NFPA® 86

Standard for Ovens and Furnaces

2015 Edition

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NFPA® 86

Standard for

Ovens and Furnaces

2015 Edition

This edition of NFPA 86, *Standard for Ovens and Furnaces*, was prepared by the Technical Committee on Ovens and Furnaces. It was issued by the Standards Council on April 29, 2014, with an effective date of May 19, 2014, and supersedes all previous editions.

This edition of NFPA 86 was approved as an American National Standard on May 19, 2014.

Origin and Development of NFPA 86

The history of the NFPA standards for ovens and furnaces goes back to NBFU 34, *Regulations of the Board of Fire Underwriters for Finishing Processes (other than paint spraying) Dip Tanks, Hardening and Tempering Tanks, Flow Coat Work, Japanning and Enameling Including Ovens as Recommended by the National Fire Protection Association*, which was issued in 1926. Subsequently, the ovens part of NBFU 34 was separated and issued as NBFU 86, *Regulations of the National Board of Fire Underwriters for Ovens For Japan, Enamel, and Other Flammable Finishes as Recommended by the National Fire Protection Association*, in 1931. In 1948, NBFU 86 became NFPA 86-T, *Tentative Standards for Class A Oven Design, Location and Equipment*. The document was issued as a standard in 1950 and titled NFPA 86, *Standards for Class A Ovens and Furnace Design, Location and Equipment*.

The 1985 edition of NFPA 86 was the first edition of the standard in its current form. It was created from the combination of the former NFPA 86A, *Standard for Ovens and Furnaces — Design, Location and Equipment*, and NFPA 86B, *Standard for Industrial Furnaces — Design, Location and Equipment*.

The committee introduced changes in the definitions of Class A and Class B ovens, which were published in the 1982 edition of NFPA 86B and added as a tentative interim amendment in 1983 to the 1977 edition of NFPA 86A. The changes in the definitions eliminated the principal differences between the two standards, except for the ventilation requirements contained in NFPA 86A. By providing a separate chapter for ventilation requirements in the 1985 edition (Chapter 5), the Committee found it was no longer necessary or desirable to maintain two separate documents that addressed the same subjects.

The changes that were incorporated into the 1985 edition included the following:

(1) A new chapter dealing with low-oxygen atmosphere ovens was added.
(2) The definitions of subjects contained in the text were updated and new definitions provided.
(3) The text was refined in an effort to make the document more understandable.
(4) The material was rearranged to comply with the NFPA *Manual of Style*.

The 1995 edition of NFPA 86 correlated with NFPA 86C, *Standard for Industrial Furnaces Using a Special Processing Atmosphere*, and NFPA 86D, *Standard for Industrial Furnaces Using Vacuum as an Atmosphere*. It also refined and updated the standard to more current technologies, provided increased requirements in several areas, and expanded the explanatory material in the appendixes.

The 1999 edition of NFPA 86 included changes to the technical requirements in several areas and many refinements that clarified the technical requirements. Changes were also provided to more clearly distinguish mandatory requirements from nonmandatory recommendations and explanatory material. Nonmandatory notes were relocated to the appendixes.

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The 2003 edition of NFPA 86 was a complete revision that incorporated NFPA 86C, *Standard for Industrial Furnaces Using a Special Processing Atmosphere*, and NFPA 86D, *Standard for Industrial Furnaces Using Vacuum as an Atmosphere*. This new, combined document provided one standard for ovens and furnaces of all types. Also, in accordance with the *Manual of Style for NFPA Technical Committee Documents*, referenced publications were listed in Chapter 2 and all definitions moved to Chapter 3.

The 2007 edition of NFPA 86 continued to bring the standard into compliance with the *Manual of Style for NFPA Technical Committee Documents* and to update requirements. Requirements for logic systems and programmable logic controller–based systems replaced the requirement that programmable logic controllers be specifically listed for combustion safety service, since listed controllers were no longer available. Unenforceable text was (1) revised to be enforceable, (2) deleted, or (3) relocated to Annex A. Where appropriate, repetitive text was replaced by tables. The former Chapter 14, Inspection, Testing and Maintenance, was renumbered and renamed as Chapter 7, Commissioning, Operations, Maintenance, Inspection, and Testing. Requirements for operations and maintenance throughout the standard were then relocated to that chapter.

In the 2011 edition, the scope of NFPA 86 was clarified to exclude fluid heaters, and reference was made to the new NFPA 87, *Recommended Practice for Fluid Heaters*. All requirements for fire protection were relocated to Chapter 9. Chapter 13, which covers Class C furnaces, was revised to clarify the requirements for the introduction and removal of special atmospheres. The requirements for repeated pre-ignition purge were revised to recognize the unique characteristics of ovens utilizing pulse firing of burners. In addition, the requirements for safety shutoff valves that must close when a burner experiences a loss of flame signal were clarified.

The 2015 edition of NFPA 86 includes several changes to Chapter 3 due to the addition of definitions for *burner management system*, *flame failure response time*, *flame detector*, *hardwired*, *combustion safeguard*, and pressure regulator types. The Committee also deleted requirements from Chapter 12 applicable to arc melting furnaces (or electric arc furnaces) as the provisions have not been maintained and the Committee no longer has the relevant expertise. The Committee added procedures for placing equipment into service based on purging practices in NFPA 54 and NFPA 56. The Committee modified the standard to clarify the types of acceptable devices used for combustion safety service. The Committee added a requirement prohibiting manifolding vent lines from different pressure levels. As a result of introducing definitions for *burner management system* and *combustion safeguard*, the Committee modified requirements in Chapter 8 for logic systems for both BMS logic and programmable logic controller (PLC) systems. The Committee modified requirements for Class A and Class C ovens and furnaces, including the development of new requirements on fire protection and safety ventilation for Class A ovens.

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Richard A. Gallagher, *Chair*
Zurich Services Corporation, DE [I]

Richard J. Martin, *Secretary*
Martin Thermal Engineering, CA [SE]

Gary S. Andress, Liberty Mutual Property, MA [I]
Kevin J. Carlisle, Karl Dungs, Inc., MN [M]
Rep. Industrial Heating Equipment Association
Erik W. Christiansen, Exponent, Inc., CA [SE]
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Dan Curry, Eclipse, Inc., IL [M]
Robert Daley, Solar Atmospheres Manufacturing, Inc., PA [M]
John Dauer, SCC, Inc., IL [M]
Thomas B. George, Tokio Marine Management, Inc., CA [I]
John E. Higginbotham, Alcoa, Inc., TN [U]
E. Richard Huggins, Technical Standards & Safety Authority (TSSA), ON Canada [E]
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Kai-Eric Jensen, Jensen Industries, Inc., MI [M]
Frank J. Kaczmarczyk, Carpenter Technology Corporation, PA [U]
Joseph A. (Jak) Kozma III, AFC-Holcroft LLC, MI [M]
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Scott D. Musser, RPA Engineering, PA [SE]
Raymond Ostrowski, Consultant-Industrial Safety, AZ [SE]
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Michael C. Polagye, FM Global, MA [I]
Geoffrey A. Raifsnider, Global Finishing Solutions, WI [M]
Raymond E. Serafini, Jr., Linde, LLC, PA [IM]
Jason Sroczynski, Jayco Enterprises Inc., OH [SE]
Mark V. Stender, Surface Combustion, Inc., OH [M]
Franklin R. Switzer, Jr., S-afe, Inc., NY [SE]
Grant F. Tiefenbruck, 3M Company, MN [U]
Jay D. Tindall, Paragon Risk Engineering, PA [I]
Algirdas Underys, A. Finkl & Sons Co., IL [U]
Rep. Forging Industry Association
Peter J. Willse, XL Global Asset Protection Services, CT [I]

Alternates

Bryan R. Baesel, Eclipse/CEC Combustion Safety, Inc., OH [M]
(Alt. to D. Curry)
Amy Brown, FM Global, MA [I]
(Alt. to M. C. Polagye)
Elliott Davis, Selas Heat Techology Company LLC, OH [M]
(Alt. to K. J. Carlisle)
James J. Garmaker, 3M Company, MN [U]
(Alt. to G. F. Tiefenbruck)
Keith A. Hancock, Surface Combustion, Inc., OH [M]
(Alt. to M. V. Stender)
Brent D. Hill, Liberty Mutual Property, TX [I]
(Alt. to G. S. Andress)
Scott Johnston, Caterpillar Incorporated, IL [U]
(Alt. to R. Conklen)
William M. Keough, AFC-Holcroft LLC, MI [M]
(Alt. to J. A. Kozma III)
Bruce L. Mickelson, Honeywell International, Inc., MN [M]
(Alt. to D. M. Perry)
Delmar R. "Trey" Morrison III, Exponent, Inc., IL [SE]
(Alt. to E. W. Christiansen)
Glen R. Mortensen, Zurich Services Corporation, IL [I]
(Alt. to R. A. Gallagher)
Peter S. Pinto, SCC, Inc., IL [M]
(Alt. to J. Dauer)
Lee M. Rebodos, Paragon Risk Engineering, TX [I]
(Alt. to J. D. Tindall)
William M. Rucki, Fives North American Combustion, Inc., OH [M]
(Alt. to T. Jablkowski)
J. William Sheppard, Sheppard & Associates, LLC, MI [SE]
(Alt. to R. Ostrowski)
Robert J. Wilson, Solar Manufacturing Inc., PA [M]
(Alt. to R. Daley)

Guy R. Colonna, NFPA Staff Liaison

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Committee Scope: This Committee shall have primary responsibility for documents on safeguarding against fire and explosion hazards associated with industrial ovens, furnaces, and related equipment that are used in the processing of combustible or non-combustible materials in the presence of air, vacuum, or other special atmospheres and are heated by electricity, fossil fuels, or other heating sources.

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Information on referenced publications can be found in Chapter 2 and Annex M.

Chapter 1 Administration

1.1* Scope. This standard shall apply to Class A, Class B, Class C, and Class D ovens, dryers, and furnaces; thermal oxidizers; and any other heated enclosure used for processing of materials and related equipment.

1.1.1 The terms *ovens*, *dryers*, and *furnaces* are used interchangeably and shall also apply to other heated enclosures used for processing of materials.

1.1.2* Within the scope of this standard, a Class A, Class B, or Class C oven is any heated enclosure operating at approximately atmospheric pressure and used for commercial and industrial processing of materials.

1.1.3 A Class A oven shall be permitted to utilize a low-oxygen atmosphere.

1.1.4 This standard shall apply to bakery ovens and Class A ovens, in all respects, and where reference is made to ANSI Z50.1, *Bakery Equipment — Safety Requirements,* those requirements shall apply to bakery oven construction and safety.

1.1.5 This standard shall apply to atmosphere generators and atmosphere supply systems serving Class C furnaces and to furnaces with integral quench tanks or molten salt baths.

1.1.6* This standard shall apply to Class D ovens and furnaces operating above ambient temperatures to over 5000°F (2760°C) and at pressures normally below atmospheric to 10^{-8} torr (1.33×10^{-6} Pa).

1.1.7 This standard shall not apply to the following:

(1) *Coal or other solid fuel–firing systems
(2) Listed equipment with a heating system(s) that supplies a total input not exceeding 150,000 Btu/hr (44 kW)
(3) Fired heaters in petroleum refineries and petrochemical facilities that are designed and installed in accordance with API STD 560, *Fired Heaters for General Refinery Services*, 2007; API RP 556, *Instrumentation and Control Systems for Fired Heaters and Steam Generators*, 1997; and API RP 2001, *Fire Protection in Refineries*, 2005.
(4) Fluid heaters as defined in NFPA 87, *Recommended Practice for Fluid Heaters*
(5) Electric arc furnaces and submerged arc furnaces

1.2 Purpose. This standard provides the requirements for furnaces to minimize the fire and explosion hazards that can endanger the furnace, the building, or personnel.

1.3 Application.

1.3.1* This entire standard shall apply to new installations and to alterations or extensions to existing equipment.

1.3.2 The requirements of Chapters 1 through 10 shall apply to equipment described in subsequent chapters except as modified by those chapters.

1.3.3 Chapter 7 shall apply to all operating furnaces.

1.3.4 Section 6.2 shall apply to the following:

(1) Furnace heating systems fired with fuel gases, including the following:
  (a) Natural gas
  (b) Mixed gas
  (c) Manufactured gas
  (d) Liquefied petroleum gas (LP-Gas) in the vapor phase
  (e) LP-Gas/air systems
(2) Gas-burning portions of dual-fuel or combination burners

1.3.5 Section 6.3 shall apply to the following:

(1) Combustion systems for furnaces fired with No. 2, No. 4, No. 5, and No. 6 industrial fuel oils as specified by ASTM D 396, *Standard Specifications for Fuel Oils*
(2) Oil-burning portions of dual-fuel and combination burners

1.3.6 Section 6.4 shall apply to combustion systems using oxygen (oxy-fuel) or oxygen-enriched air with gas or liquid fuels.

1.3.7 Section 6.6 shall apply to all types of heating systems where electrical energy is used as the source of heat.

1.3.8 Section 6.7 shall apply to the following:

(1) All types of systems where water, steam, or other heat-transfer fluids are the source of heat through the use of heat exchangers
(2) Heat-transfer fluid system between the oven supply and the return isolation valves for the oven being served

1.4 Retroactivity. The provisions of this standard reflect a consensus of what is necessary to provide an acceptable degree of protection from the hazards addressed in this standard at the time the standard was issued.

1.4.1 Unless otherwise specified, the provisions of this standard shall not apply to facilities, equipment, structures, or installations that existed or were approved for construction or installation prior to the effective date of the standard. Where specified, the provisions of this standard shall be retroactive.

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1.4.2 In those cases where the authority having jurisdiction determines that the existing situation presents an unacceptable degree of risk, the authority having jurisdiction shall be permitted to apply retroactively any portions of this standard deemed appropriate.

1.4.3 The retroactive requirements of this standard shall be permitted to be modified if their application clearly would be impractical in the judgment of the authority having jurisdiction and only where it is clearly evident that a reasonable degree of safety is provided.

1.5* Equivalency. Nothing in this standard is intended to prevent the use of systems, methods, or devices of equivalent or superior quality, strength, fire resistance, effectiveness, durability, and safety over those prescribed by this standard.

1.5.1 Technical documentation shall be submitted to the authority having jurisdiction to demonstrate equivalency.

1.5.2 The system, method, or device shall be approved for the intended purpose by the authority having jurisdiction.

1.6 Units and Formulas.

1.6.1 SI Units. Metric units of measurement in this standard are in accordance with the modernized metric system known as the International System of Units (SI).

1.6.2 Primary and Equivalent Values. If a value for a measurement as given in this standard is followed by an equivalent value in other units, the first stated value shall be regarded as the requirement. A given equivalent value might be approximate.

1.6.3 Conversion Procedure. SI units have been converted by multiplying the quantity by the conversion factor and then rounding the result to the appropriate number of significant digits.

Chapter 2 Referenced Publications

2.1 General. The documents or portions thereof listed in this chapter are referenced within this standard and shall be considered part of the requirements of this document.

2.2 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169-7471.

NFPA 10, *Standard for Portable Fire Extinguishers,* 2013 edition.

NFPA 11, *Standard for Low-, Medium-, and High-Expansion Foam,* 2010 edition.

NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems,* 2011 edition.

NFPA 13, *Standard for the Installation of Sprinkler Systems,* 2013 edition.

NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection,* 2012 edition.

NFPA 17, *Standard for Dry Chemical Extinguishing Systems,* 2013 edition.

NFPA 17A, *Standard for Wet Chemical Extinguishing Systems,* 2013 edition.

NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems,* 2014 edition.

NFPA 30, *Flammable and Combustible Liquids Code,* 2015 edition.

NFPA 31, *Standard for the Installation of Oil-Burning Equipment,* 2011 edition.

NFPA 54, *National Fuel Gas Code,* 2015 edition.

NFPA 55, *Compressed Gases and Cryogenic Fluids Code,* 2013 edition.

NFPA 58, *Liquefied Petroleum Gas Code,* 2014 edition.

NFPA 68, *Standard on Explosion Protection by Deflagration Venting,* 2013 edition.

NFPA 70®, National Electrical Code®, 2014 edition.

NFPA 79, *Electrical Standard for Industrial Machinery,* 2015 edition.

NFPA 87, *Recommended Practice for Fluid Heaters,* 2015 edition.

NFPA 91, *Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Noncombustible Particulate Solids,* 2010 edition.

NFPA 750, *Standard on Water Mist Fire Protection Systems,* 2015 edition.

2.3 Other Publications.

2.3.1 ANSI Publications. American National Standards Institute, Inc., 25 West 43rd Street, 4th Floor, New York, NY 10036.

ANSI Z50.1, *Bakery Equipment — Safety Requirements,* 2006.

2.3.2 API Publications. American Petroleum Institute, 1220 L Street, NW, Washington, DC 20005-4070.

API STD 560, *Fired Heaters for General Refinery Services*, 2007.

API RP 556, *Instrumentation and Control Systems for Fired Heaters and Steam Generators*, 1997.

API RP 2001, *Fire Protection in Refineries*, 2005.

2.3.3 ASME Publications. American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016-5990.

Boiler and Pressure Vessel Code, 2007.

ASME B31.1, *Power Piping,* 2007.

ASME B31.3, *Process Piping,* 2008.

2.3.4 ASTM Publications. ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959.

ASTM D 396, *Standard Specifications for Fuel Oils,* 2009.

2.3.5 CGA Publications. Compressed Gas Association, 4221 Walney Road, 5th Floor, Chantilly, VA 20151-2923.

CGA G-4.1, *Cleaning Equipment for Oxygen Service*, 2004.

2.3.6 IEC Publications. International Electrical Commission, 3, rue de Varembé, P.O. Box 131, CH - 1211, Geneva 20, Switzerland.

IEC 61508, *Functional Safety of Electrical/Electronic/Programmable Electronic Safety-Related Systems*, 2010.

2.3.7 Other Publications.

Merriam-Webster's Collegiate Dictionary, 11th edition, Merriam-Webster, Inc., Springfield, MA, 2003.

2.4 References for Extracts in Mandatory Sections.

NFPA 54, *National Fuel Gas Code,* 2015 edition.

NFPA 69, *Standard on Explosion Prevention Systems,* 2014 edition.

NFPA 70®, National Electrical Code®, 2014 edition.

NFPA 85, *Boiler and Combustion Systems Hazards Code,* 2011 edition.

NFPA 99, *Health Care Facilities Code,* 2015 edition.

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NFPA 211, *Standard for Chimneys, Fireplaces, Vents, and Solid Fuel–Burning Appliances,* 2013 edition.

NFPA 302, *Fire Protection Standard for Pleasure and Commercial Motor Craft,* 2015 edition.

NFPA 820, *Standard for Fire Protection in Wastewater Treatment and Collection Facilities,* 2012 edition.

Chapter 3 Definitions

3.1 General. The definitions contained in this chapter shall apply to the terms used in this standard. Where terms are not defined in this chapter or within another chapter, they shall be defined using their ordinarily accepted meanings within the context in which they are used. *Merriam-Webster's Collegiate Dictionary*, 11th edition, shall be the source for the ordinarily accepted meaning.

3.2 NFPA Official Definitions.

3.2.1* Approved. Acceptable to the authority having jurisdiction.

3.2.2* Authority Having Jurisdiction (AHJ). An organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, an installation, or a procedure.

3.2.3 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.

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

3.2.5 Shall. Indicates a mandatory requirement.

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

3.2.7 Standard. A document, the main text of which contains only mandatory provisions using the word "shall" to indicate requirements and which is in a form generally suitable for mandatory reference by another standard or code or for adoption into law. Nonmandatory provisions are not to be considered a part of the requirements of a standard and shall be located in an appendix, annex, footnote, informational note, or other means as permitted in the *Manual of Style for NFPA Technical Committee Documents*.

3.3 General Definitions.

3.3.1 Afterburner. See 3.3.49.2.1.

3.3.2 Air.

3.3.2.1 ***Burnout Air.*** Air introduced into a furnace chamber for the purpose of burning out flammable atmospheres, residual soot, or other carbonaceous material.

3.3.2.2 ***Combustion Air.*** The air necessary to provide for the complete combustion of fuel and usually consisting of primary air, secondary air, and excess air. [**211,** 2013]

3.3.2.3 ***Primary Air.*** All air supplied through the burner.

3.3.2.4 ***Process Control Air.*** Air introduced to a furnace containing a special atmosphere to establish a controlled oxygen level or carbon potential.

3.3.2.5 ***Reaction Air.*** All the air that, when reacted with gas in an endothermic generator by the indirect addition of heat, becomes a special atmosphere gas.

3.3.2.6 ***Secondary Air.*** All the combustion air that is intentionally allowed to enter the combustion chamber in excess of primary air.

3.3.3 Automatic Fire Check. A flame arrester equipped with a check valve to shut off the fuel gas supply automatically if a backfire occurs.

3.3.4 Backfire Arrester. A flame arrester installed in fully premixed air–fuel gas distribution piping to terminate flame propagation therein, shut off fuel supply, and relieve pressure resulting from a backfire.

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

3.3.5.1 ***Atmospheric Burner.*** A burner used in a low-pressure fuel gas or atmospheric system that requires secondary air for complete combustion.

3.3.5.2 ***Atomizing Burner.*** A burner in which oil is divided into a fine spray by an atomizing agent, such as steam or air.

3.3.5.3 ***Blast Burner.*** A burner delivering a combustible mixture to the combustion zone under a pressure that is normally above 0.3 in. w.c. (75 kPa).

3.3.5.4 ***Combination Fuel Gas and Oil Burner.*** A burner designed to burn either fuel gas or oil or to burn both simultaneously.

3.3.5.5 ***Dual-Fuel Burner.*** A burner designed to burn either fuel gas or oil but not to burn both simultaneously.

3.3.5.6 ***Line Burner.*** A burner whose flame is a continuous line.

3.3.5.7 ***Multiple-Port Burner.*** A burner having two or more separate discharge openings or ports.

3.3.5.8 ***Nozzle Mixing Burner.*** A burner in which the fuel and air are introduced separately to the point of ignition.

3.3.5.9 ***Premix Burner.*** A burner in which the fuel and air are mixed prior to the point of ignition.

3.3.5.10 ***Pressure Atomizing Burner.*** An atomizing burner in which oil under high pressure is forced through small orifices to emit liquid fuel in a finely divided state.

3.3.5.11 ***Radiant Burner.*** A burner designed to transfer a significant part of the combustion heat in the form of radiation.

3.3.5.12 ***Radiant Tube Burner.*** A burner designed to provide a long flame within a tube to ensure substantially uniform radiation from the tube surface.

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3.3.5.13 ***Rotary Atomizing Burner.*** An atomizing burner in which oil is atomized by applied centrifugal force, such as by a whirling cone or plate.

3.3.5.14 ***Self-Piloted Burner.*** A burner in which the pilot fuel is issued from the same ports as the main flame or merges with the main flame to form a common flame envelope with a common flame base.

3.3.6* Burner Management System. The field devices, logic system, and final control elements dedicated to combustion safety and operator assistance in the starting and stopping of fuel preparation and burning equipment and for preventing misoperation of and damage to fuel preparation and burning equipment. [**85,** 2011]

3.3.7 Burner System. One or more burners operated as a unit by a common safety shutoff valve(s).

3.3.8 Burner Turndown. The ratio of maximum to minimum burner fuel–input rates.

3.3.9 Burn-In. The procedure used in starting up a special atmosphere furnace to replace air within the heating chamber(s) and vestibule(s) with flammable special atmosphere.

3.3.10 Burn-Out. The procedure used in shutting down or idling a special atmosphere to replace flammable atmosphere within the heating chamber(s) and vestibule(s) with nonflammable atmosphere.

3.3.11 Combustion Safeguard. A safety device or system that responds to the presence or absence of flame properties using one or more flame detectors and provides safe start-up, safe operation, and safe shutdown of a burner under normal and abnormal conditions.

3.3.12 Controller.

3.3.12.1 ***Continuous Vapor Concentration Controller.*** A device that measures, indicates, and directly or indirectly controls the concentration of a flammable vapor–air mixture as expressed in percentage of the lower flammable limit (LFL).

3.3.12.2 ***Continuous Vapor Concentration High-Limit Controller.*** A device designed to initiate reduction of the vapor concentration if the concentration exceeds a predetermined set point.

3.3.12.3 ***Programmable Controller.*** A digital electronic system designed for use in an industrial environment that uses a programmable memory for the internal storage of user-oriented instructions for implementing specific functions to control, through digital or analog inputs and outputs, various types of machines or processes.

3.3.12.4 ***Temperature Controller.*** A device that measures the temperature and automatically controls the input of heat into the furnace.

3.3.13* Cryogenic Fluid. A fluid produced or stored at very low temperatures.

3.3.14* Cut-Away Damper. A restricting airflow device that, when placed in the maximum closed position, allows a minimum amount of airflow past the restriction.

3.3.15 Direct-Fired Air Makeup Unit. A Class B fuel-fired heat utilization unit operating at approximately atmospheric pressure used to heat outside replacement air for the process.

3.3.16* Explosion-Resistant (Radiant Tube). A radiant tube or radiant tube heat recovery system that does not fail catastrophically when subjected to the maximum deflagration pressure caused by the ignition of an accumulation of a stoichiometric mixture of the selected fuel(s) and air.

3.3.17 Flame Arrester. A device that prevents the transmission of a flame through a flammable gas/air mixture by quenching the flame on the surfaces of an array of small passages through which the flame must pass. [**69,** 2014]

3.3.18 Flame Detector. A safety device directly responsive to flame properties that senses the presence or absence of flame using flame sensors.

3.3.19 Flame Failure Response Time (FFRT). The period of time that starts with the loss of flame and ends with the de-energizing of the safety shutoff valve(s).

3.3.20* Flame Propagation Rate. The speed at which a flame progresses through a combustible fuel–air mixture.

3.3.21* Flame Rod. A sensor that employs an electrically insulated rod of temperature-resistant material that extends into the flame being supervised, with a voltage impressed between the rod and a ground connected to the nozzle or burner.

3.3.22* Flammable Limits. The range of concentration of a flammable gas in air within which a flame can be propagated, with the lowest flammable concentration known as the lower flammable limit (LFL) and the highest flammable concentration known as the upper flammable limit (UFL).

3.3.23 Fuel Gas. A gas used as a fuel source, including natural gas, manufactured gas, sludge gas, liquefied petroleum gas–air mixtures, liquefied petroleum gas in the vapor phase, and mixtures of these gases. [**820,** 2012]

3.3.24 Fuel Gas System.

3.3.24.1 ***High Pressure Fuel Gas System.*** A fuel gas system using the kinetic energy of a jet of 1 psig (7 kPa) or higher gas pressure to entrain from the atmosphere all, or nearly all, the air required for combustion.

3.3.24.2 ***Low Pressure or Atmospheric Fuel Gas System.*** A fuel gas system using the kinetic energy of a jet of less than 1 psig (7 kPa) gas pressure to entrain from the atmosphere a portion of the air required for combustion.

3.3.25 Fuel Oil. A liquid fuel used as a fuel source, including Grades 2, 4, 5, or 6 fuel oils as defined in ASTM D 396, *Standard Specifications for Fuel Oils.*

3.3.26 Fume Incinerator. Any separate or independent combustion equipment or device that entrains the process exhaust for the purpose of direct thermal or catalytic destruction, which can include heat recovery.

3.3.27 Furnace.

3.3.27.1 ***Atmosphere Furnace.*** A furnace built to allow heat processing of materials in a special processing atmosphere.

3.3.27.2 ***Batch Furnace.*** A furnace into which the work charge is introduced all at once.

3.3.27.3* ***Class A Furnace.*** An oven or furnace that has heat utilization equipment wherein there is a potential explosion or fire hazard that could be occasioned by the presence of flammable volatiles or combustible materials processed or heated in the furnace.

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3.3.27.4* ***Class B Furnace.*** An oven or furnace that has heat utilization equipment wherein there are no flammable volatiles or combustible materials being heated.

3.3.27.5* ***Class C Furnace.*** An oven or furnace that has a potential hazard due to a flammable or other special atmosphere being used for treatment of material in process.

3.3.27.6* ***Class D Furnace.*** An oven or furnace that is a pressure vessel that operates under vacuum for all or part of the process cycle.

3.3.27.7 ***Continuous Furnace.*** A furnace into which the work charge is more or less continuously introduced.

3.3.27.8 ***Molten Salt Bath Furnace.*** A furnace that employs salts heated to a molten state, excluding aqueous alkaline baths, hot brine, or other systems utilizing salts in solution.

3.3.27.9 ***Plasma Arc Furnace.*** A furnace that employs the passage of an electric current between a pair of electrodes or between electrodes and the work and that ionizes a gas (such as argon) and transfers energy in the form of heat.

3.3.28 Gas.

3.3.28.1 ***Ballast Gas.*** Atmospheric air or a dry gas that is admitted into the compression chamber of rotary mechanical pumps to prevent condensation of vapors in the pump oil by maintaining the partial pressure of the condensable vapors below the saturation value.

3.3.28.2 ***Inert Gas.*** See 3.3.67.5, Inert Special Atmosphere (Purge Gas).

3.3.28.3 ***Reaction Gas.*** A gas that, when reacted with air in an endothermic generator by the addition of heat, becomes a special atmosphere gas.

3.3.29 Gas Analyzer. A device that measures concentrations, directly or indirectly, of some or all components in a gas or mixture.

3.3.30* Gas Quenching. The introduction of a gas into a furnace for the purpose of cooling the work.

3.3.30.1 ***High Pressure Gas Quenching.*** Gas-cooling at pressures greater than 15 psig.

3.3.31 Guarded. Covered, shielded, fenced, enclosed, or otherwise protected by means of suitable covers, casings, barriers, rails, screens, mats, or platforms to remove the likelihood of approach or contact by persons or objects to a point of danger. [**70:**100]

3.3.32* Hardwired. The method of interconnecting signals or interlocks to a logic system or between logic systems using a dedicated interconnection for each individual signal.

3.3.33 Heating System.

3.3.33.1* ***Dielectric Heating System.*** A heating system similar to an induction heater, but using frequencies that generally are higher (3 MHz or more) than those used in induction heating.

3.3.33.2 ***Direct-Fired External Heating System.*** A heating system in which the burners are in a combustion chamber effectively separated from the work chamber and arranged so that products of combustion from the burners are discharged into the work chamber by a circulating fan or blower.

3.3.33.3* ***Direct-Fired Heating System.*** A heating system in which the products of combustion enter the work chamber.

3.3.33.4 ***Direct-Fired Internal Heating System.*** A heating system in which the burners are located within the work chamber.

3.3.33.5 ***Indirect-Fired Heating System.*** A heating system in which the products of combustion do not enter the work chamber.

3.3.33.6* ***Indirect-Fired Internal Heating System.*** A heating system of gastight radiators containing burners not in contact with the oven atmosphere.

3.3.33.7* ***Induction Heating System.*** A heating system by means of which a current-carrying conductor induces the transfer of electrical energy to the work by eddy currents.

3.3.33.8 ***Radiant Tube Heating System.*** A heating system with tubular elements open at one or both ends in which each tube has an inlet burner arrangement where combustion is initiated, a suitable length where combustion occurs, and an outlet that discharges outside the work chamber for the combustion products formed.

3.3.33.9* ***Resistance Heating System.*** A heating system in which heat is produced by current flow through a resistive conductor.

3.3.33.10 ***Tubular Heating System.*** A radiant heating system in which resistive conductors are enclosed in glass, quartz, or ceramic envelopes that can contain a special gas atmosphere.

3.3.34 Ignition Temperature. The lowest temperature at which a gas–air mixture can ignite and continue to burn; also referred to as *auto-ignition temperature.*

3.3.35* Implosion. The rapid inward collapsing of the walls of a vacuum component or device as the result of failure of the walls to sustain the atmospheric pressure.

3.3.36 Interlock.

3.3.36.1 ***1400°F (760°C) Bypass Interlock.*** A device designed to permit specific permitted logic when the combustion chamber is proved to be above 1400°F (760°C).

3.3.36.2 ***Excess Temperature Limit Interlock.*** A device designed to cut off the source of heat if the operating temperature exceeds a predetermined temperature set point.

3.3.36.3 ***Proved Low-Fire Start Interlock.*** A burner start interlock in which a control sequence ensures that a high–low or modulated burner is at a reduced firing rate for reliable ignition before the burner can be ignited.

3.3.36.4 ***Safety Interlock.*** A device required to ensure safe startup and safe operation and to cause safe equipment shutdown.

3.3.37* Limiting Oxidant Concentration (LOC). The concentration of oxidant below which a deflagration cannot occur.

3.3.38 LOC. See 3.3.37, Limiting Oxidant Concentration (LOC).

3.3.39 Lower Flammable Limit (LFL). See 3.3.22, Flammable Limits.

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3.3.40 Mixer.

3.3.40.1 ***Air–Fuel Gas Mixer.*** A mixer that combines air and fuel gas in the proper proportions for combustion.

3.3.40.2* ***Air Jet Mixer.*** A mixer using the kinetic energy of a stream of air issuing from an orifice to entrain the fuel gas required for combustion.

3.3.40.3 ***Gas Jet Mixer [Atmospheric Inspirator (Venturi) Mixer].*** A mixer using the kinetic energy of a jet of fuel gas issuing from an orifice to entrain all or part of the air required for combustion.

3.3.40.4 ***Proportional Mixer.*** A mixer comprising an inspirator that, when supplied with air, draws all the fuel gas necessary for combustion into the airstream, and a governor, zero regulator, or ratio valve that reduces incoming fuel gas pressure to approximately atmospheric.

3.3.41 Mixing Blower. A motor-driven blower to supply air–fuel gas mixtures for combustion through one or more fuel burners or nozzles on a single-zone industrial heating appliance or on each control zone of a multizone installation. Mixing machines operated at 10 in. w.c. (2.49 kPa) or less static pressure are considered mixing blowers.

3.3.42 Mixing Machine. An externally powered mechanical device that mixes fuel and air and compresses the resultant mixture to a pressure suitable for delivery to its point of use.

3.3.43 Molten Bath Salt. See 3.3.27.8, Molten Salt Bath Furnace.

3.3.44 Muffle. An enclosure within a furnace to separate the source of heat from the work and from any special atmosphere that might be required for the process.

3.3.45 Oil Separator. An oil reservoir with baffles used to minimize the discharge of oil mist from the exhaust of a rotary mechanical vacuum pump.

3.3.46 Operator. An individual trained and responsible for the startup, operation, shutdown, and emergency handling of the furnace and associated equipment.

3.3.47 Outgassing. The release of adsorbed or occluded gases or water vapor, usually by heating, such as from a vacuum tube or other vacuum system.

3.3.48 Oven. See 3.3.27.1 through 3.3.27.9, Furnace definitions.

3.3.48.1* ***Low-Oxygen Oven.*** An oven that utilizes a low-oxygen atmosphere to evaporate solvent to facilitate solvent recovery.

3.3.49 Oxidizer.

3.3.49.1 ***Catalytic Oxidizer.*** See 3.3.49.2, Thermal Oxidizer.

3.3.49.1.1 ***Direct Catalytic Oxidizer.*** A combustion system in which the burner(s) directly heats volatile organic compounds (VOCs) or hydrocarbons (HCs) to the destruction temperature, prior to their introduction to a destruction catalyst, without heat recovery to the incoming gases, and in which the catalytic destruction temperature is lower than the noncatalytic (direct thermal) destruction temperature.

3.3.49.1.2 ***Recuperative Catalytic Oxidizer.*** A combustion system in which the burner(s) directly heats VOCs or HCs to the catalytic destruction temperature prior to their introduction to a destruction catalyst, after which products of combustion are used to indirectly heat the incoming gas stream before it contacts the burner flame, and in which the catalytic destruction temperature is lower than the noncatalytic (direct thermal) destruction temperature.

3.3.49.1.3 ***Regenerative Catalytic Oxidizer (RCO).*** A combustion system in which the burner(s) directly heats VOCs or HCs after the gas stream is preheated to the destruction temperature by the periodic flow reversal of the gas stream through beds of ceramic heat recovery media with a coating or layer of catalyst that alternately have been heated by the product gases during an exhaust cycle and then have given up their heat to the incoming reactant gases during an inlet cycle.

3.3.49.2 ***Thermal Oxidizer.*** An independently controlled, enclosed combustion system whose purpose is to destroy VOC, HC gases or vapors, or both, using elevated temperature, residence time, mixing, excess oxygen, and, in some cases, catalysts.

3.3.49.2.1 ***Afterburner (Direct Thermal Oxidizer).*** A direct thermal oxidizer, installed in series and downstream of process equipment, that generates VOC or HC; also referred to as *secondary combustion chamber.*

3.3.49.2.2 ***Direct Thermal Oxidizer.*** A combustion system in which the burner(s) directly heats VOCs or HCs to the destruction temperature without heat recovery to the incoming gases.

3.3.49.2.3 ***Flameless Thermal Oxidizer.*** A direct recuperative or regenerative combustion system in which the burner(s) preheats the heat storage media prior to the introduction of VOCs or HCs and in which, subsequently, the destruction is carried out in the interstices of the heat storage media in a flameless, self-sustaining manner.

3.3.49.2.4 ***Recuperative Thermal Oxidizer.*** A combustion device in which the burner(s) directly heats VOCs or HCs to the destruction temperature and in which the hot products of combustion are used to indirectly heat the incoming gas stream before it contacts the burner flame.

3.3.49.2.5 ***Regenerative Thermal Oxidizer.*** A combustion device in which the burner(s) directly heats VOCs or HCs after the gas stream is preheated to the destruction temperature by the periodic flow reversal of the gas stream through heat storage media that alternately have been heated by the product gases during an exhaust cycle and then have given up their heat to the incoming reactant gases during an inlet cycle.

3.3.50 Partial Pressure. The pressure, in absolute units, exerted by a particular gas in a gas mixture. [**99,** 2015]

3.3.51 Pilot. A flame that is used to light the main burner.

3.3.51.1 ***Burn-off Pilot.*** A pilot that ignites special processing atmosphere discharging from the furnace or generator.

3.3.51.2 ***Continuous Pilot.*** A pilot that burns throughout the entire period that the heating equipment is in service, regardless of whether the main burner is firing.

3.3.51.3 ***Flame Curtain Pilot.*** A pilot that ignites a flame curtain.

3.3.51.4 ***Intermittent Pilot.*** A pilot that burns during light-off and while the main burner is firing.

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3.3.51.5 ***Interrupted Pilot.*** A pilot that is ignited and burns during light-off and is automatically shut off at the end of the trial-for-ignition period of the main burner(s).

3.3.51.6 ***Proved Pilot.*** A pilot whose flame is supervised by a flame detector that senses the presence of the pilot flame.

3.3.52 Pipe Burner. A burner consisting of a tube or pipe with ports or tips spaced over its length.

3.3.53 Plasma Arc. A heating process in which an ionized gas, such as nitrogen or argon, is used to conduct electrical current.

3.3.54 Pressure Regulator. A device placed in a gas line for reducing, controlling, and maintaining the pressure in that portion of the piping system downstream of the device.

3.3.54.1 ***Line Pressure Regulator.*** A pressure regulator placed in a gas line between the service regulator and the appliance (equipment) regulator.

3.3.54.2 ***Monitoring Pressure Regulator.*** A pressure regulator in a nonregulated state and set in series with another pressure regulator for the purpose of automatically taking over, in an emergency, control of the pressure downstream of the regulator in cases where pressure exceeds a set maximum.

3.3.54.3 ***Series Pressure Regulator.*** A pressure regulator in series with one service or line pressure regulator.

3.3.54.4 ***Service Pressure Regulator.*** A pressure regulator installed by the serving gas supplier to reduce and limit the service line gas pressure to delivery pressure.

3.3.55 Pressure Relief Valve. A valve that automatically opens and closes a relief vent, depending on whether the pressure is above or below a predetermined value. [**54,** 2015]

3.3.56 Pump.

3.3.56.1 ***Diffusion Pump.*** A vacuum pump in which a stream of heavy molecules, such as those of mercury or oil vapor, carries gas molecules out of the volume being evacuated.

3.3.56.2 ***Gas Ballast Pump.*** A mechanical pump (usually of the rotary type) that uses oil to seal the clearances between the stationary and rotating compression members. The pump is equipped with an inlet valve through which a suitable quantity of atmospheric air or "dry" gas (ballast gas) can be admitted into the compression chamber to prevent condensation of vapors in the pump oil by maintaining the partial pressure of the condensable vapors in the oil below the saturation value (sometimes called a *vented-exhaust mechanical pump*).

3.3.56.3 ***Holding Pump.*** A backing (fore) pump used to hold a diffusion pump at efficient operating conditions while a roughing pump reduces system pressure to a point at which a valve between the diffusion pump and the system can be opened without stopping the flow of vapor from the nozzles.

3.3.56.4 ***Rotary Blower Pump.*** A pump without a discharge valve that moves gas by the propelling action of one or more rapidly rotating members provided with lobes, blades, or vanes; also referred to as *mechanical booster pump* where used in series with a mechanical backing (fore) pump.

3.3.56.5* ***Roughing Pump.*** The pump used to reduce the system pressure to the level at which a diffusion or other vacuum pump can operate.

3.3.56.6 ***Vacuum Pump.*** A compressor for exhausting air and noncondensable gases from a space that is to be maintained at subatmospheric pressure.

3.3.57 Pump-Down Factor. The product of the time to pump down to a given pressure and the displacement (for a service factor of 1) divided by the volume of the system ($F = tD/V$).

3.3.58 Pump Fluid. The operating fluid used in diffusion pumps or in liquid-sealed mechanical pumps (sometimes called *working medium, working fluid*, or *pump oil*).

3.3.59 Purge. The replacement of a flammable, indeterminate, or high-oxygen-bearing atmosphere with another gas that, when complete, results in a nonflammable final state.

3.3.60 Readily Accessible. Capable of being reached quickly and safely for effective use under emergency conditions without the aid of tools. [**302,** 2015]

3.3.61 Roughing Line. A line running from a mechanical pump to a vacuum chamber through which preliminary pumping is conducted to a vacuum range at which a diffusion pump or other high vacuum pump can operate.

3.3.62* Safe-Start Check. A test incorporated in a combustion safeguard that prevents start-up if a flame-detected condition exists due to component failure within the combustion safeguard or flame detector(s) due to the presence of actual or simulated flame.

3.3.63* Safety Device. An instrument, a control, or other equipment that acts, or initiates action, to cause the furnace to revert to a safe condition in the event of equipment failure or other hazardous event.

3.3.64 Safety Relay. A relay listed for safety service.

3.3.65 Safety Shutdown. Stopping operations by means of a safety control or interlock that shuts off all fuel and ignition energy in a manner necessitating manual restart.

3.3.66 Scf. One cubic foot of gas at 70°F (21°C) and 14.7 psia (an absolute pressure of 101 kPa).

3.3.67 Special Atmosphere. A prepared gas or a gas mixture that is introduced into the work chamber of a furnace to replace air, generally to protect or intentionally change the surface of the material undergoing heat processing (heat treatment).

3.3.67.1 ***Carrier Gas Special Atmosphere.*** A gas or liquid component of a special atmosphere that represents a sufficient portion of the special atmosphere gas volume in the furnace so that, if the flow of the gas or liquid component ceases, the total flow of the special atmosphere in the furnace is not sufficient to maintain a positive pressure in the furnace.

3.3.67.2 ***Flammable Special Atmosphere.*** A special atmosphere in which gases are known to be flammable and predictably ignitible where mixed with air.

3.3.67.3 ***Generated Special Atmosphere.*** A special atmosphere created in an ammonia dissociator, exothermic generator, or endothermic generator by dissociation or chemical reaction of reaction air and reaction gas.

3.3.67.4 ***Indeterminate Special Atmosphere.*** A special atmosphere that contains components that, in their pure state, are flammable but that, in the mixtures used (diluted with nonflammable gases), are not reliably and predictably flammable.

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3.3.67.5 ***Inert Special Atmosphere (Purge Gas).*** A special atmosphere of nonflammable gases that contains less than 1 percent oxygen.

3.3.67.6 ***Nonflammable Special Atmosphere.*** A special atmosphere of gases that are known to be nonflammable at any temperature.

3.3.67.7 ***Synthetic Special Atmosphere.*** A special atmosphere such as those of anhydrous ammonia, hydrogen, nitrogen, or inert gases obtained from compressed gas cylinders or bulk storage tanks and those derived by chemical dissociation or mixing of hydrocarbon fluids, including mixtures of synthetic and generated atmospheres.

3.3.68 Supervised Flame. A flame whose presence or absence is detected by a flame detector.

3.3.69 Switch.

3.3.69.1 ***Closed Position Indicator Switch.*** A switch that indicates when a valve is within 0.040 in. (1 mm) of its closed position but does not indicate proof of closure.

3.3.69.2 ***Differential Flow Switch.*** A switch that is activated by the flow of a gaseous or liquid fluid. This flow is detected by measuring pressure at two different points to produce a pressure differential across the sensor.

3.3.69.3 ***Flow Switch.*** A switch that is activated by the flow of a fluid in a duct or piping system.

3.3.69.4 ***Limit Switch.*** A switch that actuates when an operating limit has been reached.

3.3.69.5 ***Manual Emergency Switch.*** A discrete electromechanical push button–type self-latching device that is used to initiate a safety shutdown.

3.3.69.6 ***Pressure Switch.***

3.3.69.6.1 ***Atomizing Medium Pressure Switch.*** A pressure-activated switch arranged to effect a safety shutdown or to prevent the oil burner system from being actuated in the event of inadequate atomizing medium pressure.

3.3.69.6.2 ***Combustion Air Pressure Switch.*** A pressure-activated switch arranged to effect a safety shutdown or to prevent the burner system from being actuated when the combustion air pressure is below its design set point.

3.3.69.6.3 ***High Fuel Pressure Switch.*** A pressure-activated switch arranged to effect a safety shutdown of the burner system in the event of abnormally high fuel pressure.

3.3.69.6.4 ***Low Fuel Pressure Switch.*** A pressure-activated switch arranged to effect a safety shutdown of the burner system in the event of abnormally low fuel pressure.

3.3.69.7* ***Proof-of-Closure Switch.*** A switch installed in a safety shutoff valve that activates only after the valve is fully closed.

3.3.69.8 ***Rotational Switch.*** A switch that usually is driven directly by the fan wheel or fan motor shaft and in which a switch contact closes when the speed of the fan shaft or drive motor reaches a certain predetermined rate.

3.3.70 Tank.

3.3.70.1 ***Integral Liquid or Salt Media Quench-Type Tank.*** A quench-type tank connected to the furnace so that the work is under a protective atmosphere from the time it leaves the heating zone until it enters the tank containing a combustible, noncombustible, or salt quench medium.

3.3.70.2 ***Open Liquid or Salt Media Quench-Type Tank.*** A quench-type tank in which work from the furnace is exposed to air before and upon entering the tank containing a combustible, noncombustible, or salt quench medium.

3.3.71 Time.

3.3.71.1 ***Evacuation Time.*** The time required to pump a given system from atmospheric pressure to a specified pressure; also referred to as *pump-down time* or *time of exhaust.*

3.3.71.2 ***Roughing Time.*** The time required to pump a given system from atmospheric pressure to a pressure at which a diffusion pump or other high vacuum pump can operate.

3.3.72 Trial-for-Ignition Period (Flame-Establishing Period). The interval of time during light-off that a combustion safeguard allows the fuel safety shutoff valve to remain open before the flame detector is required to supervise the flame.

3.3.73 Vacuum. A space in which the pressure is far below atmospheric pressure so that the remaining gases do not affect processes being carried out in the space.

3.3.73.1 ***High Vacuum.*** A vacuum with a pressure between 1×10^{-3} torr and 1×10^{-5} torr (millimeters of mercury).

3.3.73.2 ***Low Vacuum.*** A vacuum with a pressure between 760 torr and 1×10^{-3} torr (millimeters of mercury).

3.3.74 Vacuum Gauge. A device that indicates the absolute gas pressure in a vacuum system.

3.3.75 Vacuum Pumping System. A system of pumps, valves and associated piping and wiring, related protective equipment, and measuring and control instrumentation that produce and control the level of vacuum in a vacuum furnace.

3.3.76 Vacuum System. A chamber with walls capable of withstanding atmospheric pressure and an opening through which gas can be removed through a pipe or manifold to a pumping system, and including all pumps, gauges, valves, and other components.

3.3.77 Vacuum-Type Insulation. A highly reflective double-wall structure with high vacuum between the walls; used as insulation in cryogenic systems for the reduction of heat transfer.

3.3.78 Valve.

3.3.78.1 ***Air Inlet Valve.*** A valve used for letting atmospheric air into a vacuum system; also called a *vacuum breaker.*

3.3.78.2* ***Safety Shutoff Valve.*** A normally closed valve installed in the piping that closes automatically to shut off the fuel, atmosphere gas, or oxygen in the event of abnormal conditions or during shutdown.

3.3.78.3 ***Equipment Isolation Valve.*** A manual shutoff valve for shutoff of the fuel to each piece of equipment.

3.3.78.4 ***Emergency Shutoff Valve.*** A manual shutoff valve to allow the fuel to be turned off in an emergency.

3.3.79* Valve Proving System. A system used to check the closure of safety shutoff valves by detecting leakage.

3.3.80 Vent Limiter. A fixed orifice that limits the escape of gas from a vented device into the atmosphere.

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3.3.81 Ventilation. A supply of fresh air to, and exhaust from, a furnace that provides a vigorous, distributed flow of air through all sections of the furnace.

3.3.81.1* ***Safety Ventilation.*** The ventilation necessary to dilute atmosphere within a Class A oven to not exceed the maximum permitted percent of the Lower Flammable Limit (LFL).

3.3.82 Water-Cooling System for Vacuum Furnaces. The apparatus, equipment, and method used to cool vacuum chamber walls, electrical terminals, seals, workload, and the interior of the furnace where applicable.

Chapter 4 General

4.1* Approvals, Plans, and Specifications.

4.1.1 Before new equipment is installed or existing equipment is remodeled, complete plans, sequence of operations, and specifications shall be submitted for approval to the authority having jurisdiction.

4.1.1.1 Plans shall be drawn that show all essential details with regard to location, construction, ventilation, piping, and electrical safety equipment. A list of all combustion, control, and safety equipment giving manufacturer and type number shall be included.

4.1.1.2* Wiring diagrams and sequence of operations for all safety controls shall be provided.

4.1.1.3 Plans shall include the furnace class (e.g., Class A, B, C, or D).

4.1.1.4 If a furnace is modified and/or its process load is changed from the original design, the furnace class shall be evaluated and either confirmed to remain as the original class or reassigned to a new class.

4.1.2 Any deviation from this standard shall require approval from the authority having jurisdiction.

4.1.3 Electrical.

4.1.3.1* All wiring shall be in accordance with *NFPA 70, National Electrical Code*, NFPA 79, *Electrical Standard for Industrial Machinery*, and as described hereafter.

4.1.3.2 Where seal leakage or diaphragm failure in a device can result in flammable gas or flammable liquid flow through a conduit or cable to an electrical ignition source, a conduit seal or a cable type that is sealed shall be installed.

4.1.3.3 Wiring and equipment installed in hazardous (classified) locations shall comply with the applicable requirements of *NFPA 70, National Electrical Code*.

4.1.3.4* The installation of an oven in accordance with the requirements of this standard shall not in and of itself require a change to the classification of the oven location.

4.2 Safety Labeling.

4.2.1 A safety design data form or a nameplate that states the operating conditions for which the furnace system was designed, built, altered, or extended shall be accessible to the operator.

4.2.2 A warning label stating that the equipment shall be operated and maintained according to instructions shall be provided.

4.2.3 The warning label shall be affixed to the furnace or control panel.

4.3 Pressure Vessels. All pressure vessels and heat exchangers shall be designed, fabricated, and tested in accordance with the ASME *Boiler and Pressure Vessel Code,* Section VIII.

Chapter 5 Location and Construction

5.1 Location.

5.1.1 General.

5.1.1.1* Furnaces and related equipment shall be located so as to protect personnel and buildings from fire or explosion hazards.

5.1.1.2 Furnaces shall be located so as to be protected from damage by external heat, vibration, and mechanical hazards.

5.1.1.3 Furnaces shall be located so as to make maximum use of natural ventilation, to minimize restrictions to adequate explosion relief, and to provide sufficient air supply for personnel.

5.1.1.4* Where furnaces are located in basements or enclosed areas, sufficient ventilation shall be supplied so as to provide required combustion air and to prevent the hazardous accumulation of vapors.

5.1.1.5 Furnaces designed for use with special atmospheres or fuel gas with a specific gravity greater than air shall be located at or above grade and shall be located so as to prevent the escape of the special atmosphere or fuel gas from accumulating in basements, pits, or other areas below the furnace.

5.1.2 Structural Members of the Building.

5.1.2.1 Furnaces shall be located and erected so that the building structural members are not affected adversely by the maximum anticipated temperatures *(see 5.1.4.3)* or by the additional loading caused by the furnace.

5.1.2.2 Structural building members shall not pass through or be enclosed within a furnace.

5.1.3 Location in Regard to Stock, Processes, and Personnel.

5.1.3.1 Furnaces shall be located so as to minimize exposure to power equipment, process equipment, and sprinkler risers.

5.1.3.2 Unrelated stock and combustible materials shall be located at a distance from a furnace, a furnace heater, or ductwork so that the combustible materials will not be ignited, with a minimum separation distance of 2.5 ft (0.8 m).

5.1.3.3 Furnaces shall be located so as to minimize exposure of people to possible injury from fire, explosion, asphyxiation, and hazardous materials and shall not obstruct personnel travel to exitways.

5.1.3.4* Furnaces shall be designed or located so as to prevent an ignition source to flammable coating dip tanks, spray booths, and storage and mixing rooms for flammable liquids or to prevent exposure to flammable vapor or combustible dusts.

5.1.3.5 The requirement of 5.1.3.4 shall not apply to integral quench systems.

5.1.3.6 Equipment shall be protected from corrosive external processes and environments, including fumes or materials from adjacent processes or equipment that produces corrosive conditions when introduced into the furnace environment.

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5.1.4 Floors and Clearances.

5.1.4.1 Space shall be provided above and on all sides for the following:

(1) Inspection, maintenance, and operation purposes
(2) Operation of explosion venting
(3) Operation and unobstructed discharge of sprinklers

5.1.4.2 In addition to the requirement of 5.1.4.1, provisions shall be included for the installation of automatic sprinklers and the functioning of explosion venting, if applicable.

5.1.4.3* Furnaces shall be constructed and located to keep temperatures at combustible floors, ceilings, and walls less than 160°F (71°C).

5.1.4.4 Where electrical wiring is present in floor channels, the wiring shall be installed in accordance with *NFPA 70, National Electrical Code*.

5.1.4.5 Floors in the area of mechanical pumps, oil burners, or other equipment using oil shall be provided with a noncombustible, nonporous surface to prevent floors from becoming soaked with oil.

5.2 Furnace Design.

5.2.1 Furnaces and related equipment shall be designed to minimize the fire hazard inherent in equipment operating at elevated temperatures.

5.2.2 Furnace components exposed simultaneously to elevated temperatures and air (oxygen) shall be constructed of noncombustible material.

5.2.3* Furnace structural supports and material-handling equipment shall be designed with the structural strength needed to support the furnace and work when operating at maximum operating conditions, including maximum temperature.

5.2.4* Furnaces shall withstand the strains imposed by expansion and contraction, as well as static and dynamic mechanical loads.

5.2.5 Heating devices and heating elements of all types shall be constructed or located so as to resist mechanical damage from falling work, material handling, or other mechanical hazards.

5.2.6 Furnace and related equipment shall be designed and located so as to provide access for required inspection and maintenance.

5.2.6.1* Ladders, walkways, or access facilities shall be provided so that equipment can be operated or accessed for testing and maintenance.

5.2.6.2 Means shall be provided for entry by maintenance and other personnel.

5.2.7 Radiation shields, refractory material, and insulation shall be retained or supported so they do not fall out of place under designed use and maintenance.

5.2.8 External parts of furnaces that operate at temperatures in excess of 160°F (71°C) shall be guarded by location, guard rails, shields, or insulation to prevent accidental contact with personnel.

5.2.8.1 Bursting discs or panels, mixer openings, and other parts of the furnace from which flame or hot gases could be discharged shall be located or guarded to prevent injury to personnel.

5.2.8.2 Where impractical to provide adequate shields or guards required by 5.2.8, warning signs or permanent floor markings visible to personnel entering the area shall be provided.

5.2.9 Observation ports or other visual means for observing the operation of individual burners shall be provided and shall be protected from radiant heat and physical damage.

5.2.10* Each portion of a closed cooling system that can exceed the design pressure shall be equipped with the following:

(1) Pressure relief
(2) Flow switches equipped with audible and visual alarms

5.2.11 Open cooling systems utilizing unrestricted sight drains observable by the operator shall not require flow switches.

5.2.12 Where a cooling system is critical to continued safe operation of a furnace, the cooling system shall continue to operate after a safety shutdown or power failure.

5.2.13* Furnaces shall be designed to minimize fire hazards due to the presence of combustible products or residue in the furnace.

5.2.14 Furnace hydraulic systems shall utilize either fire-resistant fluids or flammable hydraulic fluids where approved and failure of hydraulic system components cannot result in a fire hazard.

5.2.15 The metal frames of furnaces shall be electrically grounded.

5.2.16* Water-cooled components, such as vacuum vessels, shall be designed with minimum wall thicknesses in accordance with vessel standards.

5.2.17 A corrosion allowance shall be specified where appropriate.

5.3* Explosion Relief.

5.3.1* Fuel-fired furnaces and furnaces that contain flammable liquids, gases, or combustible dusts shall be equipped with unobstructed explosion relief for freely relieving internal explosion pressures except in the following cases:

(1) Explosion relief shall not be required on furnaces with shell construction having 3⁄16 in. (4.8 mm) or heavier steel plate shells reinforced with structural steel beams and buckstays that support and retain refractory or insulating materials that are required for temperature endurance, which makes them unsuitable for the installation of explosion relief.
(2) Explosion-relief panels shall not be required for low-oxygen atmosphere ovens designed and protected in accordance with 13.5.12.
(3) The requirements for explosion relief shall not apply to thermal oxidizers.
(4) The requirements for explosion relief shall not apply to Class D furnaces.
(5) Explosion-relief panels shall not be required in the work chamber of indirect fired ovens where it is demonstrated by calculation that the combustible concentration in the work chamber cannot exceed 25 percent of the lower flammable limit (LFL) under any conditions.
(6)* Explosion relief shall not be required for the combustion chamber of an indirect-fired oven that incorporates a single combustion airflow path through the heat exchanger and does not recirculate the products of combustion.

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5.3.2* Explosion relief shall be based on one of the following:

(1) The amount of explosion relief area shall be at least 1 ft^2 (0.093 m^2) of relief area for each 15 ft^3 (0.424 m^3) of furnace volume.
(2) The amount of explosion relief shall be based on the requirements of NFPA 68, *Standard on Explosion Protection by Deflagration Venting*.

5.3.3 Hinged panels, openings, or access doors equipped with approved explosion-relief hardware shall be permitted to be included in the ratio specified in 5.3.2.

5.3.4 Explosion-relief vents shall be arranged so that, when open, the full vent opening provides an effective relief area.

5.3.4.1 The operation of vents to their full capacity shall not be obstructed.

5.3.4.2 Warning signs shall be posted on the vents.

5.3.5* Explosion-relief vent(s) shall be located as close as practical to each known source of ignition to minimize damage.

5.3.6 Explosion-relief vents shall be located or retained so that personnel are not exposed to injury by operation of the vents.

5.3.7* Where explosion relief is required, explosion-relief vents shall activate at a surge pressure that does not exceed the design pressure of the oven enclosure.

5.3.8* Explosion-relief vents for a long furnace shall be distributed throughout the entire furnace length with the maximum distance between explosion-relief vents not to exceed five times the oven's smallest inside dimension (width or height).

5.4* Ventilation and Exhaust System.

5.4.1* Building Makeup Air. A quantity of makeup air shall be admitted to oven rooms and buildings to provide the air volume required for oven safety ventilation and combustion air.

5.4.2 Fans and Motors.

5.4.2.1 Electric motors that drive exhaust or recirculating fans shall not be located inside the oven or ductwork, except within vacuum furnaces.

5.4.2.2 Oven recirculation and exhaust fans shall be designed for the maximum oven temperature and for material and vapors being released during the heating process.

5.4.3 Ductwork.

5.4.3.1 Ventilating and exhaust systems, where applicable, shall be installed in accordance with Chapters 1 through 5 of NFPA 91, *Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Noncombustible Particulate Solids*, unless otherwise noted in this standard.

5.4.3.2 Wherever furnace ducts or stacks pass through combustible walls, floors, or roofs, either noncombustible insulation or clearance, or both, shall be provided to prevent combustible surface temperatures from exceeding 160°F (71°C).

5.4.3.3* Where ducts pass through noncombustible walls, floors, or partitions, the space around the duct shall be sealed with noncombustible material to maintain the fire resistance rating of the barrier.

5.4.3.4 Ducts shall be constructed entirely of sheet steel or other noncombustible material capable of meeting the intended installation and conditions of service, and the installation shall be protected where subject to physical damage.

5.4.3.5 Access doors shall be provided to allow for inspection and cleaning of the interior surfaces of ducts handling flammable vapors or combustible solids.

5.4.3.6 No portions of the building shall be used as an integral part of the duct leading to the approved point of discharge.

5.4.3.7* All ducts shall be made tight throughout and shall have no openings other than those required for the operation and maintenance of the system.

5.4.3.8 All ducts shall be braced where required and shall be supported by metal hangers or brackets.

5.4.3.9 Ducts handling flammable vapors shall be designed to minimize the condensation of the vapors out of the exhaust airstream onto the surface of the ducts.

5.4.3.10 Ducts handling combustible solids shall be designed to minimize the accumulation of solids within the ducts.

5.4.3.11 Hand holes for damper, sprinkler, or fusible link inspection or resetting and for purposes of residue clean-out shall be equipped with tight-fitting doors or covers.

5.4.3.12 Exposed hot fan casings and hot ducts [temperatures exceeding 160°F (71°C)] shall be guarded by location, guard rails, shields, or insulation to prevent injury to personnel.

5.4.3.13* Exhaust ducts shall not discharge near openings or other air intakes where effluents can be entrained and directed to locations creating a hazard.

5.4.3.14 A collecting and venting system for radiant tube heating systems shall be provided in accordance with Section 6.5.

5.5 Mountings and Auxiliary Equipment.

5.5.1 Pipes, valves, and manifolds shall be mounted so as to provide protection against damage by heat, vibration, and mechanical hazard.

5.5.2 Furnace systems shall have provisions such as motion stops, lockout devices, or other safety mechanisms to prevent injury to personnel during maintenance or inspection.

5.5.3 Instrumentation and control equipment shall meet the following criteria:

(1) Located for ease of observation, adjustment, and maintenance
(2) Protected from physical and thermal damage and other hazards

5.5.4 Auxiliary equipment such as conveyors, racks, shelves, baskets, and hangers shall be noncombustible and designed to facilitate cleaning.

5.5.5 External Heat Exchangers. External heat exchangers used for the purpose of extracting heat from a recirculating cooling gas shall be enclosed in a vacuumtight chamber that has a leak rate not exceeding the leak rate specified by the manufacturer for the furnace chamber.

5.5.5.1 Heat exchangers, components, and connections shall be free from water and air leaks.

5.5.5.2 Heat exchangers shall be installed or located to prevent damage from vibration and thermal damage due to expansion and contraction.

5.5.5.3 Heat exchanger components shall have the design strength to resist permanent deformation while exposed to the

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simultaneous maximum pressure of the coolant source and the maximum vacuum or pressure attained in the furnace.

5.5.6 Fans and Motors for Gas Quenching Systems.

5.5.6.1 Fans shall not be exposed to any temperature in excess of their design temperature rating.

5.5.6.2 Electric fan motors shall be interlocked to prevent operation at less than a chamber pressure of 7 psi (48 kPa) absolute in order to prevent motor failure.

5.5.6.3 Where motor windings are exposed to argon gas or other ionizing gases, the voltage on the motor shall be limited to 260 volts maximum.

5.5.7 Quenching Gas. When introduced at the quenching temperature, the recirculating gas shall be one that is not harmful to the heating elements, furnace heat shields or insulation, or work.

Chapter 6 Furnace Heating Systems

6.1 General.

6.1.1 For the purposes of this chapter, the term *furnace heating system* shall include the heating source, the associated piping and wiring used to heat the furnace, and the work therein as well as the auxiliary quenches, atmosphere generator, and other components.

6.1.2 All components of the furnace heating system and control cabinet shall be grounded.

6.2* Fuel Gas–Fired Units.

6.2.1 General. Burners, along with associated mixers, valves, regulators, safety controls, and other auxiliary components, shall be selected for the intended application, type, and pressure of the fuel gases to be used and temperatures to which they are subjected.

6.2.2* Combustion Air.

6.2.2.1 The fuel-burning system design shall provide a supply of clean combustion air delivered in amounts prescribed by the furnace designer or burner manufacturer across the full range of burner operation.

6.2.2.2 Products of combustion shall not be mixed with the combustion air supply.

6.2.2.3 The requirement of 6.2.2.2 shall not prevent the use of flue gas recirculation systems specifically designed to accommodate such recirculation.

6.2.2.4* Where primary or secondary combustion air is provided mechanically, combustion airflow or pressure shall be proven and interlocked with the safety shutoff valves so that fuel gas cannot be admitted prior to establishment of combustion air and so that the gas is shut off in the event of combustion air failure.

6.2.2.5 Where a secondary air adjustment is provided, adjustment shall include a locking device to prevent an unintentional change in setting.

6.2.3 Fuel Gas Supply Piping.

6.2.3.1* An emergency shutoff valve shall be provided that meets the following requirements:

(1) It shall be remotely located away from the furnace so that fire or explosion at a furnace does not prevent access to the valve.
(2) It shall be readily accessible.
(3) It shall have permanently affixed visual indication of the valve position.
(4) A removable handle shall be permitted provided all the following requirements are satisfied:
  (a) The valve position shall be clearly indicated whether the handle is attached or detached.
  (b) The valve handle shall be tethered to the gas main no more than 3 ft (1 m) from the valve in a manner that does not cause personnel safety issues and that allows trouble-free reattachment of the handle and operation of the valve without untethering the handle.
(5) It shall be able to be operated from full open to full close and return without the use of tools.

6.2.3.2 Installation of LP-Gas storage and handling systems shall comply with NFPA 58, *Liquefied Petroleum Gas Code*.

6.2.3.3 Piping from the point of delivery to the equipment isolation valve shall comply with NFPA 54, *National Fuel Gas Code*. *(See 6.2.4.2.)*

6.2.3.4 An equipment isolation valve shall be provided.

6.2.4 Equipment Fuel Gas Piping.

6.2.4.1 Equipment Isolation Valves. Equipment isolation valves shall meet the following requirements:

(1) They shall be provided for each piece of equipment.
(2) They shall have permanently affixed visual indication of the valve position.
(3) They shall be quarter-turn valves with stops.
(4) Wrenches or handles shall remain affixed to valves and shall be oriented with respect to the valve port to indicate the following:
  (a) An open valve when the handle is parallel to the pipe
  (b) A closed valve when the handle is perpendicular to the pipe
(5) They shall be readily accessible.
(6) Valves with removable wrenches shall not allow the wrench handle to be installed perpendicular to the fuel gas line when the valve is open.
(7) They shall be able to be operated from full open to full close and return without the use of tools.

6.2.4.2* Piping and Fittings.

(A) Fuel gas piping materials shall be in accordance with NFPA 54, *National Fuel Gas Code*.

(B) Fuel gas piping shall be sized to provide flow rates and pressure to maintain a stable flame over the burner operating range.

6.2.5 Control of Contaminants.

6.2.5.1 A sediment trap or other acceptable means of removing contaminants shall be installed downstream of the equipment isolation valve and upstream of all other fuel gas system components.

6.2.5.2 Sediment traps shall have a vertical leg with a minimum length of three pipe diameters [minimum of 3 in. (80 mm)] of the same size as the supply pipe as shown in Figure 6.2.5.2.

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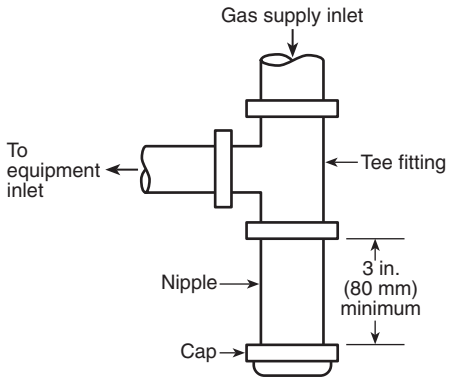

FIGURE 6.2.5.2 Method of Installing a Tee Fitting Sediment Trap. [54:Fig. 9.6.7]

6.2.5.3* A gas filter or strainer shall be installed in the fuel gas piping and shall be located downstream of the equipment isolation valve and sediment trap and upstream of all other fuel gas system components.

6.2.6 Pressure Regulators, Pressure Relief Valves, and Pressure Switches.

6.2.6.1 A pressure regulator shall be furnished wherever the plant supply pressure exceeds the burner operating or design parameters or wherever the plant supply pressure is subject to fluctuations, unless otherwise permitted by 6.2.6.2.

6.2.6.2 An automatic flow control valve shall be permitted to meet the requirement of 6.2.6.1, provided it can compensate for the full range of expected source pressure variations.

6.2.6.3* Regulators, relief valves, and switches shall be vented to an approved location, and the following criteria also shall be met:

(1) Heavier-than-air flammable gases shall be vented outside the building to a location where the gas is diluted below its LFL before coming in contact with sources of ignition or re-entering the building.
(2) Vents shall be designed to prevent the entry of water and insects without restricting the flow capacity of the vent.

6.2.6.4* Fuel gas regulators, ratio regulators, and zero governors shall not be required to be vented to an approved location in the following situations:

(1) Where backloaded from combustion air lines, air–gas mixture lines, or combustion chambers, provided that gas leakage through the backload connection does not create a hazard
(2) Where a listed regulator–vent limiter combination is used
(3) Where a regulator system is listed for use without vent piping
(4) A regulator incorporating a leak limiting system, which prevents or restricts the escape of gas into a space large enough and with sufficient natural ventilation so that the escaping gas does not present a hazard

6.2.6.5* A pressure switch shall not be required to be vented if it employs a vent limiter rated for the service intended.

6.2.6.6 Fuel gas regulators and zero governors shall not be backloaded from oxygen or oxygen-enriched air lines.

6.2.6.7 Vent lines from multiple furnaces shall not be manifolded together.

6.2.6.8 Vents from systems operating at different pressure control levels shall not be manifolded together.

6.2.6.9 Vents from systems served from different pressure-reducing stations shall not be manifolded together.

6.2.6.10 Vents from systems using different fuel sources shall not be manifolded together.

6.2.6.11 Vent lines from multiple regulators and switches of a single furnace, where manifolded together, shall be piped in such a manner that any gas being vented from one ruptured diaphragm does not backload the other devices.

6.2.6.12 The cross-sectional area of the manifold line shall not be less than the greater of the following:

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

6.2.6.13* A vent between safety shutoff valves, where installed:

(1) Shall not be combined with other vents
(2)*Shall terminate to an approved location

6.2.7 Overpressure Protection.

6.2.7.1 Overpressure protection shall be provided in either of the following cases:

(1) When the supply pressure exceeds the pressure rating of any downstream component
(2) When the failure of a single upstream line regulator or service pressure regulator results in a supply pressure exceeding the pressure rating of any downstream component

6.2.7.2 Overpressure protection shall be provided by any one of the following:

(1) A series regulator in combination with a line regulator or service pressure regulator
(2) A monitoring regulator installed in combination with a line regulator or service pressure regulator
(3) A full-capacity pressure relief valve
(4) An overpressure cutoff device, such as a slam-shut valve or a high-pressure switch in combination with an adequately rated shutoff valve

6.2.7.3* When a relief valve is used to comply with 6.2.7.1, the relief valve shall be a full-capacity relief type.

6.2.7.4 Token relief valves and internal token relief valves shall not be permitted to be used as the only overpressure protection devices.

6.2.8 Flow Control Valves. Where the minimum or maximum flow of combustion air or the fuel gas is critical to the operation of the burner, flow valves shall be equipped with limiting means and with a locking device to prevent an unintentional change in the setting.

6.2.9 Air–Fuel Gas Mixers.

6.2.9.1* General. Subsection 6.2.9 shall apply only to mixtures of fuel gas with air and not to mixtures of fuel gas with oxygen or oxygen-enriched air. Oxygen shall not be introduced into air–fuel gas mixture piping, fuel gas mixing machines, or air–fuel gas mixers.

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6.2.9.2 Proportional Mixing.

(A) Piping shall be designed to provide a uniform mixture flow of pressure and velocity needed for stable burner operation.

(B) Valves or other obstructions shall not be installed between a proportional mixer and burners, unless otherwise permitted by 6.2.9.2(C).

(C) Fixed orifices shall be permitted for purposes of balancing.

(D) Any field-adjustable device built into a proportional mixer (e.g., gas orifice, air orifice, ratio valve) shall incorporate a device to prevent unintentional changes in the setting.

(E) Where a mixing blower is used, safety shutoff valves shall be installed in the fuel gas supply and shall interrupt the fuel gas supply automatically when the mixing blower is not in operation or in the event of a fuel gas supply failure.

(F) Mixing blowers shall not be used with fuel gases containing more than 10 percent free hydrogen (H_2).

(G) Mixing blowers having a static delivery pressure of more than 10 in. w.c. (2.49 kPa) shall be considered mixing machines.

6.2.9.3 Mixing Machines.

(A)* Automatic fire checks shall be provided in piping systems that distribute flammable air–fuel gas mixtures from a mixing machine.

(B) The automatic fire check shall be installed at the burner inlet(s), and the manufacturer's installation guidelines shall be followed.

(C) A separate, manually operated gas valve shall be provided at each automatic fire check for shutting off the flow of an air–fuel mixture through the fire check after a flashback has occurred.

> **CAUTION:** These valves shall not be reopened after a flashback has occurred until the fire check has cooled sufficiently to prevent reignition of the flammable mixture and has been properly reset.

(D) The valves required by 6.2.9.3 shall be located upstream of the inlets of the automatic fire checks.

(E)* A backfire arrester with a safety blowout device shall be installed in accordance with the manufacturer's instructions near the outlet of each mixing machine that produces a flammable air–fuel gas mixture.

(F) Where a mixing machine is used, safety shutoff valves shall be installed in the fuel gas supply and shall interrupt the fuel gas supply automatically when the mixing machine is not in operation or in the event of an air or fuel gas supply failure.

6.2.10 Fuel Gas Burners.

6.2.10.1 All burners shall maintain the stability of the designed flame shape, without flashback or blowoff, over the entire range of turndown that is encountered during operation under both of the following conditions:

(1) Where supplied with combustion air (oxygen-enriched air or oxygen)
(2) Where supplied with the designed fuels in the designed proportions and in the designed pressure ranges

6.2.10.2 Burners shall be used only with the fuels for which they are designed.

6.2.10.3 All pressures required for operation of the combustion system shall be maintained within the design ranges throughout the firing cycle.

6.2.10.4 Burners shall have the ignition source sized and located in a position that provides ignition of the pilot or main flame within the design trial-for-ignition period.

6.2.10.5 Burners that cannot be ignited at all firing rates shall have provision to adjust the burner firing rate during light-off to a level that ensures ignition of the main flame without flashback or blowoff.

6.2.10.6 Radiant tube heating systems using metallic tubes open at one or both ends shall not require explosion resistance validation.

6.2.10.7* A manufacturer's claim of explosion-resistant radiant tube heating systems using nonmetallic tubes or metallic tubes sealed in at both ends shall be validated.

6.2.11 Fuel Ignition.

6.2.11.1* The ignition source (e.g., electric spark, hot wire, pilot burner, handheld torch) shall be applied at the design location with the designed intensity to ignite the air–fuel mixture.

6.2.11.2 Fixed ignition sources shall be mounted to prevent unintentional changes in location and in direction with respect to the main flame.

6.2.11.3 Pilot burners shall be considered burners, and all provisions of Section 6.2 shall apply.

6.2.12 Dual-Fuel and Combination Burners. Where fuel gas and fuel oil are to be fired individually (dual-fuel) or simultaneously (combination), the provisions of Sections 6.2, 6.3, and 8.13 shall apply equally to the respective fuels.

6.3* Oil-Fired Units.

6.3.1 General. Burners, along with associated valving, safety controls, and other auxiliary components, shall be selected for the type and pressure of the fuel oil to be used and for the temperatures to which they are subjected.

6.3.2* Combustion Air.

6.3.2.1 The fuel-burning system design shall provide for a supply of clean combustion air delivered in the amounts prescribed by the furnace designer or burner manufacturer across the full range of burner operation.

6.3.2.2 Products of combustion shall not short-circuit back into the combustion air, except where so designed.

6.3.2.3 Where primary or secondary combustion air is provided mechanically, combustion airflow or pressure shall be proved and interlocked with the safety shutoff valves so that oil cannot be admitted prior to establishment of combustion air and so that the oil is shut off in the event of combustion air failure.

6.3.2.4 Where a secondary air adjustment is provided, adjustment shall include a locking device to prevent an unintentional change in setting.

6.3.3 Oil Supply Piping.

6.3.3.1 The fuel oil supply to a furnace shall be capable of being shut off at a location remote from the furnace so that fire or explosion at the furnace does not prevent access to the fuel oil shutoff.

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6.3.3.2 The fuel oil shutoff shall be by either of the following:

(1) Emergency shutoff valve that meets the following requirements:
   (a) It shall be remotely located away from the furnace so that fire or explosion at a furnace does not prevent access to this valve.
   (b) It shall be readily accessible.
   (c) It shall have permanently affixed visual indication of the valve position.
   (d) A removable handle shall be permitted provided all the following requirements are satisfied:
      i. The valve position shall be clearly indicated whether the handle is attached or detached.
      ii. The valve handle shall be tethered to the gas main no more than 3 ft (1 m) from the valve in a manner that does not cause personnel safety issues and that allows trouble-free reattachment of the handle and operation of the valve without untethering the handle.
   (e) It shall be able to be operated from full open to full close and return without the use of tools.
(2) Means for removing power to the positive displacement fuel oil pump

6.3.3.3 Where a shutoff is installed in the discharge line of an oil pump that is not an integral part of a burner, a pressure relief valve shall be connected to the discharge line between the pump and the shutoff valve and arranged to return surplus oil to the supply tank or to bypass it around the pump, unless the pump includes an internal bypass.

6.3.3.4* All air from the supply and return piping shall be purged initially, and air entrainment in the oil shall be minimized.

6.3.3.5 Suction, supply, and return piping shall be sized with respect to oil pump capacity.

6.3.3.6* Where a section of oil piping can be shut off at both ends, relief valves or expansion chambers shall be installed to release the pressure caused by thermal expansion of the oil.

6.3.3.7 An equipment isolation valve shall be provided.

6.3.4 Equipment Oil Piping.

6.3.4.1 Manual Shutoff Valves.

(A) Individual manual shutoff valves for equipment isolation shall be provided for shutoff of the fuel to each piece of equipment.

(B) Manual shutoff valves shall be installed to avoid oil spillage during servicing of supply piping and associated components.

(C) Manual shutoff valves shall display a visual indication of the valve position.

(D) Quarter-turn valves with removable wrenches shall not allow the wrench handle to be installed perpendicular to the fuel oil line when the valve is open.

(E) The user shall keep separate wrenches (handles) affixed to valves and keep the wrenches oriented with respect to the valve port to indicate the following:

(1) An open valve when the handle is parallel to the pipe
(2) A closed valve when the handle is perpendicular to the pipe

(F)* Valves shall be maintained in accordance with the manufacturer's instructions.

(G) Lubricated valves shall be lubricated and subsequently leak tested for valve closure at least annually.

6.3.4.2 Piping and Fittings.

(A) Fuel oil piping materials shall be in accordance with NFPA 31, *Standard for the Installation of Oil-Burning Equipment.*

(B) Fuel oil piping shall be sized to provide flow rates and pressure to maintain a stable flame over the burner operating range.

6.3.4.3* Oil Filters and Strainers. An oil filter or strainer shall meet the following criteria:

(1) Be selected for the maximum operating pressure and temperature anticipated
(2) Be selected to filter particles larger than the most critical clearance in the fuel oil system
(3) Be installed in the fuel oil piping system downstream of the equipment isolation valve and upstream of all other fuel oil piping system components

6.3.4.4 Pressure Regulation. Where the oil pressure exceeds that required for burner operation or where the oil pressure is subject to fluctuations, either a pressure regulator or an automatic flow control valve that can compensate for the full range of expected source pressure variations shall be installed.

6.3.4.5* Pressure Gauges. Pressure gauges shall be isolated or protected from pulsation damage during operation of the burner system.

6.3.5 Flow Control Valves. Where the minimum or maximum flow of combustion air or the fuel oil is critical to the operation of the burner, flow valves shall be equipped with a limiting means and with a locking device to prevent an unintentional change in the setting.

6.3.6 Oil Atomization.

6.3.6.1* Oil shall be atomized to droplet size as required for combustion throughout the firing range.

6.3.6.2 The atomizing device shall be accessible for inspection, cleaning, repair, replacement, and other maintenance as required.

6.3.7 Oil Burners.

6.3.7.1 All burners shall maintain both the stability of the designed flame shape over the entire range of turndown encountered during operation where supplied with combustion air (oxygen-enriched air or oxygen) and the stability of designed fuels in the designed proportions and in the designed pressure ranges.

6.3.7.2 All pressures required for the operation of the combustion system shall be maintained within the design ranges throughout the firing cycle.

6.3.7.3 All burners shall be supplied with fuel oil of the grade for which they have been designed and with fuel oil that has been preconditioned, where necessary, to the viscosity required by the burner design.

6.3.7.4 Burners shall have the ignition source sized and located in a position that provides ignition of the pilot or main flame within the design trial-for-ignition period.

(A) Self-piloted burners shall have a transition from pilot flame to main flame.

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(B) Burners that cannot be ignited at all firing rates shall have provision to reduce the burner firing rates during light-off to a lower level, which ensures ignition of the main flame without flashback or blowoff.

6.3.7.5 If purging of oil passages upon termination of a firing cycle is required, it shall be done prior to shutdown with the initial ignition source present and with all associated fans and blowers in operation.

6.3.8 Fuel Ignition.

6.3.8.1* The ignition source shall be applied at the design location with the design intensity to ignite the air–fuel mixture.

6.3.8.2 Fixed ignition sources shall be mounted so as to prevent unintentional changes in location and in direction with respect to the main flame.

6.3.8.3 Pilot burners shall be considered burners.

6.3.9 Dual-Fuel and Combination Burners. Where fuel gas and fuel oil are fired individually (dual-fuel) or simultaneously (combination), the provisions of Sections 6.2, 6.3, and 8.13 shall apply equally to the respective fuels.

6.4* Oxygen-Enhanced Fuel-Fired Units.

6.4.1 General. The requirements of Section 6.4 shall be in addition to those in Sections 6.2 and 6.3 and Chapter 8.

6.4.2 Combustion Systems Utilizing Oxygen.

6.4.2.1 Oxygen storage and delivery systems shall comply with NFPA 55, *Compressed Gases and Cryogenic Fluids Code*.

6.4.2.2 Oxygen shall not be introduced into inlet or discharge piping of air compressors or blowers that are internally lubricated with petroleum oils, greases, or other combustible substances.

6.4.3 Oxygen Piping and Components.

6.4.3.1 Design, materials of construction, installation, and tests of oxygen piping shall comply with the applicable sections of ASME B31.3, *Process Piping*.

6.4.3.2* Materials and construction methods used in the installation of the oxygen piping and components shall be compatible with oxygen.

6.4.3.3* Piping and components that come in contact with oxygen shall be cleaned prior to admitting gas.

6.4.3.4* Air introduced into oxygen passages in burners, such as cooling air, shall be free of particulate matter, oil, grease, and other combustible materials.

6.4.3.5 A remotely located shutoff valve shall be provided to allow the oxygen to be turned off in an emergency.

6.4.3.6 The shutoff valve shall be located so that fire or explosion at a furnace does not prevent access to the valve.

6.4.3.7 Oxygen from pressure relief devices and purge outlets shall not be released into pipes or manifolds where it can mix with fuel.

6.4.3.8* Oxygen from pressure relief devices and purge outlets shall be vented to an approved location by vents designed to prevent the entry of water and insects.

6.4.3.9 Means shall be provided to prevent oxygen, fuel, or air from intermixing in burner supply lines due to valve leakage, burner plugging, or other system malfunctions.

6.4.3.10* Oxygen piping and components shall be inspected and maintained.

6.4.3.11 If glass tube flowmeters are used in oxygen service, safeguards against personnel injury from possible rupture shall be provided.

6.4.3.12* The piping fed from a cryogenic supply source shall be protected from excessive cooling by means of an automatic low-temperature shutoff device.

6.4.3.13 Piping and controls downstream of an oxygen pressure-reducing regulator shall be able to withstand the maximum potential upstream pressure or shall be protected from overpressurization by means of a pressure relief device.

6.4.4 Oxygen Flow Control Valves.

6.4.4.1 Where the minimum or the maximum flow of oxygen or oxygen-enriched air is critical to the operation of the burner, flow control valves shall be equipped with limiting means and a locking device to prevent an unintentional change in the setting.

6.4.4.2 Where the source oxygen pressure exceeds that required for burner operation or where the source pressure is subject to fluctuations, either an oxygen pressure regulator or an automatic flow control valve that can compensate for the full range of expected source pressure variations and complies with 6.4.4.1 shall be installed.

6.4.5 Oxygen-Enriched Combustion Air.

6.4.5.1 Filters shall be installed in the air blower intake to minimize contamination of the oxygen-enriched air piping.

6.4.5.2* Devices, such as diffusers, that are used to disperse oxygen into an airstream shall be designed to prevent jet impingement of oxygen onto interior surfaces of the air piping.

6.4.5.3 Oxygen-enriched combustion air shall not be introduced into a burner before the oxygen has been uniformly mixed into the airstream.

6.4.5.4 Branching of the enriched-air piping shall not be permitted before a uniform mixture of oxygen and air has been attained.

6.5 Flue Product Venting.

6.5.1 A means shall be provided to ensure ventilation of the products of combustion from fuel-fired equipment.

6.5.2 The following shall apply to collecting and venting systems for radiant tube–type heating systems:

(1) The system shall be of a capacity to prevent an explosion or fire hazard due to the flow of unburned fuel through the radiant tubes.
(2)*The system shall be capable of dilution of the rated maximum input capacity of the system to a noncombustible state.
(3)*A radiant tube–type heating system provided with two safety shutoff valves interlocked with combustion safeguards shall be exempt from the requirements of 6.5.2.

6.6 Electrically Heated Units.

6.6.1 Safety Equipment. Safety equipment, including airflow interlocks, time relays, and temperature switches, shall be in accordance with Chapter 8.

6.6.2* Electrical Installation. All parts of the electrical installation shall be in accordance with *NFPA 70, National Electrical Code*.

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6.6.3 Resistance Heating Systems.

6.6.3.1 The provisions of 6.6.3 shall apply to resistance heating systems, including infrared lamps, such as quartz, ceramic, and tubular glass types.

6.6.3.2 Construction.

(A) The heater housing shall be constructed so as to provide access to heating elements and wiring.

(B) Heating elements and insulators shall be supported securely or fastened so that they do not become easily dislodged from their intended location.

(C) Heating elements that are electrically insulated from and supported by a metallic frame shall have the frame electrically grounded.

(D) Open-type resistor heating elements shall be supported by electrically insulated hangers and shall be secured to prevent the effects of motion induced by thermal stress, which could result in adjacent segments of the elements touching one another, or the effects of touching a grounded surface.

(E) External parts of furnace heaters that are energized at voltages that could be hazardous as specified in *NFPA 70, National Electrical Code*, shall be guarded.

6.6.4 Induction and Dielectric Heating Systems.

6.6.4.1 Induction and dielectric heating systems shall be designed and installed in accordance with *NFPA 70, National Electrical Code*.

6.6.4.2 Construction.

(A)* Combustible electrical insulation shall be reduced to a minimum.

(B) Protection shall be installed to prevent overheating of any part of the equipment in accordance with *NFPA 70, National Electrical Code*.

(C) Where water cooling is used for transformers, capacitors, electronic tubes, spark gaps, or high frequency conductors, it shall be arranged as follows:

(1) Cooling coils and connections shall be arranged so that leakage or condensation does not damage the electrical equipment.
(2) The cooling water supply shall be interlocked with the power supply so that loss of water cuts off the power supply.
(3) Where there is more than one waterflow path, the flow interlock required in 6.6.4.2(C)(2) shall be provided for each parallel waterflow path.

(D) Where forced ventilation by motor-driven fans is necessary, the following features shall be provided:

(1) The air supply shall be interlocked with the power supply.
(2) An air filter shall be provided at the air intake.

(E) The conveyor motor and the power supply of dielectric heaters of the conveyor type used to heat combustible materials shall be interlocked to prevent overheating of the material being treated.

(F) Dielectric heaters used for treating highly combustible materials shall be designed to prevent a disruptive discharge between the electrodes.

6.7* Fluid Heating Systems.

6.7.1 General.

6.7.1.1* Piping and fittings shall be in accordance with ASME B31.1, *Power Piping*.

6.7.1.2 The following shall apply to insulated piping containing combustible heat transfer fluid:

(1) Closed-cell, nonabsorptive insulation shall be used.
(2) Fibrous or open-cell insulation shall not be permitted.

6.7.1.3* Oven isolation valves shall be installed as follows:

(1) They shall be installed in the fluid supply and return lines.
(2) If a combustible heat transfer fluid is used, they shall be installed within 5 ft (1.5 m) of the oven.

6.7.1.4 Enclosures or ductwork for heat exchanger coils shall be of noncombustible construction with access openings provided for maintenance and cleaning.

6.7.1.5 Heat exchangers or steam coils shall not be located on the floor of an oven or in any position where paint drippage or combustible material can accumulate on the coils.

6.7.2 Safety Devices.

6.7.2.1 System equipment shall be operated within the temperature and pressure limits specified by the supplier or manufacturer of the heat transfer medium and by the manufacturer of the equipment.

6.7.2.2 If the oven atmosphere is recirculated over the heat exchanger coils, a noncombustible filtration system shall be used if combustible particulates can deposit on the heat exchanger surface.

6.7.2.3 The filtration system and heat exchanger specified in 6.7.2.2 shall be cleaned on a regular schedule.

Chapter 7 Commissioning, Operations, Maintenance, Inspection, and Testing

7.1 Commissioning.

7.1.1* Commissioning shall be required for all new installations or for any changes that affect the safety system.

7.1.2 All apparatus shall be installed and connected in accordance with the system design.

7.1.3* During commissioning, all furnace piping that conveys flammable liquids or flammable gases shall be inspected for leaks.

7.1.4 The furnace shall not be released for operation before the installation and testing of the required safety systems have been successfully completed.

7.1.4.1* Burner management system logic shall be tested and verified for compliance with the design criteria when the burner management system logic is installed, replaced, repaired, or updated.

7.1.4.2 Documentation shall be provided that confirms that all related safety devices and safety logic are functional.

7.1.5 Any changes to the original design made during commissioning shall be reflected in the documentation.

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7.1.6* Set points of all safety interlock settings shall be documented.

7.1.7* A confirmed source of flammable gas shall be provided to the inlet of the equipment isolation valve(s) each time a flammable gas supply is placed into service or restored to service. *(See 6.2.4.1 and 13.5.11.10.2.1.)*

7.2 Training.

7.2.1* Personnel who operate, maintain, or supervise the furnace shall be thoroughly instructed and trained in their respective job functions under the direction of a qualified person(s).

7.2.2 Personnel who operate, maintain, or supervise the furnace shall be required to demonstrate an understanding of the equipment, its operation, and practice of safe operating procedures in their respective job functions.

7.2.3 Personnel who operate, maintain, or supervise the furnace shall receive regularly scheduled refresher training and shall demonstrate understanding of the equipment, its operation, and practice of safe operating procedures in their respective job functions.

7.2.4 The training program shall cover startup, shutdown, and lockout procedures in detail.

7.2.5 The training program shall be kept current with changes in equipment and operating procedures, and training materials shall be available for reference.

7.3 Operations.

7.3.1 The furnace shall be operated in accordance with the design parameters.

7.3.2 Personnel instructed and trained per 7.2.1 shall be present within the facility when Class C or D furnaces are operating with material movement, unless the design or a hazard analysis permits unattended operation.

7.3.3 Operating instructions that include all of the following shall be provided by the furnace manufacturer:

(1) Schematic piping and wiring diagrams
(2) Startup procedures
(3) Shutdown procedures
(4) Emergency procedures, including those occasioned by loss of special atmospheres, electric power, inert gas, or other essential utilities
(5) Maintenance procedures, including interlock and valve tightness testing

7.3.4* When the original equipment manufacturer no longer exists, the user shall develop inspection, testing, and maintenance procedures.

7.3.5 Operating procedures shall be established that cover normal and emergency conditions.

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

7.3.7 Procedures shall be consistent with safety requirements and shall be kept current with changes in equipment and personnel.

7.3.8* Where different modes of operation are possible, procedures shall be prepared for each operating mode and for switching from one mode to another.

7.3.9 Personnel shall have access to operating instructions at all times.

7.3.10 Safety devices shall not be removed or rendered ineffective.

7.4 Inspection, Testing, and Maintenance.

7.4.1 Safety devices shall be maintained in accordance with the manufacturer's instructions.

7.4.2 It shall be the responsibility of the furnace manufacturer to provide instructions for inspection, testing, and maintenance.

7.4.3 It shall be the responsibility of the user to establish, schedule, and enforce the frequency and extent of the inspection, testing, and maintenance program, as well as the corrective action to be taken.

7.4.4 All safety interlocks shall be tested for function at least annually.

7.4.5* The set point of temperature, pressure, or flow devices used as safety interlocks shall be verified at least annually.

7.4.6 Safety device testing shall be documented at least annually.

7.4.7 Calibration of continuous vapor concentration high limit controllers shall be performed in accordance with the manufacturer's instructions and shall be performed at least once per month.

7.4.8 Pressure and explosion relief devices shall be visually inspected at least annually to ensure that they are unobstructed and properly labeled.

7.4.9* Valve seat leakage testing of safety shutoff valves and valve proving systems shall be performed in accordance with the manufacturer's instructions.

7.4.9.1 Testing frequency shall be at least annually.

7.4.9.2 The installation of a valve proving system or a valve with proof of closure shall not replace the requirement for seat leakage testing in 7.4.9.1.

7.4.10 Safety Shutoff Valve Replacement.

7.4.10.1 Safety shutoff valves that are used to comply with 8.5.1.8(4) and are not proved closed shall be replaced before they exceed their maximum allowable number of lifetime open–closed cycles.

7.4.10.2* The number of safety shutoff valve cycles shall be determined by one of the following ways:

(1) Counting of actual safety shutoff valve open-closed cycles
(2) Estimated time to reach 90 percent of lifetime total cycles based on normal cycling rates

7.4.11 Manual shutoff valves shall be maintained in accordance with the manufacturer's instructions.

7.4.12* Lubricated manual shutoff valves shall be lubricated and subsequently leak tested for valve closure at least annually.

7.4.13* Equipment isolation valves and emergency shutoff valves shall be exercised at least annually.

7.4.14* Oxygen piping and components shall be inspected and maintained in accordance with CGA G-4.1, *Cleaning Equipment for Oxygen Service.*

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7.4.15* The temperature indication of the excess temperature limit interlock shall be verified to be accurate.

7.4.16 Whenever any safety interlock is replaced, it shall be tested for function.

7.4.17 Whenever any temperature, pressure, or flow device used as a safety interlock is replaced, the set point setting shall be verified.

7.4.18 An inspection shall be completed at least annually to verify that all designed safety interlocks are present and have not been bypassed or rendered ineffective.

7.4.19* When a quantity of flammable gas that can result in a hazardous condition is released as part of installation, commissioning, testing, maintenance, or decommissioning, the gas shall be vented to an approved location.

7.5 Record Retention. Records of inspection, testing, and maintenance activities shall be retained for a period of 1 year or until the next inspection, testing, or maintenance activity, whichever is longer.

7.6* Procedures. The user's operational and maintenance program shall include procedures that apply to entry into equipment in accordance with all applicable regulations.

Chapter 8 Safety Equipment and Application

8.1* General. For the purpose of this chapter, the term *furnace heating system* shall include the heating source, associated piping and wiring used to heat the furnace, auxiliary quenches, and the work therein.

8.2 Safety Device Requirements.

8.2.1* Except as permitted by Section 8.4, combustion safeguards, flame detectors, excess temperature limit interlocks, and safety shutoff valves shall be listed for combustion safety service or approved if a listed device is not commercially available.

8.2.2* Safety devices not identified in 8.2.1 shall be listed for the service intended or approved if a listed device is not commercially available.

8.2.3* Safety devices shall be applied and installed in accordance with this standard and the manufacturer's instructions.

8.2.4 Electric relays and safety shutoff valves shall not be used as substitutes for electrical disconnects and manual shutoff valves.

8.2.5 Regularly scheduled inspection, testing, and maintenance of all safety devices shall be performed. *(See Section 7.4.)*

8.2.6 Safety devices shall be installed, used, and maintained in accordance with the manufacturer's instructions.

8.2.7 Safety devices shall be located or guarded to protect them from physical damage.

8.2.8 Safety devices shall not be bypassed electrically or mechanically.

8.2.8.1 The requirement in 8.2.8 shall not prohibit safety device testing and maintenance in accordance with 8.2.5. Where a system includes a "built-in" test mechanism that bypasses any safety device, it shall be interlocked to prevent operation of the system while the device is in the test mode, unless listed for that purpose.

8.2.8.2 The requirement in 8.2.8 shall not prohibit a time delay applied to the action of pressure-proving, flow-proving, or proof-of-closure safety switch as used in accordance with 8.8.1.3(3), where the following conditions exist:

(1) There is an operational need demonstrated for the time delay.
(2) The use of a time delay is approved.
(3) The time delay feature is not adjustable beyond 5 seconds.
(4) A single time delay does not serve more than one pressure-proving or flow-proving safety device.
(5) The time from an abnormal pressure or flow condition until the holding medium is removed from the safety shutoff valves does not exceed 5 seconds.

8.2.9* At least one manual emergency switch shall be provided to initiate a safety shutdown.

8.2.10* A safety shutdown of the heating system shall require manual intervention of an operator to re-establish normal operation of the system.

8.2.11* Where transmitters are used in place of switches for safety functions, the following shall apply:

(1) The transmitter shall be safety integrity level (SIL) 2 capable.
(2) Transmitter failure shall be detected and initiate a safety shutdown.
(3) The transmitter shall be dedicated to safety service unless listed for simultaneous process and safety service.

8.3* Burner Management System Logic.

8.3.1 General.

8.3.1.1 Purge and ignition trials shall be performed using either devices listed for such service or programmable controllers used in accordance with Section 8.4.

8.3.1.2 The activation of any safety interlock required in Chapter 8 shall result in a safety shutdown.

8.3.1.3 Safety interlocks shall meet one or more of the following criteria:

(1) Be hardwired without relays in series and ahead of the controlled device
(2) Be connected to an input of a programmable controller logic system complying with Section 8.4
(3) Be connected to a relay that represents a single safety interlock that is configured to initiate safety shutdown in the event of power loss
(4) Be connected to a listed safety relay that represents one or more safety interlocks and initiates safety shutdown upon power loss

8.3.1.4* Electrical power for safety control circuits shall be dc or single-phase ac, 250 volt maximum, one-side grounded, with all breaking contacts in the ungrounded, fuse-protected, or circuit breaker–protected line.

8.4* Programmable Logic Controller Systems.

8.4.1 Programmable logic controller (PLC)–based systems listed for combustion safety service shall be used in accordance with the listing requirements and the manufacturer's instructions.

8.4.2* Where PLCs are not listed for combustion safety service or as combustion safeguard, the PLC and its associated input and output (I/O) used to perform safety functions shall be as follows:

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(1) Third-party certified to IEC 61508, *Functional Safety of Electrical/Electronic/Programmable Electronic Safety-Related Systems*, safety integrity level (SIL) 2 or greater
(2) Applied to achieve at least an SIL 2 capability per the manufacturer's safety manual

8.4.2.1 Software.

(A) Access to the PLC and its logic shall be restricted to authorized personnel.

(B) Software shall be documented as follows:

(1) Labeled to identify elements or a group of elements containing safety software
(2) Labeled to describe the function of each element containing safety software

(C) A listing of the program with documentation shall be available.

8.4.3 Any PLC shall be permitted to perform purge timing.

8.4.4* Safety PLCs.

(A) Where used for combustion safety service, safety PLCs shall have the following characteristics:

(1) The processor and the I/O shall be listed for control reliable service with an SIL rating of at least 2.
(2) Access to safety functions shall be separate from access to nonsafety functions.
(3) Access to PLC logic dedicated to safety functions shall be restricted to prevent unauthorized changes.
(4)*All safety function sensors and final elements shall be independent of operating sensors and final elements.

(B) Safety PLCs shall not implement the following:

(1) Manual emergency switches
(2) Continuous vapor concentration high-limit controllers

8.5 Safety Control Application for Fuel-Fired Heating Systems.

8.5.1 Pre-ignition (Prepurge, Purging Cycle).

8.5.1.1* Prior to each furnace heating system startup, provision shall be made for the removal of all flammable vapors and gases that have entered the heating chambers during the shutdown period.

8.5.1.2* A timed pre-ignition purge shall be provided.

(A) At least four system volumes of fresh air or inert gas shall be introduced during the purging cycle.

(B) The system volume shall include the heating chambers and all other passages that handle the recirculation and exhaust of products of combustion.

(C) To begin the timed pre-ignition purge interval, all of the following conditions shall be satisfied:

(1)*The minimum required pre-ignition airflow is proved.
(2)*At least one safety shutoff valve is proved closed between all pilot burners and the fuel supply for ovens with total pilot capacity over 400,000 Btu/hr.
(3) At least one safety shutoff valve is proved closed between all main burners and the fuel supply for ovens with total capacity over 400,000 Btu/hr

(D) The minimum required pre-ignition airflow shall be proved and maintained throughout the timed pre-ignition purge interval.

(E) Failure to maintain the minimum required pre-ignition purge airflow shall stop the pre-ignition purge and reset the purge timer.

8.5.1.3 A furnace heating system, either alone or as part of multiple furnaces feeding into one fume incinerator, shall not be purged into an operating incinerator unless otherwise permitted by 8.5.1.4.

8.5.1.4 A furnace heating system shall be permitted to be purged into an operating incinerator if it can be demonstrated that the flammable vapor concentration entering the fume incinerator cannot exceed 50 percent of the LFL.

8.5.1.5 Pre-ignition purging of radiant tube–type heating systems shall be provided, unless otherwise permitted by 8.5.1.6.

8.5.1.6 Pre-ignition purging of radiant tube–type heating systems shall not be required where the systems are arranged and designed such that either of the following conditions is satisfied:

(1) The tubes are of metal construction and open at one or both ends. If heat recovery systems are used, they shall be of explosion-resistant construction.
(2) The entire radiant tube heating system, including any associated heat recovery system, is of explosion-resistant construction.

8.5.1.7 Prior to the re-ignition of a burner after a burner shutdown or flame failure, a pre-ignition purge shall be accomplished.

CAUTION: Repeated ignition attempts can result in a combustible concentration greater than 25 percent of the LFL. Liquid fuels can accumulate, causing additional fire hazards.

8.5.1.8* Repeating the pre-ignition purge shall not be required where any one of the following conditions is satisfied:

(1) The heating chamber temperature is proved to be above 1400°F (760°C).
(2) For a multiburner fuel-fired system not proved to be above 1400°F (760°C), all of the following conditions are satisfied:
  (a)*At least one burner remains operating in the common combustion chamber of the burner to be re-ignited.
  (b) The burner(s) remaining in operation shall provide ignition without explosion of any unintended release of fuel through other burners that are not in operation.
(3)*For fuel gas–fired burner systems and assuming that all safety shutoff valves fail in the full open position, it can be demonstrated that the combustible concentration in the heating chamber and all other passages that handle the recirculation and exhaust of products of combustion cannot exceed 25 percent of the LFL.
(4) All of the following conditions are satisfied (does not apply to fuel oil systems):
  (a) The number of safety shutoff valves required to close in 8.8.1.3 and 8.8.2.1 will close between the burner system and the fuel gas supply when that burner system is off.
  (b) Safety shutoff valve seat leak testing is performed on at least a semiannual basis.
  (c) The burner system uses natural gas, butane, or propane fuel gas.

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(d)*It can be demonstrated based on the leakage rate, that the combustible concentration in the heating chamber and all other passages that handle the recirculation and exhaust of products of combustion cannot exceed 25 percent of the LFL.
(e) The minimum airflow used in the LFL calculation in 8.5.1.8(4)(d) is proved and maintained during the period the burner(s) are off.

8.5.2* Trial-for-Ignition Period.

8.5.2.1 The trial-for-ignition period of any pilot or main gas burner shall not exceed 15 seconds, unless both of the following conditions are satisfied:

(1) A written request for an extension of the trial-for-ignition period is approved by the authority having jurisdiction.
(2) It is determined that 25 percent of the LFL cannot be exceeded in the extended time.

8.5.2.2 The trial-for-ignition period of any pilot or main oil burner shall not exceed 15 seconds.

8.5.2.3 Where direct spark ignition systems cause a false flame signal in required flame detectors and combustion safeguards, the electrical spark shall be terminated after the main burner trial-for-ignition period.

8.5.3 Ignition of Main Burners — Fuel Gas or Oil. Where a reduced firing rate is required for ignition of the burner, an interlock shall be provided to prove that the control valve has moved to the design position prior to each attempt at ignition.

8.6 Ventilation Safety Devices.

8.6.1* Where a fan is essential for purge or safety ventilation of an oven or allied equipment, fan operation shall be proved and interlocked into the burner management system.

8.6.1.1 Electrical interlocks and flow switches shall be arranged in the safety control circuit so that loss of ventilation or airflow shuts down the heating system of the affected section, or, if necessary, loss of ventilation shall shut down the entire heating system as well as the conveyor.

8.6.1.2 Air pressure switches shall not be used to prove airflow where dampers downstream of the pressure switch can be closed to the point of reducing airflow below the minimum required.

8.6.1.3 Air suction switches shall not be used to prove airflow where dampers upstream of the pressure switch can be closed to the point of reducing airflow below the minimum required.

8.6.1.4 Switches used to prove airflow on systems where the air is contaminated with any substance that might condense or otherwise create a deposit shall be selected and installed to prevent interference with the performance of the switch.

8.6.2 Dampers capable of being adjusted to a position that can result in an airflow below the minimum required shall be equipped with one of the following features arranged to prevent oven operation when airflow is below the minimum required:

(1) Mechanical stops
(2) Cut-away dampers
(3) Limit switches interlocked into the safety circuitry

8.7 Combustion Air Safety Devices.

8.7.1 Where air from the exhaust or recirculating fans is required for combustion of the fuel, the minimum required airflow shall be interlocked according to Section 8.7.

8.7.2 Where a combustion air blower is used, the minimum combustion airflow or source pressure needed for burner operation shall be proved prior to each attempt at ignition.

8.7.3 Motor starters on equipment required for combustion of the fuel shall be interlocked into the burner management system.

8.7.4* Combustion air minimum pressure or flow shall be interlocked into the burner management system. by any of the following methods:

(1) A low pressure switch that senses and monitors the combustion air source pressure
(2) A differential pressure switch that senses the differential pressure across a fixed orifice in the combustion air system
(3) An airflow switch

8.7.5* Where it is possible for combustion air pressure to exceed the maximum safe operating pressure, a high pressure switch interlocked into the burner management system shall be used.

8.7.6 In any combustion system where the combustion air supply can be diverted to an alternate flow path other than to a burner (e.g., to a regenerative burner system's exhaust path), that burner's associated combustion air flow path valve(s) shall be proved open, and its alternate air flow path valve(s) shall be proved closed, before that burner's fuel safety shutoff valve(s) are energized.

8.8 Safety Shutoff Valves (Fuel Gas or Oil).

8.8.1 General.

8.8.1.1 Safety shutoff valves shall be a key safety control to protect against explosions and fires.

8.8.1.2* Each safety shutoff valve required in 8.8.2.1 and 8.8.3.1 shall automatically shut off the fuel to the burner system after interruption of the holding medium (such as electric current or fluid pressure) by one of the interlocking safety devices, combustion safeguards, or operating controls, unless otherwise permitted by 8.8.1.3.

8.8.1.3* In fuel gas systems or oil systems where multiple burners or pilots operate as a burner system firing into a common heating chamber, shutting off of fuel at one or more burners shall comply with 8.8.1.2 or shall shut off those burner(s) by closing a single safety shutoff valve as long as a second safety shutoff valve between the fuel supply, and the burners shall close when any of the following conditions occurs:

(1) Upon activation of any safety interlock common to the burner system
(2)*Where the individual burner safety shutoff valves do not have proof of closure and it is demonstrated, based on available airflow, that the number of failed burners will result in the furnace being above 25 percent of the LFL, assuming the single burner safety shutoff valve(s) fails in the open position
(3) Where individual burner safety shutoff valves have proof of closure and any of the following conditions occur:
  (a) Where flame supervision is used, the individual burner safety shutoff valve not proved closed after loss of flame signal
  (b) Where flame supervision is not used, the individual burner safety shutoff valve not proved closed when the furnace is not proved to be above 1400°F (760°C)
  (c) Upon loss of flame signal at all burners in the burner system

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8.8.1.4 Safety shutoff valves shall not be used as modulating control valves unless they are designed as both safety shutoff and modulation valves and tested for concurrent use.

8.8.1.5 The use of listed safety shutoff valves designed as both a safety shutoff valve and a modulating valve and tested for concurrent use shall be permitted.

8.8.1.6 Safety shutoff valves shall not be open-close cycled at a rate that exceeds that specified by its manufacturer.

8.8.1.7 Valve components shall be of a material selected for compatibility with the fuel handled and for ambient conditions.

8.8.1.8 Safety shutoff valves in systems containing particulate matter or highly corrosive fuel gas shall be operated at time intervals in accordance with the manufacturer's instructions in order to maintain the safety shutoff valves in operating condition.

8.8.1.9 Valves shall not be subjected to supply pressures in excess of the manufacturer's ratings.

8.8.1.10* Valves shall be selected to withstand the maximum anticipated backpressure of the system.

8.8.1.11 Local visual position indication shall be provided at each safety shutoff valve to burners or pilots in excess of 150,000 Btu/hr (44 kW).

(A) The local visual position indication shall directly indicate the physical position, closed and open, of the valve.

(B) Where lights are used for position indication, the absence of light shall not be used to indicate open or closed position.

(C) Indirect indication of valve position, such as by monitoring operator current voltage or pressure, shall not be permitted.

8.8.1.12 Safety shutoff valves shall meet one of the following requirements:

(1) The safety shutoff valves shall close in 1 second or less upon being de-energized.
(2) Where safety shutoff valve closure time exceeds 1 second, the combined time for safety shutoff valve closure and flame failure response shall not exceed 5 seconds.

8.8.2 Fuel Gas Safety Shutoff Valves.

8.8.2.1 Each main and pilot fuel gas burner system shall be separately equipped with either of the following:

(1) Two safety shutoff valves piped in series
(2) For radiant tube–fired burner systems only, a single safety shutoff valve where either of the following conditions is satisfied:
    (a) The tubes are of metal construction and open at one or both ends. If heat recovery systems are used, they shall be of explosion-resistant construction.
    (b) The entire radiant tube heating system, including any associated heat recovery system, is of explosion-resistant construction.

8.8.2.2* Where a safety shutoff valve is required to be proved closed, the following shall apply:

(A) A proved closed condition shall be accomplished by either of the following means:

(1) A proof-of-closure switch incorporated in a listed safety shutoff value assembly in accordance with the terms of the listing
(2) A valve proving system

(B) Auxiliary and closed position indicator switches shall not satisfy the proved closed requirement of 8.8.2.2(A).

8.8.2.3 Means for testing all fuel gas safety shutoff valves for valve seat leakage shall be installed.

8.8.3 Oil Safety Shutoff Valves.

8.8.3.1 One oil safety shutoff valve shall be required, except that two safety shutoff valves shall be required where any one of the following conditions exists:

(1) The pressure is greater than 125 psi (862 kPa).
(2) The fuel oil pump operates without the main oil burner firing, regardless of the pressure.
(3) The fuel oil pump operates during the fuel gas burner operation of combination gas and oil burners.

8.8.3.2* Where two safety shutoff valves are required by 8.8.3.1 and where the burner system capacity exceeds 400,000 Btu/hr (117 kW), at least one of the safety shutoff valves between each burner and the fuel supply shall be proved closed and interlocked with the pre-ignition purge interval.

8.8.3.3 Where an oil safety shutoff valve is required to be proved closed in 8.8.3.2, it shall be accomplished by the use of a proof-of-closure switch incorporated in a listed safety shutoff valve assembly in accordance with the terms of the listing.

8.9* Fuel Pressure Switches (Gas or Oil).

8.9.1 A low fuel pressure switch or sensor shall be provided and shall be interlocked into the burner management system.

8.9.2 A high fuel pressure switch or sensor shall be provided and shall meet the following criteria:

(1) It shall be interlocked into the burner management system.
(2) It shall be located downstream of the final pressure-reducing regulator.

8.9.3 Pressure switch or sensor settings shall be made in accordance with the operating limits of the burner system.

8.10 Flame Supervision.

8.10.1* Each burner shall have a supervised flame monitored by a flame detector and combustion safeguard that are interlocked into the burner management system unless otherwise permitted in 8.10.2.

8.10.2 The following shall not require a supervised flame:

(1) Burner flames for radiant tube–type heating systems where a means of ignition is provided and the systems are arranged and designed such that either of the following conditions is satisfied:
    (a) The tubes are of metal construction and open at one or both ends. If heat recovery systems are used, they shall be of explosion-resistant construction.
    (b) The entire radiant tube heating system, including any associated heat recovery system, is of explosion-resistant construction.
(2) Burner flames at burners interlocked with a 1400°F (760°C) bypass interlock that prevents burner operation when the temperature in the zone where the burner is located is less than 1400°F (760°C).

8.10.3* The flame failure response time shall be 4 seconds or less.

8.10.4 A safe-start check shall be performed during each burner startup sequence.

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8.10.5 Where a supervised flame is required for a burner, each pilot and main burner flame shall be equipped with flame supervision in one of the following ways:

(1) Main and pilot flames supervised with independent flame sensors
(2) Main and interrupted pilot flames supervised with a single flame sensor
(3)*Self-piloted burner supervised with a single flame sensor

8.10.6* Line burners, pipe burners, and radiant burners, where installed adjacent to one another or connected with flame-propagating devices, shall be considered to be a single burner and shall have at least one flame detector installed to sense burner flame at the end of the assembly farthest from the source of ignition.

8.10.7 Where a combustion safeguard is required for a burner flame, flame supervision shall not be required in the burner management system of a furnace zone when that zone temperature is greater than 1400°F (760°C) and the following criteria are met:

(1) When the zone temperature drops to less than 1400°F (760°C), the burner is interlocked to allow its operation only if flame supervision has been re-established.
(2) A 1400°F (760°C) bypass interlock is used to meet the requirement of 8.10.2(2).

8.11 Fuel Oil Atomization (Other Than Mechanical Atomization).

8.11.1 The pressure of the atomizing medium shall be proved and interlocked into the burner management system.

8.11.2 The low pressure switch used to supervise the atomizing medium shall be located downstream from all valves that can shut off flow or cause pressure drop of the atomization medium.

8.11.2.1 The low pressure switch used to supervise the atomizing medium shall be permitted to be located upstream of atomizing media balancing orifices and balancing valves provided the balancing devices are equipped with a locking device to prevent an unintentional change in the setting.

8.11.3 Where the atomizing medium requires modulation, an additional low atomizing medium pressure switch, located upstream of the modulating valve, shall be provided to meet the requirements of 8.11.1.

8.12* Fuel Oil Temperature Limit Devices. Where equipment is used to regulate fuel oil temperature, fuel oil temperature limit devices shall be provided and interlocked into the burner management system if it is possible for the fuel oil temperature to rise above or fall below the temperature range required by the burners.

8.13 Multiple-Fuel Systems.

8.13.1* Safety equipment in accordance with the requirements of this standard shall be provided for each fuel used.

8.13.2 Where dual-fuel burners, excluding combination burners, are used, positive provision shall be made to prevent the simultaneous introduction of both fuels.

8.14 Air–Fuel Gas Mixing Machines.

8.14.1 Safety shutoff valves shall be installed in the fuel gas supply connection of any mixing machine.

8.14.2 The safety shutoff valves shall be arranged to shut off the fuel gas supply automatically when the mixing machine is not in operation or in the event of an air or fuel gas supply failure.

8.15 Oxygen Safety Devices.

8.15.1 Two oxygen safety shutoff valves in series shall be provided in the oxygen supply line.

8.15.2 A filter or fine-mesh strainer shall precede the upstream safety shutoff valve.

8.15.3 A high oxygen flow or a high pressure limit shall be interlocked into the burner management system, with the switch located downstream of the final pressure regulator or automatic flow control valve.

8.15.4 A low oxygen flow or a low pressure limit shall be interlocked into the burner management system.

8.15.5 The oxygen safety shutoff valves shall shut automatically after interruption of the holding medium by any one of the interlocking safety devices.

8.15.6 Safety shutoff valves shall not be used as modulating control valves unless they are designed as both safety shutoff and modulation valves and tested for concurrent use.

8.15.7 A means for making tightness checks of all oxygen safety shutoff valves shall be provided.

8.15.8 Local visual position indication shall be provided for each oxygen safety shutoff valve to burners or pilots in excess of 150,000 Btu/hr (44 kW).

8.15.8.1 The position indication shall directly indicate the physical position, closed and open, of the valve.

8.15.8.2 Where lights are used for position indication, the absence of light shall not be used to indicate open or closed position.

8.15.8.3 Indirect indication of valve position, such as by monitoring operator current voltage or pressure, shall not be permitted.

8.15.9 Oxygen-Enriched Burners.

8.15.9.1 Where oxygen is added to a combustion air line, an interlock shall be provided to allow oxygen flow only when airflow is proved continuously.

8.15.9.2 Airflow shall be proved in accordance with the requirements of Section 8.6.

8.15.9.3 Upon loss of oxygen flow, the flow of fuel shall shut off, except where there is no interruption in the flow of combustion air and the control system is able to revert automatically to a safe air–fuel ratio before a hazard due to a fuel-rich flame is created.

8.15.10 Burner systems employing water or other liquid coolants shall be equipped with a low coolant flow limit switch located downstream of the burner and interlocked into the burner management system.

8.15.10.1 A time delay in the shutdown of the oxygen-enriched burner system shall not be permitted except where an alarm is activated and it can be demonstrated that such a delay cannot create a hazard, and the system is approved.

8.15.10.2 Coolant piping systems shall be protected from freezing.

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8.15.10.3 Coolant piping systems shall be protected from overpressurization.

8.16* Excess Temperature Limit Interlock.

8.16.1 An excess temperature limit interlock shall be provided and interlocked into the burner management system, unless permitted by 8.16.2.

8.16.2 An excess temperature limit interlock shall not be required for Class B, Class C, or Class D furnaces where it can be demonstrated that the maximum temperature limit specified by the furnace manufacturer cannot be exceeded.

8.16.3 Operation of the excess temperature limit interlock shall cut off the heating system before the oven's maximum temperature, as specified by the oven manufacturer, is exceeded.

8.16.4 Operation of the excess temperature limit interlock shall require manual reset before restart of the furnace or affected furnace zone.

8.16.5 Open-circuit failure of the temperature-sensing components of the excess temperature limit interlock shall cause the same response as an excess temperature condition.

8.16.6* Excess temperature limit interlocks shall be equipped with temperature indication.

8.16.7* The temperature-sensing element of the excess temperature limit interlock shall be selected for the temperature and atmosphere to which they are exposed.

8.16.8* The temperature-sensing element of the excess temperature limit interlock shall be located where recommended by the oven manufacturer or designer.

8.16.9* The excess temperature limit interlock shall indicate its set point in temperature units that are consistent with the primary temperature-indicating controller.

8.16.10 The operating temperature controller and its temperature-sensing element shall not be used as the excess temperature limit interlock.

8.17 1400°F (760°C) Bypass Interlock.

8.17.1 Where flame supervision is switched out of the burner management system or unsupervised burners are brought online, as permitted by 8.10.7 or 8.10.2, a 1400°F (760°C) bypass interlock shall be used.

8.17.2 Open circuit failure of the temperature-sensing components shall cause the same response as an operating temperature less than 1400°F (760°C).

8.17.3* The 1400°F (760°C) bypass interlock shall be equipped with temperature indication.

8.17.4* The temperature-sensing components of the 1400°F (760°C) bypass interlock shall be rated for the temperature and the atmosphere to which they are exposed.

8.17.5 The temperature-sensing element of the 1400°F (760°C) bypass interlock shall be located so that unsupervised burners are not allowed to operate at temperatures below 1400°F (760°C).

8.17.6 The 1400°F (760°C) bypass interlock set point shall not be set below 1400°F (760°C) and shall indicate its set point in units of temperature (degrees Fahrenheit or degrees Celsius) that are consistent with the primary temperature-indicating controller.

8.17.7 Visual indication shall be provided to indicate when the 1400°F (760°C) bypass interlock is in the bypass mode.

8.17.8* The operating temperature interlock and its temperature-sensing element shall not be used as the 1400°F (760°C) bypass interlock.

8.18 Electrical Heating Systems.

8.18.1 Heating Equipment Controls.

8.18.1.1* Electric heating equipment shall be equipped with a main disconnect device or with multiple devices to provide back-up circuit protection to equipment and to persons servicing the equipment.

8.18.1.2 The disconnecting device(s) required by 8.18.1.1 shall be capable of interrupting maximum available fault current as well as rated load current.

8.18.1.3 Shutdown of the heating power source shall not affect the operation of equipment such as conveyors, ventilation or recirculation fans, cooling components, and other auxiliary equipment, unless specifically designed to do so.

8.18.1.4 Resistance heaters larger than 48 amperes shall not be required to be subdivided into circuits of 48 amperes or less.

8.18.1.5* The capacity of all electrical devices used to control energy for the heating load shall be selected on the basis of continuous duty load ratings where fully equipped for the location and type of service proposed.

8.18.1.6 All controls using thermal protection or trip mechanisms shall be located or protected to preclude faulty operation due to ambient temperatures.

8.18.2* Excess Temperature Limit Interlock.

8.18.2.1 Excess temperature limit interlocks shall be installed in accordance with one of the following:

(1) An excess temperature limit interlock shall be installed and interlocked into the burner management system.
(2) Class B, Class C, or Class D furnaces shall not be required to have an excess temperature where it can be demonstrated that the maximum temperature limit specified by the furnace manufacturer cannot be exceeded.

8.18.2.2 Operation of the excess temperature limit interlock shall shut off the heating system before the oven's maximum temperature, as specified by the oven manufacturer, is exceeded.

8.18.2.3 Operation of the excess temperature limit interlock shall require manual reset before restart of the furnace or affected furnace zone.

8.18.2.4 Open circuit failure of the temperature-sensing components of the excess temperature limit interlock shall cause the same response as an excess temperature condition.

8.18.2.5* Excess temperature limit interlocks shall be equipped with temperature indication.

8.18.2.6* The temperature-sensing components of the excess temperature limit interlock shall be rated for the temperature and atmosphere to which they are exposed.

8.18.2.7* The temperature-sensing element of the excess temperature limit interlock shall be located where recommended by the oven manufacturer or designer.

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8.18.2.8* The excess temperature limit interlock shall indicate its set point in temperature units that are consistent with the primary temperature-indicating controller.

8.18.2.9 The operating temperature controller and its temperature-sensing element shall not be used as the excess temperature limit controller.

8.19* Fluid-Heated Systems — Excess Temperature Limit Interlock.

8.19.1 Excess temperature limit interlocks shall be installed in accordance with one of the following:

(1) An excess temperature limit interlock shall be installed and interlocked into the burner management system.
(2) Class B, Class C, or Class D furnaces shall not be required to have an excess temperature limit interlock where it can be demonstrated that the maximum temperature limit specified by the furnace manufacturer cannot be exceeded.

8.19.2* Interrupting the supply of heat transfer fluid shall not cause damage to the remainder of the heat transfer system.

8.19.3 Operation of the excess temperature limit interlock shall shut off the heating system before the oven's maximum temperature, as specified by the oven manufacturer, is exceeded.

8.19.4 Operation of the excess temperature limit interlock shall require manual reset before the flow of heat transfer fluid is re-established.

8.19.5 Open circuit failure of the temperature-sensing components of the excess temperature limit interlock shall cause the same response as an excess temperature condition.

8.19.6* Excess temperature limit interlocks shall be equipped with temperature indication.

8.19.7* The temperature-sensing components of the excess temperature limit interlock shall be rated for the temperature and atmosphere to which they are exposed.

8.19.8* The temperature-sensing element of the excess temperature limit interlock shall be located where recommended by the oven manufacturer or designer.

8.19.9* The excess temperature limit interlock shall indicate its set point in temperature units that are consistent with the primary temperature-indicating controller.

8.19.10 The operating temperature controller and its temperature-sensing element shall not be used as the excess temperature limit interlock.

Chapter 9 Fire Protection

9.1* General. A study shall be conducted to determine the need for fixed or portable fire protection systems for ovens, furnaces, or related equipment.

9.1.1 The determination of the need for fire protection systems shall be based on a review of the fire hazards associated with the equipment.

9.1.2 Where determined to be necessary, fixed or portable fire protection systems shall be provided.

9.1.3* Written procedures shall be established outlining actions to be taken in response to an unintended fire involving an oven system.

9.2* Types of Fire Protection Systems.

9.2.1* Where automatic sprinklers are provided, they shall be installed in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*, unless otherwise permitted by 9.2.2.

9.2.2 Where sprinklers that protect only ovens are installed and connection to a reliable fire protection water supply is not feasible, a domestic water supply connection shall be permitted to supply these sprinklers subject to the approval of the authority having jurisdiction.

9.2.3* Where water spray systems are provided, they shall be installed in accordance with NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*.

9.2.4* Where carbon dioxide protection systems are provided, they shall be installed in accordance with NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems*.

9.2.5 Where foam extinguishing systems are provided, they shall be installed in accordance with NFPA 11, *Standard for Low-, Medium-, and High-Expansion Foam*.

9.2.6* Where dry chemical protection systems are provided, they shall be installed in accordance with NFPA 17, *Standard for Dry Chemical Extinguishing Systems*.

9.2.7 Where water mist systems are provided, they shall be installed in accordance with NFPA 750, *Standard on Water Mist Fire Protection Systems*.

9.3 Special Considerations.

9.3.1 Where water from a fixed protection system could come in contact with molten materials, such as molten salt or molten metal, shielding shall be provided to prevent water from contacting the molten material.

9.3.2* Galvanized pipe shall not be used in sprinkler or water spray systems in ovens, furnaces, or related equipment.

9.3.3 Where sprinklers are selected for the protection of ovens, furnaces, or related equipment, the use of closed-head sprinkler systems shall be prohibited, and only deluge sprinkler systems shall be used where the following conditions exist:

(1) In equipment where temperatures can exceed 625°F (329°C)
(2) Where flash fire conditions can occur

9.4 Drawings and Calculations. Prior to the beginning of installation of a fixed fire protection system, installation drawings and associated calculations depicting the arrangement of fixed protection installations shall be submitted to the authority having jurisdiction for review and approval.

9.5 Means of Access. Where manual fire protection is determined to be necessary as a result of the review required in Section 9.1, doors or other effective means of access shall be provided in ovens and ductwork so that portable extinguishers and hose streams can be used effectively in all parts of the equipment.

9.6 Inspection, Testing, and Maintenance of Fire Protection Equipment. All fire protection equipment shall be inspected, tested, and maintained as specified in the following standards:

(1) NFPA 10, *Standard for Portable Fire Extinguishers*
(2) NFPA 11, *Standard for Low-, Medium-, and High-Expansion Foam*
(3) NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems*
(4) NFPA 13, *Standard for the Installation of Sprinkler Systems*

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(5) NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*
(6) NFPA 17, *Standard for Dry Chemical Extinguishing Systems*
(7) NFPA 17A, *Standard for Wet Chemical Extinguishing Systems*
(8) NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*
(9) NFPA 750, *Standard on Water Mist Fire Protection Systems*

Chapter 10 Thermal Oxidizer

10.1 General. For the purposes of this chapter, the term *thermal oxidizer* shall include the following:

(1) Afterburners
(2) Direct thermal oxidizers
(3) Direct catalytic oxidizers
(4) Fume incinerators
(5) Recuperative thermal oxidizers
(6) Recuperative catalytic oxidizers
(7) Regenerative thermal oxidizers
(8) Regenerative catalytic oxidizers
(9) Flameless thermal oxidizers
(10) Other devices that can restrict ventilation of ovens

10.2 Location and Construction.

10.2.1* The design and construction of fume incinerators shall comply with all requirements for Class A ovens in this standard, except for the requirements for explosion relief.

10.2.2 Precautions shall be taken to reduce fire hazards where the relative location of equipment or the type of fumes generated are such that combustible liquids can condense or solids can be deposited between the generating process and the afterburner.

10.2.3* Direct Fuel Injection Systems.

10.2.3.1 Two safety shutoff valves in series shall be provided in the fuel injection supply line.

10.2.3.2 A filter or fine-mesh strainer shall precede the upstream safety shutoff valve.

10.2.3.3 Safety shutoff valves shall not be used as modulating control valves unless they are designed as both safety shutoff and modulation valves and tested for concurrent use.

10.2.3.4 Means for testing all fuel safety shutoff valves for valve seat leakage shall be installed.

10.2.3.5 Local visual position indication shall be provided for each safety shutoff valve.

(A) The position indication shall directly indicate the physical position, closed and open, of the valve.

(B) Where lights are used for position indication, the absence of light shall not be used to indicate open or closed position.

(C) Indirect indication of valve position, such as by monitoring operator current voltage or pressure, shall not be permitted.

10.2.3.6 The safety shutoff valves in 10.2.3.1 shall shut off the injected fuel after interruption of the holding medium by any one of the interlocking safety devices or operating controls.

10.2.3.7 Where the introduced capacity exceeds 400,000 Btu/hr (117 kW), at least one of the safety shutoff valves in 10.2.3.1 shall be proved closed and interlocked with the pre-ignition purge interval.

(A) A proved closed condition shall be accomplished by either of the following means:

(1) A proof-of-closure switch
(2) A valve proving system

(B) Auxiliary and closed position indicator switches shall not satisfy the proved-closed requirement of 8.8.2.2.

10.3 Heating Systems. (Reserved)

10.4 Commissioning, Operations, Maintenance, Inspection, and Testing. (Reserved)

10.5 Fire Protection. (Reserved)

10.6 Safety Equipment and Application.

10.6.1* Thermal oxidizers shall not reduce the required safety ventilation specified in this standard.

10.6.2* Direct-Fired Fume Incinerators.

10.6.2.1* The design and operation of combustion systems and controls shall comply with all parts of this standard pertaining to direct-fired ovens.

10.6.2.2* An excess temperature limit interlock shall be installed to prevent uncontrolled temperature rise in the fume incinerator, and operation of the interlock shall cause the following:

(1) Interruption of fuel to the fume incinerator burner
(2) Interruption of the source of fumes to the incinerator

10.6.3 Direct Heat Recovery Systems.

10.6.3.1 Proved fresh air shall be introduced into the system to provide the oxygen necessary for combustion of hydrocarbons as well as primary burner fuel.

10.6.3.2 Fresh air shall be introduced through openings that supply air directly to each zone circulating system.

10.6.3.3* Where direct heat recovery systems are employed and portions of the incinerator exhaust gases are utilized as the heat source for one or more of the zones of the fume-generating oven, one of the following precautions shall be taken to prevent recycling unburned solvent vapors and unburned fuel.

(1) Mechanical means such as fixed dampers shall be used to ensure that the ratio of fresh air to recycled exhaust cannot reduce the destruction efficiency of the incinerator below specification or 90 percent, whichever is higher.
(2) Oxygen sensors in the air stream to the incinerator are interlocked to divert recycled exhaust gases to atmosphere if levels drop below specifications for the incinerator.
(3) A continuous vapor concentration high-limit controller is provided in accordance with 11.6.10.

10.6.4* Catalytic Fume Incinerators.

10.6.4.1 The requirements in 10.6.2 for direct-fired fume incinerators shall apply to catalytic fume incinerators.

10.6.4.2* An additional excess temperature limit interlock shall be located downstream from the discharge of the catalyst bed for thermal protection of the catalyst elements, and operation of the interlock shall cause the following:

(1) Interruption of fuel to the burner
(2) Interruption of the source of fumes

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10.6.4.3* Process exhaust ventilation shall be provided to maintain vapor concentrations that cannot generate temperatures at which thermal degradation of the catalyst can occur.

10.6.4.4* A differential pressure (*P*) high limit switch, measuring across the catalyst bed, shall be used to detect particulate contamination, and operation of the switch shall cause the following:

(1) Interruption of fuel to the fume incinerator burner
(2) Interruption of the source of fumes to the incinerator

10.6.4.5* Where catalysts are utilized with direct heat recovery, a maintenance program shall be established, and frequent tests of catalyst performance shall be conducted so that unburned or partially burned vapors are not reintroduced into the process oven.

Chapter 11 Class A Ovens and Furnaces

11.1 General. (Reserved)

11.2 Location and Construction. (Reserved)

11.3 Heating Systems. (Reserved)

11.4 Commissioning, Operations, Maintenance, Inspection, and Testing.

11.4.1* Safety Design Data Form.

11.4.1.1 Solvent Atmosphere Ovens. The safety design data form or nameplate for solvent atmosphere ovens shall include all of the following design data:

(1) Solvent used
(2) Number of gallons (liters) per batch or per hour of solvent and volatiles entering the oven
(3) Required purge time
(4) Oven operating temperature
(5) Exhaust blower rating for the number of gallons (liters) of solvent per hour or batch at the maximum operating temperature

11.4.1.2 Low-Oxygen Ovens. For low-oxygen ovens, the maximum allowable oxygen concentration shall be included in place of the exhaust blower ratings.

11.4.2 On completion of an oven installation, airflow tests shall be conducted on the ventilation systems under the oven operating conditions, with flow control devices at their minimum settings.

11.4.3 The airflow tests required by 11.4.2 shall be repeated when the flammable or combustible vapor loadings are increased or when modifications are made to the ventilation system.

11.4.4* Operation and maintenance of a low-oxygen oven and its associated recovery equipment shall be performed by the user in accordance with the manufacturer's recommendations.

11.5 Fire Protection.

11.5.1 Upon activation of an oven's fire protection system, the following actions shall be initiated:

(1) Safety shutdown of the oven.
(2) Discontinue the introduction of flammable or combustible material.
(3) Position damper(s) to maintain the minimum airflow through all oven passages to provide the required safety ventilation or demonstrate by calculation that the combustible concentration in the work chamber cannot exceed 25 percent of the lower flammable limit (LFL) under any conditions.
(4) Keep fan(s) in operation to maintain the required safety ventilation or demonstrate by calculation that the combustible concentration in the work chamber cannot exceed 25 percent of the lower flammable limit (LFL) under any conditions.
(5) Shut down the recirculation air and exhaust air systems and close the damper(s) where the type of automatic fire protection system requires that ventilation be discontinued.

11.6 Safety Ventilation for Class A Ovens.

11.6.1 General Safety Ventilation Requirements.

11.6.1.1 Air circulation shall be used to minimize the volume of flammable concentration regions that are present at the point of evaporation within the oven.

11.6.1.2 Combustible solids or substrate material shall not require safety ventilation unless flammable constituents evolve in the process of heating.

11.6.1.3 The determination of safety ventilation shall be based on all of the following:

(1) Volume of products of combustion entering the oven heating chamber
(2) Weight or volume of flammable or combustible constituents released during the heating process, based on maximum loading
(3) Solvent that requires the greatest amount of ventilation air per gallon (liter) when a combination of solvents is used
(4) Design of the oven heating and ventilation system with regard to all of the following:
    (a) Materials to be processed
    (b) Temperature to which processed materials are raised
    (c) Method of heating with regard to direct or indirect venting of combustion products versus alternative use of steam or electrical energy
    (d) General design of the oven with regard to continuous or batch-type operation
    (e) Type of fuel and chemicals to be used and any by-products generated in the heating chamber

11.6.1.4* Published chemical properties shall be used where chemical manufacturer's data are not available.

11.6.1.5 Safety ventilation shall be maintained until all flammable vapors are removed or have been released from the oven and associated equipment.

11.6.1.6 Class A ovens shall be mechanically ventilated.

11.6.1.7* If reduction of safety ventilation by accumulation of deposits is possible for the oven's intended use, the fan design shall be selected to prevent this accumulation.

11.6.1.8 Class A ovens shall be ventilated directly to the outdoor atmosphere or indirectly to the outdoor atmosphere through a fume incinerator in accordance with Chapter 10 or through other approved volatile organic compound (VOC) or particulate pollution control devices.

11.6.1.9 Exhaust duct openings shall be located in the areas of greatest concentration of vapors within the oven enclosure.

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11.6.1.10* Safety ventilation shall be proved by one of the following:

(1) A dedicated exhaust fan proved in accordance with Section 8.6
(2) The presence of at least the required fresh air flow into the system proven in accordance with 11.6.1.11
(3) The presence of at least the required exhaust flow out of the system proven in accordance with 11.6.1.11
(4) A continuous vapor concentration high- limit controller in accordance with 11.6.10

11.6.1.11 Safety ventilation shall be arranged to meet the following design characteristics:

(1) The reduction of air flow below the minimum required by 11.6.1 shall activate the ventilation safety devices provided in accordance with Section 8.6.
(2) The physical arrangement of dampers, fans, ducts, chambers, and passages shall ensure that a short-circuited airflow cannot occur without activating the ventilation safety devices provided in accordance with Section 8.6.

11.6.1.12 Where used, multiple exhaust fans, manifolded together, shall be designed so that the operation of one or more exhaust fans does not result in backflow to an idle oven or reduced exhaust flow due to increased manifold pressure.

11.6.1.13 Ovens in which the temperature is controlled by varying airflow shall be designed so that the air required for safety ventilation is maintained during all operating conditions.

11.6.1.14 A separate exhaust system shall be used for exhausting the products of combustion from indirect-fired heating systems or indirect-fired internal heating systems, unless otherwise permitted by 11.6.1.15.

11.6.1.15 All indirect-fired ovens shall be equipped with one of the following:

(1) Separate exhaust systems for removing the products of combustion and the process stream
(2) A single exhaust system for removing both the products of combustion and the process stream when the temperature of the products of combustion is reduced by the addition of fresh air to a point where it is insufficient to cause ignition of any combustible fumes in the oven exhaust system and with approval from the AHJ

11.6.1.16* Air supplied into the oven shall be circulated to produce a uniform distribution and movement in all parts of the oven and through the work in process.

11.6.2 Interlocks.

11.6.2.1* Interlocks for exhaust and recirculation fans shall be installed in accordance with Sections 8.6 and 8.7.

11.6.2.2 Electrical interlocks obtained through interconnection with a motor starter shall be provided for exhaust and recirculation fans.

11.6.2.3 Conveyors or sources of flammable or combustible material shall be interlocked to shut down upon the occurrence of excess temperature or if either the exhaust system or the recirculation system fails.

11.6.2.4 Where combustible materials are continuously admitted to the oven, and stopping or reducing the material flow can result in a hazardous condition, interlocks shall be provided to shut down the heating system upon stoppage or reduction of material flow.

11.6.3 Heat Recovery and Pollution Control Devices.

11.6.3.1* If the installation of heat recovery devices and pollution control devices reduces the combustion airflow or exhaust flow below that required for purge or safety ventilation, the purge flow rate or purge time shall be increased to compensate for the reduction.

11.6.3.2 Heat recovery devices and pollution control devices shall be designed and maintained to prevent reduction or loss of safety ventilation due to such factors as the condensation of flammable volatiles and foreign materials.

11.6.3.3 Heat recovery devices and pollution control devices shall be designed to minimize fire hazards due to the presence of combustible products or residue.

11.6.4 Fresh Air Supply and Exhaust.

11.6.4.1 Ovens in which flammable vapors are being produced or are combined with the products of combustion shall be exhausted.

11.6.4.2 All ovens shall have the exhaust fan motor starter and airflow switch interlocked to prevent operation of the heating units unless the exhaust fans are running.

11.6.4.3 Devices that control the volume of fresh air admitted to the oven and the vapors or gases exhausted from the oven shall be designed so that when at the minimum setting they exceed the volume required for safety ventilation.

11.6.5* Determination and Calculation of Required Safety Ventilation Corrections for Temperature and Altitude. The correction factors in 11.6.5.1 and 11.6.5.2 shall be determined and reserved for use in the subsequent calculations to determine the minimum required safety ventilation.

11.6.5.1 Temperature Correction Factors.

(A)* Temperature correction factors for volume shall be applied because the volume of gas varies in direct proportion to its absolute temperature.

(B) Volume correction factors shall be determined in accordance with one of the following equations or by using Table 11.6.5.1(B):

[11.6.5.1(B)]

$$\frac{t^\circ\text{F} + 460^\circ\text{F}}{70^\circ\text{F} + 460^\circ\text{F}} = \text{correction factor (U.S. customary units)}$$

$$\frac{t^\circ\text{C} + 273^\circ\text{C}}{21^\circ\text{C} + 273^\circ\text{C}} = \text{correction factor (SI units)}$$

where:
t = exhaust temperature

11.6.5.2 Altitude Correction Factor.

(A)* The altitude correction factors for volume in Table 11.6.5.2(A) shall be applied, unless otherwise permitted by 11.6.5.2.

(B) Correction factors shall not be required at altitudes lower than 1000 ft (305 m) above sea level.

11.6.5.3 Ventilation shall be added to ensure the removal of products of combustion in direct-fired process ovens.

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Table 11.6.5.1(B) Temperature–Volume Conversion Factors (at Sea Level)

Temp. °F	Temp. °C	Conv. Factor	Temp. °F	Temp. °C	Conv. Factor	Temp. °F	Temp. °C	Conv. Factor
70	21	1	300	149	1.43	950	510	2.66
100	38	1.06	350	177	1.53	1000	538	2.75
110	43	1.075	400	204	1.62	1050	566	2.85
120	49	1.09	450	232	1.72	1100	593	2.94
130	54	1.11	500	260	1.81	1150	621	3.04
140	60	1.13	550	288	1.90	1200	649	3.13
150	66	1.15	600	316	2.00	1250	677	3.23
175	79	1.20	650	343	2.09	1300	704	3.32
200	93	1.24	700	371	2.19	1350	732	3.42
225	107	1.29	750	399	2.28	1400	760	3.51
250	121	1.34	850	454	2.47			
275	135	1.38	900	482	2.57			

Table 11.6.5.2(A) Altitude Correction Factors

Altitude ft	Altitude m	Correction Factor
0	0	1.00
1,000	305	1.04
2,000	610	1.08
3,000	915	1.12
4,000	1,220	1.16
5,000	1,524	1.20
6,000	1,829	1.25
7,000	2,134	1.30
8,000	2,438	1.35
9,000	2,743	1.40
10,000	3,048	1.45

11.6.6 Method for Calculating Ventilation Rate for Products of Combustion.

11.6.6.1 The method for calculating the ventilation rate for products of combustion shall be as follows:

(1) The minimum oven exhaust volume for safety ventilation in continuous process ovens, including powder coating ovens, where a direct-fired combustion system (within or remote from the oven chamber) is used shall include the volume of combustion products from burners.
(2) The value used for the products of combustion shall be 183 scfm (5.18 standard m^3/min) per 1,000,000 Btu/hr (293.1 kW) burner rating.
(3) The products of combustion shall be adjusted for the oven operating temperature and the altitude.
(4) The adjusted value shall be added to the value determined from 11.6.8.4.

11.6.6.2 The products of combustion ventilation value determined in 11.6.6.1 shall be corrected for the exhaust stream temperature and the altitude to determine the actual flow as follows:

(1) Apply the temperature correction factor from 11.6.5.1.
(2) Apply the altitude correction factor from 11.6.5.2.

11.6.7* Method for Calculating Ventilation Rate for Powder Curing Ovens. The method for calculating the minimum ventilation rate for powder curing ovens shall be as follows:

(1) The safety ventilation required for powder curing ovens shall be based on the percentage of volatile content of the powder released (R) during the oven cure cycle. If a percentage is not available, the safety ventilation shall be calculated by assuming that 9 percent of the mass of the powder is volatile and the remaining mass is inert.
(2) The safety ventilation shall then be determined by treating the volatile components released as xylene in accordance with 11.6.8.4 for continuous process ovens and with 11.6.9.3 for batch process ovens.

11.6.8* Continuous Process Ovens.

11.6.8.1* Rate of Solvent Vapor Ventilation. The safety ventilation rate of continuous process ovens shall be designed, maintained, and operated to do either of the following:

(1) Prevent the vapor concentration in the oven exhaust from exceeding 25 percent of the LFL
(2) Where a continuous solvent vapor indicator and controller is provided in accordance with 11.6.10, prevent the vapor concentration in the oven exhaust from exceeding 50 percent of the LFL

11.6.8.2 Where a continuous solvent vapor indicator and controller is provided, it shall be arranged to do one of the following to prevent the vapor concentration in the oven exhaust from exceeding 50 percent of the LFL:

(1) Alarm and shut down the oven heating systems
(2) Alarm and operate additional exhaust fans
(3) Alarm and shut down the solvent input to the oven

11.6.8.3* LFL Correction Factor.

(A) The LFL value for continuous process ovens shall be corrected for the oven operating temperature in accordance with one of the following formulas or by using Table 11.6.8.3(A):

[11.6.8.3(A)]

$$LFL_t = LFL_{77°F}\ [1 - 0.000436\ (t°F - 77°F)]$$

$$LFL_t = LFL_{25°C}\ [1 - 0.000784\ (t°C - 25°C)]$$

where:
t = oven temperature

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Table 11.6.8.3(A) Oven Temperature Correction Factors

Oven Temperature °F	Oven Temperature °C	LFL Correction Factor
77	25	1.00
212	100	0.94
300	149	0.90
400	204	0.86
500	260	0.81

(B) For batch process ovens, the temperature multiplier specified in 11.6.9.2 shall be used.

11.6.8.4* Methods for Determining Solvent Safety Ventilation Rate.

(A) Method A shall be calculated as follows:

(1) Determine the volume (ft^3 or m^3) of vapor per amount of solvent by using one of the following equations:

[11.6.8.4(A)a]

$$\frac{ft^3 \text{ vapor}}{\text{gal solvent}} = \left(\frac{8.328}{0.075}\right)\left(\frac{SpGr}{VD}\right)$$

$$\frac{m^3 \text{ vapor}}{\text{L solvent}} = \left(\frac{0.998}{1.200}\right)\left(\frac{SpGr}{VD}\right)$$

where:

1 gal water = 8.328 lb at 70°F
Dry air at 70°F = 0.075 lb/ft^3 and 29.9 in. Hg
SpGr = specific gravity of solvent (water = 1.0)
VD = vapor density of solvent vapor (air = 1.0)
1 L water = 0.998 kg at 21°C
Dry air at 21°C = 1200 kg/m^3 and 0.76 m Hg

(2) Determine the volume of barely explosive mixture per amount of solvent using one of the following equations:

[11.6.8.4(A)b]

$$\frac{ft^3 \text{ barely explosive mixture}}{\text{gal solvent}} = \left(\frac{ft^3}{\text{gal solvent}}\right)\left(\frac{100}{LFL_T}\right)$$

$$\frac{m^3 \text{ barely explosive vapor}}{\text{L solvent}} = \left(\frac{m^3}{\text{L solvent}}\right)\left(\frac{100}{LFL_T}\right)$$

where:

LFL_T = lower flammable limit (percentage by volume in air), corrected for temperature

(3) Determine the volume of diluted mixture at 25 percent LFL per amount (gal or L) of solvent evaporated in the process using one of the following equations:

[11.6.8.4(A)c]

$$\frac{ft^3 \text{ diluted mixture @ 25\% } LFL}{\text{gal solvent evaporated}} = 4\left(\frac{ft^3 \text{ barely explosive mixture}}{\text{gal solvent evaporated}}\right)$$

$$\frac{m^3 \text{ diluted mixture @ 25\% } LFL}{\text{L solvent evaporated}} = 4\left(\frac{m^3 \text{ barely explosive mixture}}{\text{L solvent evaporated}}\right)$$

(B) Method B shall be calculated by determining the volume of vapor per amount of solvent using one of the following equations:

[11.6.8.4(B)a]

$$\frac{ft^3 \text{ diluted mixture @ 25\% } LFL}{\text{gal solvent evaporated}} = 4\left(\frac{8.329}{0.075}\right)\left(\frac{SpGr}{VD}\right)\left(\frac{100}{LFL_T}\right)$$

[11.6.8.4(B)b]

$$\frac{m^3 \text{ diluted mixture @ 25\% } LFL}{\text{L solvent evaporated}} = 4\left(\frac{0.998}{1.200}\right)\left(\frac{SpGr}{VD}\right)\left(\frac{100}{LFL_T}\right)$$

(C)* Method for Estimating Solvent Safety Ventilation Rate. Continuous process ovens shall have a rate of safety ventilation for volatile materials of 12,000 ft^3 (340 m^3) of fresh air referred to 70°F (21°C) (at sea level) per 1 gal (3.8 L) of solvent evaporated in the oven, where all the following conditions are met:

(1) The elevation is below 1000 ft (305 m).
(2) The oven operating temperature is at or below 350°F (177°C).
(3) The volume of air that dilutes the vapor from 1 gal of solvent to the lower flammable limit (LFL) rendered barely flammable for the solvent used is less than 2640 scf/gal (19.75 standard m^3/L).
(4) The rate of safety ventilation is corrected for the temperature of the exhaust stream exiting the oven.

11.6.8.5* The required minimum rate of exhaust air flow, at standard atmosphere and temperature, shall be determined by multiplying the cubic feet of diluted mixture at 25 percent LFL per gallon of solvent evaporated in the process by the maximum allowable gallons per minute of solvent entering the process oven, as follows:

[11.6.8.5]

$$\begin{matrix}ft^3 \text{ or } m^3 \text{ of exhaust to} \\ \text{prove safety ventilation}\end{matrix} = \left(\frac{\text{gal or L of solvent entering the oven}}{\text{min}}\right)\left(\frac{ft^3 \text{ or } m^3 \text{ diluted mixture @ 25\% } LFL_T}{\text{gal or L of solvent evaporated}}\right)$$

11.6.8.6 The safety ventilation value determined in 11.6.8.4 shall be corrected for the exhaust stream temperature and altitude to determine the actual flow, as follows:

(1) Apply the temperature correction factor from 11.6.5.1.
(2) Apply the altitude correction factor from 11.6.5.2.

11.6.8.7 The products of combustion in direct-fired process ovens shall be accounted for by implementing one of the following approaches:

(1) The safety ventilation shall be increased to include the products of combustion ventilation rate determined in 11.6.6.
(2) A continuous vapor concentration high-limit controller shall be provided in accordance with 11.6.10.

11.6.9* Batch Process Ovens.

11.6.9.1* Solvent Vapor Ventilation. The rate of solvent vapor ventilation (safety ventilation) shall be calculated and provided to ensure that the maximum solvent vapor concentration cannot exceed 25 percent of the LFL during operation.

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11.6.9.2 Ventilation LFL Correction Factor. A ventilation correction factor shall be determined to adjust for the impact of temperature on the LFL value for batch process ovens as follows:

(1) Batch ovens operating at temperatures from 250°F to 500°F (121°C to 260°C) shall have the volume increased by a multiplier of 1.4.
(2) Batch ovens operating above 500°F (260°C) shall have the volume of air increased by a multiplier determined by test.

11.6.9.3* Methods for Determining Solvent Safety Ventilation Rate. In batch process ovens, the rate of safety ventilation air shall be either calculated using 11.6.9.3 or estimated using 11.6.9.3.

(A) Method for Calculating Ventilation Rate. The minimum safety ventilation rate shall be one of the following:

(1) 440 scfm of air per gal (3.29 standard m^3/min of air per L) of solvent
(2) Other than 440 scfm (3.29 standard m^3/min) where ventilation is provided, with exhaust fans and other devices to prevent average concentration in the oven from exceeding 25 percent of the LFL
(3) A continuous vapor concentration high limit controller meeting one of the following criteria:
    (a) The controller is arranged to alarm and shut down the oven heating system.
    (b) The controller is arranged to operate additional exhaust fans at a predetermined vapor concentration not exceeding 50 percent of the LFL. The amount of ventilation air in standard cubic feet (standard cubic meters) that is rendered barely flammable by the vapor generated in gallons per hour (liters per hour) of solvent in use is determined, and the determined value then is multiplied by an empirical factor of 10 and divided by 60 minutes/hour to obtain the safety ventilation in standard cubic feet per minute (standard cubic meters per minute).

(B) Method for Estimating Rate of Ventilation. Batch ovens shall have a minimum safety ventilation rate either of that given in 11.6.9.3 or as follows:

(1) The safety ventilation rate of batch ovens shall be designed and maintained to provide 440 scfm of air per gal (3.29 standard m^3/min of air per L) of flammable volatiles in each batch.
(2)*Where the solvent used requires a volume of air greater than 2640 standard ft^3 to dilute vapor from 1 gal of solvent to the LFL (19.75 standard m^3/L), safety ventilation shall be adjusted in proportion to the ratio of the actual volume of air necessary to render 2640 ft^3/gal (19.75 m^3/L) barely explosive.

CAUTION: Caution shall be used where applying this method to products of low mass that can heat up quickly (such as paper or textiles) or materials coated with very highly volatile solvents. Either condition can produce too high a peak evaporation rate for this method to be used.

11.6.9.4* Correction factors shall be applied as follows:

(1) The temperature correction factor determined in 11.6.5.1 shall be applied to adjust for the impact of temperature on exhaust efficiency.
(2) The altitude correction factor determined in 11.6.5.2 shall be applied to adjust for the impact of temperature on exhaust efficiency.
(3) The temperature correction factor determined in 11.6.9.2 shall be applied to adjust for the impact of temperature on the LFL.

11.6.10 Continuous Vapor Concentration High Limits and Controllers.

11.6.10.1 Where the safety ventilation rate in the oven has been designed to provide vapor concentrations between 25 percent and 50 percent of the LFL, a continuous vapor concentration high limit controller shall be provided.

11.6.10.2* The continuous vapor concentration high limit controller shall be capable of detecting and responding to process upset conditions to initiate reduction of the vapor concentration before the concentration exceeds 50 percent of the LFL.

11.6.10.3* Where an oven having multiple heating zones and at least one heating zone is operating at or above 25 percent of the LFL, all other heating zones shall be equipped with either of the following:

(1) A continuous vapor concentration high limit controller
(2) Without a continuous vapor concentration high limit controller where it can be demonstrated that a heating zone cannot exceed 25 percent of the LFL in the case of an accidental increase in solvent input

11.6.10.4* Where a continuous vapor concentration controller is used to modulate the flow of fresh air or exhaust from an oven or zone, the following criteria shall apply:

(1) A secondary protection system shall be required to prevent an analyzer failure from causing a hazardous condition.
(2) The secondary protection system shall have a separate continuous vapor concentration high limit controller for each zone.
(3) Limits on damper travel (set for 50 percent LFL for the highest design solvent input) for each zone shall be permitted in lieu of the requirement of 11.6.10.3(2).

11.6.10.5 The continuous vapor concentration controller and the continuous vapor concentration high limit controller shall be calibrated for the application and solvents used.

11.6.10.6 Where a variety of solvents is used, the solvent to which the controller is least sensitive shall be the primary calibration reference.

11.6.10.7 A record of primary and subsequent calibrations shall be maintained and reviewed for drift in the controller response.

11.6.10.8 Alarms shall be provided to indicate any sample, flow, circuit, or controller power failures.

(A) Activation of an alarm shall initiate action to reduce the solvent concentration to a minimum.

(B) The activation of the malfunction alarm shall require operator intervention in accordance with 11.6.10.10.

11.6.10.9* Activation of the continuous vapor concentration high limit controller shall alarm and initiate the automatic reduction of the solvent concentration to a minimum.

11.6.10.10 When the continuous vapor concentration high limit controller alarm (required by 11.6.10.9) is activated, the

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process shall be prevented from restarting until the vapor concentration is below the limit level and the operator has manually reset the system.

11.6.10.11 Continuous vapor alarms shall be calibrated and maintained in accordance with the following:

(1) The sensor and the sample system shall be maintained at a temperature that prevents condensation, and sampling lines shall be clean and airtight.
(2) The system shall be secured against unauthorized adjustment.
(3) Maintenance shall be performed in accordance with manufacturer's instructions.
(4) Calibration shall be performed in accordance with manufacturer's instructions and shall be performed at least once per month.

11.7 Low-Oxygen Atmosphere Class A Ovens with Solvent Recovery.

11.7.1 General.

11.7.1.1 In low-oxygen atmosphere Class A ovens with solvent recovery limiting oxygen concentration, oxygen concentration shall be maintained by the addition of inert gas.

11.7.1.2* The equipment, including fans and web seals, shall be gastight to avoid admission of air.

11.7.2* An oxygen analyzer and controller shall be installed to limit oxygen concentration to below the value where no mixture is flammable (limiting oxidant concentration) by increasing the flow of inert gas or reducing flammables into the oven.

11.7.2.1 During startup and shutdown, sufficient inert gas flow shall be provided to be outside the flammable region.

11.7.2.2* Solvent shall be recovered and sent to a solvent storage system.

11.7.3 Oven Design. The oven shall be designed to accommodate the performance of the following procedures for system operation:

(1) Operational procedures to avoid flammable region of the solvent at all times
(2) Starting and purging of the oven with inert gas to lower the oxygen content to a predetermined level
(3) Heating of the recirculating oven atmosphere to the required process temperature
(4) Introduction of the workload into the oven enclosure
(5) Continuous operation
(6) Shutdown procedures to avoid the flammable region of the solvent
(7) Emergency shutdown procedures

11.7.4 Oven Construction and Location. The following requirements shall be met:

(1) Explosion relief shall not be required for low-oxygen atmosphere Class A ovens with solvent recovery.
(2) The oven enclosure and any ductwork to and from the enclosure shall be gastight, and access doors shall meet the following criteria:
    (a) They shall be gasketed to minimize leakage.
    (b) They shall be designed to prevent opening during operation.
(3)*The oven and the oven end openings shall be designed to minimize the entrance of air and the exit of solvent vapors.
(4) The oven atmosphere circulation system shall be designed to provide sufficient flow throughout the entire oven and the ductwork system to minimize condensation of the flammable solvent.

11.7.5* Inert Gas Generation and Storage Systems. The oven system shall have an inert gas supply for oxygen control and purging.

11.7.5.1 Inert gas for reduction and control of oxygen within the oven enclosure and associated equipment shall be nitrogen, carbon dioxide, or other inert gas.

11.7.5.2 Vessels, controls, and piping that maintain their integrity at the maximum/minimum design pressures and temperatures shall be provided.

11.7.5.3 ASME tank relief devices shall be provided and sized, constructed, and tested in accordance with ASME *Boiler and Pressure Vessel Code*, Section VIII, Division 1.

11.7.5.4 Bulk storage systems shall be rated and installed to ensure reliable and uninterrupted flow of inert gas to the user equipment as necessary.

11.7.5.5 Where inert gases are used as safety purge media, the following criteria shall be met:

(1) The minimum volume stored is sufficient to purge all connected low-oxygen atmosphere ovens with a minimum of five oven volumes *(see 11.7.6.1)*, unless otherwise permitted by 11.7.6.2.
(2) The recirculating fans are kept operating during the purge.

11.7.5.6 The stored volume shall be permitted to be reduced, provided that both of the following conditions are met:

(1) Mixing is adequate.
(2) The stored volume is sufficient to reduce the concentration in the oven to the LFL in air.

11.7.6 Vaporizers Used for Liquefied Purging Fluids.

11.7.6.1 Vaporizers utilized to convert cryogenic fluids to the gas state shall be ambient air-heated units so that their flow is unaffected by a loss of power, unless otherwise permitted by 11.7.6.2.

11.7.6.2 Where powered vaporizers are used, one of the following conditions shall be met:

(1) The vaporizer has a reserve heating capacity sufficient to continue vaporizing at least five oven volumes at the required purge flow rate following power interruption.
(2) Reserve ambient vaporizers are piped to the source of supply and meet the following criteria:
    (a) The vaporizers are not affected by a freeze-up or flow stoppage of gas from the power vaporizer.
    (b) The vaporizers are capable of evaporating at least five oven volumes at the required purge flow rate.
(3) Purge gas is available from an alternative source that fulfills the requirements of 11.7.5.4, 11.7.5.5, 11.7.6.3, and 11.7.6.6.

11.7.6.3 Vaporizers shall be rated by the industrial gas supplier or the owner to vaporize at 150 percent of the highest purge gas demand for all connected equipment.

11.7.6.4 Winter temperature extremes in the locale shall be taken into consideration by the agency responsible for rating the vaporizers specified in 11.7.6.3.

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11.7.6.5 It shall be the user's responsibility to inform the industrial gas supplier of additions to the plant that materially increase the inert gas consumption rate, so that vaporizer and storage capacity can be enlarged in advance of plant expansion.

11.7.6.6* The vaporizer shall be protected against flow demands that exceed its rate of capacity when such demands can cause closure of a low-temperature shutoff valve.

11.7.6.7 A temperature indicator shall be installed in the vaporizer effluent piping.

11.7.6.8 An audible or visual low-temperature alarm shall be provided to alert oven operators whenever the temperature is in danger of reaching the set point of the low-temperature flow shutoff valve so that they can begin corrective actions in advance of the flow stoppage.

11.7.7 Inert Gas Flow Rates.

11.7.7.1* Inert gas shall be provided to dilute air infiltration to prevent the creation of a flammable gas–air mixture within the oven.

11.7.7.2 Means shall be provided for metering and controlling the flow rate of the inert gas.

11.7.7.3 The flow control shall be accessible and located in an illuminated area or illuminated so that an operator can monitor its operation.

11.7.7.4 Where an inert gas flow control unit is equipped with an automatic emergency inert purge, a manually operated switch located on the face of the unit and a remote switch that activates the purge shall be provided.

11.7.7.5 The pressure of the inert gas system shall be regulated to prevent overpressurizing of components in the system, such as glass tube flowmeters.

11.7.8 Inert Gas Piping System.

11.7.8.1 The piping system for inert gas shall be sized to allow the full flow of inert gas to all connected ovens at the maximum demand rates.

11.7.8.2 Solders that contain lead shall not be used to join pipes.

11.7.8.3* Piping that contains cryogenic liquids or that is installed downstream of a cryogenic gas vaporizer shall be constructed of metals that retain strength at cryogenic temperatures.

11.7.8.4 Piping and piping components shall be in accordance with ASME B31.3, *Process Piping*.

11.7.9 Safety Equipment and Application.

11.7.9.1* The oven shall be analyzed continuously and controlled for oxygen content by modulating the addition of inert gas.

(A) The sample point shall be in the condensing system for each zone or multiple zones.

(B) The oven shall have a minimum of two analyzers to provide redundancy.

11.7.9.2 Provision shall be made for power outages by one of the following:

(1) An emergency standby power generator is provided for emergency shutdown during a power failure.
(2) Alternative safety shutdown procedures for power failure are employed.

11.7.9.3* Provisions shall be made to restrict entry into the oven where the atmosphere could be hazardous to human health.

11.7.10 Inert Gas Introduction and Starting the Production Line. The following procedures shall be accomplished for inert gas introduction and starting the production line:

(1) Verifying that all personnel are out of the oven enclosure, all guards are in place, and all doors are closed
(2) Verifying that the volume of inert gas is in storage and that the inert gas supply and solvent recovery systems are operational and ready to start production
(3) Verifying that the solvent recovery system interfaced with the oven is operational and prepared to receive solvent-laden gas prior to starting production
(4) Starting the recirculation fans in the oven enclosure prior to introduction of inert gas to ensure that effective oxygen purging occurs once inert gas enters the enclosure
(5) *Purging the oven enclosure with inert gas until the enclosure oxygen concentration is three percentage points below the limiting oxidant concentration (LOC) that is able to support combustion of the solvents used
(6) Heating the recirculating oven gas to the required operating temperature

11.7.11* Production Running.

11.7.11.1 The oven enclosure oxygen concentration shall be maintained at least three percentage points below the LOC of the solvent during normal operation.

11.7.11.2 If it is not possible to maintain the oxygen concentration at least one percentage point below the LOC, the emergency purge shall be activated, and the solvent input shall be stopped.

11.7.11.3 If the oven temperature is not above the solvent dew point, the oven shall be purged and shut down, and corrective action shall be taken.

11.7.12 Oven Shutdown and Entry. When an oven is shut down and it is necessary to enter, the following steps shall be taken:

(1) *Flow to and from the solvent recovery system shall be continued, and the system shall be purged with inert gas until the solvent vapor concentration in the oven enclosure is no greater than the solvent concentration at the LOC.
(2) Flow to and from the solvent recovery system shall be discontinued, and oven heaters shall be de-energized.
(3) Air shall be introduced into the oven enclosure until the oxygen level reaches a minimum of 19.5 percent.

11.7.13 Emergency Procedures.

11.7.13.1 In the event of electrical power failure, the equipment or procedures required by 11.7.13.2 shall be operated.

11.7.13.2 The oven shall shut down automatically when the emergency purge cycle is initiated.

11.7.13.3 The oxygen analyzer that initiates the emergency purge cycle shall be hard-wired to bypass all other process control instrumentation.

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11.7.13.4 The oven enclosure shall have a vent line that does the following:

(1) Opens automatically when the emergency purge cycle is initiated, to avoid pressurizing the oven enclosure
(2) Discharges to an approved location away from building makeup air and ignition sources

Chapter 12 Class B Ovens and Furnaces

12.1 General. (Reserved)

12.2 Location and Construction. (Reserved)

12.3 Heating Systems. (Reserved)

12.4 Commissioning, Operations, Maintenance, Inspection, and Testing. (Reserved)

12.5 Safety Equipment.

12.5.1* Ventilation of Class B Ovens and Furnaces. Where the installation of heat recovery devices and pollution control devices reduce the combustion airflow or exhaust flow below that required for purge, the purge flow rate or purge time shall be increased to compensate for the reduction.

12.6 Fire Protection. (Reserved)

Chapter 13 Special Atmospheres for Class C Ovens and Furnaces

13.1 General. (Reserved)

13.2 Location and Construction. (Reserved)

13.3 Heating Systems. (Reserved)

13.4 Commissioning, Operations, Maintenance, Inspection, and Testing. (Reserved)

13.5 Safety Equipment.

13.5.1 Requirements for Special Atmospheres.

13.5.1.1 Subsection 13.5.1 shall apply to the equipment used to generate or to store special atmospheres and to meter or control their flows to atmosphere furnaces.

(A) Subsection 13.5.1 shall also apply to generated and synthetic special atmospheres.

(B) All the requirements in this standard for furnace heating systems shall apply to generator heating systems, unless otherwise specified in this section.

13.5.1.2 The selection and operation of the equipment used to produce or store special atmospheres shall be the responsibility of the user and shall be subject to the authority having jurisdiction.

13.5.1.3* Unwanted, normal operating, and emergency releases of fluids (gases or liquids) from special atmosphere generators, storage tanks, gas cylinders, and flow control units shall be disposed of to an approved location.

13.5.1.4 Venting of unwanted flammable atmosphere gas shall be done by controlled venting to an approved location outside the building or by completely burning the atmosphere gas and venting the products of combustion to an approved location.

13.5.1.5 Nonflammable and nontoxic gasses shall be vented to an approved location outside the building at a rate that does not pose a hazard of asphyxiation.

13.5.1.6 Water-cooled atmosphere generators shall be provided with valves on the cooling water inlet.

(A) Piping shall be arranged to ensure that equipment jackets are maintained full of water.

(B) Closed cooling water systems shall comply with 5.2.10.

(C) Open cooling water systems shall comply with 5.2.11.

13.5.2* Exothermic Generators.

13.5.2.1* Use of Copper Copper and copper alloy components or materials shall not be used in exothermic atmosphere gas generators, cooling systems, heat exchangers, and distribution systems where they will be exposed to makeup, reacting, or final product exothermic atmosphere gas.

13.5.2.2 Protective Equipment.

(A) Protective equipment shall be selected and applied separately for the fuel gas and air, and interlocks shall be provided.

(B) The protective devices shall shut down the system and shall require manual resetting after any utility (fuel gas, air, power) failure or mechanical failure.

(C) Observation ports or other visual means shall be provided to observe the operation of individual burners.

(D) The required protective equipment shall include the following:

(1) Air supply or mechanical mixer shutoff in the event of loss of fuel gas for any reason
(2) A device that shuts off the air from a remote supply in case of power failure or abnormally low or abnormally high fuel gas pressure at the generator
(3) Flow indicators, meters, or differential pressure devices on the fuel gas and air supply piping, or a test burner with flashback protection in the air–gas mixture line, to aid a trained operator in checking the air–gas ratio
(4) A visual and audible alarm when the safety shutoff valve is closed

(E) Exothermic generators shall stop the combustion air supply when the fuel supply is stopped.

13.5.3* Endothermic Generators — Protective Equipment.

13.5.3.1 Protective equipment shall be selected and installed separately for the reaction gas and the fuel gas.

13.5.3.2 Where a common gas supply for both the reaction and the fuel gases is used, the same high gas pressure switch shall be permitted to serve both.

13.5.3.3 The protective equipment shall shut down the system, which shall require manual resetting after any utility (fuel gas, fuel air, power) failure or mechanical failure.

13.5.3.4 Observation ports shall be provided to allow viewing of burner operation under all firing conditions.

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13.5.3.5* Protective equipment for the reaction section of endothermic generators shall include the following:

(1) Safety shutoff valve(s) in the reaction gas supply piping requiring manual operation for opening shall close under any of the following conditions:
   (a) Low reaction gas pressure
   (b) High reaction gas pressure
   (c) Loss of reaction air supply
   (d) Low generator temperature
   (e) Power failure
(2) A low pressure switch in the reaction gas supply piping shall close the safety shutoff valve and shut off the reaction air supply in case of abnormally low reaction gas pressure at the mixer.
(3) Where the system is subject to abnormally high reaction gas pressure, a high pressure switch shall be installed in the reaction gas supply piping that operates as follows when the gas reaction pressure exceeds a predetermined upper value:
   (a) The device closes the safety shutoff valve.
   (b) The device shuts off the reaction air supply.
(4) When an air blower or compressed air line is used to supply the reaction, a low pressure switch in the reaction air supply piping shall close the safety shutoff valve and shut off the reaction air supply in case of abnormally low reaction air pressure.
(5) A device that shuts off reaction air in case of power failure or abnormally low or abnormally high reaction gas pressure at the mixer shall be included.
(6) A means for making tightness checks of all reaction gas safety shutoff valves shall be included.
(7) A valve shall be designated the main shutoff valve and shall be located upstream of the safety shutoff valve and shall be accessible for normal and emergency shutdown.
(8) A generator temperature control to prevent the flow of reaction air and reaction gas unless the generator is at the minimum generator temperature specified by the generator manufacturer shall be included.
(9) Automatic fire check protection shall be included.
(10) A visual and audible alarm when the reaction gas safety shutoff valve is closed shall be included.

13.5.3.6 Visual and audible alarms shall be provided to indicate when the heating system is shut down.

13.5.3.7 Sections 8.5 and 8.10 shall not apply to the heating systems of endothermic gas generators.

13.5.4* Ammonia Dissociators.

13.5.4.1 Construction.

(A) Ammonia dissociators shall be designed and constructed to withstand the maximum attainable pressure.

(B) All equipment, components, valves, fittings, and other related items shall be chemically compatible with ammonia.

(C) Use of brass or other copper alloy components in contact with ammonia or dissociated ammonia shall be prohibited.

13.5.4.2 Protective Equipment.

(A)* Protective equipment for the dissociation vessel shall include the following:

(1) A relief valve in the high pressure ammonia supply line, upstream of the pressure-reducing regulator, vented to an approved location, and meeting the following criteria:
   (a) Relief shall be set at 100 percent of the design pressure of the ammonia supply manifold.
   (b) The relief devices provided shall be sized, constructed, and tested in accordance with the ASME *Boiler and Pressure Vessel Code*, Section VIII.
(2) A relief valve in the low pressure ammonia line, located between the high pressure–reducing regulator and the dissociation vessel, that is vented to an approved location and meeting the following criteria:
   (a) Relief shall be set at 100 percent of the design pressure of the dissociation vessel.
   (b) The relief devices provided shall be sized, constructed, and tested in accordance with the ASME *Boiler and Pressure Vessel Code*, Section VIII, Division 1.
(3) A manual shutoff valve between the pressure-reducing regulator and the dissociator that is accessible to the operator for emergency and normal shutdown
(4) Generator temperature control to prevent flow of ammonia unless the dissociation vessel is at operating temperature, with minimum dissociation vessel temperature specified by the ammonia dissociator manufacturer
(5) A safety shutoff valve in the ammonia supply line to the generator located downstream of the manual shutoff valve and arranged to close automatically when abnormal conditions of pressure and temperature are encountered
(6) A visual and audible alarm that is initiated when the ammonia supply safety shutoff valve is closed

(B) Protective equipment for the dissociator heating system shall conform to the requirements for endothermic generators as specified in 13.5.3.

13.5.5* Bulk Storage and Generated Supply Systems for Special Atmospheres.

13.5.5.1 General.

(A) Piping and piping components shall be in accordance with ASME B31.3, *Process Piping*.

(B) Locations for tanks and cylinders containing flammable or toxic fluids shall comply with the applicable NFPA standards.

(C) Storage tanks and their associated piping and controls shall comply with the following standards:

(1) Liquefied petroleum gas systems shall be in accordance with NFPA 58, *Liquefied Petroleum Gas Code*.
(2) Fuel gas systems shall be in accordance with NFPA 54, *National Fuel Gas Code*.
(3) Hydrogen storage systems shall be in accordance with NFPA 55, *Compressed Gases and Cryogenic Fluids Code*.
(4)*Flammable or combustible liquid systems shall be in accordance with NFPA 30, *Flammable and Combustible Liquids Code*.

(D) Where inert purge gas is required by this standard, the following shall apply:

(1) It shall be available at all times and be sufficient for five volume changes of all connected atmosphere furnaces.
(2) If the inert gas has a flammable gas component, it shall be analyzed on a continuous basis to verify that the oxygen content is less than 1 percent and the combined combustible gas concentration remains less than 25 percent of the LFL.

(E) Bulk storage systems shall be rated and installed to provide the required flow of special atmospheres to the user

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equipment if an interruption of the flow can create an explosion hazard.

(F) Where inert gases are used as safety purge media, the minimum volume stored shall be the amount required to purge all connected special atmosphere furnaces with at least five furnace volume changes wherever the flammable atmospheres are being used.

13.5.5.2 Storage Systems for Special Atmospheres. Tanks containing purge media shall be provided with a low-level audible and visual alarm that meets the following criteria:

(1) The alarm is situated in the area normally occupied by furnace operators.
(2) The low-level alarm set point is established to provide time for an orderly shutdown of the affected furnace(s).
(3) The minimum contents of a tank containing a purge medium at the low-level alarm set point is sufficient to purge all connected atmosphere furnaces with at least five volume changes.

13.5.6* Special Processing Gas Atmosphere Gas Mixing Systems. Where gas mixing systems that incorporate a surge tank mixing scheme that cycles between upper and lower set pressure limits, the following shall apply:

(1)*Pipes feeding gas atmosphere mixing systems shall contain manual isolation valves.
(2) The effluents from the relief devices used to protect a gas atmosphere mixing system shall be piped to an approved location.
(3) Piping and components shall be in accordance with ASME B31.3, *Process Piping*.
(4) The use of liquids shall not be permitted in gas atmosphere mixing systems.
(5) Means shall be provided for metering and controlling the flow rates of all gases.
(6) Flow control of the blended atmosphere gas shall be in compliance with each furnace's applicable special atmosphere flow requirements and protective equipment.
(7) Atmosphere gas mixers that create nonflammable or indeterminate gas mixtures shall be provided with the following:
   (a) Gas analyzers or other equipment for continuously monitoring and displaying the flammable gas composition
   (b) Automatic controls to shut off the flammable gas flow when the flammable component concentration rises above the operating limit
(8) If the creation of a gas mixture with a flammable gas content that is higher than intended results in the risk of explosions where none existed, controls shall be provided to shut off the flammable gas flow automatically when the flammable gas concentration rises above the operating limit.
(9) When the flammable gas concentration in a mixed gas exceeds the established high limit, an alarm shall be actuated to alert personnel in the area.
(10) Restart of flammable gas flow after a high concentration limit interruption shall require manual intervention at the site of the gas mixer.
(11) Safety shutoff valves used to admit combustible gases to the gas mixer shall be normally closed and capable of closing against maximum supply pressure.
(12) Atmosphere gas mixers installed outdoors shall be selected for outdoor service or placed in a shelter that provides weather protection.
(13) Where a gas mixer is sited in a shelter, the temperature within shall be maintained in accordance with the manufacturer's recommendations.

13.5.7 Flow Control of Special Atmospheres.

13.5.7.1* Processes and equipment for controlling flows of special atmospheres shall be designed, installed, and operated to maintain a positive pressure within connected furnaces.

13.5.7.2 The flow rates used shall restore positive internal pressure without infiltration of air during atmosphere contractions when furnace chamber doors close or workloads are quenched.

13.5.7.3* Where the atmosphere is flammable, its flow rate shall be sufficient to provide stable burn-off flames at vent ports.

13.5.7.4 Means shall be provided for metering and controlling the flow rates of all fluids comprising the special atmosphere for a furnace.

(A) Devices with visible indication of flow shall be used to meter the flows of carrier gases, carrier gas component fluids, inert purge gases, enrichment gases, or air.

(B)* Devices that meter the flow of inert purge gases shall meter and visibly indicate the flow rate by mechanical means.

(C) The installation of flow control equipment shall meet the following criteria:

(1) It shall be installed at the furnace, at the generator, or in a separate flow control unit.
(2) It shall be accessible and located in an illuminated area so that its operation can be monitored.

13.5.7.5 When flow rates and piping arrangements create a risk of flame strike back and burning within the furnace piping, it shall not be permissible to manifold flammable special atmospheres and process control air or admit both via a common inlet.

13.5.8 Synthetic Atmosphere Flow Control. Synthetic atmosphere flow control units shall have the additional capabilities specified in 13.5.8.1 through 13.5.8.11.

13.5.8.1 An atmosphere flow control unit equipped with an inert purge mode shall have a manually operated switch on the face of the unit that actuates the purge.

13.5.8.2 A safety interlock shall be provided for preventing the initial introduction of flammable fluids into a furnace before the furnace temperature has risen to 1400°F (760°C).

13.5.8.3* When a flammable liquid is used as a carrier gas and introduced in the liquid state, a second low temperature interlock shall be provided if flow of the liquid state is continued at less than 1400°F (760°C). The second interlock shall interrupt the flow of the flammable liquid atmosphere into a furnace when the furnace temperature is less than the temperature needed to reliably dissociate the liquid special atmosphere used.

13.5.8.4 Automatically operated flow control valves shall halt flows of combustible fluids in the event of a power failure.

13.5.8.5 Resumption of combustible fluid flow following a power failure shall require manual intervention (reset) by an operator after power is restored.

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13.5.8.6 Where the flammable fluid flow is interrupted, one of the following shall apply:

(1) The flow control unit shall automatically admit a flow of inert gas that restores positive pressure and shall initiate an audible and visual alarm, unless otherwise permitted by 13.5.8.6(2).
(2) Manual inert gas purge shall be provided for furnaces where operators are present and able to effect timely shutdown procedures subject to the authority having jurisdiction.

13.5.8.7 Means shall be provided to test for leakfree operation of safety shutoff valves for flammable or toxic fluids.

13.5.8.8 Safety relief valves to prevent overpressurizing of glass tube flowmeters and all other system components shall be in accordance with ASME B31.3, *Process Piping*.

13.5.8.9 The effluents from relief valves used to protect control unit components containing flammable or toxic fluids shall be piped to an approved disposal location.

13.5.8.10 Alternative valves meeting the following criteria shall be provided for manually shutting off the flow of flammable fluids into a furnace:

(1) They shall be separate from the atmosphere control unit.
(2) They shall be accessible to operators.
(3) They shall be located remotely from the furnace and the control unit.

13.5.8.11* Pipes feeding atmosphere flow control units shall contain isolation valves.

13.5.8.12 Automatic excess flow shutoff protection shall be provided for each liquid special atmosphere.

(1)*The excess flow sensor shall be located immediately downstream of the filter required in 13.5.11.10.5.
(2) Upon detection of liquid special atmosphere excess flow, the liquid special atmosphere safety shutoff valve shall close.

13.5.9 Piping Systems for Special Atmospheres.

13.5.9.1 Piping shall be sized for the full flow of special atmospheres to all connected furnaces at maximum demand rates.

13.5.9.2 Pressure vessels and receivers shall be constructed of materials compatible with the lowest possible temperature of special processing atmospheres, or controls shall be provided to stop the flow of gas when the minimum temperature is reached.

(A) A low temperature shutoff device used as prescribed in 13.5.9.2 shall not be installed so that closure of the device can interrupt the main flow of inert safety purge gas to connected furnaces containing indeterminate special processing atmospheres.

(B) If closure of a low temperature shutoff device creates any other hazard, an alarm shall be provided to alert furnace operators or other affected persons of this condition.

(C) The user shall consult with the industrial gas supplier to select the low temperature shutoff device, its placement, and a shutoff set point temperature.

13.5.9.3 Flammable liquid piping shall be supported and isolated from vibration sources that could damage it, and allowance for expansion and contraction due to temperature changes shall be made.

13.5.9.4 Pipes conveying flammable liquids shall contain pressure relief valves that protect them from damage due to expansion of such liquids when heated.

13.5.9.5 Discharge of flammable liquids from the relief valves shall be piped to an approved location.

13.5.9.6 Means shall be provided for automatically releasing accumulations of inert pressurizing gas from elevated sections of piping that otherwise could inhibit or disrupt the flow of the liquid.

13.5.9.7 Gas vented from the gas relief devices required by 13.5.9.6 shall be disposed of in an approved manner.

13.5.9.8 Use of aluminum or lead components, including solders that contain lead, or other incompatible materials in tanks, piping, valves, fittings, filters, strainers, or controls that might have contact with methanol liquid or vapor shall not be permitted.

13.5.9.9 Solders that contain lead shall not be used to join pipes containing flammable liquids.

13.5.9.10 Use of brass or other copper alloy components in tanks, piping, filters, strainers, or controls that might have contact with ammonia shall not be permitted.

13.5.10* Special Atmospheres and Furnaces as Classified in 13.5.11.

13.5.10.1 Indeterminate Atmospheres. Indeterminate atmospheres shall be treated as flammable atmospheres with the following considerations:

(1) Where one special atmosphere is replaced with another special atmosphere (e.g., flammable replaced with nonflammable) that can cause the atmosphere to become indeterminate at some stage, burn-in or burn-out procedures shall not be used.
(2) In the case of any indeterminate atmosphere, inert gas purge procedures alone shall be used for introduction and removal of special processing atmospheres.

13.5.10.2 Automatic Cycling. Automatic cycling of a furnace (e.g., quenching, load transfer from a heated zone to a cold vestibule) shall not be permitted where the special atmosphere has become indeterminate during the replacement of a flammable atmosphere with a nonflammable or an inert atmosphere (or vice versa) until the special atmosphere in all furnace chambers has been verified as either flammable, nonflammable, or inert.

13.5.10.3 Furnace Type. The type of furnace shall be determined in accordance with Table 13.5.10.3.

13.5.11 Design Requirements for the Introduction, Use, and Removal of Flammable and Indeterminate Special Atmospheres from Furnaces.

13.5.11.1 General.

(A) Flammable and indeterminate atmosphere gases shall be introduced, used, and removed from furnaces without creating an uncontrolled fire, deflagration, or explosion.

(B)* Special atmosphere furnaces that use flammable or indeterminate special atmospheres shall be designed and maintained to minimize the unintended infiltration of air into the furnace.

Documents
Document Sharing Hub
Full document details: NFPA 86 2015