

NFPA 86D

Standard for Industrial Furnaces Using Vacuum as an Atmosphere

1999 Edition



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

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NFPA 86D

Standard for

Industrial Furnaces Using Vacuum as an Atmosphere

1999 Edition

This edition of NFPA 86D, *Standard for Industrial Furnaces Using Vacuum as an Atmosphere*, was prepared by the Technical Committee on Ovens and Furnaces and acted on by the National Fire Protection Association, Inc., at its May Meeting held May 17–20, 1999, in Baltimore, MD. It was issued by the Standards Council on July 22, 1999, with an effective date of August 13, 1999, and supersedes all previous editions.

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

This edition of NFPA 86D was approved as an American National Standard on August 13, 1999.

Origin and Development of NFPA 86D

With the increased use of vacuum furnaces in industry, a sectional committee under the Committee on Ovens and Furnaces was organized in 1974 to prepare a standard covering Class D Furnaces. The first edition was adopted by the Association at the 1976 NFPA Fall Meeting. Editorial revisions were made in the 1978 edition. The 1985 edition included a complete rewrite of the foreword, the development of a new Chapter 12 for mandatory referenced publications, and a revision of Appendix F.

The 1990 edition was a complete revision that incorporated a variety of technical and editorial changes, including a new Appendix A, and consolidated appendix information in accordance with the *NFPA Manual of Style*.

The 1995 edition of NFPA 86D provided correlation with NFPA 86, *Standard for Ovens and Furnaces*, and NFPA 86C, *Standard for Industrial Furnaces Using a Special Processing 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.

This edition of NFPA 86D includes changes to the technical requirements in several areas. Also included are many refinements to clarify the technical requirements. Changes are also provided to more clearly distinguish mandatory requirements from nonmandatory recommendations and explanatory material. Nonmandatory notes have been relocated into the appendixes.

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

Committee Scope: This Committee shall have primary responsibility for documents on control of fire and explosion hazards in drying ovens for japan, enamel, and other finishes, bakery ovens, core ovens, annealing and heat treating furnaces, and other special atmosphere furnaces, including equipment for other special atmospheres.

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

Information on referenced publications can be found in Chapter 13 and Appendix G.

FOREWORD

Explosions and fires in fuel-fired and electric heat utilization equipment constitute a loss potential in life, property, and production. This standard is a compilation of guidelines, rules, and methods applicable to the safe operation of this type of equipment.

There are other conditions and regulations not covered in this standard, such as toxic vapors; hazardous materials; noise levels; heat stress; and local, state, and federal regulations (EPA and OSHA), that should be considered when designing and operating furnaces.

Causes of practically all failures can be traced to human error. The most significant failures include inadequate training of operators, lack of proper maintenance, and improper application of equipment.

Users and designers must utilize engineering skill to bring together that proper combination of controls and training necessary for the safe operation of the equipment. This standard classifies furnaces as follows.

Class A ovens and furnaces are heat utilization equipment operating at approximately atmospheric pressure 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.

Such flammable volatiles or combustible materials can, for instance, originate from any of the following: (1) paints, powders, inks, and adhesives from finishing processes, such as dipped, coated, sprayed, and impregnated materials; (2) substrate material; (3) wood, paper, and plastic pallets, spacers, or packaging materials; or (4) polymerization or other molecular rearrangements.

Potentially flammable materials, such as quench oil, waterborne finishes, cooling oil, or cooking oils, that present a hazard are ventilated according to Class A standards.

Class B ovens and furnaces are heat utilization equipment operating at approximately atmospheric pressure wherein there are no flammable volatiles or combustible materials being heated.

Class C ovens and furnaces are those in which there is a potential hazard due to a flammable or other special atmosphere being used for treatment of material in process. This type of furnace can use any type of heating system and includes a special atmosphere supply system(s). Also included in the Class C classification are integral quench furnaces and molten salt bath furnaces.

Class D furnaces are vacuum furnaces that operate at temperatures above ambient to over 5000°F (2760°C) and at pressures from vacuum to several atmospheres during heating using any type of heating system. These furnaces can include the use of special processing atmospheres. During gas quenching, these furnaces may operate at pressures from below atmospheric to over 100 psig.

Chapter 1 General**1-1 Scope.**

1-1.1 This standard shall apply to 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).

1-1.2* **Types of Furnaces.** The user's requirements for vacuum processing shall determine the type of furnace walls, the size of the furnace, the special atmospheres required, or the reduction from normal atmosphere down to a special vacuum of 10^{-8} torr (1.33×10^{-6} Pa).

1-2 Purpose. Because the heat processing of materials can involve a serious fire and explosion hazard that can endanger the furnace and the building in which the process is located and possibly the lives of employees, adequate safeguards shall be provided as appropriate for the location, equipment, and operation of such furnaces.

1-3 Application.

1-3.1 The requirements of Chapters 1 through 5 shall apply to equipment described in subsequent chapters except as modified by those chapters.

1-3.2* This entire standard shall apply to new installations or alterations or extensions to existing equipment.

1-3.3 Section 1-5 and Chapter 11 shall apply to all operating furnaces.

1-3.4 No standard can guarantee the elimination of furnace fires and explosions. Technology in this area is under constant development, which is reflected in fuel, special processing atmospheres, flammable vapors, and quench systems, with regard to the type of equipment and the characteristics of the various fluids. Therefore, the designer is cautioned that the standard is not a design handbook. The standard does not eliminate the need for the engineer or competent engineering judgment. It is intended that a designer capable of applying more complete and rigorous analysis to special or unusual problems shall have latitude in the development of furnace designs. In such cases, the designer shall be responsible for demonstrating and documenting the safety and validity of the design.

1-4* Approvals, Plans, and Specifications.

1-4.1 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.

1-4.1.1 Plans shall be drawn and shall 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.

1-4.1.2 Wiring diagrams and sequence of operations for all safety controls shall be provided. Ladder-type schematic diagrams are recommended.

1-4.2 Any deviation from this standard shall require special permission from the authority having jurisdiction.

1-4.3 Electrical.

1-4.3.1* All wiring shall be in accordance with NFPA 70, *National Electrical Code*®, NFPA 79, *Electrical Standard for Industrial Machinery*, and as described hereafter.

1-4.3.2 Wiring and equipment installed in hazardous (classified) locations shall comply with the applicable requirements of NFPA 70, *National Electrical Code*.

1-4.3.3* 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.

1-5 Operator and Maintenance Personnel Training.

1-5.1 All operating, maintenance, and appropriate supervisory personnel shall be thoroughly instructed and trained under the direction of a qualified person(s) and shall be required to demonstrate understanding of the equipment and its operation to ensure knowledge of and practice of safe operating procedures.

1-5.2 All operating, maintenance, and appropriate supervisory personnel shall receive regularly scheduled retraining and testing to maintain a high level of proficiency and effectiveness.

1-5.3 Personnel shall have access to operating instructions at all times.

1-5.4 Operator training shall include the following, where applicable:

- (1) Combustion of fuel–air mixtures
- (2) Explosion hazards
- (3) Sources of ignition, including autoignition (e.g., by incandescent surfaces)
- (4) Functions of control and safety devices
- (5) Handling of special atmospheres
- (6) Handling of low-oxygen atmospheres
- (7) Handling and processing of hazardous materials
- (8) Confined space entry procedures
- (9) Vacuum technology
- (10) Operating instructions (*see 1-5.5*)

1-5.5 Operating instructions shall be provided by the equipment manufacturer and shall include all of the following:

- (1) Schematic piping and wiring diagrams
- (2) Start-up 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

1-6 Equipment Maintenance. All equipment shall be maintained in accordance with the manufacturer's instructions.

1-7 Safety Labeling.

1-7.1 A suitable, clearly worded, and prominently displayed safety design data form or manufacturer's nameplate shall be provided that states the safe operating conditions for which the furnace system was designed, built, altered, or extended.

1-7.2 A warning label shall be provided by the manufacturer stating that the equipment shall be operated and maintained according to instructions. This label shall be permanently affixed to the furnace.

Chapter 2 Definitions

2-1 Definitions. The following definitions shall apply to NFPA 86, *Standard for Ovens and Furnaces*; NFPA 86C, *Standard for Industrial Furnaces Using a Special Processing Atmosphere*; and NFPA 86D, *Standard for Industrial Furnaces Using Vacuum as an Atmosphere*.

Afterburner. See *Incinerator, Fume*.

Air, Combustion. All the air introduced with fuel to supply heat in a furnace.

Air, Primary. All air supplied through the burner.

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

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

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

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

Approved.* Acceptable to the authority having jurisdiction.

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

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.

Bath, Molten Salt. See *Furnace, Molten Salt Bath*.

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.

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 a nonflammable atmosphere.

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.

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

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

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

Burner, Combination Fuel Gas and Oil. A burner that can burn either fuel gas or oil, or both simultaneously.

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

Burner, Line. A burner whose flame is a continuous "line."

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

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

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

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

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

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

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

Burner, Self-Piloted. 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.

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

Check, Safe-Start. A checking circuit incorporated in a safety control circuit that prevents light-off if the flame-sensing relay of the combustion safeguard is in the unsafe (flame-present) position due to component failure within the combustion safeguard or due to the presence of actual or simulated flame.

Cock, Supervising. A special approved cock incorporating in its design a means for positive interlocking with a main fuel safety shutoff valve so that, before the main fuel safety shutoff valve can be opened, all individual burner supervising cocks must be in the fully closed position.

Combustion Safety Circuitry. That portion of the oven control circuitry that contains the contacts for the required safety interlocks and the excess temperature limit controller(s). These contacts are arranged in series ahead of the safety shutoff valve(s) holding medium.

Controller, Continuous Vapor Concentration. A device that measures, indicates, and directly or indirectly controls the concentration of a flammable vapor-air mixture in percentage of the lower explosive limit (LEL).

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

Controller, Programmable. 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.

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

Cryogenic Fluid. A fluid produced or stored at very low temperatures. In the context of this standard, cryogenic fluid generally refers to gases made at low temperatures and stored at the user site in an insulated tank for use as an atmosphere or atmosphere constituent (e.g., nitrogen, argon, carbon dioxide, hydrogen, oxygen).

Damper, Cut-Away. A restricting airflow device that, when placed in the maximum closed position, allows a minimum amount of airflow past the restriction. Cut-away dampers normally are placed in the exhaust or fresh air intake ducts to ensure that the required minimum amount of exhaust or fresh air is handled by the ventilating fans.

Explosion-Resistant (Radiant Tube). The ability of a radiant tube or radiant tube heat recovery system to withstand the overpressure developed by the combustion of a stoichiometric ratio of approximately 10 volumes of combustion air to one volume of natural gas (or the stoichiometric ratio of other gaseous fuel). The radiant tube or the radiant tube heat recovery system may experience bulging and distortion but should not fail catastrophically.

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

Flame, Supervised. A flame whose presence or absence is detected by a flame sensor connected to a combustion safeguard.

Flame Arrester. A device installed in the small branch piping of a fully premixed air-fuel gas mixture to retard a flame front originating from a backfire.

Flame Propagation Rate. The speed at which a flame progresses through a combustible fuel-air mixture. This rate is a function of the temperature and the mixture conditions existing in the combustion space, burner, or piping under consideration.

Flame Rod. A detector 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. The resulting electrical current, which passes through the flame, is rectified, and this rectified current is detected and amplified by the combustion safeguard.

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

Fuel Gas. Gas used for heating, such as natural gas, manufactured gas, undiluted liquefied petroleum gas (vapor phase only), liquefied petroleum gas-air mixtures, or mixtures of these gases.

Fuel Gas System, High Pressure. A 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.

Fuel Gas System, Low Pressure or Atmospheric. A 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.

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

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

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

Furnace, Class A. An oven or furnace that has heat utilization equipment operating at approximately atmospheric pressure 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. Flammable volatiles or combustible materials can include, but are not limited to, any of the following: (1) paints, powders, inks, and adhesives from finishing processes, such as dipped, coated, sprayed, and impregnated materials; (2) substrate material; (3) wood, paper, and plastic pallets, spacers, or packaging materials; or (4) polymerization or other molecular rearrangements. In addition, potentially flammable materials, such as quench oil, water-borne finishes, cooling oil, or cooking oils, that present a hazard are ventilated according to Class A standards.

Furnace, Class B. An oven or furnace that has heat utilization equipment operating at approximately atmospheric pressure wherein there are no flammable volatiles or combustible materials being heated.

Furnace, Class C. 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. This type of furnace can use any type of heating system and includes a special atmosphere supply system(s). Also included in the Class C classification are integral quench furnaces and molten salt bath furnaces.

Furnace, Class D. An oven or furnace that operates at temperatures above ambient to over 5000°F (2760°C) and at pressures from vacuum to several atmospheres during heating using any type of heating system. These furnaces can include the use of special processing atmospheres. During inert gas quenching, these furnaces may operate at pressures from below atmospheric to over 100 psig.

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

Furnace, Molten Salt Bath. A furnace that employs salts heated to a molten state. These do not include aqueous alkali

line baths, hot brine, or other systems utilizing salts in solution.

Furnace, Plasma Arc. A furnace that employs the passage of an electric current between either a pair of electrodes or between electrodes and the work, and ionizing a gas (such as argon) and transferring energy in the form of heat.

Gas, Ballast. 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 (also called *vented exhaust*).

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

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

Gas Quenching. The introduction of a gas, usually nitrogen or argon (in certain situations helium or hydrogen may be used), into the furnace to a specific pressure [usually between -2.5 psig to 15 psig (0.85 bar to 2.05 bar)] for the purpose of cooling the work. The gas is recirculated over the work and through a heat exchanger by means of a fan or blower.

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

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

Guarded. Covered, shielded, fenced, enclosed, or otherwise protected by such means as suitable covers or casings, barriers, rails or screens, mats, or platforms.

Heater, Dielectric. A heater similar to an induction heater, but using frequencies that generally are higher (3 MHz or more) than those used in induction heating. This type of heater is useful for heating materials that commonly are thought to be nonconductive. Examples of uses include heating plastic preforms before molding, curing glue in plywood, drying rayon cakes, and other similar applications.

Heater, Direct-Fired External. 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.

Heater, Direct-Fired Internal. A heating system in which the burners are located within the work chamber.

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

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

Heating System, Indirect-Fired Internal. A heating system of gastight radiators containing burners not in contact with the oven atmosphere. Radiators might be designed to withstand explosion pressures from ignition of air-fuel mixtures in the radiators.

Heating System, Induction. A heating system by means of which a current-carrying conductor induces the transfer of electrical energy to the work by eddy currents. (See NFPA 70, *National Electrical Code*, Article 665.)

Heating System, Radiant Tube. A heating system with tubular elements open at one or both ends. Each tube has an inlet burner arrangement where combustion is initiated, a

suitable length where combustion occurs, and an outlet for the combustion products formed.

Heating System, Resistance. A system in which heat is produced by current flow through a resistive conductor. Resistance heaters can be of the open type, with bare heating conductors, or insulated sheath type, with conductors covered by a protecting sheath that can be filled with electrical insulating material.

Heating System, Tubular. A form of radiant heater in which resistive conductors are enclosed in glass, quartz, or ceramic envelopes that can contain a special gas atmosphere.

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. This can be followed by an outward scattering of pieces of the wall if the wall material is not ductile, thus causing possible danger to nearby equipment and personnel.

Incinerator, Fume. 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.

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

Interlock, Proved Low-Fire Start. A burner start interlock in which a control sequence ensures that a high-low or modulated burner is in the low-fire position before the burner can be ignited.

Interlock, Safety. A device required to ensure safe start-up and safe operation and to cause safe equipment shutdown.

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.

Limiting Oxidant Concentration (LOC). The concentration of oxidant below which a deflagration cannot occur. Materials other than oxygen can act as oxidants.

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.

LOC. See *Limiting Oxidant Concentration*.

Lower Explosive Limit (LEL). See *Range, Explosive*.

Mixer, Air Jet. A mixer using the kinetic energy of a stream of air issuing from an orifice to entrain the fuel gas required for combustion. In some cases, this type of mixer can be designed to entrain some of the air for combustion as well as the fuel gas.

Mixer, Air-Fuel Gas. A system that combines air and fuel gas in the proper proportion for combustion.

Mixer, Gas Jet [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.

Mixer, Proportional. A mixer comprised of 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.

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.

Mixing Machine. A mixer using mechanical means to mix fuel and air and to compress the resultant mixture to a pressure suitable for delivery to its point of use. Mixers in this group utilize either a centrifugal fan or some other type of mechanical compressor with a proportioning device on its intake through which fuel and air are drawn by the fan or compressor suction.

Muffles. Enclosures within a furnace to separate the source of heat from the work and from any special atmosphere that might be required for the process.

Operator. An individual trained and responsible for the start-up, operation, shutdown, and emergency handling of the furnace and associated equipment.

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

Oven. See *Furnace* definitions.

Oven, Low-Oxygen. An oven that utilizes a low-oxygen atmosphere to evaporate solvent to facilitate solvent recovery. These ovens normally operate at high solvent levels and can operate safely in this manner by limiting the oxygen concentration within the oven enclosure.

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

Pilot, Burn-off. A pilot that ignites the flame curtain or special processing atmosphere discharging from the furnace or generator.

Pilot, Continuous. A pilot that burns throughout the entire period that the heating equipment is in service, whether or not the main burner is firing.

Pilot, Expanding. A pilot that burns at a set turndown throughout the entire period that the heating equipment is in service, but burns without turndown during light-off of the main burner.

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

Pilot, Interrupted. 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).

Pilot, Proved. A pilot flame supervised by a combustion safeguard that senses the presence of the pilot flame.

Pilot Flame Establishing Period. The interval of time during light-off that a safety control circuit allows the pilot fuel safety shutoff valve to remain open before the combustion safeguard proves the presence of the pilot flame.

Pressure, Partial. The pressure that is exerted by one component of a mixture of gases if it is present alone in a container.

Pressure, Ultimate. The limiting pressure approached in the vacuum system after sufficient pumping time to establish that further reductions in pressure would be negligible (sometimes called the *ultimate vacuum*).

Pump, Diffusion. 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.

Pump, Gas Ballast. 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*).

Pump, Holding. A backing (fore) pump used to hold a diffusion pump at efficient operating conditions while a roughing pump reduces the 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.

Pump, Rotary Blower. 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, such as a roots blower. It is sometimes called a *mechanical booster pump* where used in series with a mechanical backing (fore) pump.

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

Pump, Vacuum. A compressor for exhausting air and non-condensable gases from a space that is to be maintained at sub-atmospheric pressure.

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 ($F = t D/V$).

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

Range, Explosive.* The range of concentration of a flammable gas in air within which a flame can be propagated. The lowest flammable concentration is the lower explosive limit (LEL). The highest flammable concentration is the upper explosive limit (UEL).

Regulator, Pressure. A device that maintains a constant outlet pressure under varying flow.

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.

Safeguard, Combustion. A safety control directly responsive to flame properties; it senses the presence or absence of flame and de-energizes the fuel safety valve in the event of flame failure within 4 seconds of the loss of flame signal.

Safety Device. An instrument, 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. Safety devices are redundant controls, supplementing controls utilized in the normal operation of a furnace system. Safety devices act automatically, either alone or in conjunction with operating controls, when conditions stray outside of design operating ranges and endanger equipment or personnel.

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

Shall. Indicates a mandatory requirement.

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

Special Atmosphere. Prepared gas or gas mixtures that are 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).

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

Special Atmosphere, Flammable. Gases that are known to be flammable and predictably ignitable where mixed with air.

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

Special Atmosphere, Indeterminate. Atmospheres that contain components that, in their pure state, are flammable but that, in the mixtures used (diluted with nonflammable gases), are not reliably and predictably flammable.

Special Atmosphere, Inert (Purge Gas). Nonflammable gases that contain less than 1 percent oxygen.

Special Atmosphere, Nonflammable. Gases that are known to be nonflammable at any temperature.

Special Atmosphere, Synthetic. Those atmospheres such as 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. Synthetic atmospheres include mixtures of synthetic and generated atmospheres.

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 shall be located in an appendix, footnote, or fine-print note and are not to be considered a part of the requirements of a standard.

Switch, Atomizing Medium Pressure. A pressure-activated device arranged to effect a safety shutdown or to prevent the

burner system from being actuated in the event of inadequate atomizing medium pressure.

Switch, Combustion Air Pressure. A pressure-activated device arranged to effect a safety shutdown or to prevent the burner system from being actuated in the event the combustion air supplied to the burner or burners falls below that recommended by the burner manufacturer.

Switch, Differential Flow. 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.

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

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

Switch, Limit. A switching device that actuates when an operating limit has been reached.

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

Switch, Rotational. A device that usually is driven directly by the fan wheel or fan motor shaft. When the speed of the fan shaft or drive motor reaches a certain predetermined rate to provide a safe minimum airflow, a switch contact closes.

Tank, Integral Liquid or Salt Media Quench Type. A 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.

Tank, Open Liquid or Salt Media Quench Type. A 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.

Temperature, Ignition. The lowest temperature at which a gas-air mixture can ignite and continue to burn. This also is referred to as the autoignition temperature.

Time, Evacuation. The time required to pump a given system from atmospheric pressure to a specified pressure (also known as *pump-down time* or *time of exhaust*).

Time, Roughing. 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.

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

Turndown, Burner. The ratio of maximum to minimum burner fuel-input rates.

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.

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

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

Vacuum System. A chamber or chambers having walls capable of withstanding atmospheric pressure and having an opening through which the gas can be removed through a pipe or manifold to a pumping system. A complete vacuum system contains all pumps, gauges, valves, and other components necessary to carry out a particular process.

Valve, Air Inlet. A valve used for letting atmospheric air into a vacuum system. The valve also is called a vacuum breaker.

Valve, Safety Shutoff. A normally closed (closed when de-energized) 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. The valve can be opened either manually or automatically, but only after the solenoid coil or other holding mechanism is energized.

Ventilated. A system provided with a method to allow circulation of air sufficient to remove an excess of heat, fumes, or vapors.

Ventilation, Proven. A sufficient supply of fresh air and proper exhaust to outdoors with a sufficiently vigorous and properly distributed air circulation to ensure that the flammable vapor concentration in all parts of the furnace or furnace enclosure is safely below the lower explosive limit at all times.

Chapter 3 Location and Construction

3-1 Location.

3-1.1 General.

3-1.1.1 Furnaces and related equipment shall be located so as to protect personnel and buildings from fire or explosion hazards. Hazards to be considered include molten metal or other molten material spillage, quench tanks, hydraulic oil ignition, overheating of material in the furnace, and escape of fuel, processing atmospheres, or flue gases.

3-1.1.2 Furnaces shall be located so as to protect them from damage by external heat, vibration, and mechanical hazards.

3-1.1.3 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.

3-1.1.4* 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.

3-1.1.5 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.

3-1.2 Structural Members of the Building.

3-1.2.1 Furnaces shall be located and erected so that the building structural members are not affected adversely by the maximum anticipated temperatures (*see 3-1.4*) or by the additional loading caused by the furnace.

3-1.2.2 Structural building members shall not pass through or be enclosed within a furnace.

3-1.3 Location in Regard to Stock, Processes, and Personnel.

3-1.3.1 Furnaces shall be located so as to minimize exposure to power equipment, process equipment, and sprinkler risers. Unrelated stock and combustible materials shall be maintained at a fire-safe distance but not less than 2.5 ft (0.76 m) from a furnace, a furnace heater, or ductwork.

3-1.3.2 Furnaces shall be located so as to minimize exposure of people to the possibility of injury from fire, explosion, asphyxiation, and hazardous materials and shall not obstruct personnel travel to exitways.

3-1.3.3* Furnaces shall be designed or located so as to prevent an ignition source to flammable coating dip tanks, spray booths, storage and mixing rooms for flammable liquids, or exposure to flammable vapor or combustible dusts.

Exception: This requirement shall not apply to integral quench systems.

3-1.3.4 Equipment shall be protected from corrosive external processes and environments, including fumes or materials from adjacent processes or equipment that produce corrosive conditions when introduced into the furnace environment.

3-1.4 Floors and Clearances.

3-1.4.1 Furnaces shall be located with adequate space above and on all sides to allow inspection and maintenance. Provisions also shall be included for the installation of automatic sprinklers and the proper functioning of explosion vents, if applicable.

3-1.4.2* Furnaces shall be constructed and located to keep temperatures at combustible floors, ceilings, and walls below 160°F (71°C).

3-1.4.3 Where electrical wiring is present in the channels of certain types of floors, the wiring shall be installed in accordance with NFPA 70, *National Electrical Code*, Article 356.

3-1.4.4 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.

3-2 Furnace Design.

3-2.1 Furnaces and related equipment shall be designed to minimize the fire hazard inherent in equipment operating at elevated temperatures.

3-2.2 Furnace components exposed simultaneously to elevated temperatures and air (oxygen) shall be constructed of noncombustible material.

3-2.3 Furnace structural supports and material-handling equipment shall be designed with adequate factors of safety at the maximum operating conditions, including temperature. Furnaces shall withstand the strains imposed by expansion and contraction, as well as static and dynamic mechanical load.

3-2.4 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.

3-2.5 Furnace and related equipment shall be designed and located to allow access for required inspection and maintenance.

3-2.5.1 Ladders, walkways, and access facilities, where provided, shall be designed in accordance with 29 *CFR* 1910.24 through 29 *CFR* 1910.29 and ANSI A14.3, *Safety Requirements for Fixed Ladders*.

3-2.5.2 Means shall be provided to allow for safe entry by maintenance and other personnel. (*See also A-11-1.*)

3-2.6 Radiation shields, refractory material, and insulation shall be retained or supported so they do not fall out of place under designed use and with proper maintenance.

3-2.7 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. Bursting discs or panels, mixer openings, or other parts of the furnace from which flame or hot gases could be discharged shall be located or guarded to prevent injury to personnel.

Exception: Where impractical to provide adequate shields or guards, warning signs or permanent floor markings shall be provided to be visible to personnel entering the area.

3-2.8 Properly located observation ports shall be provided so the operator can observe the lighting and operation of individual burners. Observation ports shall be protected properly from radiant heat and physical damage.

Exception: Where observation ports are not practical, other means of visually verifying the lighting and operation of individual burners shall be provided.

3-2.9 Closed cooling systems shall have a means of relief to protect all portions of the system, if the system pressure can exceed the design pressure. Flow switches shall be provided with audible and visual alarms.

3-2.10 Open cooling systems utilizing unrestricted sight drains readily observable by the operator shall not require flow switches.

3-2.11 Where a cooling system is critical to continued safe operation, the cooling system shall continue to operate after a safety shutdown or power failure.

3-2.12* Furnaces shall be designed to minimize fire hazards due to the presence of combustible products or residue in the furnace.

3-2.13 Furnace hydraulic systems shall utilize fire-resistant fluids.

Exception: Other hydraulic fluids shall be permitted to be used if failure of hydraulic system components cannot result in a fire hazard, subject to approval by the authority having jurisdiction.

3-2.14 The metal frames of furnaces shall be electrically grounded.

3-2.15* Water-cooled components, such as vacuum vessels, shall be designed with minimum wall thicknesses in accordance with corrosion tables and vessel standards.

3-2.16 Where the vacuum chamber operates at a positive internal pressure of greater than 15 psig (103.4 kPa), the vacuum chamber shall be designed and constructed in accordance with ASME *Boiler and Pressure Vessel Code*, Section VIII, Division 1. The additional pressure due to water in the cooling jacket shall be considered in calculating maximum pressure differentials.

3-3 Explosion Relief.

3-3.1* 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.

Exception: Explosion relief shall not be required on furnaces with shell construction having $\frac{3}{16}$ -in. (4.8-mm) or heavier steel plate shells reinforced with structural steel beams and buckstays that support and retain refractory insulating materials required for temperature endurance, which make them unsuitable for the installation of explosion relief.

3-3.2 Explosion relief shall be designed as a ratio of relief area to furnace volume. The minimum design shall be at least 1 ft² (0.093 m²) of relief area for each 15 ft³ (0.424 m³) of furnace volume. Hinged panels, openings, or access doors equipped with approved explosion-relief hardware shall be permitted to be included in this ratio of 1:15.

3-3.3 Explosion-relief vents shall be arranged so that, when open, the full vent opening provides an effective relief area. The operation of vents to their full capacity shall not be obstructed. Warning signs shall be posted on the vents.

3-3.4* Explosion-relief vent(s) shall be located as close as practicable to each known source of ignition to minimize damage.

3-3.5 Explosion-relief vents shall be located or retained so that personnel are not exposed to injury by operation of the vents.

3-3.6* 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.

3-3.7* Explosion-relief vents for a long furnace shall be reasonably distributed throughout the entire furnace length. However, the maximum distance between explosion-relief vents shall not exceed five times the oven's smallest inside dimension (width or height).

3-4* Ventilation and Exhaust System.

3-4.1 Building Makeup Air. A sufficient quantity of makeup air shall be admitted to oven rooms and buildings to provide the air volume required for oven safety ventilation and adequate combustion air.

3-4.2 Fans and Motors.

3-4.2.1 Electric motors that drive exhaust or recirculating fans shall not be located inside the oven or ductwork.

Exception: Electric motors shall be permitted to be used in vacuum furnaces.

3-4.2.2 Oven recirculation and exhaust fans shall be designed for the maximum oven temperature and for material and vapors being released during the heating process.

3-4.3 Ductwork.

3-4.3.1 Ventilating and exhaust systems, where applicable, shall be installed in accordance with Chapters 1, 2, and 3 of NFPA 91, *Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Noncombustible Particulate Solids*, unless otherwise noted.

3-4.3.2 Rectangular and square ducts shall be permitted.

3-4.3.3 Wherever furnace ducts or stacks pass through combustible walls, floors, or roofs, noncombustible insulation or clearance, or both, shall be provided to prevent combustible surface temperatures from exceeding 160°F (71°C).

3-4.3.4* Where ducts pass through noncombustible walls, floors, or partitions, the space around the duct shall be sealed with noncombustible material to maintain the fire rating of the barrier.

3-4.3.5 Ducts shall be constructed entirely of sheet steel or other noncombustible material capable of meeting the intended installation and conditions of service. The installation shall be of adequate strength and rigidity and shall be protected where subject to physical damage.

3-4.3.6 Ducts handling fumes that leave a combustible deposit shall be provided with clean-out doors.

3-4.3.7 No portions of the building shall be used as an integral part of the duct.

3-4.3.8* All ducts shall be made tight throughout and shall have no openings other than those required for the operation and maintenance of the system.

3-4.3.9 All ducts shall be thoroughly braced where required and substantially supported by metal hangers or brackets.

3-4.3.10 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.

3-4.3.11 Ducts handling combustible solids shall be designed to minimize the accumulation of solids within the ducts.

3-4.3.12 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.

3-4.3.13 Exposed hot fan casings and hot ducts [temperature exceeding 160°F (71°C)] shall be guarded by location, guard rails, shields, or insulation to prevent injury to personnel.

3-4.3.14 Exhaust ducts shall not discharge near openings or other air intakes where effluents can re-enter the building.

3-4.3.15 A suitable collecting and venting system for radiant tube heating systems shall be provided. (See Section 4-5.)

3-4.4 Pump Vents.

3-4.4.1 Mechanical vacuum pumps with capacity larger than 15 ft³/min (7×10^{-3} m³/sec) shall be vented to a safe location in accordance with all applicable codes and air pollution control regulations.

3-4.4.2 An oil drip leg in accordance with the vacuum pump manufacturer's recommendation shall be designed into the vent piping system.

3-4.4.3 Vent piping shall be free from gas or oil leaks and shall be of noncombustible pipe construction.

3-4.4.4 An oil mist separator shall be provided where the discharge vapor accumulations create a hazard.

3-5 Mountings and Auxiliary Equipment.

3-5.1 Pipes, valves, and manifolds shall be mounted so as to provide protection against damage by heat, vibration, and mechanical hazard.

3-5.2 Furnace systems shall have provisions to prevent injury to personnel during maintenance or inspection. Such equipment shall be permitted to be motion stops, lockout devices, or other safety mechanisms.

3-5.3 To the extent practical, instrumentation and control equipment shall be brought to a common location and mounted for ease of observation, adjustment, and maintenance. Protection from physical and temperature damage and ambient hazards shall be provided.

3-5.4 Auxiliary equipment such as conveyors, racks, shelves, baskets, and hangers shall be noncombustible and designed to facilitate cleaning.

3-6 Pumping Systems.

3-6.1* For the purpose of Section 3-6 the term pumping systems shall include 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. (See Appendix B for general pump information.)

3-6.2 Mechanical pumps utilizing hydrocarbon oils shall not be used for pumping gases with oxygen contents greater than 25 percent by volume.

3-6.3* Diffusion pumps and other pumps employing a heating source shall include thermostats or other automatic temperature-controlling devices.

3-6.4 A fluid level gauge shall be installed on those diffusion pumps with a pump fluid capacity over 1 qt (0.95 L).

3-6.5 Where petroleum or other combustible fluids are used, the pumping system shall be designed to minimize the possibility of fluid release that might result in a fire or explosion.

3-6.6 Sufficient cooling shall be provided for diffusion pumps to prevent excess vapors from backstreaming into furnace chambers and for mechanical pumps to prevent overheating of the pump fluids.

3-7 Vacuum Gauges and Controls.

3-7.1* Vacuum gauges and vacuum controls shall be selected for a particular system with consideration to vacuum level, sensitivity, and expected contamination.

3-7.2 Vacuum gauges shall be installed so levels of vacuum can be ascertained in the furnace chamber and between vacuum pumps of multipump systems.

3-7.3 Vacuum gauge controls that operate in conjunction with sequential controls shall be interlocked to prevent damage to the furnace components or work load.

3-7.4 Hot wire filament gauges shall not be used at pressures above 1×10^{-1} torr (13.3 Pa) in the presence of explosive vapors or combustible atmospheres.

3-8 Vacuum Piping Systems.

3-8.1 Vacuum pipe lines, valves, and manifolds shall be designed to withstand differential pressures, shall have sufficient conductance for the application, and shall have a maximum leak rate as required by the process but not greater than the leak rate specified by the furnace manufacturer.

3-8.2 Isolation vacuum valves shall be installed between the mechanical fore pumps and the remaining system, including the furnace chamber. These valves, if powered, shall automatically close when there is a loss of power to the fore pump or when the control switch for the fore pump is in the OFF position.

3-8.3 Where applicable, a bypass shall be provided between the furnace and roughing and the fore pump so that the chamber can be rough-pumped while the diffusion pump remains isolated.

3-8.4 Inlet gas quenching valves shall be designed to operate at applicable pressures on the gas side and on the vacuum side.

3-8.5 Where pressurized backfilling is employed, a pressure-relief valve shall be provided on the furnace. It shall be located on the chamber side of all vacuum valves and shall be set for a safe positive pressure limit consistent with the furnace chamber design criteria. (See Section 5-20.)

3-9 Water-Cooling Systems.

3-9.1 For the purposes of Section 3-9, the term *water-cooling system* of a vacuum furnace shall include the apparatus, equipment, and method used to cool vacuum chamber walls, electrical terminals, seals, work load, and, where applicable, the interior of the furnace.

3-9.2* Cold-wall vacuum furnaces shall be specifically designed to maintain the vacuum furnace vessel at proper temperatures. The furnace vessel walls shall be maintained at safe temperatures when the furnace operates at maximum temperatures.

3-9.3* Interlocks shall be provided on closed cooling systems to prevent heating system operation without proper flow of the cooling water at the return.

3-9.4 Provision shall be made to cool the terminals if heat from the electric power terminals can damage seals during processing cycles.

3-10* Gas Quenching Systems. See also 5-20.3.

3-10.1 Internal Heat Exchanger. Internal heat exchangers installed in the furnace chamber for the purpose of extracting heat from a recirculating cooling gas shall be protected from excessive pressure, heat damage, and mechanical damage while the furnace is being loaded or unloaded.

3-10.1.1 Heat exchangers, components, and connections shall be free from water and air leaks.

3-10.1.2 Heat exchangers shall be mounted to prevent vibration or thermal damage that could cause a rupture during processing cycles.

3-10.1.3 Heat exchanger components shall have sufficient strength to resist permanent deformation while exposed to the simultaneous maximum pressure of the coolant source and the maximum vacuum or pressure attained in the furnace.

3-10.2 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.

3-10.2.1 Heat exchangers, components, and connections shall be free from water and air leaks.

3-10.2.2 Heat exchangers shall be mounted to prevent vibration or thermal damage that could cause a rupture during processing cycles.

3-10.2.3 Heat exchanger components shall have sufficient strength to resist permanent deformation while exposed to the simultaneous maximum pressure of the coolant source and the maximum vacuum or pressure attained in the furnace.

3-10.3 Fans and Motors for Gas Quenching Systems.

3-10.3.1 Fans shall not be exposed to any temperature in excess of their design temperature rating.

3-10.3.2 Electric fan motors shall be interlocked to prevent operation below a chamber pressure of 7 psi (48 kPa) absolute to prevent motor failure.

3-10.3.3 Where motor windings are exposed to argon gas or other ionizing gases, the voltage on the motor shall be limited to 260 volts maximum.

3-10.4 Quenching Gas. The recirculating gas shall be one that is not harmful to the heating elements, furnace heat shields or insulation, or work when introduced at the quenching temperature.

3-11 Heating Elements and Insulation.

3-11.1 Material for heating elements shall have a vapor pressure lower than the lowest pressure at the manufacturer's specified maximum temperature.

3-11.2 Internal electrical insulation material shall remain nonconductive through the full range of vacuum and temperature limits specified by the manufacturer.

3-12 Heat Baffles and Reflectors.

3-12.1 Baffles, reflectors, and hangers shall be designed to minimize warpage due to expansion and contraction.

3-12.2 Baffles, reflectors, and hangers shall be of heat-resistant material that minimizes sag, rupture, or cracking under normal operating limits specified by the manufacturer.

3-12.3 Baffles and reflectors shall be accessible and removable for the purpose of cleaning and repairing.

Chapter 4 Furnace Heating Systems

4-1 General.

4-1.1 For the purpose 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.

4-1.2 All components of the furnace heating system and control cabinet shall be grounded.

4-2 Fuel Gas-Fired Units.

4-2.1 Scope.

4-2.1.1* Section 4-2 shall apply to furnace heating systems fired with commercially distributed fuel gases such as natural gas, mixed gas, manufactured gas, liquefied petroleum gas (LP-Gas) in the vapor phase, and LP-Gas/air systems. Section 4-2 also shall apply to the gas-burning portions of dual-fuel or combination burners.

4-2.1.2 Burners, along with associated mixing, valving, and safety controls and other auxiliary components, shall be properly selected for the intended application, suitable for the type and pressure of the fuel gases to be used, and suitable for the temperatures to which they are subjected.

4-2.2* Combustion Air.

4-2.2.1 The fuel-burning system design shall provide for an adequate supply of clean combustion air for proper burner operation.

4-2.2.2 Precautions shall be taken to prevent insufficiently diluted products of combustion from short-circuiting back into the combustion air. This requirement shall not prevent the use of properly designed flue gas recirculation systems.

4-2.2.3 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.

4-2.2.4 In the case of an exothermic generator, loss of fuel gas shall cut off the combustion air.

4-2.2.5 Where a secondary air adjustment is provided, adjustment shall include a locking device to prevent an unintentional change in setting.

4-2.3 Fuel Gas Supply Piping.

4-2.3.1 A remotely located shutoff valve shall be provided to allow the fuel to be turned off in an emergency and shall be located so that fire or explosion at a furnace does not prevent access to this valve.

4-2.3.2 Installation of LP-Gas storage and handling systems shall comply with NFPA 58, *Liquefied Petroleum Gas Code*.

4-2.3.3 Piping from the point of delivery to the equipment isolation valve shall comply with NFPA 54, *National Fuel Gas Code*. (See 4-2.4.2.)

4-2.4 Equipment Fuel Gas Piping.

4-2.4.1 Manual Shutoff Valves and Cocks.

4-2.4.1.1 Individual manual shutoff valves for equipment isolation shall be provided for shutoff of the fuel to each piece of equipment.

4-2.4.1.2 Manual shutoff valves shall have permanently affixed visual indication of the valve position.

4-2.4.1.3 Quarter-turn valves with removable wrenches shall not allow the wrench handle to be installed perpendicular to the fuel gas line when the valve is open.

4-2.4.1.4 It shall be the user's responsibility to ensure that separate wrenches (handles) remain affixed to the valve and that they are oriented properly with respect to the valve port.

4-2.4.1.5 Valves and cocks shall be maintained and lubricated in accordance with the manufacturer's instructions.

4-2.4.2 Piping and Fittings.

4-2.4.2.1 Material for the piping and fittings that connect the equipment manual isolation valve to the burner shall meet the requirements of NFPA 54, *National Fuel Gas Code*.

4-2.4.2.2 Piping, fittings, and valves shall be sized to provide proper flow rates and pressure so as to maintain a stable flame over the burner operating range.

4-2.4.3* Fuel Filters and Strainers. For new installations, a gas filter or strainer shall be installed in the fuel gas piping to protect the downstream safety shutoff valves.

4-2.4.4* Drip Legs. A drip leg or sediment trap shall be installed for each fuel gas supply line prior to any piping devices. The drip leg shall be at least 3 in. (76 mm) long and the same diameter as the supply piping.

4-2.4.5 Pressure Regulators and Pressure Switches.

4-2.4.5.1 A pressure regulator shall be furnished wherever the plant supply pressure exceeds that required for proper burner operation or wherever the plant supply pressure is subject to excessive fluctuations.

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

4-2.4.5.2 Regulators and switches shall be vented to a safe location where vented gas cannot re-enter the building without extreme dilution. The terminating end shall be protected against water entry and shall be bug-screened. Vent piping shall be of adequate size to allow normal regulator and switch operation.

Exception No. 1: Vent piping from regulators and switches shall be permitted to terminate within a building where used with lighter-than-air fuel gases, provided the vent contains a restricted orifice and discharges into a space large enough and with sufficient natural ventilation so that the escaping gases do not present a hazard and cannot re-enter the work area without extreme dilution.

Exception No. 2: Vent piping shall not be required for regulators and switches where used with lighter-than-air fuel gases at 1 psig (7 kPa) inlet pressure or less, provided the vent connection contains a restricted orifice and discharges into a space large enough, or is ventilated well enough, so that the escaping gases do not present a hazard.

Exception No. 3: Fuel gas regulators and zero governors shall not be required to be vented if 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.

4-2.4.5.3 Fuel gas regulators and zero governors shall not be backloaded from oxygen or oxygen-enriched air lines.

4-2.4.5.4 Vent lines from multiple furnaces shall not be manifolded together.

4-2.4.5.5 Vent lines from multiple regulators and switches of a single furnace, where manifolded together, shall be piped in such a manner that diaphragm rupture of one vent line does not backload the others. The size of the vent manifold shall be not less than the area of the largest vent line plus 50 percent of the additional vent line area.

4-2.5 Flow Control Valves. Where the minimum or the maximum flow of combustion air or the fuel gas is critical to the

safe operation of the burner, flow valves shall be equipped with an appropriate limiting means and with a locking device to prevent an unintentional change in the setting.

4-2.6 Air-Fuel Gas Mixers.

4-2.6.1* General. Subsection 4-2.6 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.

4-2.6.2 Proportional Mixing.

4-2.6.2.1 Piping shall be designed to provide a uniform mixture flow of proper pressure and velocity as needed for stable burner operation.

4-2.6.2.2 Valves or other obstructions shall not be installed between a proportional mixer and burners. Fixed orifices shall be permitted for purposes of balancing.

4-2.6.2.3 Any field-adjustable device built into a proportional mixer (e.g., gas orifice, air orifice, ration valve) shall be arranged with an appropriate locking device to prevent unintentional changes in the setting.

4-2.6.2.4 Where a mixing blower is used, an approved safety shutoff valve shall be installed in the fuel gas supply connection that shuts off the fuel gas supply automatically when the blower is not in operation and in the event of a fuel gas supply failure.

4-2.6.2.5 Mixing blowers shall not be used with fuel gases containing more than 10 percent free hydrogen (H_2).

4-2.6.2.6 Mixing blowers having a static delivery pressure of more than 10 in. w.c. (2.49 kPa) shall be considered mixing machines.

4-2.6.3 Mixing Machines.

4-2.6.3.1* Automatic fire checks shall be provided in piping systems that distribute flammable air-fuel gas mixtures from a mixing machine. The automatic fire check shall be installed as close as practical to the burner inlet(s), and the manufacturer's installation guidelines shall be followed.

4-2.6.3.2 A separate, manually operated gas valve shall be provided at each automatic fire check for shutting off the flow of air-fuel mixture through the fire check after a flashback has occurred. The valves shall be located upstream as close as practicable to the inlets of the automatic fire checks.

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.

4-2.6.3.3* A backfire arrester with a safety blowout device shall be provided near the outlet of each mixing machine that produces a flammable air-fuel gas mixture. The manufacturer's installation guidelines shall be followed.

4-2.6.3.4 A listed safety shutoff valve shall be installed in the fuel gas supply connection of any mixing machine. This valve 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.

Exception: Where listed safety shutoff valves are not available for the service intended, the selected device shall require approval by the authority having jurisdiction.

4-2.7 Fuel Gas Burners.

4-2.7.1 All burners shall maintain the stability of the designed flame shape, without flashback or blow-off, over the entire range of turndown that is encountered during operation where supplied with combustion air (oxygen-enriched air or oxygen) and the designed fuels in the proper proportions and in the proper pressure ranges. Burners shall only be used with the fuels for which they are designed.

4-2.7.2 All pressures required for safe operation of the combustion system shall be maintained within the proper ranges throughout the firing cycle.

4-2.7.3 Burners shall have the ignition source sized and located in a position that provides safe and reliable ignition of the pilot or main flame.

4-2.7.3.1 Self-piloted burners shall have a safe and reliable transition from pilot flame to main flame.

4-2.7.3.2 For burners that cannot be ignited safely at all firing rates, positive provision shall be made to reduce the burner firing rates during light-off to a lower level, which ensures a safe and reliable ignition of the main flame (forced low-fire start).

4-2.7.4* Explosion resistance of nonmetallic radiant tubes shall be determined by test.

4-2.8 Fuel Ignition.

4-2.8.1* The ignition source (e.g., electric spark, hot wire, pilot burner, handheld torch) shall be applied effectively at the proper point and with sufficient intensity to ignite the air-fuel mixture.

4-2.8.2 Fixed ignition sources shall be mounted to prevent unintentional changes in location and in direction with respect to the main flame.

4-2.8.3 Pilot burners shall be considered burners, and all provisions of Section 4-2 shall apply.

4-2.9 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 4-2, 4-3, and 5-12 shall apply equally to the respective fuels.

4-3 Oil-Fired Units.

4-3.1 Scope.

4-3.1.1* Section 4-3 shall apply to 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*. It also includes the oil-burning portions of dual-fuel and combination burners.

4-3.1.2 Additional considerations that are beyond the scope of this standard shall be given to other combustible liquids not specified in 4-3.1.1.

4-3.1.3 Burners, along with associated valving, safety controls, and other auxiliary components, shall be suitable for the type and pressure of the fuel oil to be used and for the temperatures to which they are subjected.

4-3.2* Combustion Air.

4-3.2.1 The fuel-burning system design shall provide for an adequate supply of clean combustion air for proper burner operation.

4-3.2.2 Precautions shall be taken to prevent insufficiently diluted products of combustion from short-circuiting back into the combustion air. This requirement shall not prevent the use of properly designed flue gas recirculation systems.

4-3.2.3 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 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.

4-3.2.4 Where a secondary air adjustment is provided, adjustment shall include a locking device to prevent an unintentional change in setting.

4-3.3 Oil Supply Piping.

4-3.3.1 Storage tanks, their installation, and their supply piping materials shall comply with NFPA 31, *Standard for the Installation of Oil-Burning Equipment*.

4-3.3.2 A remotely located shutoff valve shall be provided to allow the fuel to be turned off in an emergency and shall be located so that fire or explosion at a furnace does not prevent access to this valve. A positive displacement oil pump shall be permitted to serve as a valve by shutting off its power.

4-3.3.3 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.

4-3.3.4* All air from the supply and return piping shall be purged initially, and air entrainment in the oil shall be minimized.

4-3.3.5 Suction, supply, and return piping shall be adequately sized with respect to oil pump capacity.

4-3.3.6* Wherever a section of oil piping can be shut off at both ends, relief valves or expansion chambers shall be used to release the pressure caused by thermal expansion of the oil.

4-3.4 Equipment Oil Piping.

4-3.4.1 Manual Shutoff Valves and Cocks.

4-3.4.1.1 Individual manual shutoff valves for equipment isolation shall be provided for shutoff of the fuel to each piece of equipment.

4-3.4.1.2 Manual shutoff valves shall be installed to avoid oil spillage during servicing of supply piping and associated components.

4-3.4.1.3 Manual shutoff valves shall display a permanently affixed visual indication of the valve position.

4-3.4.1.4 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.

4-3.4.1.5 It shall be the user's responsibility to ensure that separate wrenches (handles) remain affixed to the valve and that they are oriented properly with respect to the valve port.

4-3.4.1.6 Valves and cocks shall be maintained and lubricated in accordance with the manufacturer's instructions.

4-3.4.2 Piping and Fittings.

4-3.4.2.1 Equipment piping shall be in accordance with NFPA 31, *Standard for the Installation of Oil-Burning Equipment*.

4-3.4.2.2 Piping, fittings, and valves shall be sized to provide proper flow rates and pressure so as to maintain a stable flame over the burner operating range.

4-3.4.3 Oil Filters and Strainers.

4-3.4.3.1 An oil filter or strainer shall be installed in the oil piping to protect the downstream components.

4-3.4.3.2* The degree of filtration shall be compatible with the size of the most critical clearance being protected.

4-3.4.3.3 The filter or strainer shall be suitable for the intended pressure, temperature, and service.

4-3.4.4 **Pressure Regulators.** A pressure regulator shall be furnished wherever the plant supply pressure exceeds that required for proper burner operation or wherever the plant supply pressure is subject to excessive fluctuations.

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

4-3.4.5* **Pressure Gauges.** Pressure gauges shall be isolated or protected from pulsation damage during operation of the burner system.

4-3.5 **Flow Control Valves.** Where the minimum or the maximum flow of combustion air or the fuel oil is critical to the safe operation of the burner, flow valves shall be equipped with an appropriate limiting means and with a locking device to prevent an unintentional change in the setting.

4-3.6 Oil Atomization.

4-3.6.1* Oil shall be atomized to droplet size as required for proper combustion throughout the firing range.

4-3.6.2 The atomizing device shall be accessible for inspection, cleaning, repair, replacement, and other maintenance as required.

4-3.7 Oil Burners.

4-3.7.1 All burners shall maintain the stability of the designed flame shape over the entire range of turndown that is encountered during operation where supplied with combustion air (oxygen-enriched air or oxygen) and the designed fuels in the proper proportions and in the proper pressure ranges.

4-3.7.2 All pressures required for the safe operation of the combustion system shall be maintained within the proper ranges throughout the firing cycle.

4-3.7.3 The burner shall be supplied with fuel oil of the proper grade that has been preconditioned to the required viscosity.

4-3.7.4 Burners shall have the ignition source sized and located in a position that provides safe and reliable ignition of the pilot or main flame.

4-3.7.4.1 Self-piloted burners shall have a safe and reliable transition from pilot flame to main flame.

4-3.7.4.2 For burners that cannot be ignited safely at all firing rates, positive provision shall be made to reduce the burner firing rates during light-off to a lower level, which ensures a safe and reliable ignition of the main flame (forced low-fire start).

4-3.7.5 If purging of oil passages upon normal 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.

4-3.8 Fuel Ignition.

4-3.8.1* The ignition source (e.g., electric spark, hot wire, pilot burner, handheld torch) shall be applied effectively at the proper point and with sufficient intensity to ignite the air-fuel mixture.

4-3.8.2 Fixed ignition sources shall be mounted so as to prevent unintentional changes in location and in direction with respect to the main flame.

4-3.8.3 Pilot burners shall be considered burners, and all provisions of Section 4-2 shall apply.

4-3.9 **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 4-2, 4-3, and 5-12 shall apply equally to the respective fuels.

4-4 Oxygen-Enhanced Fuel-Fired Units.

4-4.1* **Scope.** Section 4-4 shall apply to combustion systems using oxygen (oxy-fuel) or oxygen-enriched air with gas or liquid fuels. The requirements shall be in addition to those in Sections 4-2 and 4-3 and Chapter 5.

4-4.2 Combustion Systems Utilizing Oxygen.

4-4.2.1 Oxygen storage and delivery systems shall comply with NFPA 50, *Standard for Bulk Oxygen Systems at Consumer Sites*.

4-4.2.2 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.

4-4.3 Oxygen Piping and Components.

4-4.3.1 Design, materials of construction, installation, and tests of oxygen piping shall comply with the applicable sections of ASME B31.3, *Process Piping*.

4-4.3.2* Materials and construction methods used in the installation of the oxygen piping and components shall be compatible with oxygen.

4-4.3.3* Piping and components that come in contact with oxygen shall be cleaned prior to admitting gas.

4-4.3.4* Air introduced into oxygen passages in burners, such as cooling air, shall be free of particulate matter, oil, grease, and other combustible materials.

4-4.3.5 A remotely located shutoff valve shall be provided to allow the oxygen to be turned off in an emergency and shall be located so that fire or explosion at a furnace does not prevent access to this valve.

4-4.3.6 Oxygen from pressure-relief devices and purge outlets shall not be released into pipes or manifolds where it can mix with fuel.

4-4.3.7 Oxygen from pressure-relief devices and purge outlets shall be released to a safe location.

4-4.3.8 Means shall be provided to prevent oxygen, fuel, or air to intermix in burner supply lines due to valve leakage, burner plugging, or other system malfunctions.

4-4.3.9* Oxygen piping and components shall be inspected and maintained.

4-4.3.10 If glass tube flowmeters are used in oxygen service, safeguards against personnel injury from possible rupture shall be provided.

4-4.3.11* The piping fed from a cryogenic supply source shall be protected from excessive cooling by means of an automatic low-temperature shutoff device.

4-4.3.12 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 suitable pressure-relief device.

4-4.4 Oxygen Flow Control Valves.

4-4.4.1 Where the minimum or the maximum flow of oxygen or oxygen-enriched air is critical to safe operation of the burner, flow control valves shall be equipped with an appropriate limiting means and locking device to prevent an unintentional change in the setting.

4-4.4.2 An oxygen pressure regulator shall be furnished whenever the source oxygen pressure exceeds that required for proper burner operation or wherever the source pressure is subject to excessive fluctuations.

Exception: An automatic flow control valve shall be permitted to meet this requirement, provided it can compensate for the full range of expected source pressure variations and complies with 4-4.4.1.

4-4.5 Oxygen-Enriched Combustion Air.

4-4.5.1 Filters shall be installed in the air blower intake to minimize contamination of the oxygen-enriched air piping.

4-4.5.2* Devices, such as diffusers, used to disperse oxygen into an airstream shall be designed to prevent jet impingement of oxygen onto interior surfaces of the air piping.

4-4.5.3 Oxygen-enriched combustion air shall not be introduced into a burner before the oxygen has been uniformly mixed into the airstream.

4-4.5.4 Branching of the enriched-air piping shall not be permitted before a uniform mixture of oxygen and air has been attained.

4-5 Flue Product Venting.

4-5.1 A means shall be provided to ensure adequate ventilation for the products of combustion on fuel-fired equipment.

4-5.2 Collecting and venting systems for radiant tube-type heating systems shall be of sufficient capacity to prevent an explosion or fire hazard due to the flow of unburned fuel through the radiant tubes. The system shall be capable of dilution of the rated maximum input capacity of the system to a noncombustible state.

Exception: These requirements shall not apply to radiant tube-type heating systems provided with two safety shutoff valves interlocked with combustion safeguards.

4-6 Electrically Heated Units.

4-6.1 Scope. Section 4-6 includes all types of heating systems where electrical energy is used as the source of heat.

4-6.2 Safety Equipment. Safety equipment, including airflow interlocks, time relays, and temperature switches, shall be in accordance with Chapter 5.

4-6.3* Electrical Installation. All parts of the electrical installation shall be in accordance with NFPA 70, *National Electrical Code*.

4-6.4 Resistance Heating Systems.

4-6.4.1 The provisions of 4-6.4 shall apply to resistance heating systems, including infrared lamps, such as quartz, ceramic, and tubular glass types.

4-6.4.2 Construction.

4-6.4.2.1 The heater housing shall be constructed so as to provide access to heating elements and wiring.

4-6.4.2.2 Heating elements and insulators shall be supported securely or fastened so that they do not become easily dislodged from their intended location.

4-6.4.2.3 Heating elements that are electrically insulated from and supported by a metallic frame shall have the frame electrically grounded.

4-6.4.2.4 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.

4-6.4.2.5 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.

4-6.4.3 Heater Locations. Heaters shall not be located directly under the product being heated where combustible materials can drop and accumulate.

4-6.5 Induction and Dielectric Heating Systems.

4-6.5.1 Induction and dielectric heating systems shall be designed and installed in accordance with NFPA 70, *National Electrical Code*, with special reference to Article 665.

4-6.5.2 Construction.

4-6.5.2.1* Combustible electrical insulation shall be reduced to a minimum.

4-6.5.2.2 Protection shall be installed to prevent overheating of any part of the equipment in accordance with NFPA 70, *National Electrical Code*.

4-6.5.2.3 Where water-cooling is used for transformers, capacitors, electronic tubes, spark gaps, or high-frequency conductors, cooling coils and connections shall be arranged so that leakage or condensation does not damage the electrical equipment. The cooling-water supply shall be interlocked with the power supply so that loss of water cuts off the power supply. Consideration shall be given to providing individual pressure flow interlocks for parallel waterflow paths.

4-6.5.2.4 Where forced ventilation by motor-driven fans is necessary, the air supply shall be interlocked with the power supply. An air filter shall be provided at the air intake.

4-6.5.2.5 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.

4-6.5.2.6 Dielectric heaters used for treating highly combustible materials shall be designed to prevent a disruptive discharge between the electrodes.

4-7 Fluid-Heated Systems.

4-7.1* Scope. Section 4-7 shall apply to all types of systems where water, steam, or other heat transfer fluids are the source of heat through the use of heat exchangers. Section 4-7 covers the heat transfer fluid system between the oven supply and return isolation valves for the oven being served.

4-7.2 General.

4-7.2.1* Piping and fittings shall be in accordance with ASME B31.1, *Power Piping*.

4-7.2.2 Piping containing combustible heat transfer fluid that is insulated shall use closed-cell, nonabsorptive insulation. Fibrous or open-cell insulation shall not be permitted.

4-7.2.3* Oven isolation valves shall be installed in the fluid supply and return lines. If a combustible heat transfer fluid is used, the oven isolation valves shall be installed within 5.0 ft (1.5 m) of the oven.

4-7.2.4 Enclosures or ductwork for heat exchanger coils shall be of noncombustible construction with suitable access openings provided for maintenance and cleaning.

4-7.2.5 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.

4-7.3 Safety Devices.

4-7.3.1 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.

of the equipment.

4-7.3.2 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. The filtration system and heat exchanger shall be cleaned on a regular schedule.

4-8 Heating Elements.

4-8.1* The design of heating elements can take several forms, such as rods, bars, sheets, or cloth, but shall be limited to materials that do not vaporize under minimum vacuum and maximum temperature.

4-8.2 Electrical heating equipment in a vacuum furnace shall not be operable until a sufficient vacuum level has been attained inside the furnace chamber to provide protection for the furnace elements, radiant shields, or insulation.

4-8.3* Heating element support hangers and insulators shall be of compatible materials to provide electrical insulation and nonreacting materials at specified vacuum levels and temperatures.

4-8.4 Heating element connections shall be designed to minimize arcing and disassembly problems.

4-8.5 The heating element power terminal and vessel feed-through shall be designed with consideration for vacuum integrity and heating effects. Vacuum mating surfaces shall be free from dirt and scratches and equivalent to O-ring designs.

4-8.6 Power terminal connection points to power supply cables shall be covered or housed to prevent high-current electrical hazard to personnel.

4-9* Furnace Thermal Insulation and Heat Shields.

4-9.1* Insulation shall not break down at specified vacuum levels and temperatures.

4-9.2* Multiple layers of metal heat shields shall be acceptable, assuming these materials comply with temperature and vacuum requirements.

4-9.3* Insulation shall be installed so as to prevent it from breaking up and becoming airborne, in which case it can block heat exchangers and cause vacuum valve seals to leak on furnaces that use forced gas quenching.

Chapter 5 Safety Equipment and Application

5-1 Scope.

5-1.1 Chapter 5 shall apply to safety equipment and its application to furnace heating and ventilation systems. Section 5-3 shall apply to all safety controls included in this standard.

5-1.2* 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.

5-2 General.

5-2.1 All safety devices shall be listed for the service intended. Safety devices shall be applied and installed in accordance with this standard and the manufacturer's instructions.

Exception: Where listed devices are not available for the service intended, the selected device shall require approval by the authority having jurisdiction.

5-2.2 Electric relays and safety shutoff valves shall not be used as substitutes for electrical disconnects and manual shutoff valves.

5-2.3 Purge, ignition trials, and other burner safety sequencing shall be performed only by devices listed for such service.

5-2.4 A shutdown of the heating system by any safety feature or safety device shall require manual intervention of an operator for re-establishment of normal operation of the system.

5-2.5 Regularly scheduled inspection, testing, and maintenance of all safety devices shall be performed. (See Chapter 11.)

5-2.5.1 It shall be the responsibility of the equipment manufacturer to provide operating instructions that cover start-up, shutdown, emergencies, and procedures for inspection, testing, and maintenance.

5-2.5.2 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. Documented safety inspections and testing shall be performed at least annually.

5-2.6 Safety devices shall be installed, used, and maintained in accordance with the manufacturer's instructions.

5-2.7 All combustion safety circuitry contacts for required safety interlocks and excess temperature limit controllers shall be arranged in series ahead of the safety shutoff valve holding medium.

Exception No. 1: Devices specifically listed for combustion safety service shall be permitted to be used in accordance with the listing requirements and the manufacturer's instructions.

Exception No. 2: Interposing relays shall be permitted where the conditions of (a), (b), and (c) are met:

(a) Required connected load exceeds the rating of available safety interlock devices or where necessary to perform required safety logic functions

(b) Interposing relay is configured to revert to a safe condition upon loss of power

(c) Each interposing relay serves no more than one safety interlock device

5-2.8 Safety devices shall be located or guarded to protect them from physical damage.

5-2.9 Safety devices shall not be removed or rendered ineffective.

5-2.10 Safety devices shall not be bypassed electrically or mechanically. This requirement shall not prohibit safety device testing and maintenance in accordance with 5-2.5. When 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.

5-2.11* Electrical power for safety control circuits shall be single-phase, one-side grounded, with all breaking contacts in the "hot" ungrounded, fuse-protected, or circuit breaker-protected line, and shall not exceed 120-volt potential.

5-3 Programmable Controllers for Safety Service.

5-3.1 General.

5-3.1.1 The supplier of the application software for the programmable controller shall provide the end user and the authority having jurisdiction with the documentation needed to verify that all related safety devices and safety logic are functional before the programmable controller is placed in operation.

5-3.1.2 In the event of a power failure, the programmable controller (hardware and software) shall not prevent the system from reverting to a safe default condition. A safe condition shall be maintained upon the restoration of power.

5-3.1.3 The control system shall have a separate manual emergency switch, independent of the programmable controller, that initiates a safe shutdown.

CAUTION

For some applications, additional manual action might be required to bring the process to a safe condition.

5-3.1.4 Any changes to hardware or software shall be documented, approved, and maintained in a file on the site.

5-3.1.5 The internal status of the programmable controller shall be monitored. In the event of a programmable controller failure, the system shall annunciate and cause the system to revert to a safe condition.

5-3.1.6 The system access shall be limited by incorporating measures to prevent unauthorized access to the programmable controller or its logic that could result in hazards to personnel or equipment.

CAUTION

Modems and networks require special measures to provide the necessary security.

5-3.2 Combustion Safety Functions.

5-3.2.1 Programmable controller-based systems specifically listed for combustion safety service shall be permitted where applied in accordance with the listing requirements and the manufacturer's instructions.

5-3.2.2 A programmable controller not listed for combustion safety service shall be permitted to monitor safety interlocks, or to provide burner control functions, provided that its use complies with both of the following:

- (1) The programmable controller shall not interfere with or prevent the operation of the safety interlocks.
- (2) Only isolated programmable controller contacts (not directly connected to a power source) shall be permitted to be wired in series with the safety interlocks to permit burner control functions.

5-3.2.3 The requirements of 5-2.3 shall apply to programmable controller-based systems.