

NFPA 8501

Standard for Single Burner Boiler Operation

1997 Edition



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An International Codes and Standards Organization

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NFPA 8501
Standard for
Single Burner Boiler Operation
1997 Edition

This edition of NFPA 8501, *Standard for Single Burner Boiler Operation*, was prepared by the Technical Committee on Single Burner Boilers, released by the Technical Correlating Committee on Boiler Combustion System Hazards, and acted on by the National Fire Protection Association, Inc., at its Annual Meeting held May 19–22, 1997, in Los Angeles, CA. It was issued by the Standards Council on July 24, 1997, with an effective date of August 15, 1997, and supersedes all previous editions.

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

This edition of NFPA 8501 was approved as an American National Standard on August 15, 1997.

Origin and Development of NFPA 8501

Originally, this standard was adopted at the 1964 Annual Meeting as NFPA 85A and covered natural gas-fired units. At the 1965 Annual Meeting, Tentative Standard NFPA 85C-T-1964, covering fuel oil-fired units, was combined with NFPA 85A and the combined standard was issued as NFPA 85. Revisions were adopted in 1967, 1972, and 1973.

In 1982, the committee suggested that the document be renumbered to 85A to distinguish it from the remainder of the Boiler-Furnace standards, which are referred to as the NFPA 85 series.

Major revisions in 1982 included changes to the scope of the standard so that it applied to boilers with fuel input that was greater than 12,500,000 Btu/hr (3663 kW) rather than 10,000 lb of steam per hour.

In 1987, NFPA 85A was completely revised. Various technical changes were incorporated, and other revisions were made to conform with the NFPA *Manual of Style*.

The 1992 edition was a partial revision and included a variety of changes. Foremost was the renumbering and retitling of the document to NFPA 8501, *Standard for Single Burner Boiler Operation*. This was consistent with an initiative by the NFPA Boiler project to remove the letter designations and use shorter document titles.

This latest edition is a partial revision that includes changes to improve the standard. Included are new or revised definitions, new appendix material, and revised requirements for logic control systems.

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

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This list represents the membership at the the Committee was balloted on the text of this edition. Since that time, changes in membership may have occurred. A key to classifications is found at the back of this document.

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

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

Information on referenced publications can be found in Chapter 11 and Appendix B.

FOREWORD

Technological advances in recent years, and in particular the persuasiveness of microprocessor-based hardware, make it even more important that only highly trained individuals be employed in the translation of these guidelines into operating systems. Each type of hardware has its own unique features and operational modes. It is vital that the designer of the safety system be completely familiar with the features and foibles of the specific hardware as well as possess a thorough understanding of these standards and their intent.

It is neither possible for these standards to encompass specific hardware applications nor should these standards be considered a “cookbook” for the design of a safety system.

When applying any type of equipment to a safety system, the designer must carefully consider all of the possible failure modes and the effect that each might have on the integrity of the system and the safety of the unit and personnel. In particular, no single point failure should result in an unsafe or uncontrollable condition or in a masked failure of a microprocessor-based system that could result in the operator unwittingly taking action that could lead to an unsafe condition.

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

(a) Introduction and common sections that apply to all fired fuels covered in this standard (Chapters 1 through 4)

(b) Detailed sections that are specific to the particular operation described (Chapter 5 applies to starting up a cold boiler. Chapter 6 applies to operating systems, including automatic recycling and automatic nonrecycling systems for both watertube and firetube boilers and supervised manual systems for oil- or gas-fired watertube boilers. Chapter 7 applies to simultaneous firing of fuels. Chapter 8 applies to fuel transferring. Chapter 9 applies to dual atomizers in a single burner. Chapter 10 applies to inspection and maintenance.)

When using this standard, the common sections should be used in conjunction with the sections covering the specific operation that is described.

Chapter 1 Introduction

1-1 Scope.

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

- (a) Natural gas as defined in Chapter 3
- (b) Other gas having a Btu value and characteristics that are similar to natural gas
- (c) Fuel oil of No. 2, 4, 5, or 6 grade
- (d) Gas and oil that are fired simultaneously for fuel transfer
- (e) Gas and oil that are fired simultaneously and continuously

1-1.2* This standard is not retroactive. This standard is applicable to new installations and to major alterations or extensions of existing equipment for the preparation and burning of fuel that are contracted for use subsequent to the date of this standard.

1-1.3 Furnaces, such as those of process heaters that are used in chemical and petroleum manufacture wherein steam generation is incidental to the operation of a processing system, are not covered by this standard.

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

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

1-2 Purpose.

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

1-2.2* No standard that will guarantee the elimination of furnace explosions can be promulgated. Technology in this area is under constant development, reflected in part by revisions to this standard. The user of this standard must recognize the complexity of fuel 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 and does not do away with the need for competent, engineering judgment. It is intended that a designer who is 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 the validity of the approach.

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

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

Chapter 2 General

2-1 Furnace Explosions.

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

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

2-1.3 Numerous situations can arise in connection with the operation of a boiler that will produce common explosive conditions such as the following:

(a) An interruption of the fuel or air supply or ignition energy to the burners that is sufficient to result in momentary loss of flames and is 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 a complete furnace flameout, and the ignition of the accumulation by a spark or other ignition source, such as that from attempting to light a burner

2-1.4 The conditions that are favorable to a furnace explosion as described in 2-1.3 are typical examples, and an examination of numerous reports of furnace explosions suggests that the occurrence of small explosions, furnace puffs, or near misses has been far more frequent than 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 incidences of furnace explosions.

2-1.5 In a boiler, upset conditions or control malfunction could lead to an air/fuel mixture that could result in a flameout that is followed by reignition after a combustible air/fuel ratio has been reestablished. Dead pockets could exist in the boiler enclosure or other parts of the unit where combustible mixtures can accumulate under upset furnace conditions. These accumulations can ignite with explosive force in the presence of an ignition source.

2-2 Manufacture, Design, and Engineering.

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

2-2.2 All fuel systems shall include provisions to prevent foreign substances from 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 that increase exposure to hazards.

2-2.4 This standard requires a minimum degree of automation. The trend toward more complex plants or increased automation requires added provisions for the following:

(a) Information about significant operating events permitting the operator to make a rapid evaluation of the operating situation. Usable displays of variables shall be provided that will allow the operator to avoid unsafe conditions.

(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 could 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.

2-3.2 The constructor who is responsible for the erection and installation of the equipment shall see that all pertinent apparatus is installed and connected properly.

2-3.3 The purchaser, the engineering consultant, the equipment manufacturer, and the operating company shall avoid boiler operation until such safeguards have been tested to operate properly as a system. In some instances, installing temporary interlocks and instrumentation to meet these requirements could be necessary. Any such temporary system shall be reviewed by the purchaser, the engineering consultant, the equipment manufacturer, and the operating company; and agreement shall be reached on its suitability in advance of start-up.

2-3.4 The safety interlock system and protective devices shall be tested jointly by the organization with responsibility for the system design and those who operate and maintain such systems and devices during the normal operating life of the plant. These tests and checks shall be accomplished before initial operation.

2-4 Coordination of Design, Construction, and Operation.

2-4.1 Statistics indicate that human error can be a contributing factor in the majority of furnace explosions. However, it is important to consider whether the error is also a result of the following:

- (a) Lack of understanding of, or failure to use, proper operating procedures, safeguards, and equipment
- (b) Unfavorable operating characteristics of the equipment or its controls
- (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 overlooked completely the chain of causes that triggered the operating error. Therefore, the design, installation, and functional objectives of the overall system of the components and their controls shall be integrated. Consideration shall be given to the ergonomics that will exist during the operating life of the system.

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

2-4.4 The proper integration of the various components—which consist of the boiler, burner, fuel and air supply equipment; controls, interlocks, and safety devices; operator and maintenance functions; and communication and training—shall be the responsibility of the operating company and shall be accomplished by the following steps:

- (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 improvements can be made to make the plant safer and more reliable
- (c) Maintaining documentation of plant equipment, system, and maintenance

2-5 Maintenance Organization. A program shall be provided for the maintenance of equipment at intervals that are consistent with the type of equipment, the service requirements, and the manufacturer's recommendations. (*See Chapter 10.*)

2-6 Basic Operating Objectives.

2-6.1 Basic operating objectives shall include the following:

- (a) Establish operating procedures that will result in the minimum number of manual operations.
- (b) Standardize all operating procedures. The use of interlocks is essential to minimize improper operating sequences and to stop sequences when conditions are not proper for continuation. It is particularly important that purge and start-up procedures with necessary interlocks be established and rigidly enforced. Chapters 5 and 6 describe operating sequences that have proven to be effective in boiler operation.

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

2-7* Gas and Oil Firing—Special Problems. Common hazards are involved in the combustion of solid, liquid, or gaseous

fuels. Each of these fuels has special hazards that relate to its physical characteristics.

Chapter 3 Definitions

For the purpose of this standard, terms shall have the following meanings.

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

Air/Fuel Ratio.

Air-Rich. An air/fuel ratio, supplied to a furnace, that provides more air than that required for an optimum air/fuel ratio.

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

NOTE: This is not "Air-Rich" as previously defined.

Fuel-Rich. A ratio of air to fuel supplied to a furnace that provides less air than that required for an optimum air/fuel ratio.

Theoretical Air (Stoichiometric Air). The chemically correct amount of air that is required for complete combustion of a given quantity of a specific fuel.

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

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

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

Approved.* Acceptable to the authority having jurisdiction.

Atomizer. The device in an oil burner that emits liquid fuel in a finely divided state.

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

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

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

Automatic. See Burner Management System.

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

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

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

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

Burner Management System. The control system that is dedicated to boiler safety, operator assistance in the starting and stopping of fuel preparation and burning equipment, and the prevention of misoperation of and damage to fuel preparation and fuel-burning equipment.

Types of systems used in this document include the following:

Automatic (Recycling). A system by which a furnace is purged and a burner is started, ignited, and stopped automatically and recycles on a preset pressure range.

Automatic (Nonrecycling). A system by which a furnace is purged and a burner is started, ignited, and stopped automatically but does not recycle automatically.

Manual. A system by which a furnace is purged and a burner is started, ignited, and stopped manually.

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

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

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

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

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

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

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

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

Fuel Oil. Numbers 2, 4, 5, and 6 fuel oils as defined in ASTM D 396, *Standard Specifications for Fuel Oils*.

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

Furnace. An enclosure that is designed for the combustion of fuel.

Furnace Purge. See definition of Purge.

Gas. See definitions of LP-Gas and Natural Gas.

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

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

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

High Water Temperature Switch. A temperature-actuated device that is arranged to effect a normal burner shutdown when the water temperature exceeds a preset temperature.

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

Class 1. An igniter that is applied to ignite the fuel input through the burner and to support ignition under any burner light-off or operating conditions. Its location and capacity are such that it will provide sufficient ignition energy, generally in excess of 10 percent of fuel load burner input, at its associated

burner to raise any credible combination of burner inputs of both fuel and air above the minimum ignition temperature. Class 1 igniters shall be permitted to also operate as Class 2 or Class 3 igniters.

Class 2. An igniter that is applied to ignite the fuel input through the burner under prescribed light-off conditions. It is also used to support ignition under low load or certain adverse operating conditions. The range of capacity of such igniters is generally 4 percent to 10 percent of full load burner fuel input. Class 2 igniters shall be permitted to be operated as Class 3 igniters.

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

Class 3 Special (Direct Electric Igniter). A special Class 3, high-energy, electrical igniter that is capable of directly igniting the main burner fuel.

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

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

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

Light-Off. The establishment of the combustion of fuel entering the furnace.

Light-Off Time Limit Timer. A device that is used on supervised manual systems that limits the allowable time between completion of purge and light-off. This time shall be no more than five minutes.

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

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

(a) **Hard-Wired Systems.** Individual devices and interconnecting wiring.

(b) **Microprocessor-Based Systems.**

1. Computer hardware, power supplies, I/O devices, and interconnections between these items

2. Operating systems and logic software

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

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

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