduced at the fuel nozzle, adequate means are to be provided to ensure the prescribed distribution of air and the recirculating flue gas/air mixture.

(d) All of the methods tend to increase the possibility of unburned combustibles throughout the unit and ducts. Thus, flue gas CO analyzers are recommended.

C-1.2.2 Any change in flame characteristics to reduce NOX emissions may require changing the type or relocating flame detectors on existing units.

Appendix D

Typical Pulverizer and Ignition Systems

This Appendix is not a part of the requirements of this NFPA document but is included for information purposes only.
This Appendix lists publications which are referenced within this NFPA document for information purposes only and thus is not considered part of the requirements of the document.

E-1 ASTM Publications.

American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103


Figure D-5 - Typical Direct Fired Pulverizing Subsystem
Individual External Transport Type

Figure D-6 - Typical Direct Fired Pulverizing Subsystem
Common External Transport Type