

NFPA 8504

Standard on Atmospheric Fluidized-Bed Boiler Operation

1996 Edition



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

IMPORTANT NOTICE ABOUT THIS DOCUMENT

NFPA codes, standards, recommended practices, and guides, of which the document contained herein is one, are developed through a consensus standards development process approved by the American National Standards Institute. This process brings together volunteers representing varied viewpoints and interests to achieve consensus on fire and other safety issues. While the NFPA administers the process and establishes rules to promote fairness in the development of consensus, it does not independently test, evaluate, or verify the accuracy of any information or the soundness of any judgments contained in its codes and standards.

The NFPA disclaims liability for any personal injury, property or other damages of any nature whatsoever, whether special, indirect, consequential or compensatory, directly or indirectly resulting from the publication, use of, or reliance on this document. The NFPA also makes no guaranty or warranty as to the accuracy or completeness of any information published herein.

In issuing and making this document available, the NFPA is not undertaking to render professional or other services for or on behalf of any person or entity. Nor is the NFPA undertaking to perform any duty owed by any person or entity to someone else. Anyone using this document should rely on his or her own independent judgment or, as appropriate, seek the advice of a competent professional in determining the exercise of reasonable care in any given circumstances.

The NFPA has no power, nor does it undertake, to police or enforce compliance with the contents of this document. Nor does the NFPA list, certify, test or inspect products, designs, or installations for compliance with this document. Any certification or other statement of compliance with the requirements of this document shall not be attributable to the NFPA and is solely the responsibility of the certifier or maker of the statement.

NOTICES

All questions or other communications relating to this document and all requests for information on NFPA procedures governing its codes and standards development process, including information on the procedures for requesting Formal Interpretations, for proposing Tentative Interim Amendments, and for proposing revisions to NFPA documents during regular revision cycles, should be sent to NFPA headquarters, addressed to the attention of the Secretary, Standards Council, National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

Users of this document should be aware that this document may be amended from time to time through the issuance of Tentative Interim Amendments, and that an official NFPA document at any point in time consists of the current edition of the document together with any Tentative Interim Amendments then in effect. In order to determine whether this document is the current edition and whether it has been amended through the issuance of Tentative Interim Amendments, consult appropriate NFPA publications such as the *National Fire Codes*® Subscription Service, visit the NFPA website at www.nfpa.org, or contact the NFPA at the address listed above.

A statement, written or oral, that is not processed in accordance with Section 5 of the Regulations Governing Committee Projects shall not be considered the official position of NFPA or any of its Committees and shall not be considered to be, nor be relied upon as, a Formal Interpretation.

The NFPA does not take any position with respect to the validity of any patent rights asserted in connection with any items which are mentioned in or are the subject of this document, and the NFPA disclaims liability for the infringement of any patent resulting from the use of or reliance on this document. Users of this document are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, is entirely their own responsibility.

Users of this document should consult applicable federal, state, and local laws and regulations. NFPA does not, by the publication of this document, intend to urge action that is not in compliance with applicable laws, and this document may not be construed as doing so.

Licensing Policy

This document is copyrighted by the National Fire Protection Association (NFPA). By making this document available for use and adoption by public authorities and others, the NFPA does not waive any rights in copyright to this document.

1. Adoption by Reference—Public authorities and others are urged to reference this document in laws, ordinances, regulations, administrative orders, or similar instruments. Any deletions, additions, and changes desired by the adopting authority must be noted separately. Those using this method are requested to notify the NFPA (Attention: Secretary, Standards Council) in writing of such use. The term "adoption by reference" means the citing of title and publishing information only.

2. Adoption by Transcription—**A.** Public authorities with lawmaking or rule-making powers only, upon written notice to the NFPA (Attention: Secretary, Standards Council), will be granted a royalty-free license to print and republish this document in whole or in part, with changes and additions, if any, noted separately, in laws, ordinances, regulations, administrative orders, or similar instruments having the force of law, provided that: (1) due notice of NFPA's copyright is contained in each law and in each copy thereof; and (2) that such printing and republication is limited to numbers sufficient to satisfy the jurisdiction's lawmaking or rule-making process. **B.** Once this NFPA Code or Standard has been adopted into law, all printings of this document by public authorities with lawmaking or rule-making powers or any other persons desiring to reproduce this document or its contents as adopted by the jurisdiction in whole or in part, in any form, upon written request to NFPA (Attention: Secretary, Standards Council), will be granted a nonexclusive license to print, republish, and vend this document in whole or in part, with changes and additions, if any, noted separately, provided that due notice of NFPA's copyright is contained in each copy. Such license shall be granted only upon agreement to pay NFPA a royalty. This royalty is required to provide funds for the research and development necessary to continue the work of NFPA and its volunteers in continually updating and revising NFPA standards. Under certain circumstances, public authorities with lawmaking or rule-making powers may apply for and may receive a special royalty where the public interest will be served thereby.

3. Scope of License Grant—The terms and conditions set forth above do not extend to the index of this document.

(For further explanation, see the Policy Concerning the Adoption, Printing, and Publication of NFPA Documents, which is available upon request from the NFPA.)

Copyright © 1996 NFPA, All Rights Reserved

NFPA 8504

Standard on

Atmospheric Fluidized-Bed Boiler Operation

1996 Edition

This edition of NFPA 8504, *Standard on Atmospheric Fluidized-Bed Boiler Operation*, was prepared by the Technical Committee on Fluidized-Bed 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 20–23, 1996, in Boston, MA. It was issued by the Standards Council on July 18, 1996, with an effective date of August 9, 1996, 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 8504 was approved as an American National Standard on July 26, 1996.

Origin and Development of NFPA 8504

In 1984, the Technical Committee on Boiler-Furnace Explosions began work on a document for the relatively new technology of fluidized-bed combustion system boilers. A new document, NFPA 85H, was issued in 1989. This was developed through numerous task force, subcommittee, and technical committee meetings. The document was written to provide user requirements in order to limit the hazards associated with these special systems and to broaden the NFPA 85 series of standards, which deal with safe boiler operation.

The second edition of the document constituted a major rewrite to address numerous technical issues. Foremost among the changes was the redesignation of the document from NFPA 85H, *Standard for the Prevention of Combustion Hazards in Atmospheric Fluidized Bed Combustion System Boilers*, to NFPA 8504, *Standard on Atmospheric Fluidized-Bed Boiler Operation*.

This edition of NFPA 8504 incorporates numerous changes, mostly for correlation with the other documents in the series. However, there were several technical changes made to this standard.

Technical Correlating Committee on Boiler Combustion System Hazards

Dale E. Dressel, *Chair*
Monsanto Co., MO

Merton W. Bunker, Jr., *Nonvoting Secretary*
Nat'l Fire Protection Assn., MA

Courtney D. Alvey, Lutherville, MD
William H. Axtman, Gray Gull Assoc., Inc., VA
Johnny W. (Bill) Bass, Forney Int'l Inc., TX
James R. Bostick, Bailey Controls Co., OH
Thaddeus Bukowski, Underwriters Laboratories Inc., IL
Paul L. Cioffi, Babcock & Wilcox Co., OH
William E. Cunningham, Jr., Raytheon Engr & Constructors, MA
John C. deRuyter, The DuPont Co., DE
Robert S. Elek, Kemper Nat'l Insurance Cos., OH
Ronald E. Fringeli, M & M Protection Consultants, OH
Steven K. Funk, The DuPont Co., TX
Rep. American Petroleum Inst.
Gordon G. Gaetke,
Union Carbide Corp., WV

Masaaki Kinoshita, Mitsubishi Heavy Industries Ltd, Japan
James K. Lafontaine, Pennsylvania Electric, PA
Donald J. L. Lin, Quilin Inc., TX
Francis X. Maskol, Honeywell, Inc., PA
Peter B. Matthews, Hartford Steam Boiler Inspection & Ins. Co., CT
Russell N. Mosher, American Boiler Mfrs. Assn., VA
Jerry J. Moskal, ABB Combustion Engr, Inc., CT
Michael C. Polagye, Factory Mutual Research Corp., MA
James L. Sherman, Baltimore Gas & Electric Co., MD
Robert F. Tomczak, Tampa Electric Co., FL
Rep. Edison Electric Inst.
Peter J. Gore Willse, Industrial Risk Insurers, CT
Rep. Industrial Risk Insurers
Henry K. Wong, Foster Wheeler Energy Corp., NJ

Alternates

Tetsuya Fujino, Mitsubishi Heavy Industries America, Inc., CA
(Alt. to M. Kinoshita)
Dennis P. Jenkins, Kemper Nat'l Insurance Cos., NC
(Alt. to R. S. Elek)
Kenneth N. Lawrence, Honeywell, Inc., PA
(Alt. to F. X. Maskol)
W. Scott Matz, Forney Int'l Inc., TX
(Alt. to J. W. Bass)
John P. O'Rourke, ABB Combustion Engr, Inc., CT
(Alt. to J. J. Moskal)

S. Sam Pagadala, M & M Protection Consultants, IL
(Alt. to R. E. Fringeli)
Richard J. Wachter, Industrial Risk Insurers, CT
(Alt. to P. J. G. Willse)
J. C. Waung, Babcock & Wilcox Co., OH
(Alt. to P. L. Cioffi)
William G. Yeich, Exxon Research and Engr Co., NJ
(Alt. to S. K. Funk)

Nonvoting

Shelton Ehrlich, Palo Alto, CA
Thomas B. Hamilton, Hamilton Consulting Services, NC

Robert P. Kaltenbach, Kansas City, MO

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 is also 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.

Technical Committee on Fluidized-Bed Boilers

Shelton Ehrlich, *Chair*
Palo Alto, CA

William H. Axtman, Gray Gull Assoc., Inc., VA
David D. Cole, Texas-New Mexico Power Co., TX
Arnold (Red) Conrod, Nova Scotia Power Corp., Canada
Joseph N. Darguzas, Sargent & Lundy, IL
Robert F. Eng, Foster Wheeler Energy Corp., NJ
Robert Fleck, Montana-Dakota Utilities, ND
Richard J. Gendreau, Stone & Webster Engr Corp., MA
Gerhardt O. Goldbach, Combustion Power Co., CA
Robert M. Herdman, ABB Combustion Engr, Inc., CT
Donald J. Knotts, Black & Veatch, MO
David L. Kraft, Babcock & Wilcox Co., OH
James K. Lafontaine, Pennsylvania Electric, PA
Leonard E. Little, Riley Stoker Corp., MA
Donald L. Lueckenotte, Burns & McDonnell, MO
Thomas M. McKee, U.S. Generating Co., MD

Robert H. Melvin, AC Power ACE Operation, CA
Thomas Modrak, Raytheon Engr & Constructors, PA
Brian W. Moore, Hartford Steam Boiler Inspection & Ins. Co., CT
Russell N. Mosher, American Boiler Mfrs. Assn., VA
John A. Ness, IBEW, MN
Rep. Int'l Brotherhood of Electrical Workers
W. Ben O'Brien, Tennessee Valley Authority, AL
Michael C. Polagye, Factory Mutual Research Corp., MA
Robert S. Rand, Bailey Controls, OH
Donald L. Wietzke, Ahlstrom Pyropower Corp., CA
Peter J. Gore Willse, Industrial Risk Insurers, CT
Rep. Industrial Risk Insurers
James M. Witt, Jr., Southern Co. Services Inc., AL

Alternates

Thomas J. Boyd, Electric Power Research Inst., NC
(Alt. to S. Ehrlich)

Douglas J. Campbell, Nova Scotia Power Corp., Canada
(Alt. to A. Conrod)

Joe Combs, Tennessee Valley Authority, KY
(Alt. to W. B. O'Brien)

Steven L. Edwards, Black & Veatch, MO
(Alt. to D. J. Knotts)

Blair E. Kerstetter, Riley Stoker Corp., MA
(Alt. to L. E. Little)

Gary E. Norman, ABB Combustion Engr, Inc., CT
(Alt. to R. M. Herdman)

James J. Utt, Ahlstrom Pyropower Corp., CA
(Alt. to D. L. Wietzke)

Merton W. Bunker, NFPA Staff Liaison

These lists represent the membership at the time each Committee was balloted on the text of this edition. Since that time, changes in the membership may have occurred.

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

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

Contents

Chapter 1 Introduction	8504- 5	Chapter 7 Sequence of Operations for Gas-Fired Warm-up Burners	8504-25
1-1 Scope	8504- 5	7-1 General	8504-25
1-2 Purpose	8504- 5	7-2 Gas Firing — Special Problems	8504-25
Chapter 2 General	8504- 5	7-3 Warm-up Burner Subsystem Requirements	8504-25
2-1 Furnace Explosions	8504- 5	7-4 Flame Monitoring and Tripping System	8504-26
2-2 Furnace Pressure Excursions	8504- 6	7-5 Sequence of Operations	8504-26
2-3 Manufacture, Design, and Engineering	8504- 6	7-6 Interlock System	8504-28
2-4 Installation	8504- 6	7-7 Alarm System	8504-28
2-5 Coordination of Design, Construction, and Operation	8504-7	7-8 Boiler Front Control (Supervised Manual)	8504-28
2-6 Maintenance Organization	8504- 7	Chapter 8 Sequence of Operations for Oil-Fired Warm-up Burners	8504-31
2-7 Basic Operating Objectives	8504- 7	8-1 General	8504-31
2-8 Training	8504- 7	8-2 Oil Firing — Special Problems	8504-31
2-9 Fluidized-Bed Combustion — Special Problems	8504- 8	8-3 Warm-up Burner Subsystem Requirements	8504-31
Chapter 3 Definitions	8504- 9	8-4 Flame Monitoring and Tripping System	8504-32
3-1 Definitions	8504- 9	8-5 Sequence of Operations	8504-32
Chapter 4 Equipment Requirements	8504-13	8-6 Interlock System	8504-34
4-1 Structural Design	8504-13	8-7 Alarm System	8504-34
4-2 Fuel-Burning System	8504-13	8-8 Boiler Front Control (Supervised Manual)	8504-35
4-3 Burner Management System, Logic	8504-14	Chapter 9 Interlock System	8504-37
4-4 Combustion Monitoring and Tripping Systems	8504-15	9-1 General	8504-37
4-5 Combustion Control System	8504-15	9-2 Functional Requirements	8504-37
4-6 Warm-up Burners and Lances	8504-16	9-3 System Requirements	8504-38
4-7 Power Supplies	8504-18	Chapter 10 Alarm System	8504-43
4-8 Operating Information	8504-18	10-1 Functional Requirements	8504-43
Chapter 5 Furnace Pressure Excursion Prevention	8504-18	10-2 System Requirements	8504-43
5-1 General	8504-18	Chapter 11 Referenced Publications	8504-44
5-2 Furnace Pressure Control Systems	8504-19	Appendix A Explanatory Material	8504-44
5-3 Sequence of Operations	8504-19	Appendix B Guidelines for Determining the Minimum Permitted Temperature for Feeding a Fuel into a Fluidized Bed	8504-60
5-4 Interlock System	8504-20	Appendix C Referenced Publications	8504-61
5-5 Alarm System	8504-21	Index	8504-62
Chapter 6 Sequence of Operations	8504-21		
6-1 General	8504-21		
6-2 Operational Requirements	8504-22		
6-3 Emergency Conditions Not Requiring Shutdown or Trip	8504-25		
6-4 General Operating Requirements — All Conditions	8504-25		

NFPA 8504**Standard on****Atmospheric Fluidized-Bed
Boiler Operation****1996 Edition**

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

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

Chapter 1 Introduction**1-1 Scope.**

1-1.1 This standard shall apply to boilers with a fuel input rating of 12,500,000 Btu/hr (3663 kW) or greater. This standard applies only to boilers using atmospheric fluidized-bed combustion.

1-1.2 This standard covers firing of individual or blended fuels. Where multiple main fuels are fired, additional interlocks and other provisions shall be required but are not covered by this standard.

1-1.3 This standard covers burners and lances associated with fluidized-bed boilers.

1-1.4* This standard is not retroactive. This standard shall apply to new installations and to major alterations or extensions that are contracted subsequent to the effective date of this standard.

1-1.5 Furnaces such as those of process heaters used in metallurgical, chemical, and petroleum manufacture, wherein steam generation is incidental to the operation of a processing system, are not covered by this standard.

1-1.6 Since this standard is based upon the current state of the art, its application to existing installations is not mandatory. Nevertheless, operating companies are encouraged to adopt those features of this standard that are considered applicable and reasonable for existing installations.

1-1.7 Revisions to this standard reflect the current level of knowledge and do not imply that previous editions were inadequate.

1-1.8 The furnace pressure excursion prevention chapter of this standard (Chapter 5) provides methods of minimizing the risk of furnace pressure excursions in excess of the furnace structural capability.

1-2 Purpose.

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

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

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

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

Chapter 2 General**2-1 Furnace Explosions.**

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

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

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

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

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

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

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

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

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

(g) The possible accumulation of combustibles in the windbox and ductwork under certain unusual operating, start-up, or shutdown conditions. Bed material retains heat long after a boiler shutdown and can be an ignition source even if its exposed surfaces have cooled.

2-1.4 The conditions favorable to a boiler explosion described in 2-1.3 are typical examples, and an examination of numerous reports of boiler explosions suggests that the occurrences of small explosions, furnace puffs, or near-misses have been far more frequent than usually is recognized.

2-1.5 By virtue of the more consistent ignition source available from the mass of high temperature bed material during normal operation, fluidized-bed combustion is less susceptible to furnace puffs and flameouts than burner combustion.

NOTE: During unit warm-up or operation using a slumped or semifluidized bed, the unit does not benefit from these mitigating factors.

2-1.6 Instrumentation, safety interlocks, protective devices, proper operating sequences, and a clearer understanding of the explosion problem by both designers and operators can further reduce the risks and incidence of furnace explosions, especially during start-up and light-off.

2-1.7 There can exist, in certain parts of the boiler enclosure or other parts of the unit, dead pockets that are susceptible to the accumulation of combustibles. These accumulations can ignite with explosive force in the presence of an ignition source.

2-2* Furnace Pressure Excursions.

2-2.1 Furnace structural damage can result from the occurrence of excessively high or low gas side pressure.

2-2.2 A condition that is likely to cause furnace pressure excursions in a fluidized-bed boiler is maloperation of the equipment regulating the boiler gas flow, including the air supply and flue gas removal systems. This can result in exposure of the furnace to excessive fan head capability.

NOTE: The rapid decrease in furnace gas temperatures and pressure resulting from either a rapid reduction in fuel input or a master fuel trip, which is a cause of implosions in nonfluidized-bed boilers, is not likely to occur in a fluidized-bed boiler because of the resistance to fast temperature changes provided by hot bed material and refractory.

2-2.3 On the basis of reported incidents and field tests, the maximum negative furnace pressure is determined primarily by the maximum head characteristic of the induced draft fan; a major objective of the final design shall be to limit the maximum head capacity of draft equipment to that necessary for satisfactory operation. Special consideration shall be given to fan selection and arrangement of ductwork to limit the effect of negative head.

2-2.4 With scrubbers or other high draft loss equipment for removing flue gas contaminants, a booster fan might be necessary. A bypass or other appropriate means shall be provided to counteract the potentially excessive negative pressure conditions that result from combining the suction heads of both the induced draft and booster fans.

2-3 Manufacture, Design, and Engineering.

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

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

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

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

2-3.4 This standard necessitates a minimum degree of automation. The trend toward more complex plants or increased automation shall require additional provisions for:

(a) Information regarding significant operating events that allow the operator to make a rapid evaluation of the operating situation. The operator shall be provided with continuous and usable displays of variables that allow the operator to avoid unsafe conditions. (*Also see Section 4-8.*)

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

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

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

2-4 Installation.

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

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

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

2-4.4 The safety interlock system and protective devices shall be tested jointly and checked by the organization responsible for the system design and those who operate and maintain such system and devices during the operating life of the plant. These tests shall be completed before initial operation.

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

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

- (a) Lack of proper understanding of, or failure to use, safe operating procedures;
- (b) Lack of adequate operator training;
- (c) Unfavorable operating characteristics of the equipment or its control;
- (d) Lack of functional coordination of the various components of the steam-generating system and its controls.

2-5.2 Furnace explosions have occurred as a result of unfavorable functional design. Frequently, an investigation has revealed human error and has completely overlooked the chain of causes that triggered 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 ergonomics that can affect operation of the system.

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

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

- (a) Design and operating personnel who possess a high degree of competence in this field and who are mandated to achieve these objectives;
- (b) Periodic analysis of the plant's status with respect to evolving technology so that improvements for greater safety and reliability can be implemented;
- (c) Documentation of plant equipment, systems, and maintenance.

2-6 Maintenance Organization.

2-6.1* A program shall be provided for maintenance of equipment at intervals appropriate for the type of equipment, the service requirements, and the manufacturers' recommendations.

2-7 Basic Operating Objectives.

2-7.1 Basic operating objectives shall include the following:

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

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

2-8 Training.

2-8.1 Operator Training.

2-8.1.1 The owner or the owner's agent shall be responsible for establishing a formal and ongoing program for training operating personnel. This program shall prepare personnel to operate the equipment safely and effectively. The program shall consist of study or review of operating manuals, videotapes, programmed instruction, examinations, computer simulation (if available), and supervised hands-on field training. The training program shall be consistent with the type of equipment and the hazard involved.

2-8.1.2 The owner or the owner's agent shall certify that operators are trained and competent to operate the equipment under all conditions prior to their operation of such equipment.

2-8.1.3 The owner or the owner's agent shall be responsible for periodic retraining of operators, including review of their competence.

2-8.1.4 The training program and manuals shall be reviewed periodically and kept current with changes in equipment or operating procedures. The training program and manuals covering operating and maintenance procedures shall be readily available for reference and use at all times.

2-8.1.5 Operating procedures that cover both normal and emergency conditions shall be established. Start-up and shut-down procedures, normal operating conditions, and lockout procedures shall be covered in detail in operating manuals and the associated training program.

2-8.1.6 Operating procedures shall be directly applicable to the equipment involved and shall be consistent with safety requirements and the manufacturers' recommendations.

2-8.1.7 Operators shall be trained in the proper procedures for reducing load or tripping the system wherever there is a potential for an unsafe condition that could lead to personnel danger or property damage. Operators shall be authorized to call for outside assistance in case of emergency.

2-8.2 Maintenance Training.

2-8.2.1 The owner or the owner's agent shall be responsible for establishing a formal and ongoing program for training maintenance personnel. This program shall prepare personnel to perform any required maintenance tasks safely and effectively. The program shall consist of study or review of

maintenance manuals, videotapes, programmed instruction, examinations, field training, training by the equipment manufacturers, and other modes of instruction. The training program shall be appropriate to the equipment and potential hazards involved.

2-8.2.2 Maintenance procedures and their associated training programs shall be established to cover routine and special techniques. Any possible environmental factors such as temperature, dust, contaminated or oxygen-deficient atmosphere, internal pressures, and limited access or confined space requirements shall be included.

2-8.2.3 Maintenance procedures shall be consistent with safety requirements and the manufacturers' recommendations. The procedures contained in the training programs shall be reviewed periodically and kept current with changes in equipment. They shall be used in the indoctrination and training of new maintenance personnel.

2-8.2.4 Maintenance personnel shall be trained to notify operating personnel in writing of any changes in safety and control devices.

2-8.2.5 Maintenance personnel shall be trained to be knowledgeable of and to adhere to all Occupational Safety and Health Act (OSHA) safety procedures.

2-9 Fluidized-Bed Combustion — Special Problems.

2-9.1 Heating the Bed. The bed material shall be heated to a temperature above the autoignition temperature of the main fuel prior to admitting the main fuel to the bed. This normally is accomplished using warm-up burners.

2-9.2 Char Carryover. Elutriation of char from the bed is a characteristic of fluidized-bed combustion. Although most boiler designs provide for reinjection of elutriated char into the bed, a certain amount of unburned carbon is carried in the flue gas through the boiler's heat transfer surfaces and ductwork to the baghouse or other dust collection equipment. The system design shall include provisions to minimize accumulations in the flue gas ductwork and dust collection equipment.

2-9.3 Coal Firing. Common hazards are involved in the combustion of solid, liquid, and gaseous fuels. Each of these fuels has special hazards related to its physical characteristics. The following shall be considered in the design of the coal firing systems:

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

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

(c) The raw coal delivered to the plant can contain foreign substances (e.g., scrap iron, wood shoring, rags, excelsior, rock). This foreign material can interrupt coal feed, damage or jam equipment, or become a source of ignition within the fuel-feeding equipment. The presence of foreign material can constitute a hazard by interrupting coal flow. Wet coal can cause a coal hang-up in the raw coal supply system. Wide variations in the size of raw coal can cause erratic or uncontrolled coal feeding or combustion.

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

(e) Caution shall be exercised where interpreting the meter indication for combustibles. Most meters and associated sampling systems measure only gaseous combustibles. Therefore, the lack of a meter indication of combustibles does not prove that unburned coal particles or other combustibles are not present.

(f) Coal is subject to wide variations in analysis and characteristics. Changes in the percent of volatile matter and moisture affect the ignition characteristics of the coal and can affect the minimum required bed temperature prior to admission of coal into the bed. The amount of fines in the coal also can affect its ignition and burning characteristics. The minimum bed temperature that allows the admission of coal into the bed shall account for the range of ignition characteristics.

2-9.4 Waste Fuel Firing. Common hazards involved in the combustion of waste fuels should be recognized as follows:

(a) The considerations described in 2-9.3 also apply to waste fuels.

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

(c) Waste fuels are potentially more variable in analysis and burning characteristics than conventional fuels, and, therefore, an evaluation of special fuel handling and burning safeguards could be necessary.

2-9.5 Warm-up and Auxiliary Load-Carrying Burners. The operating systems and requirements for warm-up and load-carrying burners are covered in Section 4-6.

2-9.6 Hot Bed Material. Hot bed material can be removed from the bed to maintain the desired inventory of bed material. The temperature of the material is at or near the bed operating temperature [typically 1400°F to 1600°F (760°C to 870°C)] and shall be cooled prior to disposal.

2-9.7* Personnel Hazards. A number of personnel hazards are peculiar to fluidized-bed combustion. Safety precautions for dealing with such hazards shall be required for personnel safety. These hazards include:

- (a) Hot solids;
- (b) Lime;
- (c) Hydrogen sulfide; and
- (d) Calcium sulfide.

2-9.8 Additional Problems Requiring Consideration. The following additional problems shall be given consideration:

(a) Thermal inertia of the bed, causing steam generation to continue after fuel trip;

(b) Requirements for continuity of the feed water supply for extended periods following a fuel trip or the loss of all power supply to the plant;

(c) Potential for unintended accumulations of significant quantities of unburned fuel in the bed;

(d) Potential for generation of explosive gases if the air supply to a bed is terminated before the fuel in the bed is burned out;

(e) Potential risk of explosion when reestablishing the air supply to a hot bed;

- (f) Bed solidification as a result of a tube leak; and
- (g) Structural load requirements for abnormal accumulations of ash/bed material within the boiler furnace enclosure and the solids return path.

Chapter 3 Definitions

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

Air, Infiltration. The leakage of air into a setting, furnace, boiler, or duct.

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

Air, Secondary. Air for combustion supplied to the boiler to supplement the primary air. Typically, in a bubbling bed, that portion of the air introduced through the air distributor; and, in a circulating bed, that air that enters the combustor at levels above the air distributor.

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

Air-Rich. Indicates a ratio of air to fuel supplied to a furnace that provides more air than that needed 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. Indicates a ratio of air to fuel supplied to a furnace that provides less air than that needed for an optimum air/fuel ratio.

Theoretical Air (Stoichiometric Air). The chemically correct quantity of air needed 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 or subsystem that results in a deviation from the original design specifications or criteria.

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

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

Approved. Acceptable to the authority having jurisdiction.

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

As-Fired. Refers to fuel properties entering a boiler furnace enclosure.

Ash. As a constituent of fuel, noncombustible mineral matter that remains after the complete burning of a fuel sample. (See also *Char*, *Spent Bed Material*.)

Ash, Fly. The fine particles of material that are carried outside the boiler enclosure by the gaseous products of combustion.

Ash, Fusion Temperature. The temperature at which a cone of coal or coke ash exhibits certain melting characteristics. (See *ASTM D 1857, Standard Test Method for Fusibility of Coal and Coke Ash*.)

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

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

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

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

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

NOTE: The phrase "authority having jurisdiction" is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

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

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

Bed Material. Granular particles that compose the fluidized bed.

Bed Temperature. The average temperature of the fluidized bed.

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

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

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

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

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

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

Duct Burner. A warm-up burner mounted in a duct used to heat air introduced directly into or through the bed.

Over Bed Burner. A warm-up burner located above the bed and firing over or into the bed.

Warm-up Burner. A burner having its own air supply used to warm up the bed to the ignition temperature of the main fuel. The warm-up burner also can be used for limited load carrying.

Burner Management System. The control system dedicated to boiler furnace safety, operator assistance in the starting and stopping of fuel preparation and burning equipment, and for preventing misoperation of and damage to fuel preparation and burning equipment. The burner management system includes the following functions specified in this standard: interlock system, fuel trip system, master fuel trip system, master fuel trip relay, flame monitoring and main fuel monitoring, main fuel combustion monitoring, bed temperature monitoring, and warm-up burner subsystems.

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

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

Capacity. The manufacturer's stated output rate over a period of time for which the boiler is designed to operate.

Capacity, Maximum. The highest rated capacity of a steam generator.

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

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

Coal. The general name for the natural, rock-like, brown-to-black derivative of forest-type plant material. By subsequent underground geological processes, this organic material is progressively compressed and indurated over time, ultimately becoming graphite and graphite-like material. Coal contains carbon, hydrogen, oxygen, nitrogen, and sulfur, as well as inorganic constituents that form ash after burning. There is no fixed standard for coal, but there is an almost endless variety with respect to character and composition. The basic classifications for coal are lignite, subbituminous, bituminous, and anthracite. (See ASTM D 388, *Standard Classification of Coals by Rank*.)

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

Combustion Control System. The control system that regulates the furnace fuel input, furnace air input, bed inventory, and other bed heater transfer mechanisms to maintain the bed temperature and the air/fuel ratio within the limits necessary for continuous combustion and stable bed operation throughout the operating range of the boiler in accordance with demand. This control system includes the furnace draft control where applicable.

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

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

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

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

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

Extension. An addition to the boiler system or additional subsystems.

Fans.

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

Induced Draft (ID) Fan. A device used to remove the products of combustion from the boiler mechanically by introducing a negative pressure differential.

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

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

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

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

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

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

Freeboard. The space or volume above the upper surface of the bubbling bed and below the entrance to the convective pass.

Fuel, Auxiliary. Fuel, generally gaseous or liquid, used to warm the bed material sufficiently to allow ignition of the main fuel upon injection into the heated bed material; also can be used to carry partial or full load as an alternate to the main fuel. Auxiliary fuels are fired in burners.

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

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

Fuel Gas. See LP-Gas and Natural Gas.

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

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

Furnace. The combustion chamber of a boiler.

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

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

Igniter. A device that provides proven ignition energy to light off its associated burner immediately.

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

Igniter, Class 2 (Intermittent Igniter). An igniter applied to ignite the fuel input through the burner under prescribed light-off conditions. It also is used to support ignition under low load or certain adverse operating conditions. The range of capacity of such igniters generally is 4 percent to 10 percent of the full-load burner fuel input. It shall not be used to ignite the 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 shall be permitted to be operated as Class 3 igniters.

Igniter, Class 3 (Interrupted Igniter). A small igniter applied particularly to gas and oil burners to ignite the fuel input to the burner under prescribed light-off conditions. The capacity of such igniters generally does not exceed 4 percent of the full-load burner fuel input. As part of the burner light-off procedure, the igniter is turned off when the timed trial for ignition of its associated 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 ignit-

ers to support ignition or to extend the burner control range is prohibited.

Igniter, Class 3 Special (Direct Electric Igniter). A special Class 3 high-energy electrical igniter capable of directly igniting the burner fuel. This type of igniter shall not be used unless supervision of the individual burner flame is provided.

Exception: The igniter, Class 3 special, shall be permitted to be used without supervision of the individual burner flame while scavenging (clearing) the burner.

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

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.

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

Listed. Equipment, materials, or services included in a list published by an organization 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 either that the equipment, material, or service meets identified standards or has been tested and found suitable for a specified purpose.

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.

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

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

(a) *Hardwired System.* A logic system comprised of individual devices and interconnecting wiring.

(b) *Microprocessor-Based System.* A logic system comprised of the following:

1. Computer hardware, power supplies, input/output (I/O) devices, and interconnections between these systems; or
2. An operating system and logic software.

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

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

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

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

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

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

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

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

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

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

Natural Gas. A gaseous fuel occurring in nature consisting mostly of a mixture of organic compounds (normally methane, ethane, propane, and butane). The heating value of natural gases varies from 700 Btu/ft³ to 1500 Btu/ft³ (26.1 MJ/m³ to 55.9 MJ/m³), with the majority averaging 1000 Btu/ft³ (37.3 MJ/m³).

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

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

Positive Means. The physical methods of satisfying a requirement.

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

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

Purge Rate. A constant flow of not less than 25 percent of the full-load mass airflow with the bed in a semifluidized or fluidized condition.

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

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

Recycle Ratio. The mass of material being reinjected into the fluidized bed divided by the mass of fuel being fed into the bed.

Reinjection. Refers to the return or recycling of material removed or carried from the furnace back to the furnace. Also refers to fly ash collected and returned to the furnace or combustion chamber; sometimes expressed as a percent of the total collected.

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

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

Semifluidized. A state in which a uniform flow of air that is less than that necessary to fluidize the bed is admitted and is found to be sufficient to adequately remove gaseous combustibles as agreed between the manufacturer and the authority having jurisdiction.

Set Point. A predetermined value to which an instrument is adjusted and at which it shall perform its intended function.

Shall. Indicates a mandatory requirement.

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

Sorbent. A constituent in a fluidized bed that reacts with and captures a pollutant or, more generally, a constituent that reacts with and captures another constituent.

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

Stable Bed. A fluidized bed of granular material that maintains sustained combustion at a desired temperature.

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

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

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

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

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

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

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

Supervised Manual System. A system in which a trained operator has primary responsibility for the proper start-up, operation, and normal shutdown of a boiler with interlocks to ensure that the operation follows established procedures.

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

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

Unburned Combustible. Combustible matter leaving the boiler furnace enclosure, either as a gas or solid, without completing combustion.

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

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

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

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

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

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

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

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

Chapter 4 Equipment Requirements

4-1 Structural Design.

4-1.1 Boiler Enclosure.

4-1.1.1* The boiler enclosure shall be capable of withstanding a transient pressure without permanent deformation due to yield or buckling of any support member. The minimum design pressure (*see Section 5-1*) shall be:

(a) Whichever is greater, 1.67 times the predicted operating pressure of the component or +35 in. (+8.7 kPa) of water, but shall not be in excess of the maximum head capability of the air supply fan at ambient temperature; and

(b) The maximum head capability of the induced draft fan at ambient temperature but not more negative than -35 in. (-8.7 kPa) of water.

4-1.1.2 The induced draft fan head capability increases due to significant draft losses beyond the boiler enclosure or for other reasons, such as excessive induced draft fan test block margins. Where the induced draft fan test block capability is more negative than -35 in. (-8.7 kPa) of water, consideration shall be given to an increased negative design pressure.

4-1.2 Combustion Products Removal Subsystem. The transient internal design pressure defined in 4-1.1.1 shall be taken

into consideration in the design of the air and gas flow path from the forced draft fan discharge through the stack.

4-2 Fuel-Burning System.

4-2.1 Functional Requirements.

4-2.1.1 The fuel-burning system shall function to convert continuously any ignitable fuel input into unreactive products of combustion at the same rate that the fuel and air reactants enter the furnace.

4-2.1.2 The fuel-burning system shall be sized properly, adequate to meet the operating requirements of the unit, compatible with other boiler component systems, and capable of being controlled over the full operating range of the unit.

4-2.2 System Requirements.

4-2.2.1 The fuel-burning system shall provide means for proper start-up, operation, and shutdown of the combustion process. This shall include appropriate openings and configurations in the component assemblies to allow suitable observation, measurement, and control of the combustion process.

4-2.2.2 The fuel-burning system consists of the boiler enclosure and the following subsystems: air supply, coal or other solid fuel supply or both, crusher (where utilized), bed feed, liquid or gaseous fuel lances, burners, ash removal, ash reinjection, and combustion products removal. Each shall be sized and interconnected to satisfy the following requirements:

(a) Boiler Enclosure.

1. The boiler enclosure shall be sized and arranged so that stable bed operations and stable combustion can be maintained.

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

3. Observation ports shall be provided to allow inspection of the duct and warm-up burners.

4. Means shall be provided for adequate monitoring of conditions at the bed and its ignition zone. Accessibility for maintenance shall be provided.

(b) Air Supply Subsystem.

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

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

(c) Bed Warm-up Burner Subsystem. (*See Section 4-6.*)

(d) Solid Fuel Supply.

1. The solid fuel supply subsystem shall be designed to ensure a steady fuel flow for all operating requirements of the unit.

2. The solid fuel unloading, storage, transfer, and preparation facilities shall be designed and arranged to size the fuel, to remove foreign material, and to minimize interruption of the fuel supply to the feeders. This design shall include the installation of breakers, cleaning screens, and magnetic separators where necessary. Means for detection of flow interruption and correction shall be provided to ensure a steady flow to the boiler.

3. Solid fuel feeders shall be designed with a capacity range to allow for variations in size, quality, and moisture content of the fuel as specified by the purchaser. Fuel piping to and from feeders shall be designed for free flow within the design range of solid fuel size, quality, and moisture content. Means shall be provided for proving solid fuel flow. Means shall be provided for clearing obstructions.

4. A bed feed that operates at a lower pressure than the boiler enclosure to which it is connected shall have a lock hopper or other suitable means to prevent back flow of combustion products.

5. If transport air is required, a means shall be provided to ensure a supply that is adequate for the required fuel input.

(e) *Crusher Subsystem* (where utilized in the fuel feed system).

1. Fuel crushing equipment shall produce satisfactory fuel sizing over a specified range of fuel analyses and characteristics. The crushing system shall be designed to minimize the possibility of fires starting in the system, and means shall be provided to extinguish fires. For further information, see NFPA 8503, *Standard for Pulverized Fuel Systems*.

2. The transport system shall be sized and arranged to transport the material properly throughout the crusher's operating range.

(f) *Fuel Oil or Fuel Gas Lances*. (See Section 4-6.)

(g) *Solids Removal Subsystems*.

1. The bed drain subsystem and flue gas cleaning subsystem shall be sized and arranged to remove the bed material, fly ash, and spent sorbent at a rate that is at least equal to the rate at which they are generated by the fuel-burning process during unit operation.

2. Convenient access and drain openings shall be provided.

3. The removal equipment handling hot ash from the boiler shall be designed to provide material cooling before discharging material into ash handling and storage equipment. Safety interlocks with a device to monitor cooling medium flow and material discharge temperature shall be provided to prevent fires or equipment damage.

(h) *Combustion Products Removal Subsystem*.

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

2. Convenient access and drain openings shall be provided.

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

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

5. Boilers that share a common component between the furnace outlet and the stack shall have provisions to bypass the common components for unit purge. Purge air shall not discharge into or through a common component if the other boiler(s) is in operation.

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

4-3.1 General Requirements. A logic system provides outputs in a particular sequence in response to external inputs and internal logic. The logic system for burner management shall be specifically designed so that a single failure in that system does not prevent an appropriate shutdown.

4-3.2 Specific Requirements. As a minimum, the requirements of 4-3.2.1 through 4-3.2.3.3 shall be included in the design to ensure that a logic system for burner management meets the intent of this standard.

NOTE: Some items are not applicable to specific types of logic systems (e.g., relay systems).

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

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

4-3.2.2 Design.

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

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

(c) Logic shall be protected from unauthorized changes.

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

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

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

(g) Any single component failure within the logic system shall not prevent a mandatory master fuel trip. (See 6-2.5.)

(h) The operator shall be provided with a dedicated manual switch(es) that shall actuate the master fuel trip relay independently and directly. (See also 9-3.1.4.)

4-3.2.3 Requirement for Independence. The logic system performing the safety functions for burner management shall not be combined with any other logic system. These burner management safety functions shall include, but shall not be limited to, proper purge interlocks and timing, bed temperature monitoring, mandatory safety shutdowns, and burner flame monitoring. [See A-9-2.3(i).]

4-3.2.3.1 The burner management system shall be provided with independent logic, independent input/output systems, and independent power supplies and shall be functionally and physically separate from other logic systems (e.g., boiler control system).

4-3.2.3.2 The same hardware type used for other logic systems shall be permitted to be used for burner management systems.

4-3.2.3.3 Data highway communications between the burner management system and other systems shall be permitted. However, signals that initiate mandatory master fuel trips shall be hardwired.

4-3.2.4 Logic sequences or devices intended to cause a safety shutdown, once initiated, shall cause a burner or master fuel trip, as applicable, and shall require operator action prior to resuming operation of the affected burner(s). No logic sequence or device shall be permitted that allows momentary closing and subsequent inadvertent reopening of main or ignition fuel valves.

4-4 Combustion Monitoring and Tripping Systems.

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

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

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

4-4.2* Bed Temperature Monitoring.

4-4.2.1 The bed temperature, monitored by taking a number of measurements physically located in the bed, shall provide a representative bed temperature profile under all operating conditions. If the bed is compartmented, the bed temperature of each individual compartment shall be monitored. The bed temperature(s) shall be available to the operator.

4-4.2.2 An indication of bed temperature outside the normal operating range shall be brought to the attention of the operator in order to permit remedial action.

4-4.2.3 Upon detection of a bed temperature that falls below the minimum value established for self-sustaining combustion of the fuel(s) being fired in the bed, that fuel supply shall be automatically shut down.

4-5 Combustion Control System.

4-5.1 Functional Requirements.

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

4-5.1.2 The combustion control system shall maintain the bed temperature within the limits required for continuous stable combustion for the full operating range of the boiler.

4-5.1.3 Furnace inputs and their relative rates of change shall be controlled to maintain the air/fuel ratio within the limits required for continuous combustion and stable bed conditions for the full operating range of the boiler.

NOTE: To maintain a proper air/fuel ratio, the use of gravimetric-type or calibrated volumetric-type feeders with the use of combustion airflow measurement and monitoring of the flue gas percent oxygen and low range combustibles is an acceptable method of controlling the air/fuel ratio.

4-5.2 System Requirements.

4-5.2.1 Equipment shall be provided and operating procedures established to heat the bed material prior to admitting fuel to the bed. For bed start-up, the temperature of the bed material shall be raised to the minimum value established for self-sustaining combustion of the fuel, and the bed shall be fluidized before fuel is admitted. (See *Appendix B*.)

4-5.2.2 Provisions shall be made for setting minimum and maximum limits on the fuel and air control subsystems to ensure stable bed operation and to prevent fuel and airflows beyond the capacity of the furnace. These minimum and maximum limits shall be defined by the boiler manufacturer and verified by operating tests.

4-5.2.3 Where changing the rate of furnace input, the airflow and fuel flow shall be changed simultaneously to maintain proper air/fuel ratio during and after the changes. This shall not eliminate the requirements for air lead and lag during changes in the fuel firing rate. Setting the fuel flow control on automatic without setting the airflow control set on automatic shall be prohibited, and this function shall be interlocked.

NOTE: Where fluidized-bed combustion boilers burn fuels of widely varying heat value and air demand per unit of fuel, the required air/fuel ratio limits should include provision for the calibration of the air/fuel ratio.

4-5.2.4 The control system shall prevent the demand for a fuel-rich mixture while in the automatic control mode.

4-5.2.5 Means shall be provided to limit fuel input to the air available while in the automatic control mode.

4-5.2.6 On balanced draft furnaces, furnace draft shall be maintained at the set point.

4-5.2.7 Equipment shall be designed and procedures established to allow as much on-line maintenance of combustion control equipment as practicable.

4-5.2.8 Provisions for calibration and testing of combustion control and associated interlock equipment shall be furnished.

4-5.2.9* Flue gas oxygen analyzers shall be provided for use as an operating guide. Consideration also shall be given to providing a combustibles analyzer for use as an operating guide.

4-5.2.10 Fuel gas flow meters shall be operated at constant pressure conditions or shall be pressure compensated where pressure variations introduce a significant error.

4-5.2.11 Fuel oil flow meters shall be compensated where variations in temperature or viscosity introduce a significant error.

4-5.2.12 Consideration shall be given to providing solid fuel flow measurement devices on each feeder as a part of the combustion control and solid fuel feed control systems in order to provide indexes of total fuel versus total airflow and for use as an operating guide.

4-5.2.13 Means shall be provided to maintain adequate transport/fluidizing air for transporting the required fuel, sorbent, and recycled ash material, as applicable.

4-6 Warm-up Burners and Lances.

4-6.1 Fuel Supply Subsystem, Gas.

4-6.1.1 The fuel supply equipment shall be sized and arranged to ensure a continuous fuel flow that is adequate for all operating requirements of the unit. These include coordination of the fuel control valve, burner safety shutoff valves, and associated piping volume to prevent fuel pressure transients that might result in exceeding burner limits for stable flame caused by placing burners in service or taking them out of service.

4-6.1.2 The portion of the fuel supply system located outside the boiler room shall be arranged to prevent excessive fuel gas pressure in the fuel-burning system, even in the event of a failure of the gas supply constant fuel pressure regulator(s). Usually this can be accomplished by providing full relieving capacity, vented to a safe location. Where full relieving capacity is not installed, a high gas supply pressure trip shall be provided. (See also 7-5.3.)

4-6.1.3 The fuel supply equipment shall be designed to inhibit contamination of the fuel. Convenient access to important fuel system components shall be provided. Drains shall be provided at low points in the piping.

4-6.1.4 The fuel supply equipment shall be capable of continuing the proper fuel flow during anticipated furnace pressure pulsations.

4-6.1.5 The fuel supply equipment shall be designed with careful consideration of the operating environment and ambient conditions, including severe external conditions such as fire or mechanical damage. Special attention shall be given to such factors as routes of piping and valve locations to minimize exposure to explosion hazard or high temperature sources.

4-6.1.6 As much of the fuel subsystem as is practicable shall be located outside the boiler house. A manual emergency shutoff valve shall be provided that is accessible in the event of fire in the boiler area.

4-6.1.7 A positive means to prevent leakage of gas into a furnace or duct shall be provided. Provisions shall be included to vent the piping upstream of the last shutoff valve in any line to a burner, igniter, or lance.

4-6.1.8 Provisions shall be made in the gas piping to allow testing for leakage and subsequent repair. Such provisions shall include a permanent and ready means for making easy, accurate, periodic tightness tests of the header safety shutoff valves and individual safety shutoff valves.

4-6.1.9* The discharge from atmospheric vents shall be located so that there is no possibility of the discharged gas being drawn into the air intake, ventilating system, or windows of the boiler room or adjacent buildings and shall be extended sufficiently above the boiler and adjacent structures so that gaseous discharge does not present a fire hazard.

Vents shall be sized according to Table 4-6.1.9

Table 4-6.1.9 Vent Line Sizes

Fuel Line Diameter		Vent Line Diameter	
(in.)	(mm)	(in.)	(mm)
$\leq 1\frac{1}{2}$	≤ 38	$\frac{3}{4}$	19
2	50.8	1	25.4
$2\frac{1}{2}$ to 3	64 to 76	$1\frac{1}{4}$	31.8
$3\frac{1}{2}$	89	$1\frac{1}{2}$	38
4 to 5	102 to 127	2	50.8
$5\frac{1}{2}$ to 6	140 to 152	$2\frac{1}{2}$	64
$6\frac{1}{2}$ to $7\frac{1}{2}$	165 to 191	3	76
8	203	$3\frac{1}{2}$	89
>8	203	15% of the cross-sectional area of the pipe	

4-6.1.10 The vent lines from the individual burners shall be permitted to be manifolded together. The vent lines from the individual igniters shall be permitted to be manifolded together. The cross-sectional area of the manifolded line shall not be less than the largest vent line plus 50 percent of the sum of the cross-sectional areas of the additional vent lines.

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

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

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

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

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

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

4-6.1.11 Shutoff valves shall be located as close as practicable to the igniters, burners, or lances to minimize the volume of fuel downstream of the valve.

4-6.1.12 Gas piping materials and system design shall be in accordance with ANSI B31.1, *Power Piping*.

4-6.2 Fuel Supply Subsystem, Fuel Oil.

4-6.2.1 The fuel supply equipment shall be sized and arranged to ensure a continuous fuel flow that is adequate for all operating requirements of the unit. These include coordination of the fuel control valve, burner safety shutoff valves, and associated piping volume to prevent fuel pressure transients that might result in exceeding burner limits for stable flame caused by placing burners in service or taking them out of service.

4-6.2.2 Unloading, storage, pumping, heating, and piping facilities shall be designed and arranged to inhibit contamination of the fuel. Where necessary, cleaning devices shall be provided to ensure a clean fuel to valves and burners. Convenient access to important fuel system components shall be provided. Adequate drains shall be provided.

4-6.2.3 Fill and recirculation lines to storage tanks shall discharge below the liquid level to avoid free fall, which might generate static electrical charges as well as increased vaporization.

4-6.2.4 Adequate strainers, filters, traps, sumps, and similar components shall be provided to remove harmful contaminants where practicable; materials not removed shall be accommodated by special operating and maintenance procedures. Contaminants in fuel include salt, sand, sludge, water, and other abrasive or corrosive constituents. Some fuels contain waxy materials that precipitate, clogging filters and other elements of the fuel system.

4-6.2.5 The fuel supply equipment shall be designed with careful consideration of the operating environment and ambient conditions, including severe external conditions such as fire or mechanical damage. Special attention shall be given to such factors as routes of piping and valve locations to minimize exposure to explosion hazard or to high temperature or low temperature sources. Low temperatures can increase viscosity, inhibit flow, or precipitate waxy materials. High temperatures can cause carbonization or excessive pressures and leakage due to fluid expansion in "trapped" sections of the system.

4-6.2.6 As much of the fuel supply subsystem as is practicable shall be located outside the boiler house. A manual emergency shutoff valve shall be provided that is accessible in the event of fire in the boiler area.

4-6.2.7 A means shall be provided to prevent or relieve excess pressure from expansion of entrapped oil in the fuel system. This is especially important in the case of crude oil.

4-6.2.8 Relief valve discharge passages, vents, and telltales shall be provided with suitable piping to allow the safe discharge of oil or vapors. This piping might need to be heat traced.

4-6.2.9 Shutoff valves shall be located as close as practicable to the igniters, burners, or lances to minimize the volume of fuel downstream of the valve.

4-6.2.10 Oil piping materials and system design shall be in accordance with NFPA 31, *Standard for the Installation of Oil-Burning Equipment*, and ANSI B31.1, *Power Piping*.

4-6.2.11 All instrument and control piping and other small lines containing oil shall be rugged, capable of withstanding the expected range of external temperatures, suitably protected against damage, and maintained at the proper temperature. The use of interface fluids or sealing diaphragms might be necessary with this instrumentation.

4-6.2.12 A positive means to prevent leakage of oil into a furnace or duct shall be provided.

4-6.2.13 Provisions shall be made in the oil supply system to allow testing for leakage and subsequent repair. Such provisions shall include a permanent and ready means for making easy, accurate, periodic tightness tests of all safety shutoff valves.

4-6.2.14 Fuel oil shall be delivered to the burners at the proper temperature and pressure as recommended by the burner manufacturer to ensure proper atomization.

4-6.2.15 Where heating of oil is necessary, it shall be accomplished without contamination or coking.

4-6.2.16 Adequate recirculation provisions shall be incorporated for controlling the viscosity of the oil to the burners for initial light-off and for subsequent operation. Recirculation systems shall be designed and operated to prevent excessively hot oil from entering fuel oil pumps that could cause them to vapor-bind, and subsequently interrupt the fuel oil supply.

4-6.2.17 A positive means shall be provided to prevent fuel oil from entering the burner header system through recirculating valves, particularly from the fuel supply system of another boiler.

NOTE: Check valves for this function have not proven dependable in heavy oil service.

4-6.2.18 Provisions, including an ignition source, shall be provided for clearing (scavenging) the passages of an atomizer that lead into the furnace or duct.

4-6.3 Warm-up Burner Subsystem.

4-6.3.1 General.

4-6.3.1.1 The warm-up burner subsystem shall function to supply sufficient heat energy to bring the bed to the fuel ignition temperature.

4-6.3.1.2 The warm-up burner shall meet the requirements of 4-2.1.

4-6.3.1.3 Provision shall be made for visual observation of conditions at the burner ignition zone. Additional provisions shall be made for flame detection equipment. The burner equipment shall be located in an appropriate environment with convenient access for maintenance. Special attention shall be given to fire hazards imposed by leakage or rupture of piping near the burner. The requirements of good house-keeping shall be practiced.

4-6.3.2 Subsystem Requirements.

4-6.3.2.1 Air Supply. A portion of the total air supply sufficient for light-off and flame stabilization shall be supplied to the warm-up burner(s).

4-6.3.2.2 Ignition.

(a) The ignition subsystem shall be sized and arranged to ignite the warm-up burner fuel input within the limits of the igniter classification. The subsystem shall be tested to verify that the igniters furnished meet the requirements of the class specified for the subsystem design. Igniters are designated according to use as Class 1, Class 2, or Class 3 as defined in Chapter 3 and verified by test. Many factors affect the classification of igniters, including the characteristics of the warm-up fuel, the furnace and burner design, and the igniter capacity and location relative to the warm-up fuel burner.

(b) Where Class 1 and Class 2 igniters are used, the tests described in 4-6.5 also shall be performed with the ignition subsystem in service to verify that the igniters furnished meet the requirements of the class specified in the design. The resulting extended turndown range shall be available where Class 1 igniters are in service and flame is proven.

(c) Tests shall be performed to determine transient limits in the igniter air and fuel supplies, or the warm-up burner air and fuel supplies, that do not extinguish the igniter flame or reduce the igniter's ability to perform its intended function or adversely affect other burners or igniters in operation. (See also 4-6.5.)

(d) Permanently installed igniters shall be required. They shall be individually supervised to verify that the requirements of 4-6.3.2.2(a), (b), and (c) have been met. This shall include supervision of the igniter flame and capacity.

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

4-6.3.2.3 Flame Monitoring and Tripping, Functional Requirements. The basic requirements of any flame monitoring and tripping system shall be as follows:

- (a) The warm-up burners shall meet the requirements of 4-4.1.
- (b) Each burner shall provide enough system resistance or dampening to the fuel and airflow to override anticipated furnace pulsations and maintain stable combustion.
- (c) Each burner shall be individually supervised. Upon detection of loss of burner flame, the safety shutoff valve for the burner experiencing the loss shall automatically close.
- (d) It is recognized that any fuel input that does not ignite and burn on a continuous basis creates a hazard. Regardless of the number or pattern of flame loss indications used for tripping, loss of flame indication on an operating burner or flame envelope shall initiate an alarm to warn the operator of potential hazard.
- (e) Field testing shall be required to validate basic flame tripping concepts. These tests shall be performed on representative units. The results of these tests shall be permitted to be applied to other units of similar size and arrangement, including burners/nozzles of substantially the same capacity that use similar fuels. These tests shall not replace acceptance tests relating to proof of design, function, and components.
- (f) Oil-fired warm-up burners, firing into the bed, shall be permitted to be scavenged immediately after shutdown or trip if the bed is fluidized and the bed temperature is greater than 1400°F (760°C) or if associated igniters are in service.

4-6.3.2.4 Flame Detection.

(a) *Flame Detector Sighting.* The use of flame detector sighting shall be considered in the initial burner design. Field tests shall be required to establish optimum sighting angles of burners or nozzles and also to check the effective angular range of flame detectors in relation to burners or nozzles. Methods and equipment used to reduce the emission of air pollutants can affect the burner flame, selection of the flame detector, and location/sighting of the flame detector.

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

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

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

4-6.3.2.5 Combustion Control System.

(a) The combustion control system shall be in accordance with Section 4-5.

(b) Equipment shall be provided and operating procedures established to ensure a stable flame condition at each burner and to preclude the possibility of an air/fuel ratio condition that could result in a fuel-rich condition within the furnace.

(c) Provision shall be made for setting minimum and maximum limits on the warm-up burner fuel and air control subsystems to prevent fuel flow and airflow beyond the stable flame limits of the burner(s). These minimum and maximum

limits shall be specified by the burner manufacturer and verified by operating tests. (See 7-3.2.)

(d) The control system shall prevent the demand for a fuel-rich mixture while in the automatic control mode.

4-6.4 Lance Subsystem.

4-6.4.1 Functional Requirements.

4-6.4.1.1 The lance subsystem shall function to provide alternate or supplemental fuel input to the bed.

4-6.4.1.2 The lances shall meet the requirements of 4-2.1.

4-6.4.2 Subsystem Requirements.

4-6.4.2.1 Fuel Supply System.

(a) The liquid or gaseous fuel lance subsystem shall be designed so that the fuel is supplied in a continuous manner and within the confines of stable combustion limits. Minimum bed temperature interlocks shall be furnished to ensure the combustion of fuel in the bed at all times.

(b) Provision shall be made for protecting the lance nozzles and tips.

(c) The lance equipment shall be located in an appropriate environment with access for maintenance. Special attention shall be given to fire hazards posed by leakage or rupture of piping near the lance. Good housekeeping practices shall be enforced.

4-6.4.2.2 Multiple Lances Under Common Control.

(a) A group of lances shall be permitted to be supplied from a common header whose input is controlled by a single set of fuel safety shutoff and control valves.

(b) Flow to a group of lances that is controlled from a common source shall be treated as an individual lance.

4-6.5 Burner Testing. The turn-down limits of stable flame for each burner subsystem producing a separate flame envelope shall be determined by tests without the ignition system in service. These tests shall verify that transients generated in the fuel and air subsystems do not adversely affect the burners in operation. Such transients are generated by components such as burner shutoff valves or dampers that operate at speeds faster than the speed of response of other components in the system. These tests shall include the use of those fuels expected to be used.

4-7 Power Supplies. All reasonable precautions shall be taken to ensure the availability of a failure-free power supply (electric or pneumatic) to all devices.

4-8 Operating Information. As a minimum, continuous, simultaneous trend displays of boiler steam flow, feed-water flow, total fuel flow, and total airflow as a percentage of the maximum unit load shall be provided at the operating location. Continuous, simultaneous trend displays also shall be provided at the operating location for drum level, bed temperature(s), final steam temperature, main steam pressure, and furnace draft.

Chapter 5 Furnace Pressure Excursion Prevention

5-1 General. This chapter provides methods for minimizing the risks of furnace pressure excursions in excess of furnace structural capability. This shall be accomplished by one of the following methods: