NFPA 86
Standard for Ovens and Furnaces

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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This edition of NFPA 86, *Standard for Ovens and Furnaces*, 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 86 was approved as an American National Standard on August 13, 1999.

Origin and Development of NFPA 86

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

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

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

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

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

This edition of NFPA 86 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 to the appendixes.

Origin and Development of Former NFPA 86A

The 1950 edition of NFPA 86 was tentatively adopted at the 1948 NFPA Annual Meeting and officially adopted in 1950. It superseded the 1931 edition of NFPA *Standard for Ovens for Japan, Enamel, and Other Flammable Finishes*.

The proposed revisions of the 1950 edition were published as a progress report in August 1962. Comments on the progress report were reviewed by the committee and a final revision was prepared that was adopted at the NFPA Annual Meeting in 1963. Additional amendments were prompted by the expansion of the scope to include ovens and furnaces operating at temperatures not exceeding 1400°F (760°C), and a revised edition was adopted at the NFPA Annual Meeting in 1966.

New material and editorial changes for clarification were incorporated in the 1969 edition. The 1971 edition included a new article on "Furnace Hydraulic Systems" and a new section on "Afterburner Systems." Requirements for powder coating operations were added in the 1973 edition.

The 1977 edition of NFPA 86A, *Standard for Ovens and Furnaces — Design, Location and Equipment*, was prepared by the Sectional Committee on Class A Ovens and Furnaces and superseded the 1973 edition. The 1977 edition was a complete revision, including rearrangement as well as deletion of superfluous material.

Origin and Development of Former NFPA 86B

NFPA 86B, *Standard for Industrial Furnaces — Design, Location and Equipment*, was introduced and first adopted as a tentative standard in 1968. After further study by the committee, new material was added and editorial changes were made for clarification. These amendments were adopted in May 1969, but the standard retained its tentative status. It was adopted as an official standard in 1971. In the 1973 edition, major revisions were adopted covering operator training, furnace construction and exhaust systems, combustible gas indicators, and safety shutoff valves.

The standard was revised and a new edition was published in 1974. The major revision specified the conditions under which a safety shutoff valve may be permitted to be used as a dual purpose valve.

The standard was prepared by the Sectional Committee on Class B Ovens and Furnaces and was approved by the Committee on Ovens and Furnaces.

The major revisions to the 1982 publication included the following:

(1) A revision of the definitions of Class A, Class B, and Class C ovens and furnaces
(2) A consolidation and expansion of definitions and rearrangement of material
(3) The elimination of a requirement for the location of a vent line between two approved safety shutoff valves
(4) The presentation of a standard format to correlate with NFPA 86A, *Standard for Ovens and Furnaces — Design, Location and Equipment*

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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 12 and Appendix F.

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 Class A and Class B ovens, dryers, or furnaces. The terms *ovens*, *dryers*, and *furnaces* shall be used interchangeably. Where chapters or specific paragraphs in this standard apply only to Class A or B ovens, they are so noted.

1-1.2 Within the scope of this standard, an oven shall be any heated enclosure operating at approximately atmospheric pressure and used for commercial and industrial processing of materials.

1-1.3 A Class A oven also shall be permitted to utilize a low-oxygen atmosphere.

1-1.4 This standard also shall apply to bakery ovens in all respects, and reference is made to those sections of ANSI Z50.1, *Bakery Equipment — Safety Requirements*, that shall apply to bakery oven construction and safety.

1-1.5 This standard shall not apply to the following:

(1) Coal or other solid fuel-firing systems
(2) Listed equipment with a heating system(s) that supplies a total input not exceeding 150,000 Btu/hr (44 kW). *(See definition of Listed.)*

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 10 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) 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.

1-7.3* Safety Design Data Form for Solvent Atmosphere Ovens. Safety data for solvent atmosphere ovens shall be furnished on the manufacturer's nameplate. The nameplate shall provide all the following design data:

(1) Solvent used
(2) Number of gallons per batch or per hour of solvent and volatiles entering the oven
(3) Required purge time
(4) Oven operating temperature
(5) Exhaust blower rating for the number of gallons (liters) of solvent per hour or batch at the maximum operating temperature

Exception: For low-oxygen ovens, the maximum allowable oxygen concentration shall be included in place of the exhaust blower ratings.

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.

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 as expressed 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 alkaline 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 noncondensable gases from a space that is to be maintained at subatmospheric 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 deenergized) 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 so as 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 Section 10-2.)*

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.

3-3 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 No. 1: Explosion relief shall not be required on furnaces with shell construction having $^{3}/_{16}$-in. (4.8-mm) or heavier steel plate shells reinforced with structural steel beams and buckstays that support and retain refractory or insulating materials required for temperature endurance, which make them unsuitable for the installation of explosion relief.

Exception No. 2: Explosion-relief panels shall not be required for low-oxygen atmosphere ovens designed and protected in accordance with Chapter 8.

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 ft^2

(0.093 m^2) of relief area for each 15 ft^3 (0.424 m^3) 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 [temperatures 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.)*

3-5 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.

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.

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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. When 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 Chapters 5 and 9.

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 wherever 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 the 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 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.

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.

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 the normal operation of the system.

5-2.5 Regularly scheduled inspection, testing, and maintenance of all safety devices shall be performed. *(See Chapter 10.)*

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.

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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.

5-3.3 Hardware.

5-3.3.1* A failure of programmable controller hardware shall cause the system to revert to a safe default condition.

5-3.3.2 A programmable controller shall be provided with a watchdog timer external to the CPU and memory. Failures detected by the watchdog timer shall cause the system to revert to a safe default condition.

5-3.3.3 System operation shall be tested and verified for compliance with this standard and the original design criteria whenever the programmable controller is replaced, repaired, or updated.

5-3.4 Software.

5-3.4.1 Whenever application software that contains safety logic or detection logic is modified, system operation shall be verified for compliance with this standard and the original design criteria.

5-3.4.2 The software for the programmable controller shall reside in some form of nonvolatile storage (memory that retains information on loss of system power).

5-3.4.3 Application software that contains safety logic shall be separated from all other programming. Application software that interacts with safety logic or detection logic for input/output devices shall be separated from all other programming.

5-3.4.4 Unauthorized change or corruption of software shall cause the system to revert to a safe default condition.

5-4 Safety Control Application for Fuel-Fired Heating Systems.

5-4.1 Preignition (Prepurge, Purging Cycle).

5-4.1.1 Prior to each furnace heating system start-up, provision shall be made for the removal of all flammable vapors and gases that might have entered the heating chambers during the shutdown period.

5-4.1.2 A timed preignition purge shall be provided. At least 4 standard cubic feet (scf) of fresh air or inert gas per cubic foot (4 m^3/m^3) of heating chamber volume shall be introduced during the purging cycle.

5-4.1.2.1 To begin the timed preignition purge interval, both of the following conditions shall be satisfied:

(1) The minimum required preignition airflow shall be proven *(see Sections 5-5 and 5-6 for proof of airflow requirements).*
(2) The safety shutoff valve(s) shall be closed *(see 5-7.2.2 and 5-7.3.2 for proof of closure requirements).*

5-4.1.2.2 The minimum required preignition purge airflow shall be proven and maintained throughout the timed preignition purge interval.

5-4.1.2.3 Failure to maintain the minimum required preignition purge airflow shall stop the preignition purge and reset the purge timer.

5-4.1.3 A furnace heating system, either alone or as part of multiple furnaces feeding into one fume incinerator, shall not be purged into an operating incinerator.

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

5-4.1.4 Preignition purging of radiant tube–type heating systems shall be provided.

Exception: Preignition purging of radiant tube–type heating systems shall not be required where the systems are arranged and designed such that the conditions of (a) or (b) are satisfied.

(a) The tubes are of metal construction and open at one or both ends with heat recovery systems, if used, that are of explosion-resistant construction.

(b) The entire radiant tube heating system, including any associated heat recovery system, is of explosion-resistant construction.

5-4.1.5 Prior to the reignition of a burner after a burner shutdown or flame failure, a preignition purge shall be accomplished.

Exception: Repeating the preignition purge shall not be required where the conditions of (a), (b), or (c) are satisfied.

(a) The heating chamber temperature exceeds 1400°F (760°C).

(b) For any fuel–fired system, all of the following conditions are satisfied: (1) each burner and pilot is supervised by a combustion safeguard in accordance with Section 5-9; (2) each burner system is equipped with safety shutoff valves in accordance with Section 5-7; and (3) at least one burner remains operating in the common combustion chamber of the burner to be reignited.

(c) All of the following conditions are satisfied (does not apply to fuel oil systems): (1) each burner and pilot is supervised by a combustion safeguard in accordance with Section 5-9; (2) each burner system is equipped with gas safety shutoff valves in accordance with Section 5-7; and (3) it can be demonstrated that the combustible concentration in the heating chamber cannot exceed 25 percent of the LEL.

CAUTION

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

5-4.2 Trial-for-Ignition Period.

5-4.2.1 The trial-for-ignition period of the pilot burner shall not exceed 15 seconds.

5-4.2.2 The trial-for-ignition period of the main gas burner shall not exceed 15 seconds.

Exception: The trial-for-ignition period of the main gas burner shall be permitted to exceed 15 seconds, where both the following conditions are satisfied:

(a) A written request for an extension of trial for ignition is approved by the authority having jurisdiction.

(b) It is determined that 25 percent of the LEL cannot be exceeded in the extended time.

5-4.2.3 The trial-for-ignition period of the main oil burner shall not exceed 15 seconds.

5-5 Ventilation Safety Devices.

5-5.1 Wherever a fan is essential to the operation of the oven or allied equipment, fan operation shall be proven and interlocked into the safety circuitry.

5-5.1.1 Electrical interlocks and flow switches shall be arranged in the safety control circuit so that loss of ventilation or airflow immediately shuts down the heating system of the affected section, or, if necessary, loss of ventilation shall shut down the entire heating system as well as the conveyor.

5-5.1.2 Air pressure switches shall not be used to prove airflow where dampers downstream of the pressure switch can be closed to the point of reducing flow to an unsafe operating level.

5-5.1.3 Air suction switches shall not be used to prove airflow where dampers upstream of the pressure switch can be closed to the point of reducing flow to an unsafe operating level.

5-5.1.4 Switches used to prove airflow on systems where the air is contaminated with any substance that might condense or otherwise create a deposit shall be selected and installed to prevent interference with the performance of the switch.

5-5.2 Dampers capable of being adjusted to a position that can result in an unsafe condition shall be equipped with mechanical stops, cut-away dampers, or limit switches interlocked into the safety circuitry to ensure that dampers are in a proper operating position.

5-6 Combustion Air Safety Devices.

5-6.1 Where the air from the exhaust or recirculating fans is required for combustion of the fuel, airflow shall be proven prior to an ignition attempt. Reduction of airflows to an unsafe level shall result in closure of the safety shutoff valves.

5-6.2 Where a combustion air blower is used, the minimum combustion air needed for proper burner operation shall be proven prior to each attempt at ignition.

5-6.3 Motor starters on equipment required for the combustion of the fuel shall be interlocked into the combustion safety circuitry.

5-6.4* A low pressure switch shall be used to sense and monitor combustion air pressure or differential pressure and shall be interlocked into the combustion safety circuitry.

Exception: Alternative methods of verification of minimum combustion air required for burner operation shall be permitted where both of the following conditions are satisfied.

(a) The burner can reliably operate at a combustion air pressure that is lower than the available range of pressure switches listed for this service.

(b) The alternative method is acceptable to the authority having jurisdiction.

5-6.5 Wherever it is possible for combustion air pressure to exceed a maximum safe operating pressure, as might occur where compressed air is utilized, a high pressure switch interlocked into the combustion safety circuitry shall be used.

5-7 Safety Shutoff Valves (Fuel Gas or Oil).

5-7.1 General

5-7.1.1 Safety shutoff valves shall be utilized as a key safety control to protect against explosions and fires.

5-7.1.2 Each safety shutoff valve required in 5-7.2.1 and 5-7.3.1 shall automatically shut off the fuel to the burner system after interruption of the holding medium (such as electric current or fluid pressure) by any one of the interlocking safety devices, combustion safeguards, or operating controls.

Exception: For fuel gas systems, where multiple burners or pilots operate as a burner system firing into a common heating chamber, the loss of flame signal at one or more burners shall be permitted to shut off those burner(s) by closing a single safety shutoff valve, provided the following conditions in both (a) and (b) are satisfied.

(a) For the individual burner safety shutoff valve (1) it is demonstrated based on available airflow that failure of the valve to close will result in a fuel concentration not greater than 25 percent of the LEL; or (2) the safety shutoff valve has proof of closure acceptable to the authority having jurisdiction; or (3) the fuel to the burner is monitored to verify that there is no fuel flow following operation of the burner safety shutoff valve.

(b) The safety shutoff valve upstream of the individual burner safety shutoff valves shall close for any of the following conditions: (1) activation of any operating control or interlocking safety device other than the combustion safeguard; or (2) when the individual burner valves do not have proof of closure or fuel monitoring as described in (a) and the number of failed burners are capable of exceeding 25 percent of the LEL if their single safety shutoff valves should fail in the open position; or (3) when individual burner valves have proof of closure or fuel monitoring as described in (a) and verification that the individual burner safety shutoff valve has closed following loss of flame signal at the burner is not present; or (4) loss of flame signal at all burners in the burner system or at a number of burners in the burner system that will result in unsafe operation.

5-7.1.3 Safety shutoff valves shall not be used as modulating control valves.

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

5-7.1.4 Valve components shall be of a material suitable for the fuel handled and for ambient conditions.

5-7.1.5 Safety shutoff valves in systems containing particulate matter or highly corrosive fuel gas shall be operated regularly in accordance with the manufacturer's instructions to assure their proper operation.

5-7.1.6 Valves shall not be subjected to pressures in excess of the manufacturer's ratings.

5-7.1.7 If normal inlet pressure to the fuel pressure regulator immediately upstream from the valve exceeds the valve's pressure rating, a relief valve shall be provided and it shall be vented to a safe location.

5-7.1.8 Local visual position indication shall be provided at each safety shutoff valve to burners or pilots in excess of 150,000 Btu/hr (44 kW). This indication shall directly indicate the physical position, closed and open, of the valve. Where lights are used for position indication, the absence of light shall not be used to indicate open or closed position. Indirect indication of valve position, such as by monitoring operator current voltage or pressure, shall not be permitted.

5-7.2 Fuel Gas Safety Shutoff Valves.

5-7.2.1 Each main and pilot fuel gas burner system shall be separately equipped with two safety shutoff valves piped in series.

Exception: A single safety shutoff valve shall be permitted on a radiant tube–fired burner system where the following conditions of (a) or (b) are satisfied.

(a) The tubes are of metal construction and open at one or both ends with heat recovery systems, if used, that are of explosion-resistant construction.

(b) The entire radiant tube heating system, including any associated heat recovery system, is of explosion-resistant construction.

5-7.2.2 Where the main or pilot fuel gas burner system capacity exceeds 400,000 Btu/hr (117 kW), at least one of the safety shutoff valves required by 5-7.2.1 shall be proved closed and interlocked with the preignition purge interval. *(See 5-4.1.2.1.)*

5-7.2.3* A permanent and ready means for making tightness checks of all fuel gas safety shutoff valves shall be provided.

5-7.2.4 Tightness checks shall be performed in accordance with the manufacturer's instructions. Testing frequency shall be at least annually.

5-7.3 Oil Safety Shutoff Valves.

5-7.3.1 Two safety shutoff valves shall be provided under any one of the following conditions:

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

Where none of the conditions of 5-7.3.1(1) through (3) apply, a single safety shutoff valve shall be permitted.

5-7.3.2 Where two safety shutoff valves are required by 5-7.3.1, at least one of the two safety shutoff valves shall be proved closed and interlocked with the preignition purge interval.

5-8 Fuel Pressure Switches (Gas or Oil).

5-8.1 A low pressure switch shall be provided and shall be interlocked into the combustion safety circuitry.

5-8.2 A high gas pressure switch shall be provided and interlocked into the combustion safety circuitry. The switch shall be located downstream of the final pressure-reducing regulator.

Exception: For an oil system, a high pressure switch shall not be required where the fuel supply pressure to the burners cannot exceed the operating limits of the system.

5-8.3 Pressure switch settings shall be made in accordance with the operating limits of the burner system.

5-9 Combustion Safeguards (Flame Supervision).

5-9.1 Each burner flame shall be supervised by a combustion safeguard having a maximum flame failure response time of 4 seconds or less, that performs a safe-start check, and is interlocked into the combustion safety circuitry.

Exception No. 1: The flame supervision shall be permitted to be switched out of the combustion safety circuitry for a furnace zone when that zone temperature is at or above 1400°F (760°C). When the zone temperature drops below 1400°F (760°C), the burner shall be interlocked to allow its operation only if flame supervision has been re-established. A 1400°F (760°C) bypass controller shall be used for this purpose.

Exception No. 2: Combustion safeguards on radiant tube–type heating systems shall not be required where a suitable means of ignition is provided and the systems are arranged and designed such that the following conditions of (a) or (b) are satisfied.

(a) The tubes are of metal construction and open at one or both ends with heat recovery systems, if used, and they are of explosion-resistant construction.

(b) The entire radiant tube heating system, including any associated heat recovery system, is of explosion-resistant construction.

Exception No. 3: Burners without flame supervision shall be permitted, provided these burners are interlocked to prevent their operation when the zone temperature is less than 1400°F (760°C). A 1400°F (760°C) bypass controller shall be used for this purpose.

5-9.2* Flame Supervision.

5-9.2.1 Each pilot and main burner flame shall be supervised independently.

Exception No. 1: One flame sensor shall be permitted to be used to supervise the main burner and pilot flames if an interrupted pilot is used.

Exception No. 2: One flame sensor shall be permitted to be used to supervise self-piloted burners, as defined in Chapter 2.

5-9.2.2* Line burners, pipe burners, and radiant burners, where installed immediately adjacent to one another or connected with suitable flame-propagating devices, shall be considered to be a single burner and shall have at least one flame safeguard installed to sense burner flame at the end of the assembly farthest from the source of ignition.

5-10 Fuel Oil Atomization (Other than Mechanical Atomization).

5-10.1 Adequate pressure of the atomizing medium shall be proven and interlocked into the combustion safety circuitry.

5-10.2 The low pressure switch used to supervise the atomizing medium shall be located downstream from all cocks, valves, and other obstructions that can shut off flow or cause excessive pressure drop of atomization medium.

5-11* Fuel Oil Temperature Limit Devices. Fuel oil temperature limit devices shall be provided and interlocked into the combustion safety circuitry if conditions allow the fuel oil temperature to rise above or fall below a predetermined safe level.

5-12 Multiple-Fuel Systems.

5-12.1 Safety equipment in accordance with the requirements of this standard shall be provided for each fuel used. The fact that oil or gas is considered a standby fuel shall not reduce the safety requirements for that fuel.

5-12.2 Where dual-fuel burners are used, positive provision shall be made to prevent the simultaneous introduction of both fuels.

Exception: This requirement shall not apply to combination burners.

5-13 Air–Fuel Gas Mixing Machines.

5-13.1 A safety shutoff valve shall be installed in the fuel gas supply connection of any mixing machine.

5-13.2 The safety shutoff 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.

5-14 Oxygen Safety Devices.

5-14.1 Two oxygen safety shutoff valves in series shall be provided in the oxygen supply line.

5-14.2 A filter or fine-mesh strainer shall precede the upstream safety shutoff valve.

5-14.3 There shall be a high oxygen flow or pressure limit interlocked into the combustion safety circuitry. The switch shall be located downstream of the final pressure regulator or automatic flow control valve.

5-14.4 There shall be a low oxygen flow or pressure limit interlocked into the combustion safety circuitry.

5-14.5 The oxygen safety shutoff valves shall shut automatically after interruption of the holding medium by any one of the interlocking safety devices.

5-14.6 Safety shutoff valves shall not be used as modulating control valves.

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

5-14.7 A permanent and ready means for making tightness checks of all oxygen safety shutoff valves shall be provided.

5-14.8 Local visual position indication shall be provided for each oxygen safety shutoff valve to burners or pilots in excess of 150,000 Btu/hr (44 kW). This indication shall directly indicate the physical position, closed and open, of the valve. Where lights are used for position indication, the absence of light shall not be used to indicate open or closed position. Indirect indication of valve position, such as by monitoring operator current voltage or pressure, shall not be permitted.

5-14.9 Oxygen-Enriched Burners.

5-14.9.1 Where oxygen is added to a combustion air line, an interlock shall be provided to permit oxygen flow only when airflow is proven continuously. Airflow shall be proven in accordance with the requirements of Section 5-5.

5-14.9.2 Upon loss of oxygen flow, the flow of fuel shall be permitted to continue where there is no interruption in the flow of combustion air, provided the control system can revert automatically to a safe air-fuel ratio before a hazard due to a fuel-rich flame is created.

5-14.10 Burner systems employing water or other liquid coolants shall be equipped with a low coolant flow limit switch located downstream of the burner and interlocked into the combustion safety circuitry.

5-14.10.1 A time delay shall be permitted that allows the operator to take corrective action, provided an alarm is activated and it can be proved to the authority having jurisdiction that such a delay cannot create a hazard.

5-14.10.2 Coolant piping systems shall be protected from freezing and overpressurization.

5-15 Ignition of Main Burners — Fuel Gas or Oil.

5-15.1 If a reduced firing rate is required for safe and reliable ignition of the burner (forced low-fire start), an interlock shall be provided to prove the control valve is properly positioned prior to each attempt at ignition.

5-15.2 Electrical ignition energy for direct spark ignition systems shall be terminated after the main burner trial-for-ignition period.

Exception: Continuous operation of direct spark igniters shall be permitted for radiant tube–type heating systems that do not require combustion safeguards.

5-16* Excess Temperature Limit Controller.

5-16.1 An excess temperature limit controller shall be provided and interlocked into the combustion safety circuitry, unless it can be demonstrated that a safe temperature limit cannot be exceeded.

5-16.2 Operation of the excess temperature limit controller shall cut off the source of heat before the safe temperature is exceeded.

5-16.3 Operation of the excess temperature limit controller shall require manual reset before restart of the furnace or affected furnace zone.

5-16.4 Failure of the temperature-sensing element of the excess temperature limit controller shall cause the same response as an excess temperature condition.

CAUTION

Where a thermocouple is used with an excess temperature limit controller, ruggedly constructed and conservatively rated thermocouples and extension wires shall be used to minimize the probability of a short circuit in the thermocouple or thermocouple extension wires. Thermocouple short circuits should not result in the action required by 5-16.4.

5-16.5 The temperature-sensing element of the excess temperature limit controller shall be suitable for the temperature and atmosphere to which it is exposed.

5-16.6 The temperature-sensing element of the excess temperature limit controller shall be located to sense the temperature most critical to safe operation.

5-16.7 The excess temperature limit controller set point shall be displayed or clearly marked in units of temperature (°F or °C).

5-16.8 The operating temperature controller and its temperature-sensing element shall not be used as the excess temperature limit controller.

5-17 1400°F (760°C) Bypass Controller.

5-17.1 Where permitted in accordance with 5-9.1 to switch the flame supervision out of the combustion safety circuitry or to bring unsupervised burners on-line, a 1400°F (760°C) bypass controller shall be used.

5-17.2 Failure of the temperature-sensing element shall cause the same response as an operating temperature less than 1400°F (760°C).

5-17.3 The temperature-sensing element of the 1400°F (760°C) bypass controller shall be suitable for the temperature and atmosphere to which it is exposed.

5-17.4 The temperature-sensing element of the 1400°F (760°C) bypass controller shall be located to sense the temperature most critical to safe operation.

5-17.5 The 1400°F (760°C) bypass controller set point shall not be set below 1400°F (760°C), and the set point shall be displayed or clearly marked in units of temperature (°F or °C).

5-17.6 Visual indication shall be provided to indicate when the 1400°F (760°C) bypass controller is in the bypass mode.

5-17.7 The operating temperature controller and its temperature-sensing element shall not be used as the 1400°F (760°C) bypass controller.

5-18 Electrical Heating Systems.

5-18.1 Heating Equipment Controls.

5-18.1.1* Electric heating equipment shall be equipped with a main disconnect device or with multiple devices to provide backup circuit protection to equipment and to persons servicing the equipment. Such a disconnecting device(s) shall be made capable of interrupting maximum available fault current as well as rated load current. *(See NFPA 70, National Electrical Code.)*

5-18.1.2 Shutdown of the heating power source shall not inadvertently affect the operation of equipment such as conveyors, ventilation or recirculation fans, cooling components, and other auxiliary equipment.

5-18.1.3 Branch Circuits. Branch circuits and branch circuit protection for all electrical circuits in the furnace heating system shall be provided in accordance with NFPA 70, *National Electrical Code*, and with NFPA 79, *Electrical Standard for Industrial Machinery*.

Exception: The requirements for resistance heaters larger than 48 amperes to be broken down into subdivided circuits not to exceed 48 amperes shall not apply to industrial ovens and furnaces.

5-18.1.4* The capacity of all electrical devices used to control energy for the heating load shall be selected on the basis of continuous duty load ratings where fully equipped for the location and type of service proposed.

5-18.1.5 All controls using thermal protection or trip mechanisms shall be located or protected to preclude faulty operation due to ambient temperatures.

5-18.2* Excess Temperature Limit Controller.

5-18.2.1 An excess temperature limit controller shall be provided and interlocked into the heating control circuitry.

Exception: Where it can be demonstrated that a safe temperature limit cannot be exceeded.

5-18.2.2 Operation of the excess temperature limit controller shall cut off the source of heat before the safe temperature is exceeded.

5-18.2.3 Operation of the excess temperature limit controller shall require manual reset before restart of the furnace or affected furnace zone.

5-18.2.4 Failure of the temperature-sensing element of the excess temperature limit controller shall cause the same response as an excess temperature condition.

CAUTION

Where a thermocouple is used with an excess temperature limit controller, ruggedly constructed and conservatively rated thermocouples and extension wires shall be used to minimize the probability of a short circuit in the thermocouple or thermocouple extension wires. Thermocouple short circuits should not result in the action required by 5-18.2.4.

5-18.2.5 The temperature-sensing element of the excess temperature limit controller shall be suitable for the temperature and atmosphere to which it is exposed.

5-18.2.6 The temperature-sensing element of the excess temperature limit controller shall be located to sense the temperature most critical to safe operation.

5-18.2.7 The excess temperature limit controller set point shall be displayed or clearly marked in units of temperature (°F or °C).

5-18.2.8 The operating temperature controller and its temperature-sensing element shall not be used as the excess temperature limit controller.

5-19* Fluid-Heated Systems — Excess Temperature Limit Controller.

5-19.1 Where a fluid-heated system can cause an excess temperature condition within the oven served, an excess temperature limit controller shall be provided and interlocked to interrupt the supply of heat transfer fluid to the oven.

5-19.2* Interrupting the supply of heat transfer fluid to an oven shall not cause an unsafe condition to the remainder of the heat transfer system.

5-19.3 Operation of the excess temperature limit controller shall cut off the source of heat before the safe temperature is exceeded.

5-19.4 Operation of the excess temperature limit controller shall require manual reset before re-establishing the flow of heat transfer fluid.

5-19.5 Failure of the temperature-sensing element of the excess temperature limit controller shall cause the same response as an excess temperature condition.

CAUTION

Where a thermocouple is used with an excess temperature limit controller, ruggedly constructed and conservatively rated thermocouples and extension wires shall be used to minimize the probability of a short circuit in the thermocouple or thermocouple extension wires.

5-19.6 The temperature-sensing element of the excess temperature limit controller shall be suitable for the temperature and atmosphere to which it is exposed.

5-19.7 The temperature-sensing element of the excess temperature limit controller shall be located to sense the temperature most critical to safe operation.

5-19.8 The excess temperature limit controller set point shall be displayed or clearly marked in units of temperature (°F or °C).

5-19.9 The operating temperature controller and its temperature-sensing element shall not be used as the excess temperature limit controller.

Chapter 6 Fume Incinerators

6-1 General.

6-1.1* The design and construction of fume incinerators shall comply with all requirements of Class A ovens in this standard.

Exception: The requirements for explosion relief shall not apply to fume incinerators.

6-1.2 Special precautions shall be taken to reduce the fire hazards where the relative location of equipment or the type of fumes generated are such that combustible liquids can condense or solids can be deposited between the generating process and the afterburner. *(See Chapters 3 and 11.)*

6-2* Direct-Fired Fume Incinerators.

6-2.1* The design and operation of combustion systems and controls shall comply with all parts of this standard pertaining to direct-fired ovens.

6-2.2* An excess temperature limit controller shall be provided to prevent the uncontrolled temperature rise in the fume incinerator. Operation of the excess temperature limit controller shall interrupt fuel to the fume incinerator burner and shall interrupt the source of fumes to the incinerator.

6-3 Direct Heat Recovery Systems.

6-3.1 An adequate supply of proven fresh air shall be introduced into the system to provide the oxygen necessary for combustion of hydrocarbons as well as primary burner fuel. Fresh air shall be introduced through openings that supply air directly to each zone circulating system.

6-3.2 Where direct heat recovery systems are employed and portions of the incinerator exhaust gases are utilized as the heat source for one or more of the zones of the fume-generating oven, special precautions shall be taken to prevent recycling unburned solvent vapors.

6-4* Catalytic Fume Incinerators.

6-4.1 The requirements in Section 6-2 for direct-fired fume incinerators shall apply to catalytic fume incinerators.

6-4.2* An additional excess temperature limit controller shall be located downstream from the discharge of the catalyst bed for thermal protection of the catalyst elements. Operation of the excess temperature limit controller shall interrupt fuel to the burner and shall interrupt the source of fumes.

6-4.3* Sufficient process exhaust ventilation shall be provided to maintain vapor concentrations that cannot generate temperatures at which thermal degradation of the catalyst can occur.

6-4.4* A differential pressure (ΔP) high limit switch, measuring across the catalyst bed, shall be used to detect particulate contamination. Operation of the high limit differential pressure switch shall interrupt fuel to the fume incinerator burner and shall interrupt the source of fumes to the incinerator.

6-4.5* Where catalysts are utilized with direct heat recovery, a maintenance program shall be established, and frequent tests of catalyst performance shall be conducted so that unburned or partially burned vapors are not reintroduced into the process oven.

Chapter 7 Safety Ventilation for Class A Ovens

7-1 Scope.

7-1.1 Safety ventilation within the scope of this chapter shall be a supply of fresh air and exhaust to a safe location with air recirculation to ensure that the flammable vapor concentration in all parts of the oven or dryer enclosure remain below the lower explosive limit (LEL) at all times. Although higher concentrations of flammable vapor are present at the point of evaporation, air circulation shall be used to minimize the volume of this higher concentration region.

7-1.2 The requirements of Chapters 1 through 5 and Chapters 10 and 11 shall apply except as amended by this chapter.

7-1.3 Combustible solids or substrate material shall not require safety ventilation unless flammable constituents are evolved in the process of heating.

7-2 General.

7-2.1 The determination of safety ventilation shall be based on all of the following:

(1) Volume of products of combustion entering the oven heating chamber
(2) Weight or volume of flammable or combustible constituents released during the heating process, based on maximum loading
(3) Solvent that requires the greatest amount of ventilation air per gallon (liter) when a combination of solvents is used
(4) Design of the oven heating and ventilation system with regard to all of the following:
   a. Materials to be processed
   b. Temperature to which these materials are raised
   c. Method of heating with regard to direct or indirect venting of combustion products vs. alternate use of steam or electrical energy
   d. General design of the oven with regard to continuous or batch-type operation
   e. Type of fuel and chemicals to be used and any by-products that are generated in the heating chamber

7-2.2 On completion of an oven installation, airflow tests shall be conducted on the ventilation systems under the oven operating conditions, with flow control devices at their minimum setting. These tests shall be repeated when the flammable or combustible vapor loadings are increased, or when modifications are made to the ventilation system.

7-2.3 Safety ventilation shall be maintained until all flammable vapors are removed or have been released from the oven and other associated equipment.

7-2.4 Heat Recovery and Pollution Control Devices.

7-2.4.1 The installation of heat recovery devices and pollution control devices shall not reduce the volume of safety ventilation.

7-2.4.2 Heat recovery devices and pollution control devices shall be designed and maintained to prevent reduction or loss of safety ventilation due to such factors as the condensation of flammable volatiles and foreign materials.

7-2.4.3 Heat recovery devices and pollution control devices shall be designed to minimize fire hazards due to the presence of combustible products or residue.

7-2.5* Class A ovens shall be mechanically ventilated. If reduction of safety ventilation by accumulation of deposits is possible for the oven's intended use, then the fan design shall be selected to prevent this accumulation.

7-2.6 Class A ovens shall be ventilated directly to outdoor atmosphere or indirectly to outdoor atmosphere through a fume incinerator in accordance with Chapter 6 or through other approved volatile organic compound (VOC) pollution control devices.

7-2.7 Exhaust duct openings shall be located in the area of greatest concentration of vapors within the oven enclosure.

Table 7-4.1 Temperature–Volume Conversion Table (At Sea Level)

Temp.			Temp.			Temp.		
°F	**°C**	**Factor**	**°F**	**°C**	**Factor**	**°F**	**°C**	**Factor**
70	21	1	350	177	1.53	950	510	2.66
100	38	1.06	400	204	1.62	1000	538	2.75
110	43	1.075	450	232	1.72	1050	566	2.85
120	49	1.09	500	260	1.81	1100	593	2.94
130	54	1.11	550	288	1.90	1150	621	3.04
140	60	1.13	600	316	2.00	1200	649	3.13
150	66	1.15	650	343	2.09	1250	677	3.23
175	79	1.20	700	371	2.19	1300	704	3.32
200	93	1.24	750	399	2.28	1350	732	3.42
225	107	1.29	850	454	2.47	1400	760	3.51
250	121	1.34	900	482	2.57			
275	135	1.38						
300	149	1.43						

7-2.8* A single fan shall not be used for both recirculation and exhaust.

7-2.9 Multiple exhaust fans, manifolded together, shall be designed so that the operation of one or more exhaust fans shall not create a hazard, such as backflow to an idle oven or reduced exhaust flow due to increased manifold pressure.

7-2.10 Ovens in which the temperature is controlled by varying airflow shall be designed so that the air required for safety ventilation is maintained during all operating conditions.

7-2.11 A separate exhaust fan shall be used for exhausting the products of combustion from indirect gas- or oil-fired air heaters.

Exception: On small indirect-fired installations, subject to the approval of the authority having jurisdiction, it shall be permitted to connect the heater exhaust to the oven exhaust system, provided that the temperature of the products of combustion is reduced (when necessary) by the addition of fresh air to a point where it is insufficient to cause ignition of any combustible fumes in the oven exhaust system.

7-2.12* Air supplied into the oven shall be circulated to produce a thorough distribution and movement in all parts of the oven and through the work in process.

7-2.13 Interlocks.

7-2.13.1 Interlocks for exhaust and recirculation fans shall be installed in accordance with Sections 5-5 and 5-6.

7-2.13.2 Electrical interlocks obtained through interconnection with a motor starter shall be provided for exhaust and recirculation fans.

7-2.14 Conveyors or sources of flammable or combustible material shall be interlocked to shut down on excess temperature or if either the exhaust or recirculation system fails.

7-3 Fresh Air Supply and Exhaust.

7-3.1 Ovens in which flammable vapors are being produced or into which the products of combustion are allowed to enter shall be exhausted.

7-3.2 Ovens heated by any means, including electricity, infrared lamps, or by combustion of any fuel shall have the exhaust fan motor starter and airflow switch interlocked in such a manner as to prevent operation of the heating units unless the exhaust fans are running.

7-3.3 Flow control devices that affect the volume of fresh air admitted to and the vapors or gases exhausted from the oven shall be designed so that, when at the minimum setting, they pass the volume required for safety ventilation.

7-4 Corrections for Temperature and Altitude.

7-4.1* Temperature Correction Factor. Temperature correction factors for volume shall be applied because the volume of gas varies in direct proportion to its absolute temperature. Volume correction factors shall be determined in accordance with the following relationship, or Table 7-4.1:

$$\frac{t°\text{F} + 460°\text{F}}{70°\text{F} + 460°\text{F}} = \text{correction factor (U.S. customary units)}$$

where:
t = exhaust temperature

or

$$\frac{t°\text{C} + 273°\text{C}}{21°\text{C} + 273°\text{C}} = \text{correction factor (SI units)}$$

where:
t = exhaust temperature

7-4.2* LEL Correction Factor. The LEL value for continuous process ovens shall be corrected for the oven operating temperature in accordance with the following formula, or Table 7-4.2:

$$\text{LEL}_t = \text{LEL}_{77°\text{F}}\,[1 - 0.000436(t°\text{F} - 77°\text{F})]$$

or

$$\text{LEL}_t = \text{LEL}_{25°\text{C}}\,[1 - 0.000784(t°\text{C} - 25°\text{C})]$$

where:
t = oven temperature, °F or °C

For batch process ovens, the temperature multiplier specified in 7-6.4 shall be used.

Table 7-4.2 Oven Temperature Correction Factors

Oven Temperature		LEL Correction Factor
°F	°C	
77	25	1.00
212	100	0.94
300	149	0.90
400	204	0.86
500	260	0.81

Table 7-4.3 Altitude Correction Factors

Altitude		Correction Factor
ft	m	
0	0	1.00
1,000	305	1.04
2,000	610	1.08
3,000	915	1.12
4,000	1220	1.16
5,000	1524	1.20
6,000	1829	1.25
7,000	2134	1.30
8,000	2438	1.35
9,000	2743	1.40
10,000	3048	1.45

7-4.3 Altitude Correction Factor. Altitude correction factors for volume shall be applied because the volume of a gas varies in direct proportion to the barometric pressure. Correction values shall be obtained from Table 7-4.3.

Exception: Correction factors shall not be required at altitudes below 1000 ft (305 m) above sea level.

7-5* Continuous Process Oven.

7-5.1* Rate of Solvent Vapor Ventilation. In continuous process ovens, the safety ventilation rate shall be designed, maintained, and operated to prevent the vapor concentration in the oven exhaust from exceeding 25 percent of the LEL.

Exception: The safety ventilation rate shall be permitted to be decreased where a continuous solvent vapor concentration indicator and controller is provided in accordance with Section 7-7. For such installations, the continuous indicator and controller shall be arranged to alarm and shut down the oven heating systems or operate additional exhaust fans at a predetermined vapor concentration that shall not exceed 50 percent of the LEL.

7-5.2 Method for Determining Solvent Safety Ventilation Rate.

7-5.2.1 The safety ventilation shall be determined by calculation in accordance with 7-5.2.3.

Exception: As permitted by 7-5.2.4.

7-5.2.2* Chemical properties listed in Tables 7-5.2.2(a) and (b) shall be used where chemical manufacturer's data are not available.

7-5.2.3* Method for Calculating Solvent Safety Ventilation Rate. In continuous process ovens, when the rate of safety ventilation air is calculated, the following method shall be used:

(1) One gallon of water weighs 8.328 lb at 70°F. One liter of water weighs 0.998 kg at 21°C.
(2) Dry air at 70°F and 29.9 in. Hg weighs 0.075 lb/ft^3. Dry air at 21°C and 0.76 m Hg weighs 1.200 kg/m^3.
(3) $SpGr$ = specific gravity of solvent (water = 1.0).
(4) VD = vapor density of solvent vapor (air = 1.0).
(5) LEL_T = lower explosive limit expressed in percent by volume in air, corrected for temperature.
(6) Ventilation factor of safety = four times volume calculated to be barely explosive.

U.S. Customary Units:

$$\left(\frac{8.328}{0.075}\right)\left(\frac{SpGr}{VD}\right) = \text{ft}^3 \text{ vapor/gal of solvent}$$

$$\left(\frac{\text{ft}^3 \text{ vapor}}{\text{gal solvent}}\right)\left(\frac{100 - \text{LEL}_T}{\text{LEL}_T}\right)$$

= ft^3 of barely explosive mixture/gal solvent

$$4\left(\frac{\text{ft}^3 \text{ mixture}}{\text{gal solvent}}\right)$$

= ft^3 of diluted mixture at 25% LEL_T per gal of solvent evaporated in process

Thus:

$$4\left(\frac{8.328}{0.075}\right)\left(\frac{SpGr}{VD}\right)\left(\frac{100 - \text{LEL}_T}{\text{LEL}_T}\right)$$

= ft^3 of safety ventilation air at 25% LEL_T per gal of solvent evaporated

The volume of fresh air required for safety ventilation is obtained by multiplying the factor calculated above by the gallons per minute of solvent evaporated in the oven. The resultant value is expressed as standard cubic feet per minute (scfm) of ventilation. This value is to be corrected for the temperature of the exhaust stream exiting the oven enclosure as well as for altitude with the result being actual cubic feet per minute (acfm).

SI Units:

$$\left(\frac{0.998}{1.200}\right)\left(\frac{SpGr}{VD}\right) = \text{m}^3 \text{ vapor/L of solvent}$$

$$\left(\frac{\text{m}^3 \text{ vapor}}{\text{L solvent}}\right)\left(\frac{100 - \text{LEL}_T}{\text{LEL}_T}\right)$$

= m^3 of barely explosive mixture/L of solvent

$$4\left(\frac{\text{m}^3 \text{ mixture}}{\text{L solvent}}\right)$$

= m^3 of diluted mixture at 25% LEL_T per L of solvent evaporated in process

Thus:

$$4\left(\frac{0.998}{1.200}\right)\left(\frac{SpGr}{VD}\right)\left(\frac{100 - \text{LEL}_T}{\text{LEL}_T}\right)$$

= m^3 of safety ventilation air at 25% LEL_T per L of solvent evaporated

The volume of fresh air required for safety ventilation is obtained by multiplying the factor calculated above by the liters per minute of solvent evaporated in the oven. The resultant value is expressed as standard cubic meters per minute (standard m^3/min) of ventilation. This value is to be corrected for the temperature of the exhaust stream exiting the oven enclosure as well as for altitude, with the result being actual cubic meters per minute (actual m^3/min).

7-5.2.4* Method for Estimating Solvent Safety Ventilation Rate. In continuous process ovens, where the elevation is below 1000 ft (305 m) and the oven operating temperature is at or below 350°F (177°C), and the volume of air rendered barely flammable for the solvent used is less than 2640 standard ft^3/gal (19.75 standard m^3/L), the rate of safety ventilation for volatile materials shall be a minimum of 12,000 ft^3 (340 m^3) of fresh air referred to 70°F (21°C) (at sea level) per gal (L) of solvent evaporated in the oven. This value shall be corrected for the temperature of the exhaust stream exiting the oven.

7-5.3 Method for Calculating Ventilation Rate for Products of Combustion. In continuous process ovens, including powder coating ovens, where a direct-fired combustion system (within or remote from the oven chamber) is used, the minimum oven exhaust volume for safety ventilation shall include the volume of combustion products from burners. The value used for the products of combustion shall be 183 scfm (5.18 standard m^3/min) per 1,000,000 Btu/hr (293.1 kW) burner rating. The products of combustion shall be adjusted for oven operating temperature and altitude. This value shall be added to the value determined from 7-5.2.

7-5.4* Method for Calculating Ventilation Rate for Powder Curing Ovens. The safety ventilation required for powder curing ovens shall be calculated by assuming that 9 percent of the mass of the powder is xylene and the remaining mass is inert. The safety ventilation shall then be determined for xylene in accordance with 7-5.2. and 7-5.3.

7-6* Batch Process Ovens.

7-6.1 Chemical properties listed in Tables 7-5.2.2(a) and (b) shall be used where chemical manufacturer's data are not available.

7-6.2* Method for Estimating Rate of Ventilation. In batch ovens, the safety ventilation rate shall be designed and maintained to provide at least 440 scfm of air per gal (3.29 standard m^3/min of air per L) of flammable volatiles in each batch.

Exception No. 1: As permitted in 7-6.3.

Exception No. 2: For solvents where the quantity of air necessary to render 1 gal (1 L) of solvent barely explosive exceeds 2640 ft^3 (19.75 m^3), safety ventilation shall be adjusted in proportion to the ratio of the actual volume of air necessary to render 1 gal (1 L) of these solvents barely explosive to 2640 ft^3 (19.75 m^3).

CAUTION

Caution shall be used where applying this method to products of low mass that can heat up quickly (such as paper or textiles) or materials coated with very highly volatile solvents. Either condition can produce too high a peak evaporation rate for this method to be used.

7-6.3 Method for Calculating Ventilation Rate. The 440 scfm of air per gal (3.29 standard m^3/min of air per L) of solvent shall be used unless the maximum evaporation rate is determined by tests run under actual operating conditions. Ventilation shall be furnished, with exhaust fans and other devices maintained and operating, to prevent average concentration in the oven from exceeding 25 percent of the LEL.

Exception No. 1: The safety ventilation rate shall be permitted to be decreased where a continuous solvent vapor concentration indicator and controller is provided in accordance with Section 7-7. For such installations, the continuous monitor and controller shall be arranged to alarm and shut down the oven heating system or operate additional exhaust fans at a predetermined vapor concentration that shall not exceed 50 percent of the LEL.

Exception No. 2: The safety ventilation shall be permitted to be calculated by determining the amount of ventilation air in scf (standard m^3) that is rendered barely flammable by the vapor generated in gal per hour (L per hour) of solvent in use. This value shall then be multiplied by an empirical factor of 10 and divided by 60 to obtain the safety ventilation in scfm (standard m^3/min).

Table 7-5.2.2(a) Properties of Commonly Used Flammable Liquids in U.S. Customary Units

Solvent Name	Molecular Weight	Flash Point °F	Auto Ignition °F	LEL% by Volume	UEL% by Volume	Specific Gravity Water = 1	Vapor Density Air = 1	Boiling Point °F	Lb per Gal	scf Vapor per gal	scf Vapor per lb	scf Air at LEL per gal
Acetone	58	–4	869	2.5	12.8	0.79	2.0	133	6.58	43.9	6.67	1712
n-Amyl Acetate	130	60	680	1.1	7.5	0.88	4.5	300	7.33	21.8	2.98	1961
sec-Amyl Acetate	130	89		1.0	7.5	0.88	4.5	249	7.33	21.8	2.98	2159
Amyl Alcohol	88	91	572	1.2 at 212°F	10.0 at 212°F	0.82	3.0	280	6.83	30.0	4.40	2472
Benzene	78	12	928	1.2	7.8	0.88	2.8	176	7.33	35.0	4.78	2885
Benzine	Mix	0	550	1.1	5.9	0.64	2.5		5.33	28.5	5.35	2566
n-Butyl Acetate	116	72	797	1.7	7.6	0.88	4.0	260	7.33	24.4	3.34	1413
n-Butyl Alcohol	74	98	650	1.4	11.2	0.81	2.6	243	6.75	35.3	5.23	2484
sec-Butyl Alcohol	74	75	761	1.7 at 212°F	9.8 at 212°F	0.81	2.6	201	6.75	35.3	5.23	2039
Butyl Cellosolve	118	148	472	1.1 at 200°F	12.7 at 275°F	0.90	4.1	340	7.50	24.6	3.28	2209
Butyl Propionate	130	90	799			0.88	4.5	295	7.33	21.8	2.98	
Camphor	152	150	871	0.6	3.5	0.99	5.2	399	8.24	21.1	2.55	3489
Carbon Disulfide	76	–22	194	1.3	50.0	1.26	2.6	115	10.49	53.4	5.09	4056
Cellosolve	90	110	455	1.7 at 200°F	15.6 at 200°F	0.93	3.0	275	7.75	34.6	4.46	1998
Cellosolve Acetate	132	124	715	1.7	13.0	0.98	4.7	313	8.16	23.1	2.84	1338
Chlorobenzene	113	82	1099	1.3	9.6	1.11	3.9	270	9.24	31.6	3.42	2403
Corn Oil	Mix	490	740			0.90			7.50			
Cottonseed Oil	Mix	486	650			0.90			7.50			
m-Cresol or p-Cresol	108	187	1038	1.1 at 302°F		1.03	3.7	395	8.58	30.7	3.58	2763
Cyclohexane	84	–4	473	1.3	8.0	0.78	2.9	179	6.50	29.9	4.61	2271
Cyclohexanone	98	111	788	1.1 at 212°F	9.4	0.95	3.4	313	7.91	31.2	3.95	2808
p-Cymene	134	117	817	0.7 at 212°F	5.6	0.86	4.6	349	7.16	20.7	2.93	2933
Dibutyl Phthalate	278	315	757	0.5 at 456°F		1.04	9.6	644	8.66	12.1	1.41	2399
o-Dichlorobenzene	147	151	1198	2.2	9.2	1.31	5.1	356	10.91	28.7	2.67	1276
Diethyl Ketone	86	55	842	1.6		0.81	3.0	217	6.75	30.3	4.56	1866
n-Dimethyl Formamide	73	136	833	2.2 at 212°F	15.2	0.94	2.5	307	7.83	41.5	5.37	1844
p-Dioxane	88	54	356	2.0	22.0	1.03	3.0	214	8.58	37.7	4.45	1848
Ethyl Acetate	88	24	800	2.0	11.5	0.90	3.0	171	7.50	33.0	4.45	1615
Ethyl Alcohol	46	55	685	3.3	19.0	0.79	1.6	173	6.58	55.3	8.52	1621
Ethylbenzene	106	59	810	0.8	6.7	0.87	3.7	277	7.25	26.4	3.70	3279
Ethyl Ether	74	–49	356	1.9	36.0	0.71	2.6	95	5.91	30.9	5.30	1596

Table 7-5.2.2(a) Properties of Commonly Used Flammable Liquids in U.S. Customary Units *(Continued)*

Solvent Name	Molecular Weight	Flash Point °F	Auto Ignition °F	LEL% by Volume	UEL% by Volume	Specific Gravity Water = 1	Vapor Density Air = 1	Boiling Point °F	Lb per Gal	scf Vapor per gal	scf Vapor per lb	scf Air at LEL per gal
Ethyl Lactate	118	115	752	1.5 at 212°F		1.04	4.1	309	8.66	28.4	3.32	1865
Ethyl Methyl Ether	60	–35	374	2.0	10.1	0.70	2.1	51	5.8	37.6	6.53	1842
Ethyl Propionate	102	54	824	1.9	11.0	0.89	3.5	210	7.4	28.1	3.84	1452
Ethylene Dichloride	99	56	775	6.2	16.0	1.30	3.4	183	10.8	42.3	3.96	640
Gasoline	Mix	–45	536	1.4	7.6	0.80	3.0–4.0		6.7	29.7	4.46	2094
n-Heptane	100	25	399	1.0	6.7	0.68	3.5	209	5.7	21.9	3.92	2169
n-Hexane	86	–7	437	1.1	7.5	0.66	3.0	156	5.5	24.7	4.56	2223
Kerosene (Fuel Oil #1)	Mix	100–162	410	0.7	5.0	0.83			6.9			
Linseed Oil — Raw	Mix	432	650			0.93		600	7.7			
Magiesol 47	203	215	428	0.5		0.80	7.0	464	6.7	12.7	1.91	2527
Magiesol 52	236	265	428	0.5		0.81	8.2	518	6.7	11.1	1.64	2201
Methyl Acetate	74	14	850	3.1	16.0	0.93	2.8	140	7.7	37.0	5.30	1157
Methyl Alcohol	32	52	725	6.0	36.0	0.79	1.1	147	6.6	79.5	12.25	1246
Methyl Carbitol	120	205	465	1.4	22.7	1.01	4.1	379	8.4	27.2	3.27	1945
Methyl Cellosolve	76	102	545	1.8	14.0	0.96	2.6	255	8.0	40.7	5.16	2220
Methyl Cellosolve Acetate	118	111		1.7	8.2	1.01	4.1	292	8.4	27.6	3.32	1595
Methyl Ethyl Ketone	72	16	759	1.4 at 200°F	11.4 at 200°F	0.80	2.5	176	6.7	35.8	5.44	2521
Methyl Lactate	104	121	725	2.2 at 212°F		1.10	3.6	293	9.2	34.1	3.77	1515
Mineral Spirits #10	Mix	104	473	0.8 at 212°F		0.80	3.9	300	6.7	22.9	3.43	2836
Naptha (VM&P Regular)	Mix	28	450	0.9	6.0			203–320				
Napthalene	128	174	979	0.9	5.9	1.10	4.4	424	9.2	27.7	3.06	3049
Nitrobenzene	123	190	900	1.8 at 200°F		1.25	4.3	412	10.4	32.7	3.19	1786
Nitroethane	75	82	778	3.4		1.04	2.6	237	8.7	44.7	5.23	1269
Nitromethane	61	95	785	7.3		1.13	2.1	214	9.4	59.7	6.43	758
Nitropropane-1	89	96	789	2.2		1.00	3.1	268	8.3	36.2	4.40	1609
Nitropropane-2	89	75	802	2.6	11.0	0.99	3.1	248	8.2	35.8	4.40	1343
Paraffin Oil	Mix	444				0.83–0.91						
Peanut Oil	Mix	540	833			0.90			7.5			
Perchloroethylene	166	None	None	None		1.62	5.8	250	13.5	31.1	2.36	
Petroleum Ether	Mix	<0	550	1.1	5.9	0.66	2.5		5.5	29.4	5.35	2646
Propyl Acetate	102	55	842	1.7 at 100°F	8.0	0.89	3.5	215	7.4	28.1	3.84	1626
n-Propyl Alcohol	60	74	775	2.2	13.7	0.80	2.1	207	6.7	43.0	6.53	1910

(continues)

Table 7-5.2.2(a) Properties of Commonly Used Flammable Liquids in U.S. Customary Units *(Continued)*

Solvent Name	Molecular Weight	Flash Point °F	Auto Ignition °F	LEL% by Volume	UEL% by Volume	Specific Gravity Water = 1	Vapor Density Air = 1	Boiling Point °F	Lb per Gal	scf Vapor per gal	scf Vapor per lb	scf Air at LEL per gal
i-Propyl Alcohol	60	53	750	2.0	12.7 at 200°F	0.78	2.1	181	6.5	41.9	6.53	2052
n-Propyl Ether	102	70	370	1.3	7.0	0.75	3.5	194	6.2	23.7	3.84	1798
Pyridine	79	68	900	1.8	12.4	0.98	2.7	239	8.2	40.0	4.96	2180
Rosin Oil	Mix	266	648			1.00		680	8.3			
Soy Bean Oil	Mix	540	833			0.90			7.5			
Tetrahydrofuran	72	6	610	2.0	11.8	0.89	2.5	151	7.4	39.8	5.44	1952
Toluene	92	40	896	1.1	7.1	0.87	3.1	231	7.2	31.1	4.26	2800
Turpentine	136	95	488	0.8		0.87	4.7	300	7.2	20.6	2.88	2556
Vinyl Acetate	86	18	756	2.6	13.4	0.93	3.0	161	7.7	34.8	4.56	1305
o-Xylene	106	88	867	0.9	6.7	0.88	3.7	292	7.3	26.7	3.70	2945

Table 7-5.2.2(b) Properties of Commonly Used Flammable Liquids in Metric Units

Solvent Name	Molecular Weight	Flash Point °C	Auto Ignition °C	LEL% by Volume	UEL% by Volume	Specific Gravity Water = 1	Vapor Density Air = 1	Boiling Point °C	Kg per L	scm Vapor per L	scm Vapor per kg	scm Air at LEL per L
Acetone	58	–20	465	2.5	12.8	0.79	2.0	56	0.788	0.329	0.418	12.84
n-Amyl Acetate	130	16	360	1.1	7.5	0.88	4.5	149	0.878	0.164	0.186	14.72
sec-Amyl Acetate	130	32		1.0	7.5	0.88	4.5	131	0.878	0.164	0.186	16.20
Amyl Alcohol	88	33	300	1.2 at 100°C	10.0 at 100°C	0.82	3.0	138	0.818	0.225	0.275	18.55
Benzene	78	–11	498	1.2	7.8	0.88	2.8	80	0.878	0.262	0.298	21.57
Benzine	Mix	0	288	1.1	5.9	0.64	2.5		0.639	0.213	0.334	19.19
n-Butyl Acetate	116	22	425	1.7	7.6	0.88	4.0	127	0.878	0.183	0.209	10.61
n-Butyl Alcohol	74	37	343	1.4	11.2	0.81	2.6	117	0.808	0.265	0.327	18.64
sec-Butyl Alcohol	74	24	405	1.7 at 100°C	9.8 at 100°C	0.81	2.6	94	0.808	0.265	0.327	15.30
Butyl Cellosolve	118	64	244	1.1 at 93°C	12.7 at 135°C	0.90	4.1	171	0.898	0.184	0.205	16.59
Butyl Propionate	130	32	426			0.88	4.5	146	0.879	0.164	0.186	
Camphor	152	66	466	0.6	3.5	0.99	5.2	204	0.988	0.158	0.159	26.10
Carbon Disulfide	76	–30	90	1.3	50.0	1.26	2.6	46	1.258	0.401	0.319	30.44
Cellosolve	90	43	235	1.7 at 93°C	15.6 at 93°C	0.93	3.0	135	0.928	0.259	0.278	14.95
Cellosolve Acetate	132	51	379	1.7	13.0	0.98	4.7	156	0.978	0.174	0.178	10.06
Chlorobenzene	113	28	593	1.3	9.6	1.11	3.9	132	1.108	0.238	0.214	18.04
Corn Oil	Mix	254	393			0.90			0.898			
Cottonseed Oil	Mix	252	343			0.90			0.898			
m-Cresol or p-Cresol	108	86	559	1.1 at 150°C		1.03	3.7	202	1.028	0.231	0.224	20.74

Table 7-5.2.2(b) Properties of Commonly Used Flammable Liquids in Metric Units *(Continued)*

Solvent Name	Molecular Weight	Flash Point °C	Auto Ignition °C	LEL% by Volume	UEL% by Volume	Specific Gravity Water = 1	Vapor Density Air = 1	Boiling Point °C	Kg per L	scm Vapor per L	scm Vapor per kg	scm Air at LEL per L
Cyclohexane	84	–20	245	1.3	8.0	0.78	2.9	82	0.779	0.225	0.288	17.05
Cyclohexanone	98	44	420	1.1 at 100°C	9.4	0.95	3.4	156	0.948	0.234	0.247	21.08
p-Cymene	134	47	436	0.7 at 100°C	5.6	0.86	4.6	176	0.859	0.155	0.181	22.02
Dibutyl Phthalate	278	157	403	0.5 at 236°C		1.04	9.6	340	1.038	0.090	0.087	18.01
o-Dichlorobenzene	147	66	648	2.2	9.2	1.31	5.1	180	1.308	0.216	0.165	9.58
Diethyl Ketone	86	13	450	1.6		0.81	3.0	103	0.809	0.228	0.282	14.01
n-Dimethyl Formamide	73	58	445	2.2 at 100°C	15.2	0.94	2.5	153	0.938	0.311	0.332	13.84
p-Dioxane	88	12	180	2.0	22.0	1.03	3.0	101	1.028	0.283	0.275	13.87
Ethyl Acetate	88	–4	427	2.0	11.5	0.90	3.0	77	0.898	0.247	0.275	12.12
Ethyl Alcohol	46	13	363	3.3	19.0	0.79	1.6	78	0.789	0.415	0.527	12.17
Ethylbenzene	106	15	432	0.8	6.7	0.87	3.7	136	0.869	0.199	0.229	24.62
Ethyl Ether	74	–45	180	1.9	36.0	0.71	2.6	35	0.709	0.232	0.327	11.98
Ethyl Lactate	118	46	400	1.5 at 100°C		1.04	4.1	154	1.038	0.213	0.205	14.00
Ethyl Methyl Ether	60	–37	190	2.0	10.1	0.70	2.1	11	0.699	0.282	0.404	13.83
Ethyl Propionate	102	12	440	1.9	11.0	0.89	3.5	99	0.888	0.211	0.238	10.90
Ethyl Dichloride	99	13	413	6.2	16.0	1.30	3.4	84	1.298	0.318	0.245	4.80
Gasoline	Mix	–43	280	1.4	7.6	0.80	3.0–4.0		0.799	0.222	0.278	15.66
n-Heptane	100	–4	204	1.0	6.7	0.68	3.5	98	0.679	0.164	0.241	16.23
n-Hexane	86	–22	225	1.1	7.5	0.66	3.0	69	0.659	0.186	0.282	16.69
Kerosene (Fuel Oil #1)	Mix	38–72	210	0.7	5.0	0.83			0.829			
Linseed Oil — Raw	Mix	222	343			0.93		316	0.928			
Magiesol 47	203	102	220	0.5		0.80	7.0	240	0.799	0.095	0.119	18.97
Magiesol 52	236	129	220	0.5		0.81	8.2	270	0.809	0.083	0.102	16.46
Methyl Acetate	74	–10	454	3.1	16.0	0.93	2.8	60	0.928	0.277	0.298	8.66
Methyl Alcohol	32	11	385	6.0	36.0	0.79	1.1	64	0.789	0.597	0.757	9.35
Methyl Carbitol	120	96	241	1.4	22.7	1.01	4.1	193	1.008	0.204	0.202	14.55
Methyl Cellosolve	76	39	285	1.8	14.0	0.96	2.6	124	0.958	0.306	0.319	16.67
Methyl Cellosolve Acetate	118	44		1.7	8.2	1.01	4.1	144	1.008	0.207	0.205	11.97
Methyl Ethyl Ketone	72	– 9	404	1.4 at 93°C	11.4 at 93°C	0.80	2.5	80	0.799	0.269	0.336	18.93
Methyl Lactate	104	49	385	2.2 at 100°C		1.10	3.6	145	1.098	0.256	0.233	11.37
Mineral Spirits #10	Mix	40	245	0.8 at 100°C		0.80	3.9	149	0.799	0.171	0.214	21.21

(continues)

Table 7-5.2.2(b) Properties of Commonly Used Flammable Liquids in Metric Units *(Continued)*

Solvent Name	Molecular Weight	Flash Point °C	Auto Ignition °C	LEL% by Volume	UEL% by Volume	Specific Gravity Water = 1	Vapor Density Air = 1	Boiling Point °C	Kg per L	scm Vapor per L	scm Vapor per kg	scm Air at LEL per L
Naptha (VM&P Regular)	Mix	–2	232	0.9	6.0			95–160				
Napthalene	128	79	526	0.9	5.9	1.10	4.4	218	1.098	0.208	0.189	22.89
Nitrobenzene	123	88	482	1.8 at 93°C		1.25	4.3	211	1.248	0.245	0.196	13.36
Nitroethane	75	28	414	3.4		1.04	2.6	114	1.038	0.335	0.323	9.53
Nitromethane	61	35	418	7.3		1.13	2.1	101	1.128	0.448	0.397	5.69
Nitropropane-1	89	36	421	2.2		1.00	3.1	131	0.998	0.272	0.272	12.08
Nitropropane-2	89	24	428	2.6	11.0	0.99	3.1	120	0.988	0.269	0.272	10.08
Paraffin Oil	Mix	229				0.83–0.91						
Peanut Oil	Mix	282	445			0.90			0.898			
Perchloroethylene	166	None	None	None		1.62	5.8	121	1.617	0.233	0.144	
Petroleum Ether	Mix	<–18	288	1.1	5.9	0.66	2.5		0.659	0.220	0.334	19.80
Propyl Acetate	102	13	450	1.7 at 38°C	8.0	0.89	3.5	102	0.888	0.211	0.238	12.20
n-Propyl Alcohol	60	23	413	2.2	13.7	0.80	2.1	97	0.799	0.322	0.404	14.34
i-Propyl Alcohol	60	11	399	2.0	12.7 at 93°C	0.78	2.1	83	0.779	0.314	0.404	15.41
n-Propyl Ether	102	21	188	1.3	7.0	0.75	3.5	90	0.749	0.178	0.238	13.50
Pyridine	79	20	482	1.8	12.4	0.98	2.7	115	0.978	0.300	0.307	16.37
Rosin Oil	Mix	130	342			1.00		360	0.998			
Soy Bean Oil	Mix	282	445			0.90			0.898			
Tetrahydrofuran	72	–14	321	2.0	11.8	0.89	2.5	66	0.888	0.299	0.336	14.65
Toluene	92	4	480	1.1	7.1	0.87	3.1	111	0.869	0.234	0.269	21.04
Turpentine	136	35	253	0.8		0.87	4.7	149	0.869	0.155	0.178	19.19
Vinyl Acetate	86	–8	402	2.6	13.4	0.93	3.0	72	0.928	0.262	0.282	9.80
o-Xylene	106	31	464	0.9	6.7	0.88	3.7	144	0.879	0.201	0.229	22.11

7-6.4* Correction Factors. Volumes of air specified or calculated in accordance with 7-6.2 or 7-6.3 shall be corrected for operating temperature in accordance with 7-4.1, for altitude in accordance with 7-4.3, and for products of combustion in accordance with 7-5.3. In addition, for batch ovens operating at temperatures from 250°F (121°C) to 500°F (260°C), the volume shall be increased by a multiplier of 1.4. For temperatures above 500°F (260°C), the 1.4 correction factor is not appropriate, and the correction factor shall be determined by test.

7-7 Vapor Concentration High Limits and Controllers.

7-7.1 Where the safety ventilation rate in the oven has been designed to result in vapor concentrations between 25 percent and 50 percent of the LEL, a continuous vapor concentration high limit controller shall be provided.

7-7.2* The vapor concentration high limit controller shall be capable of detecting and responding to process upset conditions in time to alarm and prevent oven operation before the concentration exceeds 50 percent of the LEL.

7-7.3* In the case of an oven having multiple ventilation zones and having at least one ventilation zone operating at or above 25 percent of the LEL, all other ventilation zones shall have a solvent vapor concentration controller. For the purposes of this subsection, a ventilation zone shall be any portion of an oven that contains an exhaust duct.

Exception: Where it can be shown that a ventilation zone cannot exceed 25 percent of the LEL in the case of an accidental increase in solvent input, a solvent vapor concentration controller shall not be required for that zone.

7-7.4 If a continuous vapor concentration controller [percent LEL (LFL) analyzer] is used to modulate the flow of fresh air or exhaust from an oven, there shall be a secondary protection system to prevent an analyzer failure from causing a hazardous condition. This system shall have limits on damper travel (set for 50 percent LEL for worst condition) or a second continuous vapor concentration high limit controller.

7-7.5 The continuous vapor concentration indicator and controller system shall be calibrated for the application and solvents used.

7-7.6 Where a variety of solvents are used, the solvent to which the controller is least sensitive shall be the primary calibration reference.

7-7.7 A record of primary and subsequent calibrations shall be maintained and reviewed for drift in the controller response.

7-7.8 Malfunction alarms shall be provided to indicate any sample, flow, circuit, or controller power failures. Activation of a malfunction alarm shall initiate action to reduce the solvent concentration to a minimum. The activation of the malfunction alarm shall require operator intervention in accordance with 7-7.10.

7-7.9* Activation of the high limit alarm shall initiate action to reduce the solvent concentration to a minimum.

7-7.10 When the high limit alarm is activated in accordance with 7-7.9, the process shall be prevented from restarting until the vapor concentration is below the limit level and the operator has manually reset the system.

7-7.11 The sensor and the sample system shall be maintained at a temperature that prevents condensation. Sampling lines shall be clean and airtight.

7-7.12 The system shall be secured against unauthorized adjustment.

7-7.13 Maintenance shall be performed in accordance with manufacturer's instructions.

7-7.14 Calibration shall be performed in accordance with manufacturer's instructions and shall be performed at least once per month.

Chapter 8 Low-Oxygen Atmosphere Class A Ovens with Solvent Recovery

8-1 Scope.

8-1.1 Low-oxygen atmosphere Class A ovens with solvent recovery shall be permitted to operate at much higher concentrations of solvent vapor by limiting oxygen concentration. Oxygen concentration shall be maintained low by the addition of inert gas.

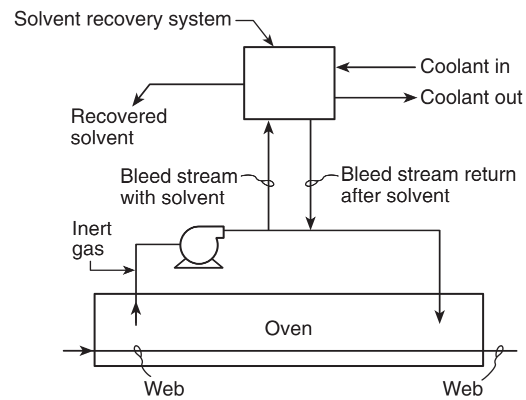
8-1.2* The equipment, including fans and web seals, shall be especially tight to avoid admission of air. *(Figure 8-1.2 is an example of such a system.)*

8-1.3* The high solvent concentrations in these oven atmospheres shall require careful operational and design considerations not normally addressed in conventional solvent evaporation ovens.

8-1.4* The appropriate analytical equipment shall be an oxygen analyzer and controller rather than a solvent vapor analyzer. The response is much slower because coater upsets are not a significant factor. Start-up and shutdown shall avoid the flammable region.

8-1.5* Solvent shall be recovered and sent to a solvent storage system.

Figure 8-1.2 An example of a low-oxygen oven with a solvent recovery system.



8-2 Application. The oven design shall accommodate performance of the following procedures for system operation:

(1) Safe, operational procedures to avoid solvent flammable region at all times
(2) Starting and purging of the oven with inert gas to lower the oxygen content to a predetermined safe level
(3) Heating of the recirculating oven atmosphere to the required process temperature
(4) Introduction of the work load into the oven enclosure
(5) Safe, continuous operation
(6) Safe shutdown procedures to avoid the flammable region of the solvent
(7) Emergency shutdown procedures

8-3 Oven Construction and Location.

8-3.1 The following requirements shall be in addition to those described in Chapter 3.

Exception: Explosion relief shall not be required for this type of oven.

8-3.2 The oven enclosure and any ductwork to and from the enclosure shall be gastight. Access doors shall be gasketed to minimize leakage and shall be designed to prevent opening during operation.

8-3.3* The oven and oven end openings shall be designed to restrict the entrance of air and the exit of solvent vapors.

8-3.4 The oven atmosphere circulation system shall be designed to provide adequate flow throughout the entire oven and ductwork system to avoid condensation of the flammable solvent.

8-4 Inert Gas Generation and Storage Systems.

8-4.1 The oven system shall have an inert gas supply for oxygen control and purging. Inert gas for reduction and control of oxygen within the oven enclosure and associated equipment shall be any of the following types:

(1) Inert gas generators that burn a combustible gas stoichiometrically to produce an inert gas after removal of water vapor
(2) Pressure swing adsorption producing nitrogen
(3) Nitrogen produced by membrane separation equipment
(4) Nitrogen, carbon dioxide, or other inert gases, produced in liquid form. Such liquefied gases are transported to the site and stored in a liquid storage tank. *(See Section 8-5.)*

8-4.2 All storage tanks and compressed gas cylinders shall comply with local, state, and federal codes relating to the types of fluids stored, their pressures, and their temperatures. The applicable NFPA standards shall be followed.

8-4.3 Vessels, controls, and piping that maintain their integrity at the maximum/minimum design pressures and temperatures shall be provided.

8-4.4 ASME tank relief devices shall be provided and sized, constructed, and tested in accordance with ASME *Boiler and Pressure Vessel Code*, Section VIII, Division 1.

8-4.5 Locations for compressed gas tanks and cylinders shall be selected with adequate consideration given to exposure to buildings, processes, personnel, and other storage facilities. Tables of distances specified in the various NFPA standards shall be followed.

8-4.6 Bulk storage systems shall be rated and installed to ensure reliable and uninterrupted flow of inert gas to the user equipment as necessary.

8-4.7 Where inert gases are used as safety purge media, the volume stored always shall be sufficient to purge all connected low-oxygen atmosphere ovens with a minimum of five oven volumes *(see 8-5.1)*. Recirculating fans shall be kept operating during the purge.

Exception: The stored volume shall be permitted to be reduced, provided both of the following conditions are met:

(a) Mixing is adequate.

(b) The stored volume is sufficient to reduce the concentration in the oven to the LEL in air.

8-5 Vaporizers Used for Liquefied Purging Fluids.

8-5.1 Vaporizers utilized to convert cryogenic fluids to the gas state shall be ambient air-heated units so that their flow is unaffected by a loss of power.

Exception: Use of powered vaporizers shall be permitted, provided one of the following conditions is met:

(a) The vaporizer has reserve heating capacity sufficient to continue vaporizing at least five oven volumes at the required purge flow rate immediately following power interruption.

(b) Reserve ambient vaporizers are provided that are piped to the source of supply so as to be unaffected by a freeze-up or flow stoppage of gas from the power vaporizer. The reserve vaporizer shall be capable of evaporating at least five oven volumes at the required purge flow rate.

(c) Purge gas is available from an alternate source that fulfills the requirements of 8-4.6, 8-4.7, 8-5.2, and 8-5.4.

8-5.2 Vaporizers shall be rated by the industrial gas supplier or the owner to vaporize at 150 percent of the highest purge gas demand for all connected equipment. Winter temperature extremes in the locale shall be taken into consideration by the agency responsible for rating them.

8-5.3 It shall be the user's responsibility to inform the industrial gas supplier of additions to the plant that materially increase the inert gas consumption rate so that vaporizer and storage capacity can be enlarged in advance of plant expansion.

8-5.4* The vaporizer shall be protected against flow demands that exceed its rate of capacity when this can cause closure of a low-temperature shutoff valve.

8-5.5 A temperature indicator shall be installed in the vaporizer effluent piping. An audible or visual low-temperature alarm shall be provided to alert oven operators whenever the temperature is in danger of reaching the set point of the low-temperature flow shutoff valve, so they can begin corrective actions in advance of the flow stoppage.

8-6 Inert Gas Flow Rates.

8-6.1 Inert gas shall be required to dilute air infiltration, which otherwise can result in the creation of a flammable gas–air mixture within the oven. The flow rate shall be permitted to be varied during the course of the process cycle.

8-6.2 Reliable means shall be provided for metering and controlling the flow rate of the inert gas.

8-6.3 The flow control shall be accessible and located in an illuminated area so that an operator can readily monitor its operation.

8-6.4 Where an inert gas flow control unit is equipped with an automatic emergency inert purge, a manually operated switch located prominently on the face of the unit, and a remote switch that activates the purge, shall be provided.

8-6.5 The pressure of the inert gas system shall be regulated to avoid overpressurizing components in the system, such as glass tube flow meters.

8-7 Inert Gas Piping System.

8-7.1 The piping system for inert gas shall be sized to allow the full flow of inert gas to all connected ovens at the maximum demand rates.

8-7.2 Solders that contain lead shall not be used to join pipes.

8-7.3* Piping that contains cryogenic liquids, or that is installed downstream of a cryogenic gas vaporizer, shall be constructed of metals that retain adequate strength at cryogenic temperatures.

8-8 Safety Equipment and Application.

8-8.1* The oven shall be analyzed continuously and controlled for oxygen content by modulating the addition of inert gas. The sample point shall be in the condensing system for each zone or multiple zones. The oven shall have a minimum of two analyzers to provide redundancy.

8-8.2 An emergency standby power generator shall be provided for emergency shutdown during a power failure.

Exception: This equipment shall not be required if alternate safety shutdown procedures for power failure are employed.

8-8.3 Provisions shall be made to restrict entry into the oven where the atmosphere could be hazardous to human health. Personnel should be provided with independent analyses of solvent and oxygen concentration before entry. *(See Chapter 10 and Appendix B.)*

8-9 Inert Gas Introduction and Starting the Production Line.

8-9.1 The following items shall be accomplished for inert gas introduction and starting the production line:

(1) The operator shall ensure that all personnel are out of the oven enclosure, all guards are in place, and doors are closed.
(2) The operator shall verify that an adequate volume of inert gas is in storage and the inert gas supply and solvent recovery systems are operational and ready to start production.
(3) The solvent recovery system interfaced with the oven shall be operational and prepared to receive solvent-laden gas prior to starting production.
(4) The recirculation fans shall be started in the oven enclosure prior to introduction of inert gas, which ensures that effective oxygen purging occurs once inert gas enters the enclosure.
(5) The oven enclosure shall be purged with inert gas until the enclosure oxygen concentration is 3 percentage points below the limiting oxidant concentration (LOC) that can support combustion of the solvents used. *(See Table A-8-1.4.)*

8-9.2 The recirculating oven gas shall be heated to the required operating temperature.

8-9.3 The production line shall be started.

8-10 Production Running.

8-10.1 The oven enclosure oxygen concentration shall be maintained at least 3 percentage points below the LOC of the solvent during normal operation. *(See Table A-8-1.4.)*

8-10.2 If the oxygen concentration cannot be maintained at least 1 percentage point below the LOC, the emergency purge shall be activated and the solvent input shall be stopped.

8-10.3 The oven temperature shall not be permitted to approach the solvent dew point temperature in the enclosure, so that solvent vapors do not condense in the oven enclosure.

8-11 Shutting Down the Production Line and Access to the Oven Interior.

8-11.1 The production line shall be stopped.

8-11.2* Flow to and from the solvent recovery system shall be continued and the system shall be purged with inert gas as required until the solvent vapor concentration in the oven enclosure is no greater than the solvent concentration at the LOC. *(See Figure A-8-11.2.)*

8-11.3 Flow to and from the solvent recovery system shall be discontinued and oven heaters shall be de-energized.

8-11.4* Air shall be introduced into the oven enclosure until the oxygen level reaches a minimum of 19.5 percent. Once this level has been reached, enclosure access shall be permitted.

8-12 Emergency Procedures.

8-12.1 In the event of electrical power failure, the emergency standby power source shall provide electric power to the purge blowers and the oven safety controls.

Exception: Emergency standby power source shall not be required if alternate safety procedures for power failures are employed.

8-12.2 The production line shall shut down automatically when the emergency purge cycle is initiated. The oxygen analyzer that initiates the emergency purge cycle shall be hard-wired to bypass all other process control instrumentation.

8-12.3 The oven enclosure shall have an adequate vent line that opens automatically when the emergency purge cycle is initiated in order to avoid pressurizing the oven enclosure. The vent shall discharge to a location away from building makeup air and ignition sources.

8-13* Special Operator Training and Maintenance. Operation and maintenance of a low-oxygen oven and its associated recovery equipment shall be performed by the user in accordance with the manufacturer's recommendations and in accordance with Chapter 10.

Chapter 9 Safety Devices for Arc Melting Furnaces

9-1* General. Safety controls for arc melting furnaces shall be designed to prevent operating the furnace unless safe operating conditions have been established and to shut down the furnace if unsafe conditions should occur during the furnace operations. These controls shall be located to be accessible at all times.

9-2 Safety Devices.

9-2.1 The furnace main disconnect shall be either a circuit breaker or fused switch equipped with all of the following accessories:

(1) Overcurrent relays with inverse time and instantaneous trips
(2) Overcurrent ground-fault relays with inverse time and instantaneous relays
(3) Undervoltage trip relay
(4) Surge protection
(5) Local and remote "close/trip" switches interlocked by a common key so that only one location is capable of being operated at any time

9-2.2 A master lockout switch with a key shall be located at the furnace operator's panel. This switch shall be connected to a circuit breaker by cables that are separated completely from any other wiring. It shall provide a positive lockout and isolation of the circuit breaker, thereby preventing accidental closure of the breaker by grounds in the closing circuit. The key shall be trapped when the switch is ON and shall be free when in the OFF position. This key shall be kept under the supervision of the authorized operator.

9-2.3 Interlocks. Interlocks shall be provided to ensure that all of the following conditions are satisfied before permitting the main disconnect to be closed:

(1) Furnace transformer heat exchangers operating
(2) Oil flowing to furnace heat exchangers (if fitted)
(3) Water flowing to furnace transformer heat exchangers (flow or pressure-proving switch)
(4) Transformer tap changer on "tap" position (if off-load tap changer fitted)
(5) Furnace transformer oil temperature within operating limits
(6) Furnace transformer winding temperature within operating limits
(7) Gas detector registering no gas in transformer tank
(8) Furnace electrode drive control gear on
(9) All supply voltages "on" and within operating limits
(10) Furnace roof and electrode swing within operating limits
(11) Furnace within specified limits of forward and backward tilt
(12) Master lockout switch "on"
(13) Safety shutoff valves on oxygen and fuel lines supplying burners proved closed

9-2.4 Interlocks for Main Furnace Structure.

9-2.4.1 The main furnace structure shall be interlocked where the arc furnace operation includes tilting of the furnace to remove molten metal at the end of the furnace heat. The furnace shall not be tilted during the melt operation, and the following interlocks shall be provided to prevent furnace "tilting" until furnace controls have been proven in a safe position. Interlocks shall be fitted to prevent tilting of the furnace unless both of the following conditions are satisfied:

(1) The roof is down.
(2) The limit switches are at forward and backward limits of travel.

9-2.4.2 Interlocks shall be fitted to prevent swinging of the roof and electrodes unless the following three conditions are satisfied:

(1) The electrode arms are up and clear of shell.
(2) The furnace tilt platform is normal and locked (if fitted).
(3) The roof is raised.

9-2.5 A compressed air line supply for unclamping electrodes shall be fitted with a solenoid valve interlocked with the furnace circuit breaker to ensure that the electrodes cannot be released unless the furnace power is OFF.

9-2.6 For burner ignition with the arc, oxy-fuel and oxygen-enriched air burner controls shall be interlocked with the furnace controls. An isolated contact on the arc furnace controls shall be provided for interconnecting the burner management system to establish that enough current is flowing through the secondary leg of the power transformer to maintain a strong arc in the furnace.

Exception: Operation of a burner shall not be required to be halted in the event of a momentary interruption of the arc, or after arc heating has been intentionally discontinued, provided the contents of the furnace are incandescent or determined to be at a temperature in excess of 1400°F (760°C).*

9-2.7 Oxy-fuel burners installed on arc-metal heating furnaces shall be exempt from the provisions of Chapters 4 and 5 that require both of the following:

(1) Burner flame pilots or igniters
(2) Combustion safeguards (flame supervision)

Chapter 10 Inspection, Testing, and Maintenance

10-1 Responsibility of the Manufacturer and of the User.

10-1.1 The equipment manufacturer shall inform the user regarding the need for operational checks and maintenance and shall provide complete and clear inspection, testing, and maintenance instructions. The final responsibility for establishing an inspection, testing, and maintenance program that ensures that the equipment is in working order shall be that of the user.

10-1.2* When the original equipment manufacturer no longer exists, plant personnel shall develop adequate operational checks and maintenance procedures.

10-2* Equipment Entry. The user's operational and maintenance program shall include procedures that apply to entry into equipment in accordance with all applicable federal, state, and local regulations.

10-3* Checklist. An operational maintenance checklist shall be maintained and is essential to the safe operation of the equipment.

10-4 Cleaning. Foreign material, parts, and residue shall be removed from recirculation blowers, exhaust blowers, heat exchangers, burner and pilot ports, combustion blowers, ductwork, and equipment interiors. Ductwork shall be checked for obstructions. Cleaning frequency shall be determined by process requirements.

10-5 Tension and Wear. Recirculation and exhaust system blowers that are driven by V-belts shall be checked for belt slippage and excessive belt wear. If slippage is detected, belts shall be adjusted or replaced.

10-6 Flammable Loading. It shall be the user's responsibility to prevent the flammable loading from exceeding the safety ventilation design capacity in accordance with 7-2.2.

Chapter 11 Fire Protection

11-1 General.

11-1.1* Ovens containing or processing sufficient combustible materials to sustain a fire shall be equipped with automatic sprinklers or water spray. This shall include sprinklers in the exhaust ducts, where necessary.

11-1.2 Where automatic sprinkler protection in accordance with 11-1.1 is not feasible or where another type of extinguishing means is better suited to provide the required protection, an automatic fire protection system as specified in Section 11-3 shall be provided subject to the approval of the authority having jurisdiction.

11-1.3 Plans showing the arrangement of fixed fire protection installations shall be submitted to the authority having jurisdiction for review and approval before the installation is started.

11-1.4 Dip tanks and drain boards included in the oven enclosure shall be protected in accordance with NFPA 34, *Standard for Dipping and Coating Processes Using Flammable or Combustible Liquids.*

11-2 Automatic Sprinkler and Water Spray Systems.

11-2.1* Automatic Sprinkler Systems. Automatic sprinkler installations shall be in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems.*

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

11-2.2 Water Spray Systems.

11-2.2.1* Water spray systems shall be fixed pipe and automatic in operation in accordance with NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection.*

11-2.2.2 Water spray systems actuated by high-speed detection devices shall be provided to protect the oven work openings where fire in an oven could involve other equipment. Mechanical manual release devices for these systems also shall be provided. Plans showing the arrangement of such protection shall be submitted to the authority having jurisdiction before the installation is started.

11-3 Supplementary Fire Protection.

11-3.1* Carbon Dioxide Extinguishing Systems. Carbon dioxide equipment shall be installed in accordance with NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems.*

11-3.2* Foam Extinguishing Systems. Foam equipment shall be installed in accordance with NFPA 11, *Standard for Low-Expansion Foam.*

11-3.3* Dry Chemical Systems. Dry chemical extinguishing equipment shall be installed in accordance with NFPA 17, *Standard for Dry Chemical Extinguishing Systems.*

11-3.4* Steam Extinguishing Systems.

11-4 Portable Protection Equipment.

11-4.1 Extinguishers. Approved portable extinguishing equipment shall be provided near the oven, oven heater, and related equipment, including dip tanks or other finishing processes operated in conjunction with the oven. Such installations shall be in accordance with NFPA 10, *Standard for Portable Fire Extinguishers.*

11-4.2 Inside Hose Connections. Inside hose protection shall be installed in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*, or NFPA 14, *Standard for the Installation of Standpipe and Hose Systems.*

11-5* Means of Access. Doors or other effective means of access shall be provided in Class A ovens and ductwork so that portable extinguishers and hose streams can be used effectively in all parts of the equipment.

11-6 Inspection, Testing, and Maintenance of Fire Protection Equipment.

11-6.1 All fire protection equipment shall be inspected, tested, and maintained at specified intervals in accordance with the following standards:

NFPA 10, *Standard for Portable Fire Extinguishers*
NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems*
NFPA 17, *Standard for Dry Chemical Extinguishing Systems*
NFPA 17A, *Standard for Wet Chemical Extinguishing Systems*
NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*

11-6.2 Records of inspections and tests shall be kept on forms prepared for this purpose and brought to the attention of management.

11-6.3 Testing shall be done by responsible personnel trained in the operation and maintenance of this type of fire protection equipment.

11-6.4 Outlets. Sprinkler heads and outlets of other extinguishing equipment shall be kept clean and free of deposits under a regular inspection program.

Chapter 12 Referenced Publications

12-1 The following documents or portions thereof are referenced within this standard as mandatory requirements and shall be considered part of the requirements of this standard. The edition indicated for each referenced mandatory document is the current edition as of the date of the NFPA issuance of this standard. Some of these mandatory documents might also be referenced in this standard for specific informational purposes and, therefore, are also listed in Appendix F.

12-1.1 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 10, *Standard for Portable Fire Extinguishers*, 1998 edition.
NFPA 11, *Standard for Low-Expansion Foam*, 1998 edition.
NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems*, 1998 edition.
NFPA 13, *Standard for the Installation of Sprinkler Systems*, 1999 edition.
NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*, 1996 edition.
NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*, 1996 edition.
NFPA 17, *Standard for Dry Chemical Extinguishing Systems*, 1998 edition.
NFPA 17A, *Standard for Wet Chemical Extinguishing Systems*, 1998 edition.
NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*, 1998 edition.
NFPA 31, *Standard for the Installation of Oil-Burning Equipment*, 1997 edition.
NFPA 34, *Standard for Dipping and Coating Processes Using Flammable or Combustible Liquids*, 1995 edition.
NFPA 50, *Standard for Bulk Oxygen Systems at Consumer Sites*, 1996 edition.
NFPA 54, *National Fuel Gas Code*, 1999 edition.
NFPA 58, *Liquefied Petroleum Gas Code*, 1998 edition.
NFPA 70, *National Electrical Code*®, 1999 edition.
NFPA 79, *Electrical Standard for Industrial Machinery*, 1997 edition.
NFPA 86C, *Standard for Industrial Furnaces Using a Special Processing Atmosphere*, 1999 edition.
NFPA 86D, *Standard for Industrial Furnaces Using Vacuum as an Atmosphere*, 1999 edition.
NFPA 91, *Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Noncombustible Particulate Solids*, 1999 edition.

12-1.2 Other Publications.

12-1.2.1 ANSI Publications. American National Standards Institute, Inc., 11 West 42nd Street, 13th floor, New York, NY 10036.

ANSI A14.3, *Safety Requirements for Fixed Ladders*, 1992.
ANSI Z50.1, *Bakery Equipment — Safety Requirements*, 1994.

12-1.2.2 ASME Publications. American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017.

ASME *Boiler and Pressure Vessel Code*, 1998.
ASME B31.1, *Power Piping*, 1995.
ASME B31.3, *Process Piping*, 1996.

12-1.2.3 ASTM Publication. American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM D 396, *Standard Specifications for Fuel Oils*, 1998.

12-1.2.4 U.S. Government Publication. U.S. Government Printing Office, Washington, DC 20402.

Code of Federal Regulations, Title 29, Parts 1910.24 through 1910.29, 1998.

Appendix A Explanatory Material

Appendix A is not a part of the requirements of this NFPA document but is included for informational purposes only. This appendix contains explanatory material, numbered to correspond with the applicable text paragraphs.

A-1-3.2 Because this standard is based on the present state of the art, application to existing installations is not mandatory. Nevertheless, users are encouraged to adopt those features of this standard that are considered applicable and reasonable for existing installations.

A-1-4 Section 1-4 includes requirements for complete plans, sequence of operations, and specifications to be submitted to the authority having jurisdiction for approval. Application forms such as those in Figures A-1-4(a) and (b) can be used or might be requested to help the authority having jurisdiction in this approval process. (Variations of the forms can depend on the type of furnace or oven being furnished, its application, and the authority having jurisdiction.) Figures A-1-4(a) and (b) are two historical examples of application forms that are based on older editions of the standard. Forms consistent with current requirements should be used.

A-1-4.3.1 The proximity of electrical equipment and flammable gas or liquid in an electrical enclosure or panel is a known risk and would be considered a classified area. Article 500 of NFPA 70, *National Electrical Code®*, should be consulted.

Conduit connecting devices handling flammable material might carry this material to an electrical enclosure if the device fails, creating a classified area in that enclosure. Sealing of such conduits should be considered.

A-1-4.3.3 Unless otherwise required by the local environment, ovens and furnaces and the surrounding area are not classified as a hazardous (classified) location. The primary source of ignition associated with an oven installation is the oven heating system or equipment or materials heated. The presence of these ignition sources precludes the need for imposing requirements for wiring methods appropriate for a hazardous (classified) location. Refer to Section 3-3 of NFPA 497, *Recommended Practice for the Classification of Flammable Liquids, Gases, or Vapors and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*, and Section 3-3 of NFPA 499, *Recommended Practice for the Classification of Combustible Dusts and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*, regarding equipment with open flames or other ignition sources. In addition, ovens or furnaces are considered unclassified internally because safety depends upon ventilation.

Figure A-1-4(a) Sample 1: furnace or oven manufacturer's application for acceptance.

SHEET 1 OF 2

MFR'S. JOB OR CONTRACT NO.	DATE

PART A — PLANS

NAME OF CUSTOMER (name of owner)					
ADDRESS (St. & No.)			CITY	STATE	
NAME OF MANUFACTURER					
ADDRESS (St. & No.)			CITY	STATE	
DRAWINGS SUBMITTED, NOS.				NO. OF SETS	
INSTALLATION	TYPE		BATCH ☐	CONTINUOUS ☐	
	CONSISTS OF				
RATED HEAT INPUT	BTU/HR	☐ GAS BTU/FT^3	☐ FUEL OIL NO. GAL/HR	☐ ELECTRIC KW	
SIZE (EXTERNAL IN FT)	LENGTH	WIDTH	HEIGHT	OPERATING TEMP. °F	
LOCATION OF EQUIPMENT	BLDG. NO. OR NAME		NO. OF FLOOR OR STORY		
FUEL SHUTOFF	ACCESSIBLE IN EVENT OF FIRE YES ☐ NO ☐	SEPARATE EXCESS TEMPERATURE LIMIT SWITCH SHUTS OFF HEAT YES ☐ NO ☐		SET FOR °F	
FIRE PROTECTION OF OIL QUENCH TANK	☐ NONE	☐ AUTOMATIC SPRINKLERS	☐ OPEN SPRINKLERS	☐ AUTOMATIC WATER SPRAY	☐ AUTOMATIC FIXED FOAM
	☐ IF OTHER, DESCRIBE				
TYPE OF WORK	HEAT TREATING METALS	☐ WITH SPECIAL FLAMMABLE ATMOSPHERE		☐ WITH SPECIAL INERT ATMOSPHERE	
	IF OTHER, DESCRIBE				
HEATING ARRANGEMENT	☐ INTERNAL DIRECT-FIRED NONRECIRCULATING	☐ INTERNAL DIRECT-FIRED RECIRCULATING	☐ EXTERNAL DIRECT-FIRED RECIRCULATING	☐ EXTERNAL INDIRECT-FIRED	
	☐ IF OTHER, DESCRIBE	MUFFLE YES ☐ NO ☐	RADIANT TUBES YES ☐ NO ☐		
	TYPE OF ELECTRIC HEATING ELEMENTS AND LOCATION				
	NO. OF MAIN BURNERS	NO. OF PILOT BURNERS			
METHOD OF LIGHTING–OFF	☐ PORTABLE TORCH	☐ FIXED	☐ PILOT	☐ OIL	☐ GAS ☐ SPARK IGNITOR
METHOD OF FIRING	☐ HI–LOW	☐ MODULATING	☐ ON–OFF	☐ CONTINUOUS	
MIXER TYPE	☐ GAS	NO. OF MAIN BURNER INSPIRATORS	☐ ZERO-GOVERNOR TYPE ☐ ATMOSPHERIC INSPIRATOR	☐ HIGH PRESSURE 1.0 PSIG OR OVER ☐ LOW PRESSURE	☐ OTHER
		NO. OF PILOT INSPIRATORS	☐ ZERO-GOVERNOR TYPE ☐ ATMOSPHERIC INSPIRATOR	☐ HIGH PRESSURE 1.0 PSIG OR OVER ☐ LOW PRESSURE	☐ OTHER
	☐ OIL	☐ AIR (16–32 OZ) ATOMIZING	☐ ROSS OR DRY SYSTEM AIR ATOMIZING		☐ OTHER
	IF OTHER, DESCRIBE (MFR. & TYPE)				

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Figure A-1-4(a) *(continued)*

SHEET 2 OF 2

PROTECTION AGAINST FUEL EXPLOSION

LIGHTING-OFF

OPENINGS INTO ROOM ☐ TOP ☐ BOTTOM				
NO FUEL & IGNITION UNTIL: ☐ TIMED PREVENTILATION BY EXH. & RECIRCULATING FANS	TIMER SETTING MIN.	☐ DOORS WIDE OPEN	☐ BURNER (F.M.) COCKS CLOSED	☐ MEANS PROVIDED FOR CHECK OF MAIN SAFETY SHUTOFF VALVE TIGHTNESS
PILOT-FLAME ESTABLISHING PERIOD AUTOMATICALLY LIMITED ☐ YES ☐ NO SEC.	TRIAL-FOR-IGNITION PERIOD AUTOMATICALLY LIMITED ☐ YES ☐ NO SEC.	OIL TEMP. INTERLOCK ☐ YES ☐ NO SET FOR °F	PROVED LOW-FIRE INTERLOCK ☐ YES ☐ NO	
MFR. & TYPE NO. OF F.M. COCKS AND TIMER	☐ COMB. AIR BLOWER CANNOT BE STARTED UNTIL END OF PREVENT. (IF TIMER USED)	☐ COMB. SAFEGUARD PROVES PILOT BEFORE MAIN SAFETY SHUTOFF VALVE OPENS		

FIRING

HEAT CUTOFF AUTOMATICALLY, REQUIRING MANUAL OPERATION TO RESTORE, ON FAILURE OF ☐ COMBUSTION AIR ☐ RECIRCULATING FAN ☐ EXHAUST FAN ☐ FUEL PRESSURE ☐ FLAME (combustion safeguard)	
☐ ROD OR SCANNER LOCATION ENSURES PILOT IGNITES MAIN FLAME	MANDATORY PURGE AFTER FLAME FAILURE ☐ YES ☐ NO

MFR. & TYPE NO.

MAIN SAFETY SHUTOFF VALVE IPS. IN.	PILOT SAFETY SHUTOFF VALVE IPS. IN.	
COMBUSTION SAFEGUARD	PRESSURE SWITCHES	AUTOMATIC FIRE CHECKS

PROTECTION AGAINST SPECIAL ATMOSPHERE EXPLOSION

ATMOSPHERE FIRST TURNED ON INTO: ☐ HEATED WORK SECTION ☐ COOLING SECTION		
IF COOLING SECTION, EXPLAIN HOW HAZARD AVOIDED		
TEMPERATURE OF THIS SECTION WHEN ATMOSPHERE TURNED ON °F	SHUTOFF °F	☐ ATMOSPHERE INTERLOCKED WITH FURNACE TEMPERATURE CONTROLLER
PRECAUTIONS WHEN TURNING ON AND SHUTTING OFF ATMOSPHERE ☐ INERT GAS PURGE ☐ BURN-OUT	☐ NO IGNITION SOURCE WHILE FURNACE ATMOSPHERE EXPLOSIVE	
IF LATTER CASE, CHECK FOR NONEXPLOSIVE ATMOSPHERE IS BY ☐ GAS ANALYZER ☐ BURNING TEST SAMPLE	☐ TIME–VOLUME MEASURE ☐ NONE	

SPECIAL ATMOSPHERE GENERATOR

MANUFACTURER AND TYPE	☐ ATMOSPHERE GENERATOR OUTPUT VENTED TO OUTDOORS UNTIL GENERATOR BURNER STABLE
ALARM AND AUTOMATIC LOCKOUT OF FUEL & COMBUSTION AIR IF FAILURE OF: ☐ FUEL ☐ COMBUSTION AIR ☐ POWER ☐ FLAME ☐ ATMOSPHERE TEMPERATURE AT GENERATOR	

MFR. & TYPE NO.

SAFETY SHUTOFF VALVES	PRESSURE SWITCHES
TEMPERATURE SWITCHES	COMBUSTION SAFEGUARDS

PART A ACCEPTED BY	☐ AS SUBMITTED ☐ SUBJECT TO ANY CHANGES INDICATED	DATE

PART B — MANUFACTURER'S INSPECTION & TEST (completed installation)

BURNERS	☐ LIGHTED ☐ MIXERS ADJUSTED ☐ TEMP. CONTROL SET ☐ ADJ. FOR STABLE LOW FLAME	
SAFETY CONTROLS	☐ ADJUSTED ☐ TESTED FOR PROPER RESPONSE	
INSTRUCTIONS	☐ CUSTOMER'S OPERATOR INSTRUCTED ☐ PRINTED OPERATING INSTRUCTIONS LEFT ☐ APPLICATION FOR ACCEPTANCE POSTED ON CONTROL PANEL	
SIGNATURES	MFRS. FIELD REP.	TEST WITNESSED BY FOR CUSTOMER DATE
PART B ACCEPTED BY	☐ AS SUBMITTED ☐ SUBJECT TO ANY CHANGES INDICATED	DATE

PART C — FIELD EXAMINATION OF COMPLETED INSTALLATION

☐ PART A CHECKED ☐ PART B CHECKED ☐ SAFETY CONTROLS TESTED ☐ ROD OR SCANNER LOCATION ASSURES PILOT IGNITES MAIN FLAME	
INSTALLATION ACCEPTABLE BY	DATE

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Figure A-1-4(b) Sample 2: furnace or oven manufacturer's application for acceptance.

SHEET 1 of 2

MFR'S. JOB OR CONTRACT NO.	DATE

PART A — PLANS

NAME & ADDRESS OF CUSTOMER (OWNER)	NAME & ADDRESS OF MANUFACTURER
DRAWINGS SUBMITTED, NOS.	NO. OF SETS

INSTALLATION	ERECTION & ADJUSTMENTS (SEE PART B) BY: ☐ MANUFACTURER ☐ CUSTOMER	IF OTHER, DESCRIBE
	SAFETY VENTILATION AIR FLOW TESTS (SEE PART B) TO BE MADE AFTER ERECTION BY: ☐ MANUFACTURER ☐ CUSTOMER	IF OTHER, DESCRIBE
	TYPE ☐ BATCH ☐ CONTINUOUS	TYPE NO. OR OTHER INFORMATION
CON-STRUCTION	☐ SHEET STEEL ON STEEL FRAME NONCOMBUSTIBLE INSULATION	IF OTHER, DESCRIBE
RATED HEAT INPUT	☐ GAS BTU/HR; ☐ FUEL OIL NO. GAL/HR	☐ ELECTRIC KW; ☐ STEAM PRESS, psig
SIZE	LENGTH (External) FT; WIDTH (External) FT; HEIGHT (External) FT	VOLUME (Internal) FT³; OPERATING TEMP. °F
LOCATION OF EQUIPMENT	BLDG. NO. OR NAME	BUILDING FLOOR CONSTRUCTION AND NO. OF FLOOR OR STORY
	AIR SPACE BETWEEN OVEN & WOOD FLOOR IN.	IF OTHER, DESCRIBE
	AIR SPACE BETWEEN STACKS, DUCTS, & WOOD BLDG. CONST. IN.	IF OTHER, DESCRIBE
	EXHAUST STACKS; DIAM. OR SIZE IN.; METAL GAUGE (USS)	☐ INSULATED; NO. OF CLEANOUT (ACCESS) DOORS
EXPLOSION VENTING AREA	OPEN ENDS FT²; LOOSE ROOF PANELS FT²	ACCESS DOORS WITH EXPLOSION LATCHES FT²
	MANUFACTURER AND TYPE LATCH; TOTAL AREA FT²	VENT RATIO $\frac{\text{VENT AREA}}{\text{INTERNAL VOLUME}}$ =
FUEL SHUTOFF	ACCESSIBLE IN EVENT OF FIRE ☐ YES	☐ NO
FIRE PROTECTION IN OVEN	☐ NONE ☐ AUTOMATIC SPRINKLERS ☐ OPEN SPRINKLERS ☐ CO_2 ☐ STEAM	DRAWINGS SUBMITTED ☐ YES ☐ NO
	☐ OTHER (DESCRIBE)	☐ SEPARATE EXCESS TEMPERATURE LIMIT SWITCH WITH MANUAL RESET; SET FOR °F
FIRE PROTECTION FOR DIP TANK & DRAINBOARD	DRAWINGS SUBMITTED ☐ YES ☐ NO; FIXED AUTO. CO_2 ☐ YES ☐ NO	☐ OTHER (DESCRIBE)
	OVERFLOW VALVES ☐ YES ☐ NO; DUMP VALVES ☐ YES ☐ NO; SALVAGE TANK ☐ YES ☐ NO	IS HEAT SHUTOFF AUTOMATICALLY ON FAILURE OF CONVEYOR ☐ YES ☐ NO
TYPE OF WORK	IMPREGNATED-COATED ABSORBENT MATERIAL ☐ PAPER ☐ CLOTH	☐ LITHOGRAPH COATING ☐ VARNISH ELECT. COILS ☐ GRAVURE PRESS ☐ FOOD BAKING ☐ CORES OR MOLDS
	METAL ☐ DIPPED ☐ FLOW-COATED ☐ SPRAYED	☐ OTHER (DESCRIBE)
SOLVENTS ENTERING OVEN	NAME OF SOLVENT USED; LENGTH OF BAKE MIN.	MAX. SOLVENT FOR WHICH OVEN DESIGNED: CONTINUOUS GAL/HR; BATCH GAL/BATCH
DESIGNED SAFETY VENTILATION	ARRANGEMENT ☐ SEPARATE CENTRIFUGAL EXHAUSTER ☐ RECIRCULATING FAN WITH SPILL ☐ NATURAL DRAFT STACK ☐ OPENINGS INTO ROOM	FILTERS ON FRESH AIR INTAKE ☐ YES ☐ NO
	FRESH AIR ADMITTED INTO OVEN CFM REFERRED TO 70° F; OPENING WITH DAMPER CLOSED: FRESH AIR INLET %, EXHAUST OUTLET %	DOES CONVEYOR STOP AUTOMATICALLY ON FAILURE OF SAFETY EXHAUST FANS ☐ YES ☐ NO
	FAN MFR. SIZE, TYPE; WHEEL DESIGN (BLADE TIP) ☐ RADIAL TIP ☐ BACKWARD INCLINED ☐ FORWARD CURVED	DIAM. IN.; TIP SPEED FT/MIN

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Figure A-1-4(b) *(continued)*

SHEET 2 OF 2

HEATING ARRANGEMENT
☐ INTERNAL DIRECT-FIRED NONRECIRCULATING ☐ INTERNAL DIRECT-FIRED RECIRCULATING ☐ EXTERNAL DIRECT-FIRED RECIRCULATING ☐ EXTERNAL INDIRECT-FIRED
☐ OTHER (DESCRIBE)
TYPE OF ELECTRIC HEATING ELEMENTS AND LOCATION
NO. OF MAIN BURNERS | NO. OF PILOT BURNERS | CAN DRIPPINGS OFF WORK FALL ON HEATING ELEMENTS ☐ YES ☐ NO

METHOD OF LIGHTING–OFF
☐ PORTABLE TORCH ☐ FIXED ☐ PILOT ☐ OIL ☐ GAS ☐ SPARK IGNITOR

METHOD OF FIRING
☐ HI–LOW ☐ ON–OFF ☐ MODULATING ☐ CONTINUOUS ☐ AUTOMATIC-LIGHTED ☐ MANUAL-LIGHTED ☐ SEMI-AUTOMATIC-LIGHTED
TYPE OF PILOT ☐ CONTINUOUS ☐ INTERRUPTED ☐ INTERMITTENT ☐ OTHER (DESCRIBE)

MIXER TYPE
☐ GAS
NO. MAIN BURNER INSPIRATORS ☐ ZERO-GOVERNOR TYPE ☐ ATMOSPHERIC INSPIRATOR ☐ HIGH PRESSURE ☐ LOW PRESSURE
NO. PILOT INSPIRATORS ☐ ZERO-GOVERNOR TYPE ☐ ATMOSPHERIC INSPIRATOR ☐ HIGH PRESSURE ☐ LOW PRESSURE
☐ OIL ☐ AIR (16–32 OZ) ATOMIZING
☐ OTHER — OTHER TYPE MIXERS OR OIL BURNERS INCLUDING PILOTS (MFR. & TYPE)

PROTECTION AGAINST FUEL EXPLOSION

LIGHTING-OFF
NO FUEL AND IGNITION UNTIL: ☐ TIMED PREVENTILATION BY EXHAUST AND RECIRC. FANS | TIMER SETTING MIN. | ☐ DOORS WIDE OPEN | ☐ BURNER (F.M.) COCKS CLOSED | ☐ MEANS PROVIDED FOR CHECK OF MAIN SAFETY SHUTOFF VALVE TIGHTNESS
PILOT-FLAME-ESTABLISHING PERIOD AUTOMATICALLY LIMITED ☐ YES ☐ NO SEC. | TRIAL-FOR-IGNITION PERIOD AUTOMATICALLY LIMITED ☐ YES ☐ NO SEC. | OIL TEMP. INTERLOCK ☐ YES ☐ NO SET FOR °F | PROVED LOW-FIRE INTERLOCK ☐ YES ☐ NO
MFR. AND TYPE NO. OF F.M. COCKS & TIMER | ☐ COMBUSTION AIR BLOWER CANNOT BE STARTED UNTIL END OF PREVENT. (IF TIMER USED) | ☐ COMBUSTION SAFEGUARD PROVES PILOT BEFORE MAIN SAFETY SHUTOFF VALVE OPENS

FIRING
HEAT CUTOFF AUTOMATICALLY, REQUIRING MANUAL OPERATION TO RESTORE, ON FAILURE OF
☐ COMBUSTION AIR ☐ RECIRCULATING FAN ☐ SAFETY EXHAUST FAN ☐ HIGH AND LOW GAS PRESSURE ☐ LOW OIL PRESSURE ☐ FLAME (Combustion Safeguard)
☐ ROD OR SCANNER LOCATION ENSURES PILOT IGNITES MAIN FLAME | MANDATORY PURGE AFTER FLAME FAILURE ☐ YES ☐ NO

MANUFACTURER & TYPE NO.
MAIN SAFETY SHUTOFF VALVE IPS. IN. | PILOT SAFETY SHUTOFF VALVE IPS. IN.
COMBUSTION SAFEGUARD | PRESSURE SWITCHES | AIRFLOW SWITCHES

PART A ACCEPTED ☐ AS SUBMITTED ☐ SUBJECT TO ANY CHANGES INDICATED | DATE
BY

PART B — MANUFACTURER'S INSPECTION & TEST

SAFETY VENTILATION CFM REF. TO 70° F | MEASURED BY (SPECIFY) ☐ PITOT ☐ OTHER | MEASURED WITH FRESH AIR INLET & EXHAUST OUTLET DAMPERS IN MAXIMUM CLOSED POSITION ☐ YES ☐ NO

BURNERS ☐ LIGHTED ☐ MIXERS ADJUSTED ☐ TEMP. CONTROL SET ☐ ADJ. FOR STABLE LOW FLAME

SAFETY CONTROLS ☐ ADJUSTED ☐ TESTED FOR PROPER RESPONSE

INSTRUCTIONS ☐ CUSTOMER'S OPERATOR INSTRUCTED ☐ PRINTED OPERATING INSTRUCTIONS LEFT ☐ APPLICATION FOR ACCEPTANCE POSTED ON CONTROL PANEL

SIGNATURES MFR'S. FIELD REP. | TEST WITNESSED BY FOR CUSTOMER | DATE

PART B ACCEPTED ☐ AS SUBMITTED ☐ SUBJECT TO ANY CHANGES INDICATED | DATE
BY

PART C — FIELD EXAMINATION OF COMPLETED INSTALLATION

☐ PART A CHECKED ☐ PART B CHECKED ☐ SAFETY CONTROLS TESTED ☐ ROD OR SCANNER LOCATION ASSURES PILOT IGNITES MAIN FLAME

ENGINEER'S SIGNATURE | DATE

A-1-7.3 Figures A-1-7.3(a) and (b) relate to 1-7.3.

Figure A-1-7.3(a) Recommended manufacturer's nameplate data.

WARNING — Do not deviate from these nameplate conditions.

SOLVENTS USED____________________
For example, alcohol, naphtha, benzene, turpentine

SOLVENTS AND VOLATILES ENTERING OVEN ____________
Gal per batch or per hr

PURGING INTERVAL ____________________
Minutes

OVEN TEMPERATURE, °F (°C) ____________________

EXHAUST BLOWER RATED FOR____________ GALLONS (CUBIC METERS) OF SOLVENT PER HOUR OR BATCH AT MAXIMUM OPERATING TEMPERATURES OF________ °F (°C)

MANUFACTURER'S SERIAL NUMBER ____________________

MANUFACTURER'S NAME AND ADDRESS

____

____

____

Figure A-1-7.3(b) Recommended safety design data form.

SAFETY DESIGN FORM
FOR SOLVENT ATMOSPHERE OVENS

THIS OVEN IS DESIGNED FOR THE CONDITIONS AS INDICATED BELOW, AND IS APPROVED FOR SUCH USE ONLY

WARNING — Do Not Deviate From These Conditions

SOLVENTS USED ____________________
For example, alcohol, naphtha, benzene, turpentine

SOLVENTS AND VOLATILES ENTERING OVEN ____________
Gal per batch or per hr

PURGING INTERVAL ____________________
Minutes

OVEN TEMPERATURE, °F (°C) ____________________

EXHAUST BLOWER RATED FOR ____________ GALLONS (CUBIC METERS) OF SOLVENT PER HOUR OR BATCH AT MAXIMUM OPERATING TEMPERATURES OF________ °F (°C)

MANUFACTURER'S SERIAL NUMBER ____________________

MANUFACTURER'S NAME AND ADDRESS

____

____

____

Above information is for checking safe performance and is not a guarantee of this equipment in any form, implied or otherwise, between buyer and seller relative to its performance.

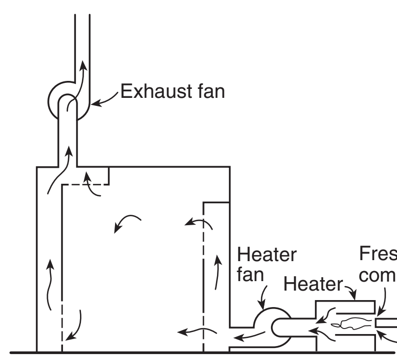
A-2-1 Approved. The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization that is concerned with product evaluations and is thus in a position to determine compliance with appropriate standards for the current production of listed items.

A-2-1 Authority Having Jurisdiction. The phrase "authority having jurisdiction" is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

A-2-1 Heating System, Direct-Fired. The following are different types of direct-fired heating systems.

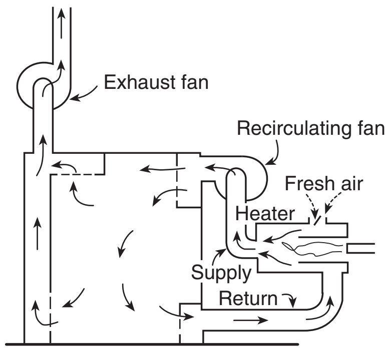
Heater: Direct-Fired, External, Nonrecirculating. A direct-fired, external heater arranged so that products of combustion are discharged into the oven chamber without any return or recirculation from the oven chamber. *[See Figure A-2-1(a).]*

Figure A-2-1(a) Example of a direct-fired, external, nonrecirculating heater.



Heater: Direct-Fired, External, Recirculating-Through. A direct-fired, external heater arranged so that oven atmosphere is recirculated to the oven heater and is in contact with the burner flame. *[See Figure A-2-1(b).]*

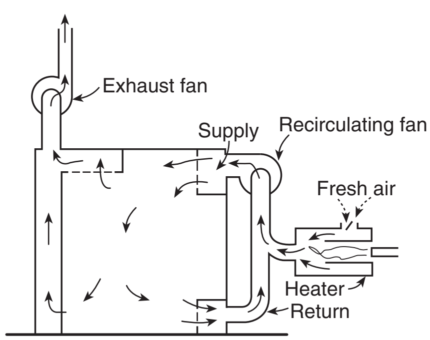
Figure A-2-1(b) Example of a direct-fired, external, recirculating-through heater.



Heater: Direct-Fired, Internal, Nonrecirculating. A combustion chamber of a recirculating oven heater that may be permitted to be built within an oven chamber not substantially separated from the oven atmosphere by gastight construction.

Heater: Direct-Fired, External, Recirculating-Not-Through. A heating system constructed so that the oven atmosphere circulates through a blower with products of combustion admitted to the recirculating ductwork, but without the oven atmosphere actually passing through the combustion chamber. *[See Figure A-2-1(c).]*

Figure A-2-1(c) Example of a direct-fired, external, recirculating-not-through heater.



A-2-1 Listed. The means for identifying listed equipment may vary for each organization concerned with product evaluation; some organizations do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

A-2-1 Pump, Roughing. The roughing pump also can be used as the backing (fore) pump for the diffusion pump, or the roughing pump can be shut off and a smaller pump can be used as the backing (fore) pump where the gas load is relatively small.

A-2-1 Range, Explosive. See NFPA 325, *Guide to Fire Hazard Properties of Flammable Liquids, Gases, and Volatile Solids.*

A-3-1.1.4 For additional information, refer to NFPA 31, *Standard for the Installation of Oil-Burning Equipment;* NFPA 54, *National Fuel Gas Code;* and NFPA 91, *Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Noncombustible Particulate Solids.*

A-3-1.3.3 The hazard is particularly severe where vapors from dipping operations could flow by means of gravity to ignition sources at or near floor level.

See NFPA 30, *Flammable and Combustible Liquids Code;* NFPA 33, *Standard for Spray Application Using Flammable and Combustible Materials;* and NFPA 34, *Standard for Dipping and Coating Processes Using Flammable or Combustible Liquids.*

A-3-1.4.2 The following procedure should be followed if the furnace is located in contact with a wood floor or other combustible floor and the operating temperature is above 160°F (71°C).

Combustible floor members should be removed and replaced with a monolithic concrete slab that extends a minimum of 3 ft (1 m) beyond the outer extremities of the furnace.

Air channels, either naturally or mechanically ventilated, should be provided between the floor and the equipment (perpendicular to the axis of the equipment or noncombustible insulation, or both). This should be adequate to prevent surface temperatures of floor members from exceeding 160°F (71°C).

A-3-2.12 Fuel-fired or electric heaters should not be located directly under the product being heated where combustible materials could drop and accumulate. Neither should they be located directly over readily ignitible materials such as cotton unless for a controlled exposure period, as in continuous processes where additional automatic provisions or arrangements of guard baffles, or both, preclude the possibility of ignition.

A-3-3.1 For additional information regarding relief of equipment and buildings housing the equipment, see NFPA 68, *Guide for Venting of Deflagrations.*

A-3-3.4 The location for explosion relief is a critical concern and needs to be close to the ignition source.

The heater box is part of the oven system and needs to have explosion relief provided. Personnel considerations and proximity to other obstructions can impact the location selected for these vents.

A-3-3.6 Industry experience indicates that a typical oven enclosure built to withstand a minimum of 0.5 psig (3.45 kPa) surge overpressure with explosion-relief panels having a maximum weight per area of 5 lb/ft^2 (24.4 kg/m^2) meets the requirements of 3-3.6.

A-3-3.7 The intent of providing explosion relief in furnaces is to limit damage to the furnace and to reduce the risk of personnel injury due to explosions. To achieve this, relief panels and doors should be sized so that their inertia does not preclude their ability to relieve internal explosion pressures.

A-3-4 For additional information, refer to NFPA 31, *Standard for the Installation of Oil-Burning Equipment;* NFPA 54, *National Fuel Gas Code;* and NFPA 91, *Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Noncombustible Particulate Solids.*

A-3-4.3.4 Ducts that pass through fire walls should be avoided.

A-3-4.3.8 All interior laps in the duct joints should be made in the direction of the flow.

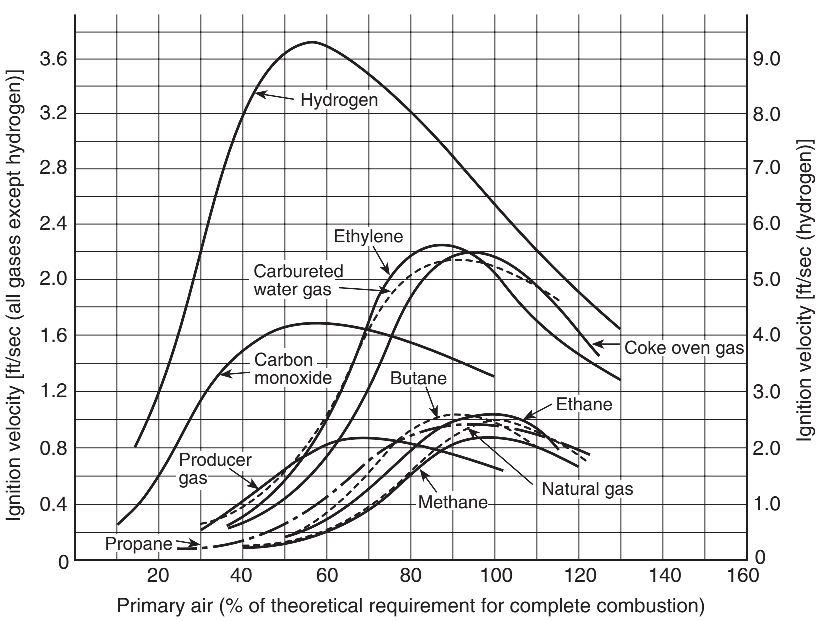
Table A-4-2.1.1 Properties of Typical Flammable Gases

Flammable Gas	Molecular Weight	Btu/ft^3	Autoignition (°F)	LEL% by Volume	UEL% by Volume	Vapor Density (Air = 1)	ft^3 Air Req'd To Burn 1 ft^3 of Gas
Butane	58	3200	550	1.9	8.5	2	31
CO	28	310	1128	12.5	74	0.97	2.5
Hydrogen	2	311	932	4	74.2	0.07	2.5
Natural gas (high Btu type)	18.6	1115	—	4.6	14.5	0.64	10.6
Natural gas (high methane type)	16.2	960	—	4	15	0.56	9
Natural gas (high inert type)	20.3	1000	—	3.9	14	0.70	9.4
Propane	44	2500	842	2.1	9.5	1.57	24

A-4-2.1.1 The term *ignition temperature* means the lowest temperature at which a gas–air mixture can ignite and continue to burn. This is also referred to as the *autoignition temperature*. Where burners supplied with a gas–air mixture in the flammable range are heated above the autoignition temperature, flashbacks can occur. In general, such temperatures range from 870°F to 1300°F (465°C to 704°C). A much higher temperature is needed to ignite gas dependably. The temperature necessary is slightly higher for natural gas than for manufactured gases, but for safety with manufactured gases, a temperature of about 1200°F (649°C) is needed, and for natural gas, a temperature of about 1400°F (760°C) is needed. Additional safety considerations should be given to dirt-laden gases, sulfur-laden gases, high-hydrogen gases, and low-Btu waste gases.

Flame Propagation and Explosive Range. The term *rate of flame propagation* means the speed at which a flame progresses through a combustible gas–air mixture under the pressure, temperature, and mixture conditions existing in the combustion space, burner, or piping under consideration. *(See Table A-4-2.1.1 and Figure A-4-2.1.1.)*

Figure A-4-2.1.1 Ignition velocity curves for typical flammable gases.

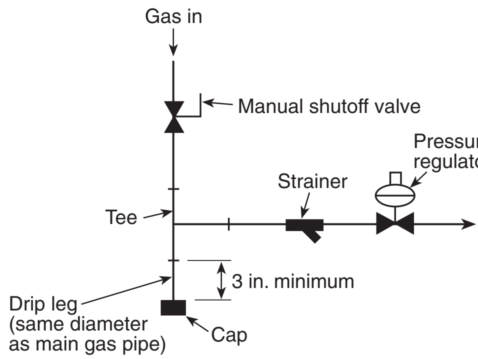


A-4-2.2 For additional information, refer to NFPA 54, *National Fuel Gas Code.*

A-4-2.4.3 Whenever the fuel train is opened for service, the risk of dirt entry exists. It is not required that existing piping be opened for the sole purpose of the addition of a filter or strainer.

A-4-2.4.4 A typical piping arrangement for a drip leg or sediment trap and gas filter or strainer is shown in Figure A-4-2.4.4.

Figure A-4-2.4.4 Typical piping arrangement for a drip leg and strainer.



A-4-2.6.1 In the design, fabrication, and utilization of mixture piping, it should be recognized that the air–fuel gas mixture might be in the flammable range.

A-4-2.6.3.1 Two basic methods generally are used. One method uses a separate fire check at each burner, the other a fire check at each group of burners. The second method generally is more practical if a system consists of many closely spaced burners.

A-4-2.6.3.3 Acceptable safety blowouts are available from some manufacturers of air–fuel mixing machines. They incorporate all the following components and design features:

(1) Flame arrester
(2) Blowout disk
(3) Provision for automatically shutting off the supply of air–gas mixture to the burners in the event of a flashback passing through an automatic fire check

A-4-2.7.4 Testing of radiant tubes should include subjecting them to thermal cycling typical for the furnace application and then verifying their ability to withstand overpressure developed by a fuel–air explosion. Overpressure testing can be done in one of the following two ways.

(a) Statically pressurize the tube until it fails. Compare this pressure to the maximum pressure (from literature) that can be developed in a contained deflagration of an optimum fuel–air mixture.

(b) After partially blocking the open end of the tube to simulate a heat exchanger, fill the tube with a well-mixed stoichiometric fuel–air mixture (10 volumes of air to one volume of fuel for natural gas). Ignite the mixture at the closed end of the tube. Measure the pressure developed. Compare this pressure to the maximum pressure (from literature) that can be developed in a contained deflagration of an optimum fuel–air mixture.

A-4-2.8.1 A burner is suitably ignited when combustion of the air–fuel mixture is established and stable at the discharge port(s) of the nozzle(s) or in the contiguous combustion tunnel.

A-4-3.1.1 In the design and use of oil-fired units, the following should be considered.

(a) Unlike fuel gases, data on many important physical/chemical characteristics are not available for fuel oil, which, being a complex mixture of hydrocarbons, is relatively unpredictable.

(b) Fuel oil has to be vaporized prior to combustion. Heat generated by the combustion commonly is utilized for this purpose, and oil remains in the vapor phase as long as sufficient temperature is present. Under these conditions, oil vapor can be treated as fuel gas.

(c) Unlike fuel gas, oil vapor condenses into liquid when the temperature falls too low and revaporizes whenever the temperature rises to an indeterminate point. Therefore, oil in a cold furnace can lead to a hazardous condition, because, unlike fuel gas, it cannot be purged. Oil can vaporize (to become a gas) when, or because, the furnace operating temperature is reached.

(d) Unlike water, for example, there is no known established relationship between temperature and vapor pressure for fuel oil. For purposes of comparison, a gallon of fuel oil is equivalent to 140 ft^3 (4.0 m^3) of natural gas; therefore, 1 oz (0.03 kg) equals approximately 1 ft^3 (0.03 m^3).

A-4-3.2 For additional information, refer to NFPA 31, *Standard for the Installation of Oil-Burning Equipment.*

A-4-3.3.4 A long circulating loop, consisting of a supply leg, a back-pressure regulating valve, and a return line back to the storage tank, is a means of reducing air entrainment.

Manual vent valves might be needed to bleed air from the high points of the oil supply piping.

A-4-3.3.6 The weight of fuel oil is always a consideration in vertical runs. When going up, pressure is lost. One hundred psig (689 kPa) with a 100-ft (30.5-m) lift nets only 63 psig (434 kPa). When going down, pressure increases. One hundred psig (689 kPa) with a 100-ft (30.5-m) drop nets 137 psig (945 kPa). This also occurs with fuel gas, but it usually is of no importance. However, it should never be overlooked where handling oils.

A-4-3.4.3.2 Customarily, a filter or strainer is installed in the supply piping to protect the pump. However, this filter or strainer mesh usually is not sufficiently fine for burner and valve protection.

A-4-3.4.5 Under some conditions, pressure sensing on fuel oil lines downstream from feed pumps can lead to gauge failure when rapid pulsation exists. A failure of the gauge can result in fuel oil leakage. The gauge should be removed from service after initial burner start-up or after periodic burner checks. An alternative approach would be to protect the gauge during service with a pressure snubber.

A-4-3.6.1 The atomizing medium might be steam, compressed air, low pressure air, air–gas mixture, fuel gas, or other gases. Atomization also might be mechanical (mechanical-atomizing tip or rotary cup).

A-4-3.8.1 A burner is suitably ignited when combustion of the air–fuel mixture is established and stable at the discharge port(s) of the nozzle(s) or in the contiguous combustion tunnel.

A-4-4.1 Oxy-fuel burners often are utilized in conjunction with arc melting furnaces to augment electric heating. Some of these burners utilize air as well. Stationary burners are attached to the furnace shell or cover, or both. Movable burners that normally are not attached to the furnace are suspended from structural members outside a furnace door. They are manipulated from the operating floor, and the oxygen and fuel are introduced into the furnace through long, concentric pipes.

Conventional flame safeguards are impractical in conjunction with oxy-fuel burners in arc furnaces because of the radio frequency noise associated with the arcs. The electric arc is a reliable means of ignition for the burners, once it has been established. After the arc has been established, the high temperatures inside an arc furnace cause the ignition of significant accumulations of oxygen and fuel.

Using oxygen to augment or to substitute for combustion air in industrial furnace heating systems presents new safety hazards for users acquainted only with air–fuel burners.

One group of hazards arises from the exceptional reactivity of oxygen. It is a potent oxidizer; therefore, it accelerates burning rates. It also increases the flammability of substances that generally are considered nonflammable in air. A fire fed by oxygen is difficult to extinguish.

Special precautions are needed to prevent oxygen pipeline fires — that is, fires in which the pipe itself becomes the fuel. Designers and installers of gaseous oxygen piping should familiarize themselves with standards and guidelines referenced in this standard on pipe sizing, materials of construction, and sealing methods. Gaseous oxygen should flow at relatively low velocity in pipelines built of ferrous materials, because friction created by particles swept through steel pipe at a high speed can ignite a pipeline. For this reason, copper or copper-based alloy construction is customary where the oxygen velocity needs to be high, such as in valves, valve trim areas, and in orifices.

Oxygen pipelines should be cleaned scrupulously to rid them of oil, grease, or any hydrocarbon residues before oxygen is introduced. Valves, controls, and piping elements that come in contact with oxygen should be inspected and certified as "clean for oxygen service." Thread sealants, gaskets and seals, and valve trim should be oxygen-compatible; otherwise they could initiate or promote fires. Proven cleaning and inspection methods are described in Compressed Gas Association guidelines provided in Appendix F.

Furnace operators and others who install or service oxygen piping and controls should be trained in the precautions and safe practices for handling oxygen. For example, smoking or striking a welding arc in an oxygen-enriched atmosphere could start a fire. Gaseous oxygen has no odor and is invisible, so those locations in which there is a potential for leaks are off-limits to smokers and persons doing hot work. The location of such areas should be posted. Persons who have been in contact with oxygen should be aware that their clothing is extremely flammable until it has been aired. Equipment or devices that contain oxygen should never be lubricated or cleaned with agents that are not approved for oxygen service.

Oxygen suppliers are sources of chemical material safety data sheets (MSDS) and other precautionary information for use in employee training. Users are urged to review the safety requirements in this standard and to adopt the recommendations.

Another group of hazards is created by the nature of oxy-fuel and oxygen-enriched air flames. Because they are exceptionally hot, these flames can damage the burners, ruin work in process and furnace internals, and even destroy refractory insulation that was intended for air–fuel heating. Oxygen burner systems and heating controls should have quick-acting, reliable means for controlling heat generation.

Air that has been enriched with oxygen causes fuel to ignite very easily, because added oxygen increases the flammability range of air–fuel mixtures. Therefore, preignition purging is critical where oxygen is used.

Oxygen is also a hazard for persons entering furnaces to perform inspections or repairs. Strict entry procedures for confined spaces should be implemented. They should include analyses for excess oxygen (oxygen contents in excess of 20.9 percent) in addition to the usual atmosphere tests for oxygen deficiency and flammability.

A-4-4.3.2 CGA G-4.4, *Industrial Practices for Gaseous Oxygen Transmission and Distribution Piping Systems*, specifies maximum gas velocity criteria, materials of construction, installation methods, joining methods, metering methods, use of filters, and specifications for oxygen-compatible sealing materials, gasket materials, and thread sealants.

A-4-4.3.3 See CGA G-4.1, *Cleaning Equipment for Oxygen Service.*

A-4-4.3.4 This requirement is intended to prevent the contamination of surfaces that must be clean for oxygen service from the oil normally present in plant compressed air.

A-4-4.3.9 See CGA G-4.4, *Industrial Practices for Gaseous Oxygen Transmission and Distribution Piping Systems.*

A-4-4.3.11 Commercial-grade carbon steel pipe exhibits a marked reduction in impact strength when cooled to sub-zero temperatures. Consequently, it is vulnerable to impact fracture if located downstream from a liquid oxygen vaporizer running beyond its rated vaporization capacity or at very low ambient temperatures.

A-4-4.5.2 Diffusers commonly are used to disperse oxygen into an airstream, effecting rapid and complete mixing of the oxygen into the air. High-velocity impingement of oxygen is a potential fire hazard.

A-4-6.5.2.1 Transformers should be of the dry, high fire–point or less flammable liquid type. Dry transformers should have a 270°F (150°C) rise insulation in compliance with Section 4.03 of NEMA TR 27, *Commercial, Institutional and Industrial Dry-Type Transformers.*

A-4-7.1 Fluid heating systems are used to heat lumber dry kilns, plywood veneer dryers, carpet ranges, textile ovens, and chemical reaction vessels. A fluid heating system typically consists of a central heat exchanger to heat the thermal fluid. Firing can be by conventional gas or oil burners. The hot gases then pass through a heat exchanger to indirectly heat the thermal fluid. The heat exchanger can be a separate, stand-alone unit or an integral part of the heater. Conventional water-tube boilers have been used as heaters, with thermal fluid replacing the water.

In addition to steam and water, special oils have been developed for this type of application, with flash points of several hundred degrees Fahrenheit. For maximum thermal efficiency, they are usually heated above their flash points, making an oil spill especially hazardous. Also, because of the high oil temperatures, it is usually necessary to keep the oil circulation through the heat exchanger at all times to prevent oil breakdown and tube fouling. Diesel-driven pumps or emergency generators are usually provided for this purpose in case of a power outage. Oil circulation can even be needed for a period of time after burner shutdown due to the residual heat in the heater.

A-4-7.2.1 Suitable relief valves should be provided where needed. Where relief valves are provided, they should be piped to a safe location. See design criteria in API RP 520 Pt I, *Sizing, Selection, and Installation of Pressure-Relieving Devices in Refineries, Part I — Sizing and Selection* and API RP 520 Pt II, *Sizing, Selection, and Installation of Pressure-Relieving Devices in Refineries, Part II — Installation.*

A-4-7.2.3 If a combustible heat transfer fluid is used, consideration should be given to the use of automatic-actuating fire-safe isolation valves. The actuating mechanism should operate even if exposed to high temperatures. Fireproofing of the mechanism to maintain operational integrity could be necessary.

A fire-safe valve is one that provides a relatively tight valve-seat shutoff during temperatures that are high enough to destroy seals. The stem packing and gasketed body joints must also be relatively liquidtight during exposure to high temperatures.

A-5-1.2 For the protection of personnel and property, careful consideration should be given to the supervision and monitoring of conditions that could cause, or could lead to, a real or potential hazard on any installation.

A-5-2.11 This control circuit and its nonfurnace-mounted or furnace-mounted control and safety components should be housed in a dusttight panel or cabinet, protected by partitions or secondary barriers, or separated by sufficient spacing from electrical controls employed in the higher voltage furnace power system. Related instruments might or might not be installed in the same control cabinet.

The door providing access to this control enclosure might include means for mechanical interlock with the main disconnect device required in the furnace power supply circuit.

Temperatures within this control enclosure should be limited to 125°F (52°C) for suitable operation of plastic components, thermal elements, fuses, and various mechanisms that are employed in the control circuit.

A-5-3.3.1 Failure modes include, but are not limited to, all of the following:

(1) Failure of CPU to execute the program
(2) Failure of the system to recognize changes in input or output status
(3) Failure of the I/O module to scan input and output signals
(4) Failure of input to respond to the action of the connected device
(5) Failure of the program to consult input or external information sources correctly
(6) Failure of output to respond to CPU instructions
(7) Failure of a memory location or register

A-5-6.4 Some systems work at very low combustion air pressures that cannot be detected reliably by conventional pressure switches. As a result, many of the combustion air pressure switches are set at a value that renders them essentially out of the circuit.

A-5-7.2.3 An example of a leak test procedure for safety shutoff valves on direct gas-fired ovens with a self-piloted burner and intermittent pilot follows.

With the oven burner(s) shut off, the main shutoff valve open, and the manual shutoff valve closed, proceed as follows.

(a) The tube should be placed in test connection 1 and immersed just below the surface of a container of water.

(b) The test connection valve should be opened. If bubbles appear, the valve is leaking and the manufacturer's instructions should be referenced for corrective action. The auxiliary power supply to safety shutoff valve No. 1 should be energized and the valve should be opened.

(c) The tube should be placed in test connection 2 and immersed just below the surface of a container of water.

(d) The test connection valve should be opened. If bubbles appear, the valve is leaking. The manufacturer's instructions should be referenced for corrective action.

This procedure is predicated on the piping diagram shown in Figure A-5-7.2.3(a) and the wiring diagram shown in Figure A-5-7.2.3(b).

A-5-9.2 Ultraviolet detectors can fail in such a manner that the loss of flame is not detected. When they are placed in continuous service, failures can be detected by using a self-checking ultraviolet detector or by periodically testing the detector for proper operation.

A-5-9.2.2 Two examples of burner arrangements considered to be a single burner with one flame safeguard installed at the end of the assembly are shown in Figures A-5-9.2.2(a) and A-5-9.2.2(b).

A-5-11 Wherever the temperature of the fuel oil can drop below a safe level, the increased viscosity prevents proper atomization. No. 2 and No. 4 fuel oils can congeal if their temperature falls below their pour point, whether or not preheaters are used.

Wherever the temperature of the fuel oil can rise above a safe level, vaporization of the oil takes place before atomization and causes a reduction in fuel volume severe enough to create substantial quenching of the flame.

Figure A-5-7.2.3(a) Example of a gas piping diagram for leak test.

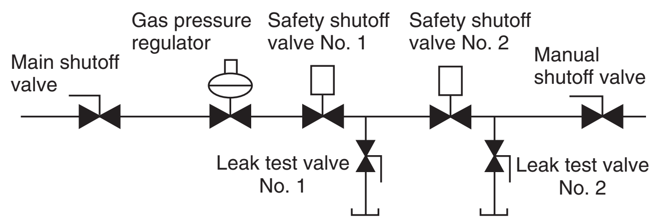


Figure A-5-7.2.3(b) Example of a wiring diagram for leak test.

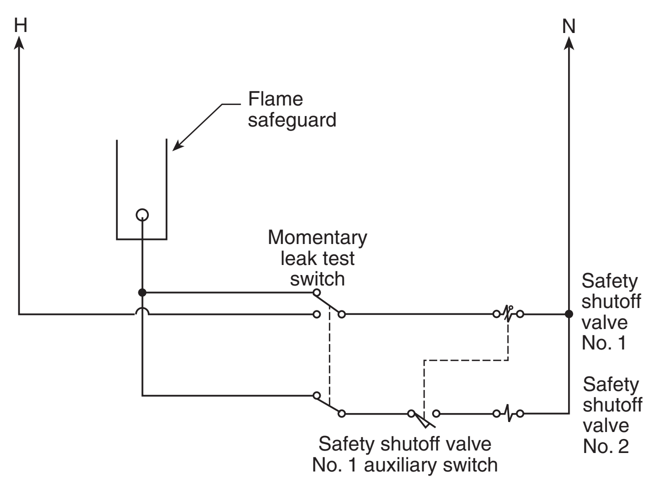


Figure A-5-9.2.2(a) An example of combustion safeguard supervising a pilot for a continuous line burner during light-off and the main flame alone during firing.

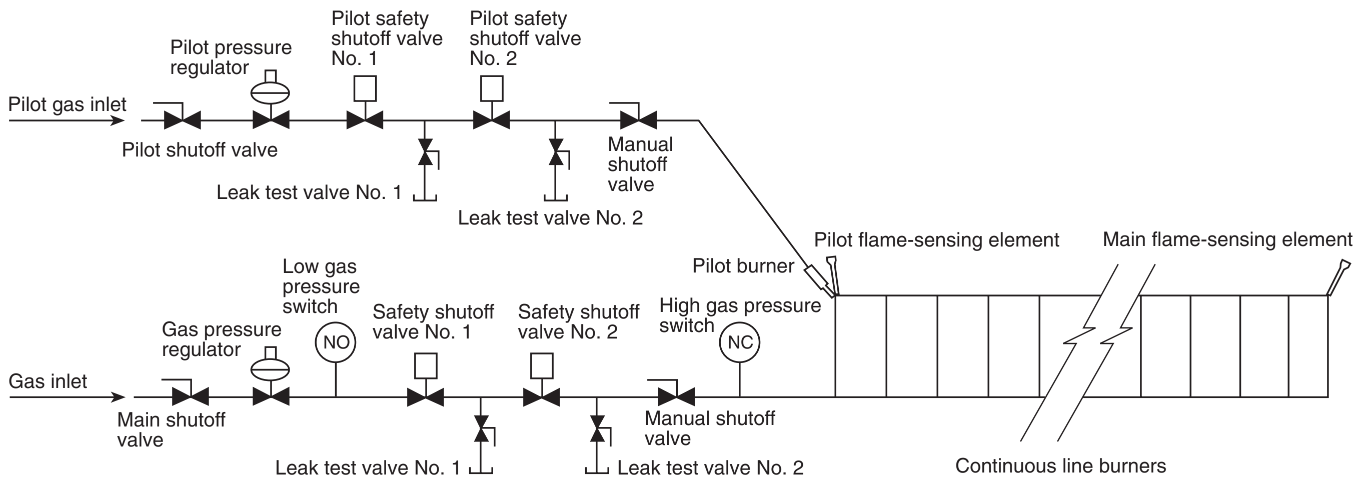
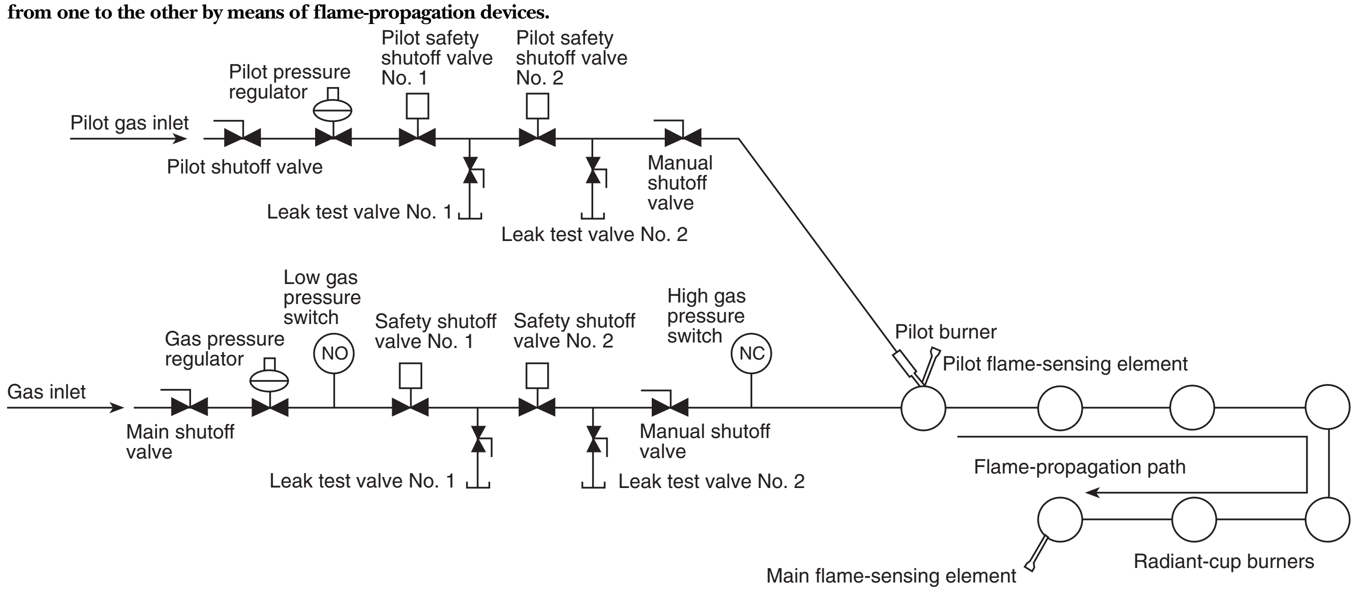


Figure A-5-9.2.2(b) An example of combustion safeguard supervising a group of radiant-cup burners having reliable flame-propagation characteristics from one to the other by means of flame-propagation devices.



A-5-16 The excess temperature set point should be set at least 100°F (56°C) below the autoignition temperature of the flammable material being processed through the oven, or 50°F (28°C) above the oven temperature control set point, whichever is applicable to the material being processed.

Should the operating temperature instrument fail and the excess temperature instrument be set between 200°F and 300°F (111°C and 167°C) above the control set point, the oven exhaust blower scfm (standard cubic feet per minute) will be reduced, lowering safety ventilation, which could cause a flammable vapor explosion.

The dwell time in high temperature, multiple-zone curing, drying, and baking ovens, designed to rapidly preheat the material, should not autoignite the material being processed, or reduce the safety ventilation, upon the failure of the temperature control instrument.

A-5-18.1.1 Abnormal conditions that could occur and require automatic or manual de-energization of affected circuits are as follows:

(1) A system fault (short circuit) not cleared by normally provided branch-circuit protection *(see NFPA 70, National Electrical Code)*
(2) The occurrence of excess temperature in a portion of the furnace that has not been abated by normal temperature-controlling devices
(3) A failure of any normal operating controls where such failure can contribute to unsafe conditions
(4) A loss of electric power that can contribute to unsafe conditions

A-5-18.1.4 The requirements of 5-18.1.4 could require derating some components as listed by manufacturers for uses such as for

Table A-5-18.1.4 Heater Ratings

Control Device	Resistance Type–Heating Devices		Infrared Lamp and Quartz Tube Heaters	
	Rating (% actual load)	Permissible Current (% rating)	Rating (% actual load)	Permitted Current (% rating)
Fusible safety switch (% rating of fuse employed)	125	80	133	75
Individually enclosed circuit breaker	125	80	125	80
Circuit breakers in enclosed panelboards	133	75	133	75
Magnetic contactors				
0–30 amperes	111	90	200	50
30–100 amperes	111	90	167	60
150–600 amperes	111	90	125	80

Note: Table A-5-18.1.4 applies to maximum load or open ratings for safety switches, circuit breakers, and industrial controls approved under current NEMA standards.

other types of industrial service, motor control, and as shown in Table A-5-18.1.4.

A-5-18.2 See Section A-5-16.

A-5-19 See Section A-5-16.

A-5-19.2 Interrupting the flow of heat transfer fluid to an oven can be accomplished by shutting down the central fluid heating system or by shutting a heat transfer fluid safety shutoff valve on both the oven supply and return lines. If heat transfer fluid safety shutoff valves are used, the central fluid heating system may need an automatic emergency loop to provide a dummy cooling load and to maintain fluid flow through the heater.

A-6-1.1 Afterburner or fume incinerator systems might or might not employ catalysts or various heat exchange devices to reduce fuel usage.

Structural supports, thermal expansion joints, protective insulation for incinerator housings, stacks, related ductwork, and heat recovery systems utilizing incinerator exhaust gases should be designed for operating temperatures of 450°F to 2000°F (232°C to 1093°C).

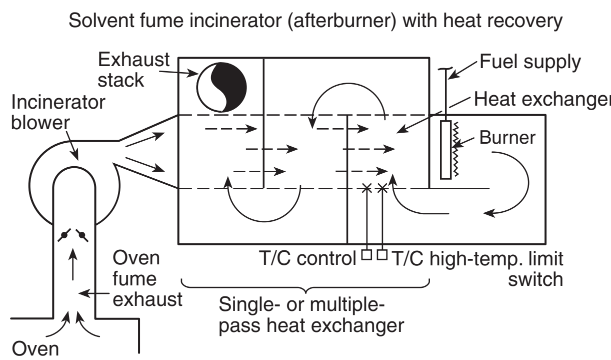
A-6-2 Fume incinerators should operate at the temperature necessary for the oxidation process and in accordance with local, state, and federal regulations. Fume incinerators or afterburners should control atmospheric hydrocarbon emissions by direct thermal oxidation, generally in the range of 1200°F to 2000°F (650°C to 1093°C). Figure A-6-2 shows a solvent fume incinerator with heat recovery.

A-6-2.1 An individual fume source, or multiple sources that feed into one fume incinerator, might cause additional hazards if fed into an operating incinerator during the purge cycle of the source. *(See 5-4.1.3.)*

A-6-2.2 Operating controls should be configured to minimize the likelihood of an excess temperature condition being caused by one or more of the following:

(1) Reduction or termination of fuel to the fume incinerator burner
(2) Interruption of the fume-generating process
(3) Dilution of hydrocarbon concentration with fresh air
(4) Partial emission stream bypass of the heat exchanger

Figure A-6-2 Example of direct thermal oxidation incinerator (afterburner) with primary heat recovery.



A-6-4 Catalytic fume incinerators should operate at the temperature necessary for the catalytic oxidation process in accordance with local, state, and federal regulations.

Catalytic fume incinerators control atmospheric hydrocarbon emissions by thermal oxidation, using a catalyst element. Oxidation occurs at or near the autoignition temperature of the contaminants, which ranges from 450°F to 950°F (232°C to 510°C).

Catalyst elements utilize various types and forms of substrates such as the following:

(1) Metal shavings
(2) Small, irregular, metal castings
(3) Formed or stamped light gauge sheet metal
(4) Ceramic- or porcelain-formed structures, pellets, or granules

Most substrates are restricted to fixed bed applications, although pellets and granules have application in fluidized beds as well. Various catalyst materials are available and include rare earth elements, precious metals such as platinum and palladium, or a few metallic salts. For commercial use, the catalyst material is bonded to or mixed in with (in the case of ceramic or porcelain structures, pellets, or granules, etc.) the substrates specified in (1) through (4).

For atmospheric pollution control, catalyst materials frequently are installed in oven exhaust streams, and the increased energy level resulting from hydrocarbon oxidation is either discharged to the outside atmosphere or recycled to the process oven, directly or by means of a heat exchange system.

The application of catalysts should recognize the inherent limitations associated with these materials, such as the inability to oxidize silicone, sulfur, and halogenated compounds (certain catalysts employing base metals, i.e., manganese or copper, are known to be halogen- and sulfur poison–resistant) as well as metallic vapors such as tin, lead, and zinc. These materials can destroy catalyst activity, whereas various inorganic particulates (dust) can mask the catalyst elements and retard activity, thus requiring specific maintenance procedures. Consultation with qualified suppliers and equipment manufacturers is recommended prior to installation.

Where applicable, catalyst afterburner exhaust gases may be permitted to be utilized as a heat source for the process oven generating the vapors or some other unrelated process. Heat recovery can be indirect, by the use of heat exchange devices, or direct, by the introduction of the exhaust gases into the process oven.

Alternately, catalytic heaters may be permitted to be installed in the oven exhaust stream to release heat from evaporated oven by-products with available energy being returned by means of heat exchange and recirculation to the oven processing zone. *[See Figures A-6-4(a) and (b).]*

Figure A-6-4(a) Example of catalyst system independent of oven heater for air pollution control.

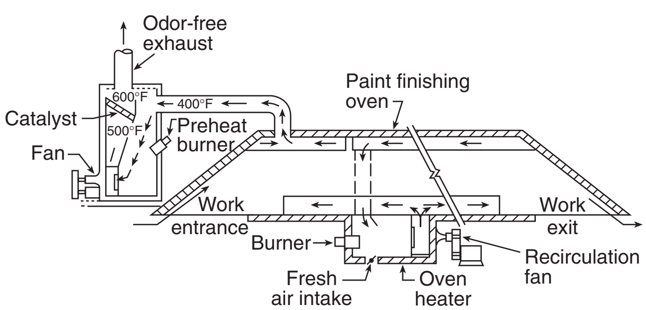
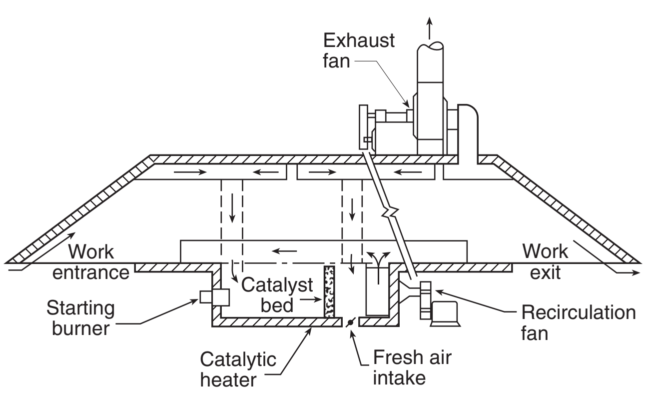


Figure A-6-4(b) Example of indirect-type catalytic oven heater for full air pollution control.



A-6-4.2 The temperature differential (ΔT) across the catalyst should be monitored to ensure that catalytic oxidation is occurring. Separate temperature-indicating instruments or controllers can be used to determine the ΔT arithmetically. Control of fuel or electrical energy for preheating the fume stream entering the catalyst can utilize temperature-measuring instruments at the catalyst inlet or discharge or at a juncture between instruments in each location. Maximum permitted afterburner temperature should be monitored only at the catalyst bed exit. The ΔT across the catalyst bed indicates the energy release and should be limited to values nondestructive to the catalyst material.

Regenerative catalyst oxidizers that employ flow reversal through the system do not produce a measurable ΔT across the catalyst bed indicative of the energy released from the oxidation of the combustibles. In regenerative catalytic oxidation systems, the flow is reversed frequently through the system to maximize utilization of process heat. One characteristic is that the measured temperature at any one point in the system's packed beds, whether in the heat matrix (ceramic packing) or in the catalyst bed, is never constant, rather a sinusoidal function of time. Measuring before and after the catalyst bed does not show energy released from volatile organic compound (VOC) oxidation. The fact that the catalyst bed is employed for VOC oxidation and heat recovery means that those temperatures measured are dependent on flow rate, duration between flow reversals, concentration of VOC, VOC species, activity of catalyst, and burner input.

A-6-4.3 Concentrations at 25 percent LEL can produce a temperature rise near 600°F (316°C) that, where added to the required inlet temperature, results in temperatures generally considered to be within a range where thermal degradation occurs.

In the event there is a high temperature shutdown of the system, the catalyst bed will need to be cooled to prevent further damage of the catalyst through thermal or high temperature breakdown. Most catalysts employ a high surface area substrate like alumina that allows for the maximum amount of catalyst material exposed to the fumes per unit of catalyst (pellet, granule, or structured packing). The surface area of the catalyst can be diminished through failure of the pore structure of the substrate at elevated temperatures [typically greater than 1200°F (649°C)], which results in less exposed catalyst material per unit of catalyst and a lower activity. This rate of thermal poisoning is a function of temperature and duration, and the net effect can be minimized by quickly cooling the catalyst to safe operating temperatures, from 450°F to 950°F (232°C to 510°C).

A-6-4.4 Oxidation performance of catalyst material is a function of temperature, velocity, and pressure drop (ΔP) through the bed, with bed size and configuration directly related to these factors. Pressure drop across the bed fluctuates with temperatures and particulate contamination. Contamination can lead to reduced safety ventilation in the upstream process.

A-6-4.5 While the definition of a catalyst is a substance that participates in a chemical reaction without being changed by it, the reality is that catalysts are affected by chemical reactions and will lose their ability to promote the desired chemical reaction over time. In order to be sure that a catalytic fume incinerator is performing as intended, it is necessary to periodically check the activity of the catalyst. The usual method for doing this is to send a sample of the catalyst to the supplier for testing. The need for obtaining these samples should be addressed in the design of the catalyst bed.

The consequence of declining catalyst activity is the incomplete destruction of the organic vapor. Among the products of a partial combustion reaction are hydrogen, carbon monoxide, and aldehydes, all of which are flammable. The impact of significant quantities of these flammable gases on the operation of a direct heat recovery system should be assessed by the equipment supplier. Other potential concerns include the odor and skin irritation that can be caused by the aldehydes.

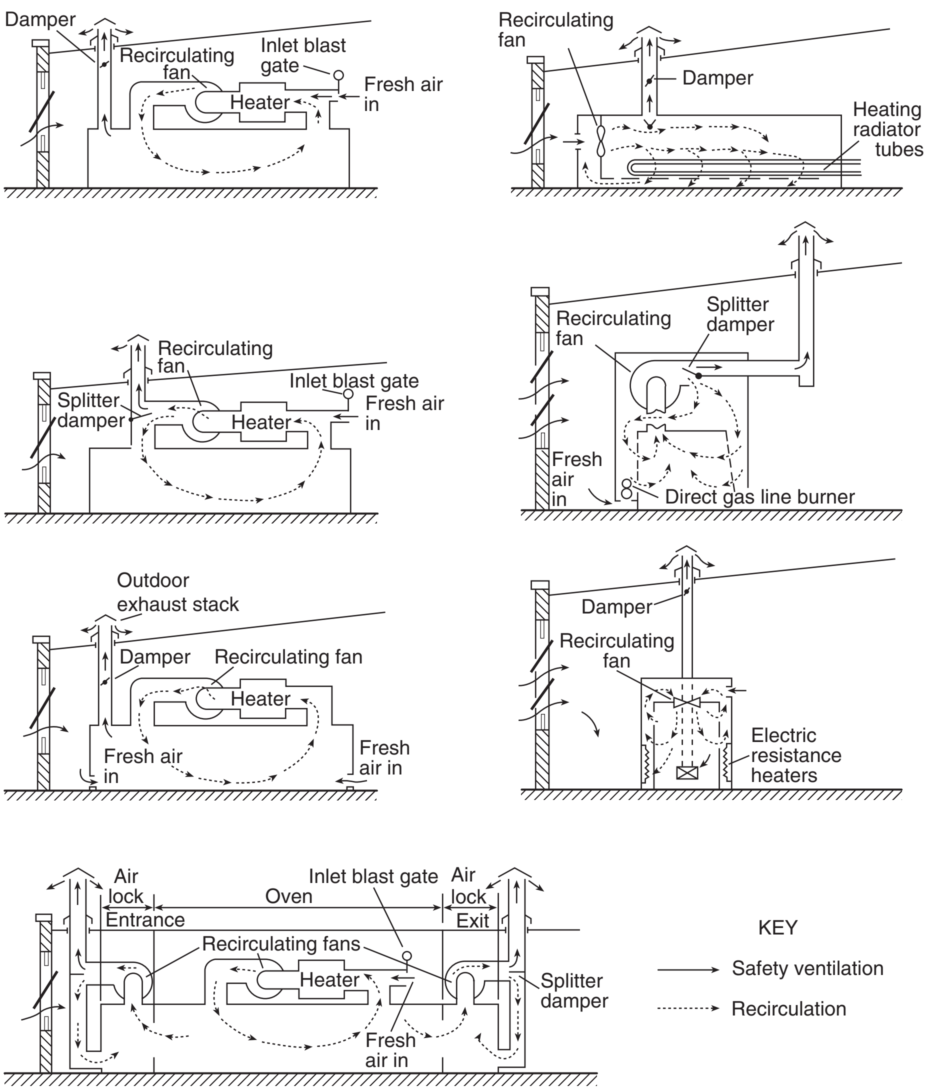
A-7-2.5 The use of propeller-type fans or blowers with forward-curved blades for applications that involve vapors that are not clean should be reviewed because of their susceptibility to accumulation of deposits and possible loss of safety ventilation.

A-7-2.8 Ovens using a single fan for both recirculation and exhaust are presently in use and manufactured. These dual-purpose fan installations have a long history of fire and explosion incidents. Figure A-7-2.8 shows examples of unacceptable safety ventilation systems.

A-7-2.12 The vapors of most volatile solvents and thinners commonly used in finishing materials are heavier than air; consequently, bottom ventilation is of prime importance *[See Tables 7-5.2.2(a) and (b)]*. Liquefied petroleum gases are heavier than air, and other fuel gases are lighter than air. *(See NFPA 325, Guide to Fire Hazard Properties of Flammable Liquids, Gases, and Volatile Solids.)*

In areas outside of the oven where volatiles are given off by material prior to entering the oven, adequate provisions should be made to exhaust vapors to the atmosphere in accordance with applicable local, state, and federal regulations.

Figure A-7-2.8 Unacceptable safety ventilation systems using a single fan (recirculation combined with spill exhaust).



A-7-4.1 *U.S. Customary Units.* For example, in order to draw 9200 ft^3/min of fresh air referred to 70°F (530°R) into an oven operating at 300°F (760°R), it is necessary to exhaust.

$$9200\left(\frac{760}{530}\right) = 13{,}192\ \text{ft}^3\text{/min of } 300°\text{F } (760°\text{R}) \text{ air}$$

SI Units. For example, in order to draw 260 m^3/min of fresh air referred to 21°C (294 K) into an oven operating at 149°C (422 K), it is necessary to exhaust

$$260\left(\frac{422}{294}\right) = 373\ \text{m}^3\text{/min of } 149°\text{C } (422\ \text{K}) \text{ air}$$

All volumes and volumetric flow values should indicate temperature and pressure conditions [e.g., 100 ft^3/min at 300°F (2.83 m^3/min at 148.9°C) and ambient pressure]. [0°F (−18°C) is equivalent to 460°R (256 K)]. *(See Table 7-4.1.)*

A-7-4.2 Most LEL values are reported at 77°F (25°C), although several are given at 212°F (100°C). The LEL value decreases at higher temperatures, so it is necessary that the LEL value for the particular solvent be corrected for the operating temperature of the oven.

The formula used in 7-4.2 was originally published in Bureau of Mines Bulletin 627.

The temperature correction factor also can be expressed approximately as a 5-percent reduction in the LEL value for each 100°F (37.8°C) rise in temperature above 77°F (25°C).

A-7-5 Explanatory Materials and Methods for Calculating Ventilation in Various Types of Ovens. The air delivered into an oven by the supply system to do the necessary work can be all fresh air (from a source outside the oven) or it can be partly fresh air and partly recirculated air from within the oven. Only the fresh air supplied provides safety ventilation, and the amount of fresh air supplied is to be equivalent to the amount of oven exhaust air to keep the system pressure in balance. The amount of air discharged from the oven by the exhaust system is a fair indication of the safety ventilation, provided the supply and exhaust systems are designed properly. The minimum amount of fresh air delivered into the oven for safety ventilation is established by the amount of solvent vaporized from the work in process. The method for determining the minimum volume of fresh air necessary for safety ventilation is provided in A-7-5.2.3.

Measurement of Quantity of Air Exhausted from an Oven. A simple method to determine the quantity of air exhausted from an oven is to measure the velocity of air through the discharge duct by means of a velometer, anemometer, pitot tube, or other suitable means. This measurement then is used to calculate the volume (cubic feet or cubic meters) of air per minute by multiplying the velocity in lineal feet per minute (lineal meters per minute) by the cross-sectional area of the exhaust duct in square feet (square meters). The temperature of the exhaust air also should be measured and the calculated volume then corrected to 70°F (21°C). The resultant quantity of air is an indication of the volume exhausted from the oven, provided the exhaust air does not mix with air external to the oven. In many ovens, particularly those of the continuous type, the exhaust ducts have been incorrectly placed in locations that allow outside air to enter the exhaust system together with the ventilation air exhausted from the oven. Only the air exhausted from the oven should be considered in calculating the safety ventilation volume. Where outside air is entrained with the oven exhaust, the volume relationship is proportional to the temperatures of the components. Temperature readings should be noted within the oven where the exhaust exits the enclosure, outside the oven where the entrained air enters the system, and at the exhaust fan discharge. From these temperature measurements, the proportion of oven air and outside air can be determined with a fair degree of accuracy.

Problem: For continuous oven: The parts of exhaust air at 300°F (149°C) and fresh air at 70°F (21°C) that, when mixed, produce a resultant temperature of 242.5°F (117°C) are determined as follows:

Temperature reading of mixed air at discharge of exhaust fan equals 242.5°F (117°C).

Temperature reading of air in oven at exhaust site equals 300°F (149°C).

Temperature reading of outside air at entrainment site equals 70°F (21°C).

U.S. Customary Units.

x = parts at 300°F
y = parts at 70°F
$242.5\ (x + y) = 300x + 70y$
$242.5x + 242.5y = 300x + 70y$
$172.5y = 57.5x$
$3y = x$

SI Units.

x = parts at 149°C
y = parts at 21°C
$117\ (x + y) = 149x + 21y$
$117x + 117y = 149x + 21y$
$96y = 32x$
$3y = x$

Therefore:

3 parts at 300°F (149°C) + 1 part at 70°F (21°C)
= 4 parts total at 242.5°F (117°C).

Thus, in this example, 75 percent of the air discharged by the exhaust fan is from inside the oven. Correcting this volume for 70°F (21°C) establishes the amount of 70°F (21°C) fresh air admitted into the oven.

In cases where all the fresh air admitted to the oven is through one or more openings where the volume(s) can be measured directly, it is not necessary to perform the preceding calculations.

A-7-5.1 Since a considerable portion of the ventilating air can pass through the oven without traversing the zone in which the majority of vapors are given off, or since uniform ventilation distribution might not exist, the 25 percent concentration level introduces a 4:1 factor of safety.

A-7-5.2.2 The data in these tables has been obtained from NFPA 325, *Guide to Fire Hazard Properties of Flammable Liquids, Gases, and Volatile Solids*, and manufacturers safety data sheets where available. Available figures from numerous sources vary over a wide range in many instances, depending on the purity or grade of samples and on the test conditions prescribed by different observers.

The importance of obtaining precise data on the rate of evaporation by actual tests on particular paint formulations in use needs to be emphasized. Some of these multiple component preparations might contain several solvents with widely differing values of LEL, specific gravity, and vapor density. Until such determinations are made, the operation should be on the side of safety. Therefore, the individual solvent whose data result in the largest required volume of air per gallon should be used as the basis for safe ventilation.

A-7-5.2.3 Theoretical Determination of Required Ventilation.

Problem: For continuous oven:

The volume of oven dilution air that would render vapor from a known volume of toluene barely flammable is determined as follows:

(1) One gallon of water weighs 8.328 lb at 70°F. One liter of water weighs 0.998 kg at 21°C.
(2) Dry air at 70°F and 29.9 in. Hg weighs 0.075 lb/ft^3. Dry air at 21°C and 0.76 m Hg weighs 1.200 kg/m^3.
(3) One cubic meter (m^3) = 1000 liters (L) = 1000 cubic decimeters (dm^3).
(4) Specific gravity (*SpGr*) of toluene = 0.87 (water = 1.0).
(5) Vapor density (*VD*) of toluene = 3.1 (air = 1.0).
(6) Lower explosive limit (LEL) of toluene in air = 1.1% by volume *[see Tables 7-5.2.2(a) and (b)]* and in the LEL calculations is expressed as 1.1 (not 0.011). This value for the LEL is at standard ambient temperature of 70°F (21°C).
(7) Measured oven exhaust temperature (t) = 300°F (149°C).
(8) Corrected LEL (LEL_T) for oven exhaust temperature:

$$(LEL)(LEL_{CF}) = 1.1\ [1 - 0.000784\ (149°C - 25°C)] = 0.99$$

(See 7-4.2.)

U.S. Customary Units.

To determine the cubic feet (ft^3) of vapor per gallon (gal) of solvent, the following calculation is used:

$$\left(\frac{8.328}{0.075}\right)\left(\frac{SpGr}{VD}\right) = \text{ft}^3/\text{gal at } 70°\text{F}$$

For this example:

$$\left(\frac{8.328}{0.075}\right)\left(\frac{0.87}{3.1}\right) = 31.16\ \text{ft}^3 \text{ vapor per gal of toluene at } 70°\text{F}$$

The LEL_T, being equivalent to 0.99 percent of the cubic feet of air rendered explosive by 1 gal of toluene:

$$31.16\left(\frac{100 - 0.99}{0.99}\right) = 3116\ \text{ft}^3 \text{ air at } 70°\text{F per gal toluene}$$

Products of combustion must be added to this volume in accordance with 7-5.3 and then corrections made for higher oven exhaust temperature, and if applicable for elevations of 1000 ft (305 m) or greater. An example of how these additional factors are applied can be found in A-7-5.4.

SI Units.

To determine the cubic meters (m^3) of vapor per liter (L) of solvent, the following calculation is used:

$$\left(\frac{0.998}{1.200}\right)\left(\frac{SpGr}{VD}\right) = \text{m}^3/\text{L at } 21°\text{C}$$

For this example:

$$\left(\frac{0.998}{1.200}\right)\left(\frac{0.87}{3.1}\right) = 0.233\ \text{m}^3 \text{ vapor per L toluene at } 21°\text{C}$$

The LEL_T, being equivalent to 0.99 percent of the cubic meters of air rendered explosive by 1 L of toluene:

$$0.233\left(\frac{100 - 0.99}{0.99}\right) = 23.30\ \text{m}^3 \text{ air at } 21°\text{C per L toluene}$$

Products of combustion must be added to this volume in accordance with 7-5.3 and then corrections made for higher oven exhaust temperature, and if applicable for elevations of 1000 ft (305 m) or greater. An example of how these additional factors are applied can be found in A-7-5.4.

Another Method of Computation.

For this example, xylene is to be used as the solvent.

(1) Specific gravity (*SpGr*) of xylene = 0.88 (water = 1.0).
(2) Molecular weight of $C_6H_4(CH_3)_2$ = 106.
(3) Lower explosive limit (LEL) of xylene in air = 0.9% by volume *[see Tables 7-5.2.2(a) and (b)]*.
(4) Corrected LEL (LEL_T) for oven exhaust temperature:

$$(LEL)(LEL_{CF}) = 0.9[1 - 0.000784(149°C - 25°C)] = 0.81$$

(See 7-4.2.)

(5) The molecular weight in pounds of any gas or vapor occupies 387 ft^3 at 70°F and 29.9 in. of mercury. The molecular weight in grams of any gas or vapor occupies 24.1 L at 21°C and 101 kPa.

U.S. Customary Units.

Weight of 1 gal xylene:

$$0.88\left(\frac{8.328\ \text{lb}\ H_2O}{\text{gal}}\right) = 7.33\ \text{lb xylene/gal}$$

Volume of 1 gal xylene, when vaporized:

$$\frac{(7.33\ \text{lb})(387\ \text{ft}^3)}{106\ \text{(molecular weight)}} = 26.76\ \text{ft}^3 \text{ xylene vapor at standard conditions}$$

The LEL_T, being equivalent to 0.81 percent of the cubic feet of air rendered explosive by 1 gal xylene:

$$26.76\left(\frac{100 - 0.81}{0.81}\right) = 3277\ \text{ft}^3 \text{ air at } 70°\text{F per gal xylene}$$

Products of combustion must be added to this volume in accordance with 7-5.3 and then corrections made for higher oven exhaust temperature, and if applicable for elevations of 1000 ft (305 m) or greater. An example of how these additional factors are applied can be found in A-7-5.4.

SI Units.

Weight of 1 L xylene, when vaporized:

$$\left(\frac{0.998\ \text{kg}\ H_2O}{\text{L}}\right)\left(\frac{1000\ \text{g}}{\text{kg}}\right)(0.88\ SpGr) = 878\ \text{g xylene/L}$$

Volume of 1 L xylene, when vaporized:

$$\frac{(878\ \text{g})(24.1\ \text{L})}{106\ \text{(molecular weight)}} = 200\ \text{L xylene vapor at standard conditions}$$

The LEL_T, being equivalent to 0.81 percent of the cubic meters of air rendered explosive by 1 L xylene:

$$200\ \text{L}\left(\frac{100 - 0.81}{0.81}\right)\left(\frac{1\ \text{m}^3}{1000\ \text{L}}\right) = 24.49\ \text{m}^3 \text{ air at } 21°\text{C per L xylene}$$

Products of combustion must be added to this volume in accordance with 7-5.3 and then corrections made for higher exhaust temperature, and if applicable for elevations of 1000 ft (305 m) or greater. An example of how these additional factors are applied can be found in A-7-5.4.

A-7-5.2.4 The basis for the general rule is that 1 gal of typical solvent produces a quantity of flammable vapor that, when diffused in air, forms approximately 2640 scf of a lean mixture