ANSI/NFPA 86 An American National Standard December 7, 1984

NFPA 86
Ovens and Furnaces
1985

NFPA

National Fire Protection Association Batterymarch Park, Quincy, MA 02269

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Policy Adopted by NFPA Board of Directors on December 3, 1982

The Board of Directors reaffirms that the National Fire Protection Association recognizes that the toxicity of the products of combustion is an important factor in the loss of life from fire. NFPA has dealt with that subject in its technical committee documents for many years.

There is a concern that the growing use of synthetic materials may produce more or additional toxic products of combustion in a fire environment. The Board has, therefore, asked all NFPA technical committees to review the documents for which they are responsible to be sure that the documents respond to this current concern. To assist the committees in meeting this request, the Board has appointed an advisory committee to provide specific guidance to the technical committees on questions relating to assessing the hazards of the products of combustion.

Statement on NFPA Procedures

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NFPA 86

Standard for

Ovens and Furnaces

1985 Edition

This first edition of NFPA 86, *Standard for Ovens and Furnaces*, representing the combination of the former NFPA 86A and NFPA 86B, was prepared by the Technical Committee on Ovens and Furnaces, and acted on by the National Fire Protection Association, Inc. at its Fall Meeting held November 12-15, 1984 in San Diego, California. It was issued by the Standards Council on December 7, 1984, with an effective date of December 27, 1984, and supersedes all previous editions.

This first edition, 1985, of this standard has been approved by the American National Standards Institute.

Origin and Development of NFPA 86

This first edition of NFPA 86 is the result of the combination of the former NFPA 86A and NFPA 86B. The Committee introduced a change in the definition of Class A and Class B ovens which was published in the 1982 edition of 86B and by a tentative interim amendment, in 1983, included in the 1977 edition of 86A.

The effect of 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, Chapter 5, for ventilation requirements in this combined document it was no longer necessary or desirable to maintain two separate documents which would address the same subjects.

Among the changes that have been incorporated into the new document are:

A new chapter has been added to the text dealing with low oxygen atmosphere ovens in keeping with recent developments in processes, the definitions of subjects contained in the text have been updated and new definitions provided, refinements in the text were made in an effort to make the document more understandable, and the material was rearranged to better comply with the NFPA manual of style.

Origin and Development of Former NFPA 86A

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

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, which was adopted at the 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 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 "After-Burner Systems." Requirements for powder coating operations were added in the 1973 edition.

The 1977 edition of the *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 much superfluous material.

Origin and Development of Former NFPA 86B

This Standard 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 still 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 published in 1974. The major revision specified the conditions under which a safety shutoff valve may be used as a dual purpose valve.

This 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:

a revision of the definitions of Class A, Class B and Class C Ovens and Furnaces;

a consolidation and expansion of definitions and rearrangement of material in a new order;

the elimination of a requirement for the location of a vent line between two approved safety shutoff valves; and

the presentation of a standard format to correlate with NFPA 86A, *Ovens and Furnaces*.

Technical Committee on Ovens and Furnaces

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This list represents the membership at the time the Committee was balloted on the text of this edition. Since that time, changes in the membership may have occurred.

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

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

Foreword

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

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

The causes of practically all failures can be traced back to human failure. The most significant failures have been found to be:

(a) Inadequate training of operators

(b) Lack of proper maintenance

(c) 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.

The standard for ovens and furnaces is set forth under classifications as follows:

Class A ovens or furnaces are heat utilization equipment operating at approximately atmospheric pressure, wherein there is a potential explosion and/or fire hazard which may be occasioned by the presence of flammable volatiles or combustible material processed or heated in the oven. Such flammable volatiles and/or combustible material may, for instance, originate from paints, powder, or finishing processes, including dipped, coated, sprayed, impregnated materials or wood, paper and plastic pallets, spacers or packaging materials. Polymerization or similar molecular rearrangements and resin curing are processes which may produce flammable residues and/or volatiles. Potentially flammable materials, such as quench oil, waterborne finishes, cooling oil, etc., in sufficient quantities to present a hazard are ventilated according to Class A standards. Ovens may also utilize low-oxygen atmosphere to evaporate solvent.

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

Class C 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 may use any type of heating system and includes the special atmosphere supply systems. Also included in the Class C standard are integral quench and molten salt bath furnaces.

Class D furnaces are vacuum furnaces which operate at temperatures above ambient to over 5000°F (2760°C) and at pressures below atmospheric using any type of heating system. These furnaces may include the use of special processing atmospheres.

Chapter 1 General

1-1 Scope. This standard applies to Class A/B ovens or furnaces. The words "ovens" and "furnaces" shall be used interchangeably. When chapters or specific paragraphs in this standard apply only to Class A or B ovens, they are so noted.

Within the scope of this standard, an oven shall be any heated enclosure operating at approximately atmospheric pressure and used by industry for the processing of materials.

A Class A oven may also utilize a low-oxygen atmosphere.

This standard also applies to bakery ovens in all respects and reference is made to those sections of the American National Standard Safety Code for Bakery Equipment, ANSI Z50.1-1977, which covers bakery oven construction and safety.

Not included in this standard are coal- (or other solid fuel-) firing systems and heating systems for furnaces having a liquid heat transfer medium.

1-2 Purpose. Since the heat processing of materials may involve a serious fire and explosion hazard endangering 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. This standard shall apply to new installations or alterations or extensions to existing equipment.

Because this standard is based upon the present state of the art, application to existing installations is not mandatory. Nevertheless, users are encouraged to adopt those features of this standard which are considered applicable and reasonable for existing installations. Inspection and maintenance (Chapter 9) shall be applied to all operating furnaces and ovens.

1-4 Definitions. For the purpose of this standard, the following definitions shall apply:

Afterburner System. See definition of Fume Incinerator.

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

Airflow Switch. See Switch, Airflow.

Air-Fuel Gas Mixer. See Mixer, Air-Fuel Gas.

Air Jet Mixer. See Mixer, Air Jet

Air, Primary. All air supplied through the burner, including atomizing and combustion air.

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

Air System, High Pressure [air pressure 5 psig (34 kPa) or higher]. A system using the kinetic energy of a jet of high pressure air to entrain fuel gas, or air and fuel gas to produce a combustible mixture.

Air System, Low Pressure [air pressure up to 5 psig (34 kPa)]. A system using the kinetic energy of a jet of low pressure air to entrain fuel gas to produce a combustible mixture where all, or nearly all, of the air required for combustion is supplied by separate means such as a combustion air blower.

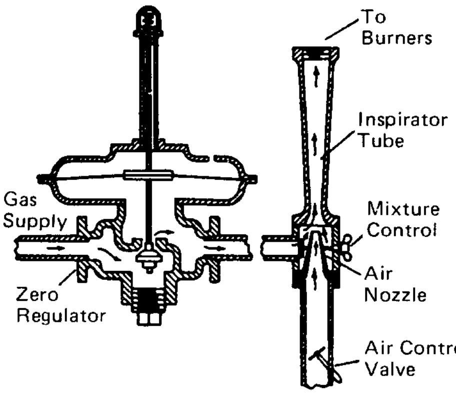


Figure 1-4.1 Example of a Typical Low Pressure Air System.

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

Approved. Acceptable to the "authority having jurisdiction."

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

Atmosphere, Special. The gas, other than air, which contacts the work as it undergoes heat processing in a furnace.

Authority Having Jurisdiction. The "authority having jurisdiction" is the organization, office or individual responsible for "approving" equipment, an installation or a procedure.

NOTE: The phrase "authority having jurisdiction" is used in NFPA documents in a broad manner since jurisdictions and "approval" agencies vary as do their responsibilities. Where public safety is primary, the "authority having jurisdiction" may be a federal, state, local or other regional department or individual such as a fire chief, fire marshal, chief of a fire prevention bureau, labor department, 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 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."

Bath, Molten Salt. See Furnaces, Molten Salt Bath.

Blower, Mixing. See Mixers.

Branch Circuit-Individual. A branch circuit that supplies only one utilization equipment.

Burners.

Burner (or Nozzle). A device through which combustion air and fuel are released into the combustion zone. If the fuel gas and air are introduced separately, the burner is said to be "nozzle-mixing"; otherwise, an air-gas mixing device is used to supply the nozzle, which then is said to be of the (partial) premixing-type. Either way, additional means are required to control or limit the flow of the fuel and air. Oil burners are always "nozzle-mixing," even if air is used for atomization.

Burner — Air or Steam Atomizing Type. A burner where oil is divided into a fine spray by an atomizing agent, such as steam or air.

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

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

Burner, Blast Tip. A small metallic or ceramic burner nozzle so made that flames will not blow away from it.

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

Burner, Diaphragm. A burner which utilizes a porous refractory diaphragm at the port so that the combustion takes place over the entire area of this refractory diaphragm.

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

Burner, Enclosed Combustion. A burner which confines the combustion in a small chamber of a furnace and only the high temperature completely combusted gases, in the form of high velocity jets or streams, are used for heating.

Burner, Excess Air. A nozzle-mixing burner delivering a fixed volume of air and a variable volume of fuel gas such that complete combustion of fuel gas occurs at all rates of firing, to provide relatively uniform flow of air and products regardless of firing rates.

Burner, Flame-Retaining Nozzle. Any burner nozzle with built-in features to hold the flame at high mixture pressures.

Burner, Line. A burner whose flame is a continuous "line" from one end to the other (normally applied to a blast burner).

Burner, Luminous Flame. A burner which discharges nonturbulent parallel strata of air and fuel gas to produce an extended flame of high luminosity.

Burner, Luminous Wall. A porous refractory liner to permit fuel gas-air mixtures to flow through, forming a luminous wall.

Burner, Multijet. A form of burner which generally consists of fuel gas manifolds with a large number of jets arranged to fire horizontally through openings in a vertical refractory plate.

Burner, Multiport. A burner having two or more separate discharge openings or ports. (These ports may be either flush or raised.)

Burner, Nozzle-Mixing. A burner in which the fuel gas and air are kept separate until discharged from the burner into the combustion chamber or tunnel. Generally used with low pressure fuel gas [up to ½ psig or 14 in. w.c. (3.5 kPa)] and low pressure air [up to 5 psig (34 kPa)].

Burner, Open Port. Any type of burner that fires across a gap into an opening in the furnace or combustion chamber wall and is not sealed into the wall.

Burner, Pipe. Any type of atmospheric or blast burner in the form of a tube or pipe with ports or tips spaced over its length.

Burner, Power. A fuel gas burner in which either fuel gas or air, or both, are supplied at pressure exceeding, for fuel gas, the line pressure, and for air, the atmospheric pressure. Examples are fuel gas burners having zero governor inspirator mixers, those supplied by blower mixers or an approved gas-mixing machine and those supplied with air by a blower, compressor, or forced-draft fan.

Burner, Premixed. A burner that utilizes a positive and dependable air-fuel gas mixer to furnish the air needed for complete combustion of the fuel supplied to the burner independently of the concentration or pressure of the atmosphere inside the enclosure where the burner fires. The zero governor inspirator mixer, the high pressure [fuel gas pressure 1.0 psi (7 kPa) or higher] atmospheric inspirator mixer, the blower mixer, and the approved fuel gas-mixing machine are illustrative of such a mixer.

Burner, Pressure. Same as Burner Blast.

Burner, Pressure-Atomizing. A burner where oil under high pressure is forced through small orifices.

Burner, Radiant. A burner designed to transfer a significant part of the combustion heat in the form of radiation from surfaces of various shapes which are usually of refractory material.

Burner, Radiant-Tube. A burner of the atmospheric, premix or nozzle-mixing type specially designed to provide a long flame within a tube to assure substantially uniform radiation from the tube surface.

Burner, Ribbon. A burner having many small closely spaced ports, usually made up by pressing corrugated metal ribbons in a slot or other shaped opening.

Burner, Ring. A burner made with one or more concentric rings. Combustion air may be supplied by natural, induced, or forced draft.

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

Burner, Self-Piloted. A burner where the pilot fuel is issued from the same ports as the main flame and/or merges with the main flame to form a common flame envelope with a common flame base. In effect, the pilot flame is simply enlarged to become the main flame.

Burner, Single Port. A burner having only one discharge opening or port.

Burner, Tunnel. A burner sealed in the furnace wall in which combustion takes place mostly in a refractory tunnel or tuyere which is really part of the burner.

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

Burner, Vaporizing. A burner where oil is vaporized by heat.

Catalytic Combustion System (Direct or Indirect Heater). A furnace heater of any construction that employs catalysts to accelerate the oxidation or combustion of fuel-air mixtures for eventual release of heat to a furnace process.

Check, Safe-Start. A checking circuit incorporated in a safety control circuit that prevents lighting-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 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.

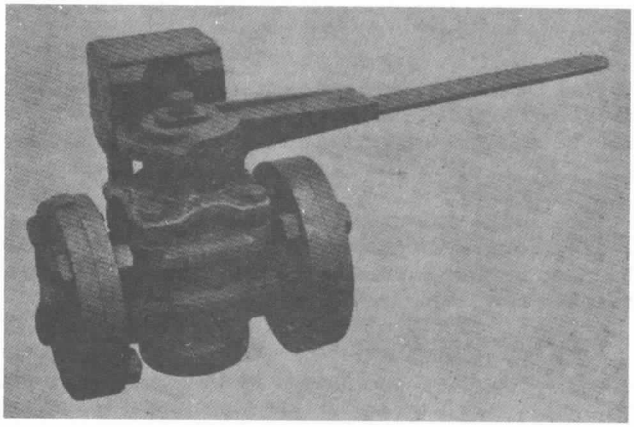


Figure 1-4.2 Example of a Supervising Cock, Electrical Interlocking.

Cock, Supervising, Electric Interlocking. A conventional straight-through cock with a special built-in switch assembly protected against tampering, and arranged so that switch contacts are closed only when the cock is in the fully closed position.

NOTE: This type of supervising cock is suitable for both gas or oil fuels. The switch contacts of all cocks are wired in series in the safety control circuit, so that all supervising cocks must be closed before the main fuel safety shutoff valve can be opened.

Cock, Supervising, Pneumatic Type. A special approved cock similar to the usual burner fuel gas cock, except that it has two side outlets which furnish a small independent passageway which is opened only after the main fuel gas passage is completely closed.

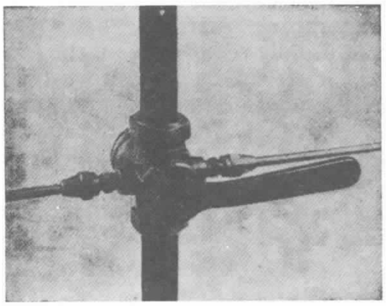


Figure 1-4.3 Example of a Supervising Cock, Pneumatic Type.

The keyway width is narrow enough in respect to size and proportions of the main fuel gas ports to ensure positive closure of the main fuel gas way before opening the side outlets. This particular type of supervising cock is not suitable for fuel oil.

Combustion Safeguard. See Safeguard, Combustion.

Continuous Vapor Concentration Indicators and Controllers. Devices which measure and indicate, directly or indirectly, in percentage of the lower explosive limit (LEL), the concentration of a flammable vapor-air mixture.

Controller, Continuous Vapor Concentration. Devices which measure and indicate, directly or indirectly, in percentage of the lower explosive limit, the concentration of a flammable vapor-air mixture.

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

Controls, Fuel Safety. Devices such as safety shutoff valves, flame detection units, fuel pressure switches (high and low), combustible gas detectors, flowmeters, firechecks, reliable ignition sources, and supervisory cocks.

Controls, Ventilation. Devices such as flow switches, pressure switches, fan shaft rotation detectors, dampers, position limit switches, time delay and electrical interlocks, which are placed in the system to ensure adequate ventilation prior to establishing the source of heat and during the operation of the heating equipment.

Cut-Off Room. See Room, Cut-Off.

Damper Cut-Away. A restricting airflow device that, when placed in the maximum closed position, will permit a minimum amount of airflow past the restriction. Cutaway dampers are normally placed in the exhaust and/or fresh air intake ducts to ensure that the required minimum amount of exhaust and/or fresh air is handled by the ventilating fans to keep the solvent vapor concentration in the furnace below the designed concentration level.

Device, Flame Detection. A device which will detect the presence or absence of flame. Flame detection devices may be based on:

(a) Flame rectification

(b) Ultraviolet radiation

(c) Infrared radiation

(d) Heat actuation.

Device, Photoelectric, Infrared and Ultraviolet Detecting. A detector based on the radiant energy of specific wave lengths of the flame. The current passing through the detector is amplified by the combustion safeguard to actuate suitably arranged relays to make or interrupt the power to the fuel safety shutoff valves.

Dielectric Heater. See Heater, Dielectric.

Direct-Fired. Any heating system where the products of combustion enter the furnace chamber and come in contact with the work in process.

Direct-Fired External Heater. See Heater, Direct-Fired External.

Direct-Fired External Nonrecirculating Heater. See Heater, Direct-Fired External Nonrecirculating.

Direct-Fired External Recirculating Heater. See Heater, Direct-Fired External Recirculating.

Direct-Fired Internal Heater. See Heater, Direct-Fired Internal.

Direct-Fired Nonrecirculating Heater. See Heater, Direct-Fired Nonrecirculating.

Direct-Fired Recirculating Not-Through Heater. See Heater, Direct-Fired Recirculating Not-Through.

Dustproof. So constructed or protected that dust will not interfere with its successful operation.

Explosive Range (Limits of Flammability). See Range, Explosive.

Excess Temperature Limit. See Limit, Excess Temperature.

Firing, High-Low. Provision for two firing rates, high and low, according to load demand.

Flame Detection Device. See Device, Flame Detection.

Flame Propagation (Rate of). See Propagation, Flame (Rate of).

Flame Rod. See Rod, Flame.

Flame, Supervised. A flame whose presence is detected by a combustion safeguard.

Flow Switch. See Switch, Flow.

Fluid. Gas or liquid.

Fuel-Air Ratio Control System, Two-Valve. A system using separate control of air and gas, both of which are under pressure. The valves controlling the air and fuel gas flow may or may not be mechanically linked or interlocked.

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

Fuel Gas, Analyzer. See Analyzer, Fuel Gas.

Fuel Gas, Atmospheric Regulator. See Zero Governor.

Fuel Gas, Commercial Manufactured. A mixture of gases usually composed of various proportions of some of the following gases:

(a) Coal gas, formed by distillation or "cracking" of bituminous coal.

(b) Coke-oven gas, produced in a similar manner as a by-product in the manufacture of coke.

(c) Carbureted water gas, formed by flowing steam through incandescent carbon. It has a low heat content, which is increased by bringing the hot gas into contact with oil so that some of the oil is broken down or "cracked" into a gas. This product is sometimes mixed with coke-oven gas.

(d) Oil gas, made by "cracking" petroleum oils, is used occasionally in manufactured gases.

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

Fuel Gas, Liquefied Petroleum. Any material which is composed predominantly of any of the following hydrocarbons, or mixtures of them: propane, propylene, butanes (normal butane or isobutane), and butylenes.

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

Fuel Gas, Natural. A mixture of gases, principally methane and ethane, obtained from gas wells and from which less volatile hydrocarbons such as propane and butane have been removed, leaving a mixture of gases which will remain in the gaseous state at all pressures and temperatures encountered in a gas distribution system.

Fuel Gas Pressure Regulator. See Regulator, Fuel Gas Pressure.

Fuel Gas, Producer. Any gas formed by blowing air and/or steam through incandescent coal, coke or charcoal.

Fuel Oil. No. 2, 4, 5 or 6 in accordance with ASTM D396, *Specifications for Fuel Oils*.

Fuel Safety Controls. See Controls, Fuel Safety.

Fume Incinerator. A separate or independent combustion system usually removed from the processing area of a furnace, or elevated temperature fume-producing device, but intended to entrain the process exhaust vapors or fumes as they are generated for the purpose of thermal decomposition and/or heat recovery.

Furnace, Batch Process. A furnace into which the work is introduced all at one time.

Furnace, Continuous Process. A furnace into which the work charge is continuously introduced.

Furnace, Plasma Arc. The passage of an electric current between either a pair of electrodes or between electrodes and the work, causing an arc which releases energy in the form of heat under the influence of an ionized gas.

Furnace, Types of. For examples, see Figures 1-4.4 through 1-4.15 and Figures 1-4.25 and 1-4.26.

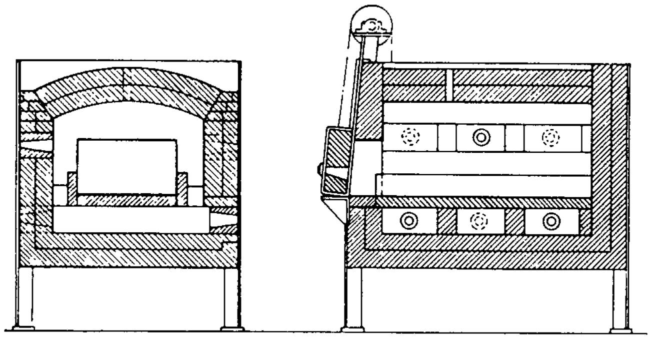


Figure 1-4.4 Example of Large Batch-type, Under- and Overfired, Semi-Muffle, Heat-Treating Furnace.

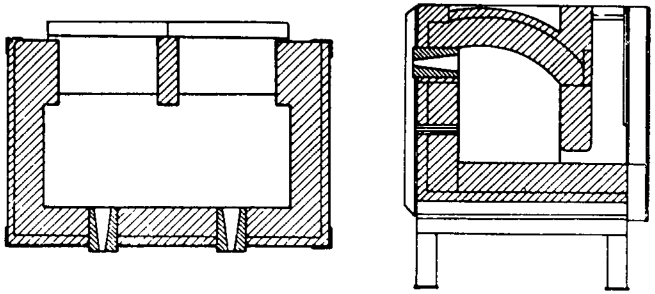


Figure 1-4.5 Example of a Slot-type, Twin Chamber Forge Furnace, Top-Fired from Rear.

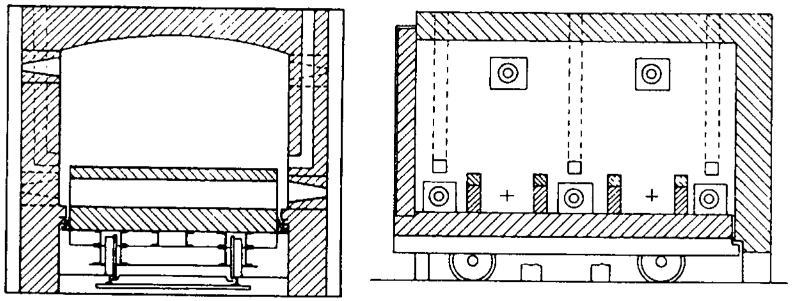


Figure 1-4.6 Example of a Car Bottom-type Furnace for Annealing, Stress Relieving, Heat-Treating, Carburizing in Boxes or Firing Ceramics; May be Under- or Overfired, or Both.

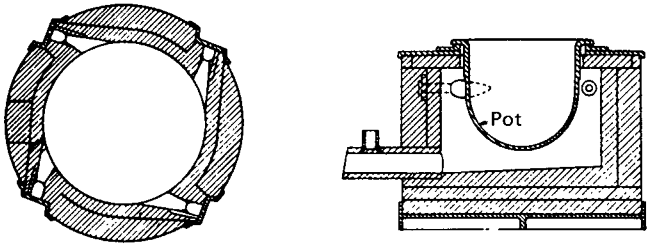


Figure 1-4.7 Example of a Circular Pot Furnace for Salt Bath Hardening and for Soft Metal Aluminum or Magnesium Melting; Burners Fire Tangentially Near Top of Furnace.

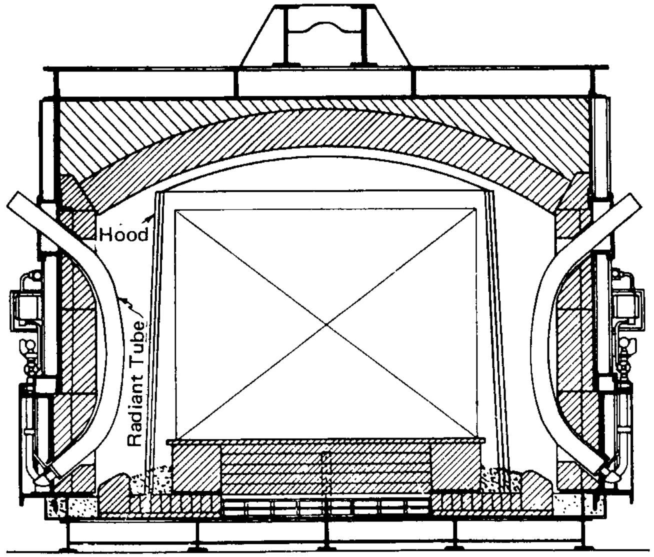


Figure 1-4.8 Example of a Radiant Tube, Muffle-type Annealing Furnace.

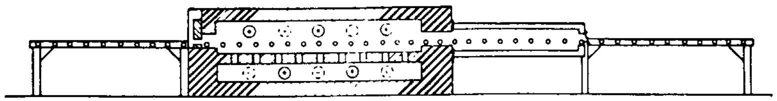


Figure 1-4.9 Example of a Continuous Roller Hearth Furnace.

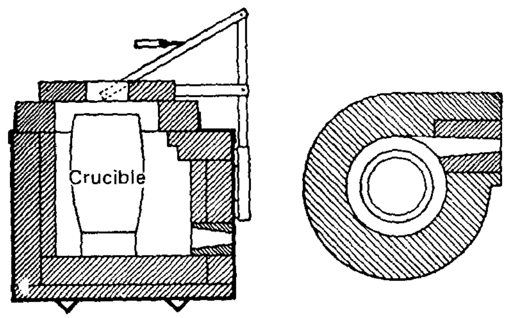


Figure 1-4.10 Example of a Stationary Crucible Melting Furnace; Burners Fire Tangentially Below Bottom of Pot.

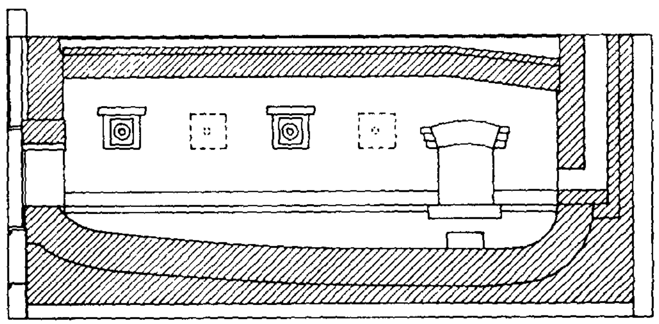


Figure 1-4.11 Example of a Reverberatory Furnace for Melting Nonferrous Metals.

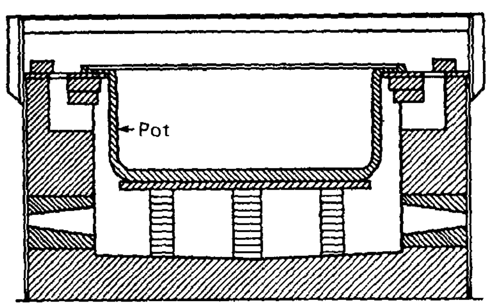


Figure 1-4.12 Example of a Rectangular Pot Furnace for Annealing, Heat-Treating, Metal Heating or Melting; Burners Fire Below Pot Bottom.

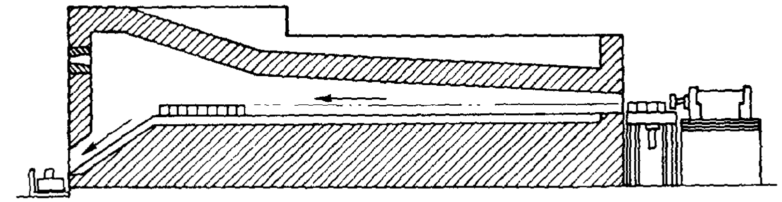


Figure 1-4.13 Example of a Pusher-type, Continuous Billet Heating Furnace.

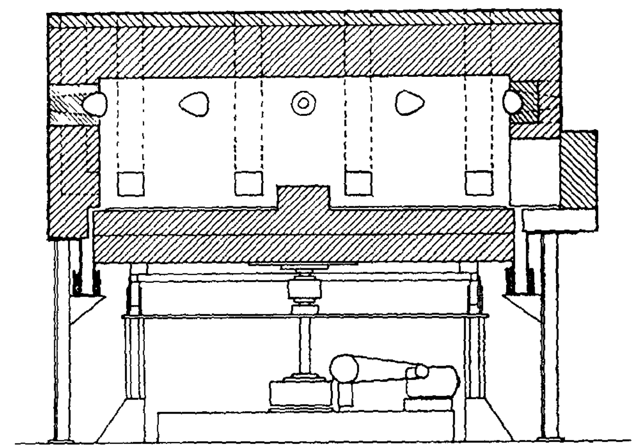


Figure 1-4.14 Example of a Rotary Hearth Forging or Heat-Treating Furnace.

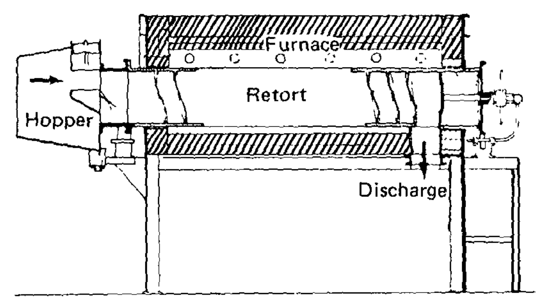


Figure 1-14.15 Example of a Continuous Revolving Retort Heat-Treating Furnace.

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

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

Heater, Direct-Fired External. Any oven heating system in which the burners are in a combustion chamber effectively separated from the oven chamber and so arranged that products of combustion from the burners are discharged into the oven chamber by a circulating fan or blower.

Heater, Direct-Fired External Nonrecirculating. Any direct-fired external heater so arranged that products of combustion are discharged into the oven chamber without any return or recirculation from the oven chamber.

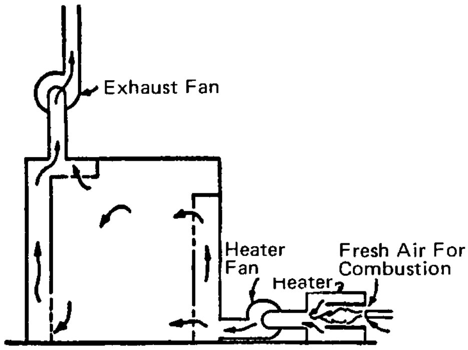


Figure 1-4.16 Example of a Direct-Fired External Nonrecirculating Heater.

Heater, Direct-Fired External Recirculating. A direct-fired external heater so arranged that oven atmosphere is recirculated to the oven heater and in contact with the burner flame.

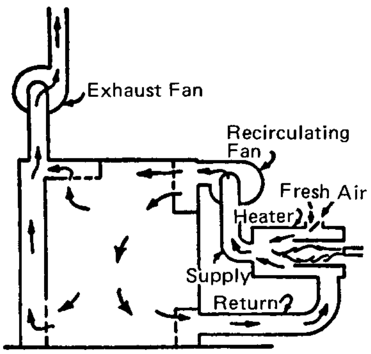


Figure 1-4.17 Example of a Direct-Fired External Recirculating Through the Heater.

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

Heater, Direct-Fired Recirculating Not Through Heater. A heating system so constructed that the oven atmosphere circulates through a blower with products of combustion admitted to the recirculating duct work, but without the oven atmosphere actually passing through the combustion chamber.

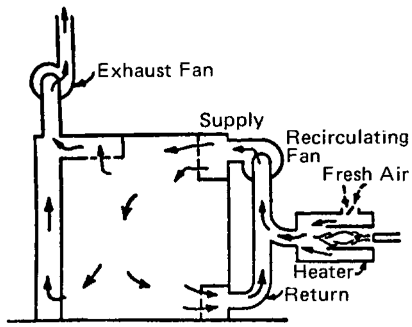


Figure 1-4.18 Example of a Direct-Fired External Recirculating Not-Through Heater.

Heater, Direct-Fired Internal. Any oven heating system in which the burners are within the oven chamber and in contact with the oven atmosphere.

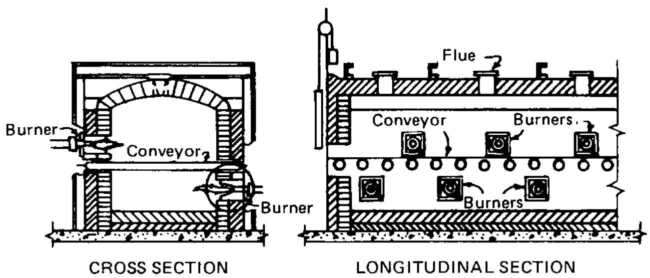


Figure 1-4.19 Example of Direct Internal-Fired Multiburner Furnace.

Heater, Indirect-Fired. Any heating system where the products of combustion do not enter the work chamber, heating being accomplished by radiation or connection from the tubes or muffles.

Heater, Indirect-Fired External. An oven heater in which burners and combustion chamber are outside of the oven chamber and the oven atmosphere is kept separate from combustion gases.

Heater, Indirect-Fired External Recirculating Not Through Heater. A system in which air is drawn or blown through the radiator of a heater without any recirculation of the oven atmosphere through the heater.

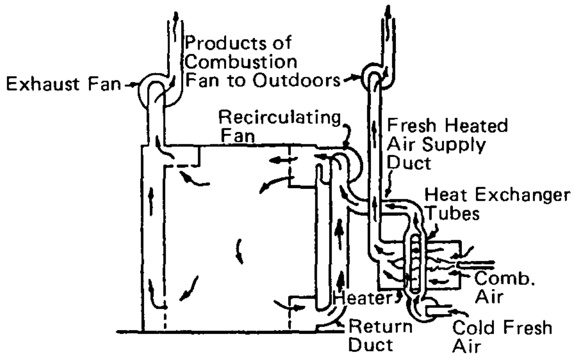


Figure 1-4.20 Example of an Indirect-Fired External Recirculating Not-Through Heater.

Heater, Indirect-Fired External Recirculating. A system in which oven atmosphere is recirculated through radiators outside the oven chamber.

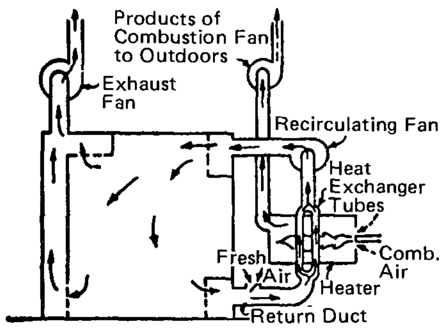


Figure 1-4.21 Example of an Indirect-Fired External Recirculating Heater.

Heater, Indirect-Fired External, Internal Radiator. A system in which products of combustion from a heater located outside the oven chamber are circulated through radiator tubes located within the oven.

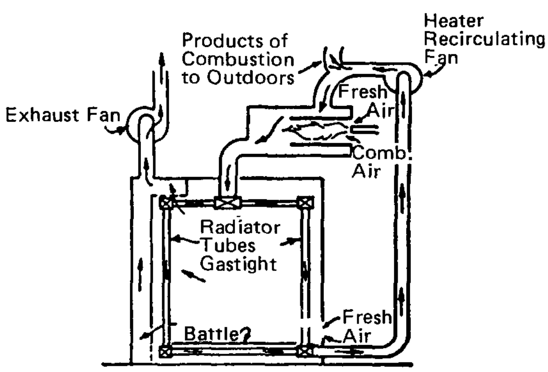


Figure 1-4.22 Example of an Indirect-Fired External, Internal Radiator.

Heater, Indirect-Fired Internal. A heating system of gastight radiators containing gas burners not in contact with the oven atmosphere. These systems may be of the types as follows:

Heater, Indirect-Fired Internal Explosion-Resisting. An indirect-fired internal heater so constructed as to withstand explosion pressure from ignition of a gas-air mixture in the radiators.

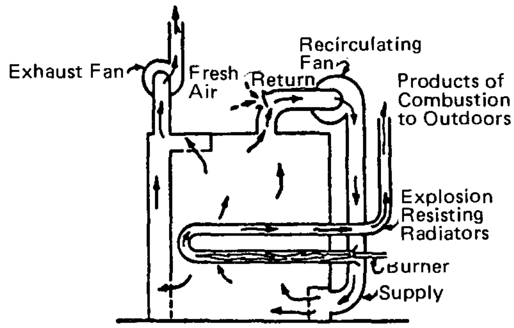


Figure 1-4.23 Example of a Indirect-Fired Internal Explosion-Resisting Heater.

Heater, Indirect-Fired Internal Not Explosion-Resisting. An indirect-fired internal heater with gastight radiators which, however, are not designed to withstand an internal explosion.

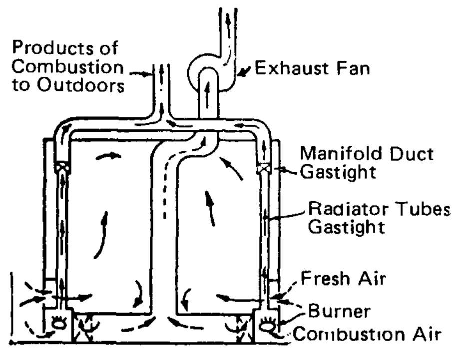


Figure 1-4.24 Example of an Indirect-Fired Internal Not Explosion-Resisting Heater.

Heater, 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 Article 665 of NFPA 70, the National Electrical Code®.*)

Heater, Radiant-Tube. Tubular elements open at one or both ends, constructed gastight of suitable heat resistant material, and capable of withstanding explosion pressure from ignition of fuel-air mixture. The tube has an inlet and/or burner arrangement where combustion is initiated, a suitable length where combustion occurs, and an outlet for the combustion products formed. The fuel-air mixture can be mixed before, during or after introduction into the tube. The introduction can be accomplished under high pressure, under slight pressure, or under suction. Ignition can be accomplished at either the inlet or the outlet of the tube.

Radiant tubes can be located in the actual heating chamber of the furnace or remotely in another chamber. In the latter instance, heat transfer is accomplished by recirculation of heated gases.

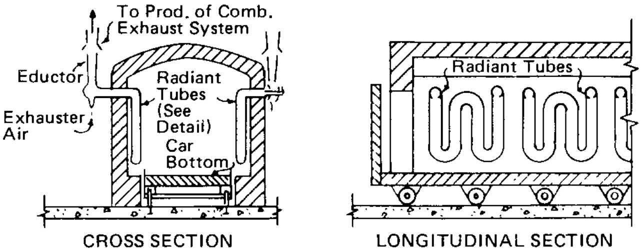


Figure 1-4.25 Example of an Indirect-Fired Radiant-Tube Furnace (Car Bottom Type).

Heater, Resistance. Any heater in which heat is produced by current flow through a resistive conductor and which utilizes the heat generated as a result. Resistance heaters may be of the "open" type with bare heating conductors or "insulated sheath" type, with conductors covered by a protecting sheath which may be filled with electrical insulating material.

Heaters, Types of. For examples see Figures 1-4.16 through 1-4.24.

Heater, Tubular. A form of resistance heater in which the resistive conductors are enclosed in glass, quartz, or ceramic envelopes that may or may not contain a special gas atmosphere.

High-Low Firing. See Firing, High-Low.

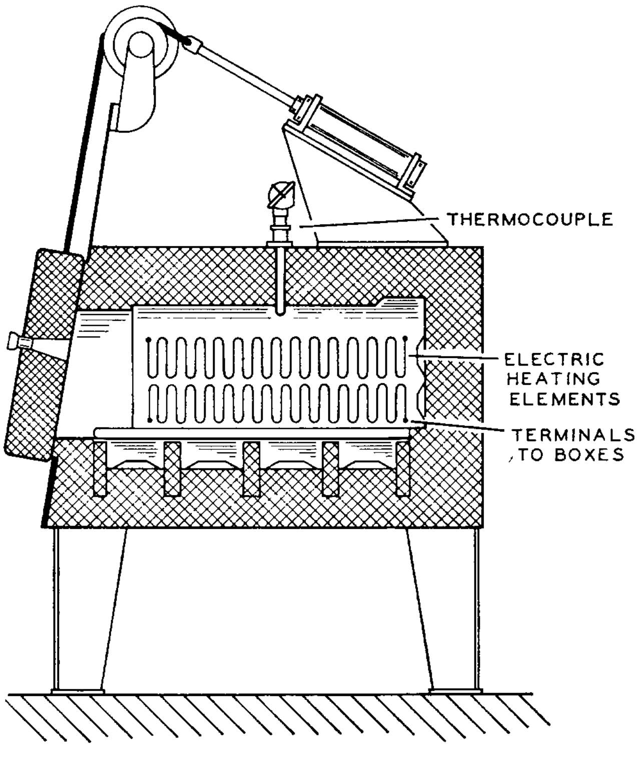


Figure 1-4.26 Example of Electric Furnace.

High Pressure Air System. See Air System, High Pressure.

Indirect-Fired Heater. See Heater, Indirect-Fired.

Ignition Systems.

Automatic-Ignited Burner. A burner ignited by direct electric ignition, or by an electric-ignited or continuous pilot.

Automatic-Lighted Industrial Heating Equipment. Fuel gas- or oil-fired industrial heating equipment such as a furnace where fuel to the main burner(s) is turned on automatically and ignited automatically (*see Automatic-Ignited Burner*).

Direct Electric Ignition. Ignition of an oil flame (and in some cases a fuel gas flame) by an electric ignition source such as a high-voltage spark or hot wire.

Manual-Ignited Burner. A burner ignited by a portable fuel gas or oil-burner torch or by an oil-soaked swab torch, placed in proximity to the burner nozzle by the operator.

Manual-Lighted Industrial Heating Equipment. Fuel Gas- or oil-fired equipment such as a furnace where fuel to the main burner(s) can be turned on only by hand and is manually or semiautomatically ignited under the supervision of the operator (*see Manual-Ignited Burner and Semiautomatic-Ignited Burner*).

Modulated Firing. Provision for gradually varying the firing rate between high-fire and low-fire, according to load demand.

Proved Low-Fire Start Interlock. A burner start in which a control sequence ensures that a high-low or modulated burner is in the low-fire position before the burner can be started, as, for example, by means of an end switch mounted on the drive shaft of the modulating motor, which is wired into the safety control circuit.

Semiautomatic-Ignited Burner. A burner ignited by direct electric ignition or by an electric-ignited pilot, electric ignition being manually activated.

Semiautomatic-Lighted Industrial Heating Equipment. The same as automatic-lighted except that on each lighting-off, placing the equipment in service from cold condition, fuel to the main burner(s) can be turned on only by hand and is manually or semiautomatically ignited under the supervision of the operator (*see Manual-Ignited Burner and Semiautomatic-Ignited Burner*).

Ignition Temperature. See Temperature, Ignition.

Indicator, Continuous Vapor Concentration. See Controller, Continuous Vapor Concentration Indicator.

Indirect-Fired External Heater. See Heater, Indirect-Fired External.

Indirect-Fired External Heater, Recirculating, Not-Through Heater. See Heater, Indirect-Fired External, Recirculating, Not-Through.

Indirect-Fired, External Heater, Internal Radiator. See Heater, Indirect-Fired, External, Internal Radiator.

Indirect-Fired Internal Heater. See Heater, Indirect-Fired Internal.

Indirect-Fired, Internal Explosion-Resisting Heater. See Heater, Indirect-Fired, Internal, Explosion-Resisting.

Indirect-Fired, Internal, Not Explosion-Resisting Heater. See Heater, Indirect-Fired, Internal, Not Explosion-Resisting.

Induction Heater. See Heater, Induction.

Inert Atmosphere Purge. See Purge, Inert Atmosphere.

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

Inspirator, Proportioning. An inspirating tube which, when supplied with air, will draw into the air stream all the fuel gas necessary for combustion.

Inspirator, Atmospheric (Venturi). A device which utilizes the kinetic energy of the fuel gas under pressure to inject all or part of the combustion air required as primary air from the ambient.

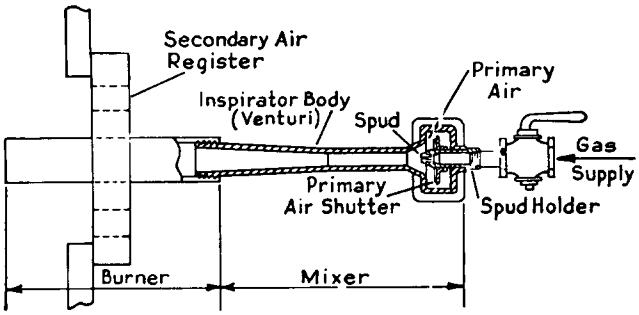


Figure 1-4.27 Example of an Atmospheric Inspirating Burner Mixer.

Inspirators, High Pressure. Operate in the approximate range of 1 to 30 psig (7 to 207 kPa) fuel gas pressure, and may or may not inject 100 percent primary air.

Inspirators, Low Pressure. Operate at about 1 psig (7 kPa) fuel gas pressure, or less, and cannot inject 100 percent combustion air.

Interlock, Proved Low-Fire Start. A burner start in which a control sequence ensures that a high-low or modulated burner is in the low-fire position before the burner can be started, as for example, by means of an end switch mounted on the drive shaft of the modulating motor, which is wired into the safety control circuit.

Labeled. Equipment or materials to which has been attached a label, symbol or other identifying mark of an organization 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.

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

Limits of Flammability. See Range, Explosive.

Listed. Equipment or materials included in a list published by an organization acceptable to the "authority having jurisdiction" and concerned with product evaluation, that maintains periodic inspection of production of listed equipment or materials and whose listing states either that the equipment or material meets appropriate standards or has been tested and found suitable for use in a specified manner.

NOTE: The means for identifying listed equipment may vary for each organization concerned with product evaluation, some of which do not recognize equipment as listed unless it is also labeled. The "authority having jurisdiction" should utilize the system employed by the listing organization to identify a listed product.

Low-Oxygen Oven. See Oven, Low-Oxygen.

Low Pressure Air System. See Air System, Low Pressure.

Mixer, Air-Fuel Gas. A system which proportions air and fuel gas and mechanically compresses the mixture for combustion purposes. A central mixing unit may be used or individual appliances may each have their own mixers.

Mixers, 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 may be designed to entrain some of the air for combustion as well as the fuel gas.

Mixers, Automatic. A mixer that automatically maintains within its rated capacity a substantially constant air fuel gas ratio at varying rates of flow. All types defined below can be designed to fit this classification.

Mixers, Gas Jet (Atmospheric Inspirator 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.

(a) The term "Atmospheric Inspirator (Venturi) Mixer" shall mean any mixer in which part or all of the combustion air (primary air) is drawn in by the inspirating effect of a fuel gas jet entering the inspirator, the remaining combustion air (secondary air), if needed, being supplied from the atmosphere in which the burner is located.

(b) If fuel gas for the jet is available at the orifice at pressures below 1 psig (7 kPa), the mixer is defined as a "low pressure atmospheric inspirator" mixer; if at 1 psig

(7 kPa) or above, the mixer is designated a "high pressure atmospheric inspirator."

Mixers, Manual. A mixer that requires manual adjustments to maintain the desired air-fuel gas ratio as rates of flow are changed.

Mixers, Mechanical. A mixer using mechanical means to mix fuel and air, neglecting any kinetic energy in the fuel and air, and compressing 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. The proportioning device may be automatic or require manual adjustment to maintain the desired air-fuel ratio as rates of flow are changed.

Mixers, Proportioning. A mixer comprised of an inspirator which, when supplied with air, will draw into the air stream all of the fuel gas necessary for combustion and a governor, zero regulator, or ratio valve which reduces incoming fuel gas pressure to approximately atmospheric. (*See Figure 1-4.1.*)

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.

Muffles. Enclosures within a furnace which separate the products of combustion from the work and from any special atmosphere which may be required for the process. Burners may be used for direct-firing of the space within the furnaces but outside the muffle, or heating of the muffle may be indirect means using radiant tubes or external furnace heaters.

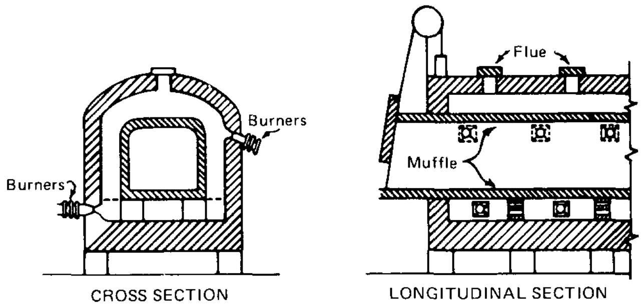


Figure 1-4.28 Example of Muffle-Type, Internal-Fired, Multiburner Furnace.

Oven, Low-Oxygen. An oven which utilizes a low-oxygen atmosphere to evaporate solvent.

Operator. The individual responsible for the light-up, operation, shutdown, and emergency handling of the furnace and its associated equipment.

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

Pilot, Continuous. A pilot that burns continuously 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 whether or not the main burner is firing, but during lighting-off it is expanded (burns without turndown) to ignite the main burner reliably.

Pilot, Flame-Establishing Period. The interval of time during lighting-off in which a safety control circuit permits the pilot fuel safety shutoff valve to be open before the combustion safeguard is required to prove the presence of the pilot flame.

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

Pilot, Interrupted. A pilot which burns during the entire pilot-flame-establishing period and/or trial-for-ignition period, and which is cut off (interrupted) at the end of this period(s) or during firing.

Pilot, Proved. A pilot flame supervised by a combustion safeguard which senses the presence of the pilot flame and which is located where it will reliably ignite the main burner before permitting the main-burner fuel safety shutoff valve to be opened.

Plasma Arc Furnace. See Furnace, Plasma Arc.

Pressure Switch. See Switch, Pressure.

Preventilation Time Delay Relay. See Relay, Preventilation Time Delay.

Primary Air. See Air, Primary.

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

Proven Ventilation. See Ventilation, Proper.

Proportioning System (automatic). A combination of one or more burner tips, nozzles, or other firing heads and a proportioning device intended to supply a fuel-air mixture to the firing point in proper proportion for combustion.

Proved Low-Fire Start Interlock. See Interlock, Proved Low-Fire Start.

Purge, Air. Positive removal of and/or dilution of flammable vapors to a point below 25 percent of the LEL with air.

Purge, Inert Atmosphere. The replacement of a flammable or high-oxygen bearing atmosphere with an inert gas to a nonflammable state, i.e., 50 percent of the lower explosive limit (LEL) or $<$ 1 percent oxygen.

Range, Explosive (Limits of Flammability). The range of concentration of a flammable gas in air within which flame is propagated. The lowest flammable concentration is the lower explosive limit (LEL). See NFPA

325M, *Fire Hazard Properties of Flammable Liquids, Gases, and Volatile Solids*.

Regulator, Fuel Gas Atmosphere. See Zero Governor.

Regulator, Fuel Gas Pressure. A diaphragm-operated valving device that maintains a constant outlet pressure under varying flow.

Relay, Preventilation Time Delay. A switch which is operated automatically after a preset time interval usually measured by a timing device.

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

Room, Cutoff. A room within a building and having at least one exterior wall.

Rotational Switch. See Switch, Rotational.

Safeguard, Combustion. A safety control responsive directly to flame properties; it senses the presence and/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.

Safe-Start Check. See Check, Safe-Start.

Safety Shutoff Valve. See Valve, Safety Shutoff.

Secondary Air. See Air, Secondary.

Shall. Indicates a mandatory requirement.

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

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

Special Atmosphere, Flammable. Gases which are known to be flammable and predictably ignitible when mixed with air.

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

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

Suction System. A system applying suction to a combustion chamber to draw in the air and/or fuel necessary to produce the desired combustible mixture.

Supervised Flame. See Flame, Supervised.

Supervising Cock. See Cock, Supervising.

Switch.

Switch, Airflow. A device actuated by the flow of air in a duct system.

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 which is activated by the flow of a gaseous or liquid fluid by a pressure differential in a diaphragm measuring two different points.

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

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

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

Switch, Rotational. A device which is usually 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 give a safe minimum airflow, a switch contact closes.

Temperature Controller. See Controller, Temperature.

Temperature, Ignition. The lowest temperature at which a gas-air mixture may ignite and continue to burn. This is also referred to as the autoignition temperature. When burners supplied with a gas-air mixture in the flammable range are heated above the autoignition temperature, flashbacks may occur. In general, such temperatures range from 870°F (466°C) to 1300°F (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.

Trial-for-Ignition Period (Flame-Establishing Period). That interval of time during lighting-off in which a safety control circuit permits the fuel safety shutoff valve to be open before the combustion safeguard is required to supervise the flame.

Two-Valve Fuel-Air Ratio Control System. A system using separate control of air and gas, both of which are under pressure. The valves controlling the air and fuel gas flow may or may not be mechanically linked or interlocked.

Valve, Safety Shutoff. A normally closed (closed when de-energized) automatic valve installed in the piping to shut off the atmosphere gas or fuel in the event of abnormal conditions or during shutdown periods.

Valve, Electric, Manual-Opening, Automatic-Closing Safety Shutoff. A valve which can be opened only after the valve is energized and must be opened manually. De-energizing the valve automatically closes the valve.

Valve, Electric-Opening, Automatic-Closing Safety Shutoff. A valve which opens automatically on energizing the valve actuating device, and closes automatically on de-energizing the actuating device.

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

Ventilation Controls. See Controls, Ventilation.

Ventilation, Proper. An adequate supply of fresh air and 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 will be safely below the lower explosive limit at all times.

Zero Governor (also called Atmospheric Regulator). A diaphragm-type regulator that maintains the fuel gas pressure at atmospheric or zero gauge pressure.

1-5 Approvals, Plans, and Specifications.

1-5.1 Before new equipment is installed or existing equipment remodeled, complete plans, sequence of operations, and specifications shall be submitted for approval to the authority having jurisdiction.

1-5.1.1 Plans shall be drawn, and show all essential details as 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.

1-5.1.2 Wiring diagrams and sequence of operations for all safety controls shall be provided.

NOTE: Where applicable, ladder-type schematic diagrams are preferred.

1-5.2 Any deviation from this standard shall require special permission from the authority having jurisdiction.

1-5.3 All wiring in and around furnaces shall be in accordance with NFPA 70, *National Electrical Code*, and as described hereafter.

1-6 Operator and Maintenance Personnel Training.

1-6.1 The selection of alert and competent personnel shall be required. It is recognized that their knowledge and training are vital to safe furnace operation and maintenance.

1-6.1.1 All personnel shall be thoroughly instructed and trained under supervision of experienced person(s), and shall be required to demonstrate understanding of the equipment and of its operation to assure knowledge of and practice of safe operating procedures.

1-6.2 Regular personnel shall receive scheduled retraining and testing to maintain a high level of proficiency and effectiveness.

1-6.3 Personnel shall have access to operating instructions at all times.

1-6.4 Operator training shall include, where applicable:

(a) Combustion of fuel-air mixtures

(b) Explosion hazards

(c) Sources of ignition including autoignition (for instance, by incandescent surfaces)

(d) Functions of control and safety devices

(e) Handling of special atmospheres.

1-6.5 Operating instructions shall be provided by the equipment manufacturer. These shall include:

(a) Schematic piping and wiring diagrams

(b) Start-up procedures

(c) Shutdown procedures

(d) Emergency procedures including those occasioned by loss of special atmospheres, electric power or other essential utilities

(e) Maintenance procedures.

1-7 Safety Design Data Form for Solvent Atmosphere Ovens.

1-7.1 Safety data for solvent atmosphere ovens shall be furnished on the manufacturer's nameplate [*see Figure 1-7.1(a)*] or on an approved form similar to Figure 1-7.1(b).

1-7.2 A suitable, clearly worded and prominently displayed oven safety design data form or manufacturer's nameplate shall be provided by the builder of each oven stating the safe operating conditions for which the oven was designed and built.

NOTE: Disregard of this information may put the apparatus in jeopardy, or result in failure to function safely, and cause it to be damaged by fire or explosion.

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 1-7.1(a) Suggested Manufacturer's Nameplate Data.

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.

Figure 1-7.1(b) Suggested Safety Design Data Form

Chapter 2 Location and Construction

2-1 Location.

2-1.1 General. Furnaces and related equipment shall be located with consideration given to the possibility of fire resulting from overheating, spillage of molten metal, quench tanks, ignition of hydraulic oil, overheating of material in furnace, etc., or from the escape of fuel and the possibility of building damage and personal injury resulting from an explosion.

2-1.2 Grade Location. Special consideration shall be given to the location of equipment using flammable fluids or when using fuels with a specific gravity greater than air.

2-1.3 Structural Members of the Building.

2-1.3.1 Furnaces shall be located and erected so that the building structural members will not be adversely affected by the maximum anticipated temperatures (*see 2-1.5*).

2-1.3.2 Structural building members shall not pass through or be enclosed within the furnaces.

2-1.4 Location in Regard to Stock and Other Processes.

2-1.4.1 Valuable Stock.

NOTE: Furnaces should be well separated from valuable stock, important power equipment, machinery and sprinkler risers, thereby securing a minimum interruption to production and protection in case of accidents to the furnace.

2-1.4.2 **Personnel.** Furnaces shall be located to minimize exposure to people from the possibility of injury from fire, explosion, asphyxiation, and toxic materials, and shall not obstruct personnel travel to exitways.

2-1.4.3 Industrial ovens and furnaces shall be safely located and protected from exposure by flammable coating dip tanks, spray booths, storage and mixing rooms for flammable liquids, or storage areas used for readily flammable materials, or exposure by or to the diffusion of flammable vapor-air mixtures.

2-1.4.4 The room in which flammable vapors and powders are produced shall be ventilated in such a manner that the atmosphere in the vicinity of the operations will be kept well below the lower explosive limit. Flow of ventilating air from the room or area shall be away from the ovens or heaters.

2-1.4.5 **Corrosion Resistance.** Equipment shall be safely located and protected from corrosive external processes and environment.

2-1.5 Floors and Clearances.

2-1.5.1 Furnaces shall be located so as to be readily accessible with adequate space above to permit installation of automatic sprinklers, the proper functioning of explosion vents, and inspection and maintenance. Roofs and floors of furnaces shall be insulated, and the space above and below ventilated, to keep temperatures at combustible ceilings and floors below 160°F (71°C).

2-1.5.2 When furnace locations on noncombustible floors are not available, then sufficient insulation and ventilation shall be provided to protect the combustible floor from damage by fire, and wood deterioration due to longtime heat exposure.

2-1.5.3 The following procedure shall be observed if the furnace is located in contact with a wood or other combustible floor and the operating temperature is above 160°F (71°C):

(a) Remove the wood or other combustible floor and replace it with a concrete slab extending at least 12 in. (305 mm) beyond the furnace outline.

(b) If the combustible floor is not removed, provide hollow tile or steel tunnels on top of floor extending to furnace outline and laid to form continuous air channels parallel with short axis of the furnace wherever possible, open at both ends for air movement, so that the surface temperature of the floor will not exceed 160°F (71°C). If the temperature at the combustible floor surface exceeds 160°F (71°C), then the air channels shall be connected on one end to a vent duct of adequate size, leading to a stack discharging to the atmosphere and provided with mechanical ventilation.

(c) When the supporting floor is of concrete, steel channels, or hollow tile, for operating temperatures above 300°F (149°C), the furnace floor shall be further insulated with suitable material equivalent in insulating value to that used for furnace walls and roof, and suitably enclosed or covered for protection against mechanical damage or abrasion. The external temperature of the floor near the furnace shall not exceed 250°F (121°C).

(d) Where electrical wiring will be present in the channels of certain types of floors, the wiring shall be installed in accordance with Article 356, Cellular Metal Floor Raceways, of NFPA 70, *National Electrical Code*.

(e) Combustible floors in the immediate area of oil burners shall be covered with noncombustible material in such a manner that the floor cannot become oil soaked. (*See NFPA 31, Standard for the Installation of Oil Burning Equipment, and/or the building code having jurisdiction.*)

(f) Adequate protection from heat and from fuel spillage shall be provided for combustible floors under heaters.

2-1.5.4 Combustible material shall be located as far as practical from a furnace, furnace heater, or ductwork.

2-1.6 Adequate plant lighting shall be provided to allow proper operation of the furnace and its associated equipment.

2-2 Furnace Design.

2-2.1 General. Furnaces and related equipment shall be designed with due regard to the fire hazard inherent in equipment operating at elevated temperatures.

2-2.2 Materials.

2-2.2.1 Furnace structures shall be constructed of noncombustible materials.

2-2.2.2 Furnace structural supports and conveyors shall be designed with adequate factors of safety at the maximum operating temperatures, consideration being given to the strains imposed by expansion.

2-2.2.3 Burners and heating elements of all types shall be substantially constructed or guarded to resist external mechanical damage from falling work, trucking, or other mechanical hazards inherent in industrial use.

2-2.2.4 Where refractory materials are used, they shall be adequately supported.

2-2.2.5 Accessibility and Mounting of Controls. Provision shall be made for the rigid attachment of control devices. Combustion safeguard mounts shall be arranged so that the electrode or other flame-detecting element is correctly positioned. Valves and control panels shall be so located that all necessary observations and adjustments may be readily made.

2-2.2.6 All parts of equipment operating at elevated temperatures shall be installed in accordance with 2-1.5.

2-2.2.7 Where impractical to guard, warning signs or permanent floor markings shall be provided or mounted so as to be visible to personnel entering the area.

NOTE 1: Exterior of furnaces in excess of 160°F (71°C) should be guarded by location, guard rails, shields or insulation to prevent accidental contact with personnel.
NOTE 2: Bursting discs or panels, mixer openings, or other parts of the furnace from which flame or hot gases may be discharged should be located or guarded to prevent injury to personnel.

2-2.2.8 Properly located observation ports shall be provided to permit the operator to observe the lighting of individual burners.

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

2-2.2.9 Closed water cooling systems shall have relief valves to protect all portions of the cooling system, when its pressure may exceed the design pressure. In addition, waterflow devices with audible/visual alarms shall be furnished.

NOTE: Open cooling systems utilizing unrestricted sight drains installed for ready observation by the operator do not require relief valves, waterflow devices, etc.

2-2.2.10 Fuel-fired heaters shall not be located directly under the product being heated where combustible materials may drop and accumulate. Neither shall they be located directly over readily ignitible materials such as cotton unless for a controlled exposure period, as in continuous processes where further automatic provisions and/or arrangements of guard baffles preclude the possibility of ignition.

2-2.2.11 The metal frames of furnaces shall in all cases be electrically grounded. (*See NFPA 77, Recommended Practice on Static Electricity.*)

2-2.3 Explosion Vents.

2-2.3.1 Furnaces which may contain flammable liquids, vapors, or gases shall be equipped with unobstructed relief vents for freely relieving internal explosion pressures. (*For additional information regarding relief of equipment and buildings housing the equipment, see NFPA 68, Guide for Explosion Venting.*)

Exception No. 1: Explosion relief panels are not required on furnaces having the following characteristics: shell construction having 3/16-in. (4.8-mm) or heavier steel plate shells reinforced with structural steel beams and buckstays, which support and retain refractory and insulating materials required for temperature endurance and thus are unsuitable for the installation therein of effective explosion vents.

Exception No. 2: Explosion relief panels are not required for low-oxygen atmosphere ovens designed and protected in accordance with Chapter 6.

2-2.3.2 Explosion relief panels shall be proportioned in the ratio of their area to the explosion-containing volume of the furnace, with due allowance being made for openings or hinged panels or access doors equipped with approved explosion-relieving hardware. The preferred ratio is 1:15, i.e., 1 sq ft (0.0929 m^2) of relief panel area to every 15 cu ft (0.4248 m^3) of furnace volume.

2-2.3.3 Arrangement of Explosion Vents.

2-2.3.3.1 Explosion-venting panels or doors shall be arranged so that, when open, the full vent opening will be an effective relief area. The operation of relief vents to their full capacity shall not be obstructed by low ceilings, piping, building columns, or walls, instrument panels, or other equipment.

NOTE 1: These vents should be provided in the form of work openings, doors or panels located in the oven walls, or gravity-retained roof panels designed to provide adequate insulation and possess the necessary structural strength.
NOTE 2: Guard rails may be needed to prevent movable equipment from obstructing wall vents. If guard rails are impractical, warning signs should be posted on the vents
NOTE 3: Explosion relief vents, where possible, should be placed in the top of the furnace or in side walls and located so that employees will not be exposed to injury.
NOTE 4: Maximum weight per panel allowed by NFPA 68, *Guide for Explosion Venting*, is 2½ lbs/sq ft (455 g/093m^2).
NOTE 5: Where practical, an explosion relief vent should be placed close to a source of ignition *(see NFPA 68, Guide for Explosion Venting)*.

2-2.3.3.2 Explosion relief vents for a long furnace shall be reasonably distributed throughout the entire furnace length.

2-2.4 Oven Ductwork.

2-2.4.1 Whenever furnace ducts or stacks pass through combustible walls, floors, or roofs, noncombustible insulation or clearance or both shall be provided to prevent surface temperatures exceeding 160°F (71°C).

2-2.4.2 Ducts shall be constructed entirely of sheet steel or other noncombustible material, and be of adequate strength and rigidity to meet the conditions of service and installation requirements, and shall be protected where subject to physical damage.

2-2.4.3 No rooms or portions of the building shall be used as an integral part of the system.

NOTE: The entire duct system should be self-contained.

2-2.4.4 All ducts shall be made tight throughout and shall have no openings other than those required for the operation and maintenance of the system.

2-2.4.5 All ducts shall be thoroughly braced where required and substantially supported by metal hangers or brackets.

NOTE: All laps in the duct joints should be made in the direction of the flow.

2-2.4.6 Where ducts pass through noncombustible walls, floors, or partitions, the space around the duct shall be sealed with noncombustible material to prevent the passage of flame and smoke.

NOTE: The passing of ducts through fire walls should be avoided.

2-2.4.7 Ducts handling fumes which leave a combustible deposit shall be provided with cleanout doors. Such ducts shall be constructed of not less than 16 gauge steel or equivalent.

2-2.4.8 Hand-holes for damper, sprinkler, or fusible link inspection or resetting, and for purposes of residue cleanout shall be equipped with tight-fitting doors or covers provided with substantial latches, except in the case of vertical sliding doors held in place by gravity.

2-2.4.9 Dampers in the ducts which affect the volume of fresh air admitted to and vapors or gases exhausted from the furnace shall be designed so that, when in closed position, they will pass the volume required for safe ventilation. If electrically or mechanically controlled dampers are used, limit switches shall be utilized to assure proper position of the dampers, including those used as gas barriers on carbon dioxide extinguishing systems.

2-2.4.10 The furnace and its location shall be designed to prevent excessive emission of objectionable fumes into the building.

2-2.4.11 All exposed hot fan casings and hot ducts within 7 ft (2.1 m) of the building floor shall be protected to prevent injury to personnel [temperature not to exceed 160°F (71°C)]. Refer to 2-2.2.7.

2-2.4.12 Exhaust ducts shall not discharge near doors, windows, or other air intakes in a manner that will permit reentry of effluents into the building.

NOTE: All air inlets outside the furnace should be protected by coarse screens and so guarded that they cannot be obstructed.

2-2.4.13 A suitable collecting and venting system for the radiant tube-type heating systems shall be provided by the user. The system shall be of sufficient capacity to render the total unburned input capacity of the radiant tubes noncombustible.

NOTE: For additional information pertaining to furnace ductwork, reference is made to NFPA 54, *National Fuel Gas Code*; NFPA 91, *Standard for the Installation of Blower and Exhaust Systems, for Dust, Stock and Vapor Removal or Conveying*; and NFPA 211, *Standard for Chimneys, Fireplaces, Vents, and Solid Fuel Burning Appliances*.

2-2.5 Access, Mountings, and Auxiliary Equipment.

2-2.5.1 Adequate facilities for access shall be provided to permit proper inspection and maintenance. Facilities shall include motion stops or lockout devices for vertical and/or horizontal movement of doors, elevators, or transfer mechanisms to minimize accidental movement.

2-2.5.2 Mountings for auxiliary equipment shall provide for mounting of control instruments and safety devices to protect against damage by heat, vibration, and mechanical equipment.

2-2.5.3 Where ladders or steps are needed to reach operating valves or other controls, they shall be noncombustible and provided as an integral part of the equipment.

2-2.5.4 Auxiliary equipment such as conveyors, racks, shelves, baskets, and hangers shall be noncombustible and designed to facilitate cleaning.

2-2.6 Hydraulic Systems.

2-2.6.1 Furnace hydraulic systems shall utilize fire-resistant fluids.

Exception: Other hydraulic fluids can be used if furnace casing temperatures are below the autoignition temperature of the fluid.

NOTE: Drawings for fluid power diagrams should follow ANSI Standards Y14.17 and Y32.10.

2-2.7 Fans.

2-2.7.1 All external fans shall be suitably interlocked as described in Chapter 4.

2-2.7.2 All external moving parts within 7 ft (2.1 m) of a working platform shall be guarded from mechanical accidents or possibilities of causing personal injury.

Chapter 3 Heating Systems

3-1 Scope.

(a) For the purpose of this standard, the term "furnace and associated equipment heating system" shall include the heating source (and associated piping/wiring) used to heat the furnace and the work therein as well as for auxiliary quenches, atmosphere generator, etc.

(b) The source of heat may be either fuel-firing or by electric heating.

3-2 Electrical Wiring. All electrical wiring, and applicable electrical components, shall be in accordance with NFPA 70, *National Electrical Code*, and as described hereafter.

3-3 Gas-Fired Units.

3-3.1 General.

(a) This section includes combustion systems for furnaces and associated equipment fired with commercially distributed fuel gases such as natural, mixed, manufactured, liquefied petroleum gas (LPG) in the vapor phase and LPG/air systems, and the gas-burning portions of dual fuel or combination burners.

(b) Additional safety considerations which are beyond the scope of this standard shall be given to dirt-laden gases, sulfur-laden gases, high-hydrogen gases, and low-Btu waste gases, where used.

3-3.2 Burner System Selection. 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 for the temperatures to which they will be subjected.

3-3.3 User's Fuel Gas Supply Piping.

3-3.3.1 Emergency shutoff valves shall be provided to permit turning off the fuel in an emergency and shall be located so that fires, and explosions, at furnaces will not prevent access to these valves.

NOTE 1: Installation of LPG storage and handling systems should comply with NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases.*
NOTE 2: Piping from the point of delivery to the equipment isolation valve should comply with NFPA 54, *National Fuel Gas Code.*

3-3.4 Equipment Fuel Gas Piping.

3-3.4.1 Manual Shutoff Valves and Cocks.

3-3.4.1.1 Individual manual shutoff valves (isolation) shall be provided for shutoff of the fuel to each piece of equipment.

3-3.4.1.2 Valves and cocks shall be maintained in accordance with the manufacturer's instructions.

NOTE 1: Particular attention is directed to the need for a proper lubrication of lubricated plug cocks.
NOTE 2: Quarter-turn valves are recommended.

3-3.4.1.3 It shall be the user's responsibility to see that separate wrenches (handles) remain affixed to the valve, and that they are properly oriented with respect to the valve port.

3-3.4.2 Equipment piping (gas train piping) is defined as the piping which connects isolation valve equipment to the air-gas mixing device (or to the burner, if nozzle-mixing).

3-3.4.2.1 Material. Material for pipe and fittings shall comply with NFPA 54, *National Fuel Gas Code.*

3-3.4.2.2 Sizing. Pipe, fittings and valving equipment shall be sized to prevent excessive pressure losses at the maximum rate of flow.

3-3.4.3 Pressure Regulator.

3-3.4.3.1 A pressure regulator shall be furnished wherever the plant supply pressure exceeds that required for proper burner operation or whenever the plant supply pressure is subject to excessive fluctuations.

3-3.4.3.2 Regulators 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 bug-screened. Vent pipe shall be of adequate size so as to not lengthen response time.

Exception: Regulators need not be vented when used with lighter-than-air fuel gases at 1 psig (6.9 kPa) inlet pressure or less, provided that the vent connection contains a restricted orifice and discharges into a space large enough, or is ventilated well enough, so that the gases escaping will not present a hazard.

3-3.4.3.3 Vent lines from multiple regulators, where manifolded together, shall be piped in such a manner that diaphragm rupture of one will not backload the others.

3-3.4.3.4 Vents from gas pressure switches, but from no other devices, may be vented into the regulator vent lines provided that switch or regulator diaphragm failure will not backload the regulator.

Exception: Regulators and zero governors may be backloaded from combustion air lines, air-gas mixture lines, and combustion chambers, provided that gas escapement through the restricted vent opening will, in itself, create no additional hazard.

3-3.5 Gas Burners.

3-3.5.1 All burners shall maintain stability of the designed flame shape, with neither flashback nor blow-off, over the entire range of turndown that will be encountered during operation when supplied with combustion air and the designed fuels in the proper proportions and in the proper pressure ranges.

NOTE 1: Burner operation may be adversely affected when other than the designed fuels are used.
NOTE 2: Attention should be paid to the burner tile maintenance in order to maintain the designed flame stability.

3-3.5.2 **Multiple-Port Burners.** Line-, ribbon-, pipe-, ring-, radiant- and diaphragm-type burners shall comply with the provisions of 3-3.5.1. In addition, they shall maintain stability of the designed flame shape throughout their entire connected length and/or area under the designed operating conditions.

3-3.5.3 **Burner Ignition.** Burners shall have the ignition source located in a position which will permit smooth and reliable ignition of the pilot/main flame over the complete stable firing range provided for in 3-3.5.1.

3-3.5.3.1 Burners having expanding pilots which are an integral part of the main burner flame shall have a reliable and smooth transition from pilot flame to main flame and from main flame to pilot flame when increasing and decreasing burner firing rates.

3-3.5.3.2 For burners which cannot be safely ignited at all firing rates encountered, positive provision shall be made to reduce the burner firing rates during light-off to a level which will assure a smooth and reliable ignition of the main flame (forced low-fire start).

3-3.6 Air-Gas Mixers.

3-3.6.1 Air-Gas Mixture Piping.

3-3.6.1.1 In the design, fabrication and utilization of mixture piping, cognizance shall be given to the fact that the mixture is in the flammable range.

3-3.6.1.2 Piping shall be designed to provide uniformity of transverse velocity at the nozzle(s) to the degree required by the nozzle(s).

NOTE: This generally requires a minimum straight run of approximately four pipe diameters immediately upstream from the nozzle.

3-3.6.1.3 Piping shall be sized to prevent excessive pressure losses (and attendant capacity reduction) and to present essentially uniform mixture pressures at multiple nozzles.

3-3.6.1.4 Total length of mixture piping shall be as short as practical within the limits of established good practice.

3-3.6.1.5 Devices which can, or may, result in pressure loss or may adversely affect the flow velocity pattern shall not be installed in the mixture piping. Fixed balancing orifices shall be installed in the mixture piping only under the direction of the responsible manufacturer.

3-3.6.1.6 Flow control valves shall not be used in the air-gas mixture piping.

Exception: Individual control of one or more nozzles can be achieved as provided in 3-3.7 and 3-3.9.

3-3.6.2 **Mixer Adjustments.** If any field-adjustable device is built into the mixer (gas orifice, air orifice, air shutter, etc.), an appropriate locking device to prevent unintentional changes in the setting shall be provided.

3-3.6.3 Mixing Blowers.

3-3.6.3.1 Mixing blowers shall not be used to function as gas-mixing machines, which are covered in 3-3.9.

3-3.6.3.2 Air-gas piping and air-gas control adjustments for mixing blowers shall comply with 3-3.6.1 and 3-3.6.2. Mixing blowers shall be subject to the same limitations as are other air-gas mixers (3-3.6.1.1 through 3-3.6.1.6).

3-3.6.3.3 Mixing blowers shall not be used with fuel gases containing more than 10 percent free hydrogen (H_2).

3-3.6.3.4 Mixing blowers shall not be utilized where 10 in. w.c. (2.49 kPa) or more mixture pressure is required.

3-3.6.3.5 Mixing blowers shall be equipped with a permanent but adjustable inlet air limit stop to assure that a minimum mixture pressure can be field-established to suit the requirements of the burners, the manifold, and the combustion environment.

3-3.7 Flow Control Valves.

3-3.7.1 Flow control valves of appropriate design shall be used to change the rate of flow of pressurized combustion air and/or the fuel gas where applicable.

3-3.7.2 Where the minimum and/or the maximum flow of combustion air and/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.

3-3.8 Combustion Air.

3-3.8.1 Whether supplied as primary or secondary air, and under positive, negative, or atmospheric pressure, the quality and quantity of the combustion air shall be equal to, or greater than, that required for proper operation of the mixer and/or burner, and for the subsequent combustion.

3-3.8.2 Fuel burning systems shall be assured of an adequate supply of combustion air. Inlet air filters shall be used on combustion blowers where required to screen out solid matter.

3-3.8.3 Precautions shall be taken to prevent insufficiently diluted products of combustion from short circuiting back into the combustion air inlet of the burner or mixer.

3-3.8.4 When primary and/or secondary air is mechanically provided, combustion airflow or pressure shall be proven and interlocked with the safety shutoff valve so that fuel gas cannot be admitted prior to establishment of combustion air, and the gas will be shut off in the event of combustion air failure.

3-3.8.4.1 Secondary Air Adjustment. When provided, adjustment shall include a locking device to prevent unintentional change in setting.

3-3.9 Gas-Mixing Machines.

3-3.9.1 General. Any combination of proportioning control devices, blowers, or compressors which supply mixtures of fuel gas and air to burners where control devices or other obstructions are installed between the mixing device and burner is defined as a "gas-mixing machine" and the provisions of 3-3.9.2, 3-3.9.3 and 3-3.9.4 shall apply.

NOTE 1: The essential difference between the mixing devices used with an air-gas mixer (3-3.6) and the gas-mixing machines is the provision for a proportioning valve which responds to changes in rate of gas delivery controlled at any point between the machine and burner. There are several distinct types of gas-mixing devices which come within the scope of this section and may supply premixed gas within the explosive range or with only part of the air required for complete combustion.

NOTE 2: A gas-mixing machine usually consists of a pressure regulator which equalizes the gas supply pressure with air fed into a proportioning valve which in turn is connected to an air compressor.

NOTE 3: Gas-mixing machines may deliver gas-air mixtures which are not within the explosive range, additional combustion air being secured at the burner, either from a burner mixer or directly from the combustion space. They also may supply mixtures within the explosive range and, when so installed, means to prevent flashbacks occurring in piping containing the flammable mixture, or to prevent damage if flashback should occur, should also be provided.

3-3.9.2 Nonexplosive Mixtures (outside flammability limits). Gas-mixing machines supplying gas-air mixtures which are above the upper explosive limit shall be installed as follows:

(a) A stop or other means shall be provided which will effectively prevent adjustment of the machine within or approaching the explosive range.

(b) If the machine is located in a small detached building or cutoff room, explosion vents shall be provided in the ratio of 1 sq ft (0.092 m^2) of vent area to each 20 cu ft (0.57 m^3) of room volume (*see NFPA 68, Guide for Explosion Venting*).

NOTE 1: The choice of location varies considerably in individual installations. In large, well-ventilated manufacturing areas there is relatively little chance of leakage accumulating in explosive gas-air mixtures and, under such conditions, the machine may well form an integral part of a furnace heating system.

NOTE 2: In considering small rooms where explosive gas-air mixtures could be formed, the machine is better located in a detached building or in a small room cut off by concrete walls bonded into the floor and ceiling and provided with explosion relief vents to outdoors. Entrance to this room should be directly from outdoors.

NOTE 3: Machines should, if practical, be constructed so that, in the event of an explosive mixture forming and flashback resulting, the machine casing will not be ruptured.

NOTE 4: Air intakes for gas-mixing machines and blowers using compressors or blowers should be taken from outdoors wherever practical.

(c) When gas-mixing machines are installed in well-ventilated areas, the type of electrical equipment shall be governed by NFPA 70, *National Electrical Code*, requirements for general service conditions, unless other hazards in the area prevail.

(d) When gas-mixing machines are installed in small detached buildings or cutoff rooms, the electrical equipment and wiring shall be installed in accordance with NFPA 70, *National Electrical Code*, requirements for hazardous (classified) locations (Article 500, Class 1, Division 2).

3-3.9.3 Explosive Mixtures (within flammability limits). Gas-mixing machines supplying gas-air mixtures within the explosive range shall be installed in accordance with 3-3.9.2 (b), (c), and (d) and the following shall also apply:

(a) Automatic fire checks and safety blowouts shall be provided.

(b) Burners used with explosive mixtures shall be designed with port areas and length of gas passage through each port such that the possibility of backfire is largely eliminated.

NOTE: When necessary to secure stability of operation, water-cooled burners may be used.

3-3.9.4 Controls for gas-mixing machines shall include interlocks and safety shutoff valves in the gas supply connection to each machine arranged to automatically shut off the gas supply in the event of air and/or gas supply failure (*see Chapter 5*).

3-3.10 Fuel Ignition.

3-3.10.1 Whenever filling of the combustion chamber with flammable air-fuel mixture can result in an explosive condition, the length of time allotted for flame ignition and the rate of fuel input at ignition shall be correlated so that the lower explosive limit with respect to the combustion chamber volume is not exceeded.

NOTE: Fuel-air mixtures of a ratio within the flammable range are ignited by means of electric arc, hot wire, pilot burner flame, hand-held torch, etc. A burner is suitably ignited when combustion of the fuel-air mixture is established and stable at the discharge port(s) of the nozzle(s) or in the contiguous combustion tunnel.

3-3.10.2 Ignition shall be effectively applied at the proper point in sufficient quantity, and with sufficient intensity to properly ignite the fuel-air mixture.

3-3.10.3 Pilot Burners. The provisions of 3-3.5 (Gas Burners) shall also apply to pilot burners.

3-3.10.4 If pilot mixers are used, the provisions of 3-3.6 (Air-Gas Mixers) shall also apply to pilot mixers.

3-3.10.5 Combustion Air. The provisions of 3-3.8 shall apply.

3-3.10.6 Fixed Pilots.

3-3.10.6.1 The pilot burner shall be located as required to reliably ignite the main flame, and as directed by the manufacturer.

3-3.10.6.2 The pilot shall be so mounted as to prevent unintentional changes in location, and in direction with respect to the main flame.

3-4 Oil-Fired Units.

3-4.1 Scope.

(a) This section includes combustion systems for furnaces fired with No. 2, No. 4, No. 5, and No. 6 industrial fuel oils as specified by ASTM D396, *Specifications for Fuel Oils*. It also includes the oil-burning portions of dual-fuel and combination burners.

(b) Additional considerations which are beyond the scope of this standard shall be given to other combustible liquids not specified in 3-4.1 (a).

3-4.2 In the design of, and the use of, oil-fired units, attention shall be given to the following:

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

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

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

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

3-4.3 Burner System Selection. 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 will be subjected.

3-4.3.1 This shall not be interpreted to imply that a burner system selected for No. 2 fuel oil must be capable of handling No. 4, No. 5, or No. 6 fuel oil, or vice versa.

3-4.4 Oil Supply Piping.

3-4.4.1 Storage tanks and their installation shall comply with NFPA 31, *Standard for the Installation of Oil Burning Equipment*.

3-4.4.2 Piping materials shall be wrought iron, steel, brass or copper. Pipe shall be connected with standard fittings or tubing with listed fittings. Connectors made of, or utilizing, combustible materials shall not be used. Unions requiring gaskets and sweat fittings employing solder having a melting point of less than 1000°F (537°C) shall not be used. Cast-iron fittings shall not be used.

3-4.4.3 Manual Shutoff Valves and Cocks.

3-4.4.3.1 Manual shutoff valves shall be installed to avoid oil spillage during servicing of supply piping and associated components.

3-4.4.3.2 Manual shutoff valves shall be provided for shutoff of the fuel to the pilot and/or burner for shutdown.

3-4.4.3.3 Valves shall be maintained in accordance with the manufacturer's instructions.

NOTE: Quarter-turn valves are recommended.

3-4.4.3.4 It shall be the user's responsibility to see that separate wrenches (handles) remain affixed to the valve, and that they are properly oriented with respect to the valve's port.

3-4.4.4 Emergency Shutoff Valves. Valves shall be provided to permit turning off the fuel in an emergency and shall be located so that fires and explosions at furnaces will not prevent access to these valves.

NOTE: A positive displacement oil pump can serve as one valve by shutting off the power to it.

3-4.4.5 All air from the supply and return piping shall be initially purged and air entrainment in the oil shall be minimized.

NOTE 1: 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.
NOTE 2: Manual vent valves may be needed to bleed air from the high points of the oil supply piping.

3-4.4.6 Suction, supply, and return piping shall be adequately sized with respect to oil pump capacity.

3-4.4.6.1 Oil shall be supplied to the furnace site properly conditioned by the user.

3-4.4.7 Whenever a section of oil piping can be shut off at both ends, consideration shall be given to the use of relief valves and/or expansion chambers to release the pressure caused by thermal expansion of the oil.

NOTE: The weight of the oil is always a consideration in vertical runs. When going up, pressure will be lost. One hundred psig (689 kPa) with a 100-ft (30.5-m) lift will net only 63 psig (434 kPa). When going down, pressure will be added. One hundred psig (689 kPa) with a 100-ft (30.5-m) drop will net 137 psig (945 kPa). This also occurs with fuel gas, but it is most often of no importance. However, it can never be overlooked when handling oil (*see Table 3-4.4.7*).

Table 3-4.4.7 Useful Conversion Data

(14.7 psig = 29.92 in. Hg = 33.9 ft H_2O = 39.89 ft .85 SG Oil)
psig = 6895 Pa; in. Hg = 3377 Pa; ft H_2O = 2986 Pa

NOTE: 14.7 psig and 29.92 in. Hg are sea level figures.

FROM \ TO	psig	in. Hg	ft H_2O	ft .85 SG Oil
One psig =	1	2.04	2.31	2.71
One in. Hg =	0.49	1	1.13	1.33
One ft H_2O =	0.43	0.88	1	1.18
One ft .85 SG Oil =	0.37	0.75	0.85	1

3-4.5 Equipment Oil Piping.

3-4.5.1 Equipment oil piping means that piping which connects from the supply leg of the circulating loop to one or more furnace burner systems.

3-4.5.2 Piping shall connect to the bottom of the supply leg (to minimize air entrainment).

3-4.5.3 Materials shall be in accordance with 3-4.4.2.

3-4.5.4 Piping shall be adequately sized for maximum flow rate.

3-4.5.5 Consideration shall be given to shutoff valves (refer to 3-4.4.3, 3-4.4.4 and 3-4.4.7).

3-4.6 Oil Train Piping.

3-4.6.1 Oil train piping means that piping which connects the equipment oil piping to the burner.

3-4.6.2 The provisions of 3-4.5.3 and 3-4.5.4 shall apply.

3-4.6.3 **Manual Shutoff Valve.** A manual shutoff valve having provision for position indication shall be located upstream from all other components to shut off the flow of oil for servicing and for other shutdowns.

3-4.6.4 Pressure Regulator.

3-4.6.4.1 A suitable pressure regulator shall be furnished whenever the plant supply pressure exceeds that required for proper burner system operation, or whenever the plant supply pressure is subject to excessive fluctuation.

3-4.6.5 Oil Filters and Strainers.

3-4.6.5.1 An oil filter shall be installed in the oil train piping to protect the downstream components.

3-4.6.5.2 The degree of filtration shall be compatible with the size of the most critical clearance being protected.

NOTE: Customarily, a filter/strainer is installed in the suction piping to protect the pump. A secondary filter/strainer is often installed in the discharge line. However, neither of these are usually fine-meshed to the point required for total burner and valving protection.

3-4.6.5.3 The filter housing and cartridge shall be suitable for the intended pressure, temperature, and service.

3-4.7 Oil Burners.

3-4.7.1 Oil Burners shall be of a type and design suitable for the intended service.

3-4.7.1.1 The burner shall accept fuel oil of the proper grade, preconditioned to the degree it requires, for subsequent combustion.

3-4.7.1.2 The burner shall self-sustain combustion beginning at the designed flame base, and throughout the firing range, without external stimulation, mechanical or otherwise.

3-4.7.2 Oil Atomization.

3-4.7.2.1 Oil shall be atomized to the droplet size as required for proper combustion throughout the firing range.

NOTE: The atomizing medium may be steam, compressed air, low pressure air, air-gas mixture, fuel gas, or other gases. Atomization may also be mechanical (mechanical-atomizing tip or rotary cup).

3-4.7.2.2 The atomizing device shall be accessible for inspection, cleaning, repair, replacement, and other maintenance as required.

3-4.7.3 Burner Ignition.

3-4.7.3.1 Burners shall ignite completely, smoothly, and reliably from the ignition source presented. If a burner cannot be safely ignited at all firing rates encountered, positive provision shall be made to assure the existence of a firing rate suitable for safe light-off.

3-4.7.4 **Burner Shutdown.** If clearance 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 allied fans and blowers in operation.

3-4.7.5 All pressures involved in the safe operation of the combustion system shall be maintained within the proper ranges throughout the firing cycle.

3-4.8 Flow Control Valves.

3-4.8.1 Flow control valves of appropriate design shall be used to change the rate of flow of pressurized combustion air and/or the fuel oil where applicable.

3-4.8.2 Where the minimum and/or the maximum flow of combustion air and/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.

3-4.9 Combustion Air.

3-4.9.1 Whether supplied as primary, secondary, or atomizing air, under positive, negative, or atmospheric pressure, the quality and quantity of the air shall be equal to, or greater than, that required for proper operation of the mixer and/or burner, and for the subsequent combustion.

3-4.9.2 Fuel burning systems shall be assured of an adequate supply of combustion air. Inlet air filters shall be used on combustion blowers where required to screen out solid matter.

3-4.9.3 Precautions shall be taken to prevent insufficiently diluted products of combustion from short-circuiting back into the combustion air inlet of the mixer.

3-4.9.4 When air pressure and/or flow is mechanically provided, it shall be proven electrically and/or pneumatically, and interlocked with the safety shutoff valve so that oil cannot be admitted prior to establishment of combustion air, and the oil will be shut off in the event of combustion air failure.

3-4.10 Dual-Fuel and Combination Burners.

3-4.10.1 When fuel gas and fuel oil are to be fired individually (dual-fuel) or simultaneously (combination), the provisions of Sections 3-3 and 3-4 shall apply equally to the respective fuels.

3-5 Electrically Heated Units.

3-5.1 General.

3-5.1.1 Scope. This section includes all types of heating systems where electrical energy is used as the source of heat.

3-5.1.2 Safety Equipment. Safety equipment including airflow interlocks, time relays, and temperature switches shall be in accordance with Chapter 4.

3-5.1.3 Electrical Installation. All parts of the electrical installation shall be in accordance with NFPA 70, *National Electrical Code*.

3-5.2 Resistance Heating Systems.

3-5.2.1 General. The following paragraphs shall apply to resistance heating systems including those of the infrared lamp types (quartz, ceramic, and tubular glass).

3-5.2.2 Enclosure.

3-5.2.2.1 External electric heating systems shall be encased in a sufficiently insulated chamber to prevent injury to personnel and property.

3-5.2.2.2 The heater housing shall be so constructed as to provide easy accessibility to heating elements and wiring.

3-5.2.2.3 Heating elements shall be securely supported so that they will not easily become dislodged from their intended location. Heating elements, electrically insulated from and supported from a metallic frame, shall have the frame electrically grounded.

3-5.2.2.4 Open-type resistor heating elements shall be supported upon electrically insulated hangers and shall be constrained from thermal-stress-induced motion, which could result in adjacent segments of the elements touching one another, or from touching a grounded surface.

3-5.2.3 Heater Locations.

3-5.2.3.1 Heaters shall not be located directly under the product being heated where combustible materials may drop and accumulate.

3-5.2.3.2 External parts of furnace heaters which operate at temperatures in excess of 160°F (71°C), or which are energized at voltages specified in Article 725 of NFPA 70, *National Electrical Code*, shall be guarded. Where impractical to guard, warning signs shall be mounted or permanent floor markings shall be provided to be visible to personnel entering the area.

3-5.2.4 Construction.

3-5.2.4.1 Where insulators are used, they shall be supported so that they will resist falling out of place.

3-5.2.4.2 All parts of equipment operating at elevated temperatures shall be installed in accordance with 2-1.5, Floors and Clearances.

3-5.2.5 Safety Devices for Resistance Heaters. (*Refer to Chapter 4.*)

3-5.3 Induction and Dielectric Heating Systems.

3-5.3.1 General. The following paragraphs shall apply to induction and dielectric heating systems. This type of heating shall be designed and installed in accordance with NFPA 70, *National Electrical Code*, with special reference to Article 665, entitled "Induction and Dielectric Heating Equipment."

NOTE: To prevent spurious radiation caused by this type of equipment and to ensure that the frequency spectrum is utilized equitably, the Federal Communications Commission (FCC) has established rules (*Code of Federal Regulations*, Title 47, Part 18) which govern the use of industrial heating equipment of this type operating above 10 kHz.

3-5.3.2 Installation. High-frequency induction equipment and dielectric heating systems shall not be installed in hazardous locations. (*See Article 665 of NFPA 70, National Electrical Code.*)

3-5.3.3 Construction.

3-5.3.3.1 Frames, enclosures, and shelves shall be of noncombustible construction and shall be sufficiently strong to resist physical damage.

3-5.3.3.2 Combustible electrical insulation shall be reduced to a minimum.

NOTE: Transformers should be of the dry, high-fire point or nonflammable-liquid type. Dry transformers should be in compliance with NEMA TR27-4.03, 150°F (302°F) rise insulation.

3-5.3.3.3 Protection shall be installed to prevent overheating of any part of the equipment, in accordance with NFPA 70, *National Electrical Code*.

3-5.3.3.4 When 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 will not damage the electrical equipment. The cooling-water supply shall be interlocked with the power supply so that loss of water will cut off the power supply. Consideration shall be given to providing individual pressure flow interlocks for parallel waterflow paths.

3-5.3.3.5 When 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.

3-5.3.3.6 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.

3-5.3.3.7 Dielectric heaters used for treating highly combustible materials shall be designed to prevent a disruptive discharge between the electrodes.

3-6 Steam Heating Systems.

3-6.1 Scope. This section includes all types of heating systems where steam is used as the source of heat and refers specifically to the steam heat exchangers, which are usually supplied from a central steam-generating source.

NOTE: The construction and controls for steam boilers are covered by ASME *Boiler and Pressure Vessel Code*, and by any applicable local or state regulations. Burners and controls for boilers using gas, oil, or pulverized coal are covered by NFPA 31, *Standard for the Installation of Oil Burning Equipment*; NFPA 85A, *Standard for the Prevention of Furnace Explosions in Fuel Oil- and Natural Gas-Fired Single Burner Boiler-Furnaces*; NFPA 85B, *Standard for the Prevention of Furnace Explosions in Natural Gas-Fired Multiple Burner Boiler-Furnaces*; NFPA 85D, *Standard for Prevention of Furnace Explosions in Fuel Oil-Fired Multiple Burner Boiler-Furnaces*; NFPA 85E, *Standard for Prevention of Furnace Explosions in Pulverized Coal-Fired Multiple Burner Boiler-Furnaces*; and NFPA 85F, *Standard for the Installation and Operation of Pulverized Fuel Systems*; and also by any applicable requirements of the authority having jurisdiction.

3-6.2 Construction.

3-6.2.1 Piping and fittings associated with steam heat exchangers shall be in accordance with the American National Standard *Code for Power Piping*, ANSI B31.1-1980. Suitable relief valves shall be provided where needed in this system.

3-6.2.2 Enclosures or ductwork for heat exchanger coils shall be of noncombustible construction with suitable access openings provided for maintenance and cleaning.

3-6.2.3 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.

3-6.3 Safety Devices. Refer to Chapter 4 for control equipment and application to steam heating systems.

3-6.4 To avoid abnormally high temperature at coil surfaces, steam pressure in heat exchanger coils shall be maintained at the minimum pressure necessary to provide the required drying temperature.

NOTE: This is usually accomplished by an automatic pressure regulating device.

3-6.5 Recirculation directly over the heat exchanger coils shall not be used if lint or other light combustibles may be carried back to and deposited on the steam coil surfaces unless the recirculated atmosphere is properly filtered.

Chapter 4 Safety Equipment and Application

4-1 General.

4-1.1 For the protection of personnel and property, consideration shall be given to the supervision and/or monitoring of conditions which may cause, or may lead to, a real or potential hazard on any given installation.

4-1.1.1 Fuel-fired units shall be provided with all safety devices in accordance with established safe practices.

4-1.1.2 Safety considerations shall extend to allied equipment, and to other proximate equipment, to avoid additional contributory hazards.

4-1.1.3 A safety shutdown of the heating system by any of the prescribed safety features or devices shall require manual intervention of an operator for reestablishment of normal operation of the system.

4-1.2 Areas of concern shall include, but shall not be limited to:

(a) Fresh ventilation air

(b) Recirculated air

(c) Combustion air

(d) Flame presence

(e) Fuel pressure and temperature

(f) Steam and electric units.

4-1.3 It shall also be noted that:

(a) The presence of safety equipment on an installation cannot, in itself, assure absolute safety of operation.

(b) There is no substitute for a diligent, capable, well-trained operator.

(c) Highly repetitive operational cycling of any safety device may reduce its life span.

(d) Electric relays and fuel safety shutoff valves are not substitutes for main shutoff cocks (valves) and disconnects.

4-1.4 Regularly scheduled inspection and maintenance of all safety devices shall be performed by the user. (*See Chapter 9.*)

4-1.4.1 It shall be the sole responsibility of the user to establish, schedule and enforce the frequency of and the extent of the inspection/maintenance program (as well as the corrective action to be taken) because only the user can know what the actual operating conditions are.

4-1.4.2 It shall be the responsibility of the equipment manufacturer to provide suitable recommendations and/or suggestions on maintenance and inspection procedures.

4-1.5 Safety devices shall be properly installed, used, and maintained in accordance with the manufacturer's instructions.

4-1.6 Safety devices shall be located to protect against physical damage and inadvertent tampering.

4-1.7 Safety devices shall not be shorted-out, nor shall they be bypassed.

4-2 Preignition (Prepurge, Purging Cycle).

4-2.1 Prior to each furnace startup, provision shall be made for the removal of flammable vapors and/or gases which may have entered during the shutdown period.

4-2.1.1 At least 4 standard cu ft (0.11 m^3) of fresh air per cu ft (m^3) of oven volume shall be introduced during the purging cycle.

Exception: Inert-atmosphere ovens may be purged with an inert gas (see Chapter 6).

4-2.1.2 Timed preignition purge shall be provided on all direct-fired furnaces in which flammable vapors or fuel can accumulate during a shutdown period.

4-2.1.3 The timed preignition purge cycle shall be repeated after each and every shutdown of the recirculating and/or exhaust fans.

Exception: Repeating the timed preignition purge cycle is not required after each and every shutdown, such as might be occasioned by a momentary or short duration stoppage, and may be omitted provided all of the following items are satisfied:

(a) Burners and pilots are supervised by an approved combustion safeguard in accordance with 4-6.4,

(b) Each burner system is equipped with gas safety shutoff valves in accordance with 4-6.2.2,

(c) It can be demonstrated that 25 percent of the lower explosive limit will not be exceeded during the time combustion-air-supply stoppage is permitted, and

(d) No flammable solvent vapors are present in the furnace.

4-2.1.4 Preignition purging of radiant-tube heating systems is not required; however, special conditions may require purging of the furnace work chamber.

4-3 Flue Product Venting. A suitable collecting and venting system for the radiant-tube type heating systems shall be provided by the user. The system shall be of sufficient capacity to render the total unburned input capacity of the radiant tubes noncombustible.

4-3.1 The flue-venting products system shall be considered as part of the plant exhaust system.

4-4 Ventilation Safety Devices.

4-4.1 Whenever any fan is essential to the operation of the oven and/or allied equipment, fan operation shall be proven and interlocked as indicated in 4-4.1.1 and 4-4.1.2.

4-4.1.1 Electrical interlocks and flow switches shall be arranged in the safety control circuit so that loss of ventilation or airflow will immediately shut down the heating system of the particular oven section affected or, if necessary, loss of ventilation shall shut down the entire oven heating system as well as the conveyor.

4-4.1.2 Air pressure switches and air suction switches shall not be used to prove airflow when dampers can be closed to the point of reducing flow to an unsafe operating level.

4-4.2 Air pressure switches shall not be installed on the pressure side of a fan handling air contaminated with any substance that might condense or otherwise deposit and interfere with the switches, sensing, or performance.

4-4.3 Adjustable or motorized dampers capable of being moved to a position which might contribute to or result in an unsafe condition shall be equipped with mechanical stops, cut-away dampers and/or limit switches interlocked into the safety circuitry to assure that dampers are in a proper operating position.

4-5 Combustion Air Safety Devices (Fuel-Fired Units).

4-5.1 When the air from the exhaust and/or recirculating fans is required for combustion of the fuel, airflow shall be proven prior to ignition attempt and reduction of airflow to an unsafe level shall result in closure of the safety valve.

4-5.2 When a combustion air blower is used, the minimum combustion air pressure required for proper burner operation shall be proven prior to each attempt for ignition as indicated.

4-5.2.1 Motor starter shall be interlocked in the safety circuitry.

4-5.2.2 A low-pressure switch shall be used to sense and monitor combustion air pressure or differential pressure and shall be interlocked into the safety circuitry.

4-5.3 Whenever it is possible for combustion air pressure to exceed a maximum safe operating pressure, as might occur when compressed air is utilized, a pressure reducing valve, high pressure switch and a low pressure switch shall be used.

4-6 Fuel Safety Devices.

4-6.1 General.

4-6.1.1 As with all safety devices, improper application and/or adjustment can result in repeated and unscheduled shutdowns. Improper corrective action (bypassing, jumpering-out, etc.) can lead to a hazardous condition, and shall not be taken to sustain production.

4-6.1.2 A manual reset feature shall be provided to prevent unintentional recycling of the safety system, or any portion of it.

4-6.2 Safety Shutoff Valves (Fuel Gas or Oil).

4-6.2.1 General.

4-6.2.1.1 The safety shutoff valve shall be the "key unit" of all safety controls used to protect against the explosion or fire hazards which could result from accidental interruption to various services or operations, such as flame failure, failure of fuel pressure, failure of combustion air pressure, failure of exhaust or recirculation fans, excessive temperatures, or power failure.

4-6.2.1.2 Safety shutoff valves shall automatically shut off the fuel to the burner system after interruption of the holding medium by any one of the interlocking safety devices. They shall be self-closing and not readily bypassed or blocked open. Safety shutoff valves shall not be used as modulating temperature control valves.

Exception No. 1: Installations requiring a valve 8 in. (200 mm) IPS or larger may employ such safety shutoff valves as a dual-purpose valve, namely a temperature control valve.

Exception No. 2: Particulate matter or corrosive materials may impair the operation of the valve. For example, coke oven gas service may employ such a safety shutoff valve as a dual-purpose valve for temperature and/or pressure control.

4-6.2.1.3 Valve components shall be of a material suitable for the fuel handled and the ambient temperature.

4-6.2.1.4 Valves shall not be subjected to pressures in excess of manufacturer's ratings.

4-6.2.1.4.1 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 shall be vented to a safe location.

4-6.2.1.5 Position indication shall be provided for safety shutoff valves to main burners in excess of 150,000 Btu/hr (44 kw).

4-6.2.1.6 Safety shutoff valves shall not be used in lieu of manual cocks/valves when shutting down.

4-6.2.2 Fuel Gas Safety Shutoff Valves.

4-6.2.2.1 When main or pilot fuel gas burner system capacity exceeds 400,000 Btu/hr (117 kw), two approved safety shutoff valves (piped in series) shall be used. If main or pilot fuel gas burner capacity is 400,000 Btu/hr (117 kw) or less, a single approved safety shutoff valve may be used in place of the double safety shutoff valves.

Exception No. 1: With a radiant tube-fired burner system a single approved safety shutoff valve may be used.

Exception No. 2: If the manufacturer decides to locate the pilot supply line downstream of the main gas safety shutoff valve, means shall be provided to prevent the introduction of gas to the main burners prior to energizing the pilot valve.

4-6.2.2.2 A permanent and ready means for making tightness checks of all main burner fuel gas safety shutoff valves shall be provided (*see Chapter 9, Inspection and Maintenance*).

4-6.2.3 Oil Safety Shutoff Valves.

4-6.2.3.1 An approved safety shutoff valve or valves shall be provided for shutting off fuel oil to the burner or burners being protected.

NOTE: Two approved safety shutoff valves should be provided under any one of the following conditions: (a) when the pressure is greater than 125 psi (862 kPa); (b) whenever the fuel oil pump operates without main oil burner firing, regardless of the pressure; (c) With combination gas/oil burners when the fuel oil pump operates during the fuel gas burner operation.

4-6.3 Fuel Pressure Switches (Gas or Oil).

4-6.3.1 A low-pressure switch shall be provided for, and interlocked with, each burner system's safety shutoff valve.

4-6.3.2 Whenever the normal fuel pressure to the pressure regulator immediately upstream from the safety shutoff valve exceeds the design limits of the burner system, a high-pressure switch shall be provided, and interlocked with the burner system's safety shutoff valve, as in 4-6.3.1.

4-6.3.3 Pressure switch settings shall be made in accordance with design limits of the burner system and/or the heating unit.

4-6.4 Combustion Safeguards (Flame Supervision).

4-6.4.1 Flame Supervision and Burner Ignition. Flame supervision of the radiant-tube burners is not required; however, a suitable means of ignition shall be provided.

4-6.4.1.1 Initial ignition can be manual or automatic.

4-6.4.1.2 Subsequent ignition can be by auxiliary pilot, by continuous self-piloted burner, or by direct-spark ignition.

4-6.4.2 Each burner flame shall be supervised by an approved combustion safeguard, having a nominal flame failure response timing of 4 seconds or less, interlocked with the safety circuitry.

Exception No. 1: It is permissible to supervise flames at the intersection of the main burner flame and the pilot flame rather than provide supervision equipment for both.

Exception No. 2: Neither interrupted pilot nor second flame sensor are required for self-piloted burners, as defined in Section 1-4.

Exception No. 3: Supervision of the main burner flame may be accomplished by either a second sensor applied to the main flame only, or by interruption of the main burner ignition pilot.

Exception No. 4: Multiple burners, where combustion safeguards for each burner are too numerous to be practical, can use continuous line-burner-type pilots for groups of burners (see 3-3.5.2). An approved combustion safeguard shall be provided at the far end of each line-burner-type pilot, away from the pilot fuel source, with sensing element located at the junction of the flame paths of both pilot and last main burner. The pilot safety shutoff valve must be initially opened by a manual momentary push button.

Exception No. 5: Where two premix burners which will reliably ignite one from the other are used, it shall be permissible to use a single approved combustion safeguard, supervising one of the burners; the supervised burner shall burn continuously at a firing rate at all times sufficient to reliably ignite the unsupervised burner.

Exception No. 6: Burners for direct-fired heating systems which supply a furnace at a fuel rate not exceeding 150,000 Btu/hr (44 kw) may be equipped with heat-actuated combustion safeguards or safety pilots. For small equipment under constant attendance, approaching in size the household gas range or very small laboratory test furnace, combustion safeguards may be omitted, subject to approval of the authority having jurisdiction.

Exception No. 7: In general, for greatest security, all burners should be protected with combustion safeguards as outlined in the foregoing sections. When this is not practical from an engineering standpoint, the maximum practical protection shall be furnished by providing a reliable source of ignition at each burner, and/or operating burners on high-low flame, and by installing devices (pressure switches and safety shutoff valves) to assure, where practical, closure of all individual burner cocks [see Figures 4-6.4.2 (a) and (b)] before the main burner safety shutoff valve can be opened, and to shut off all fuel in case of high and low fuel pressure and low air pressure, where air pressure is necessary for operation of burners and controls, subject to the approval of the authority having jurisdiction.

Exception No. 8: Radiant-tube heating systems utilizing explosion-resistant tube construction do not require combustion safeguards.

Exception No. 9: On furnace or oven zones where a combination of burners with and without flame supervision exists, it is permissible to switch the flame supervision out of the safety circuit for that zone when the zone temperature is at or above 1400°F (760°C). The burners without flame supervision shall be interlocked to prevent their operation until the zone temperature is at or above 1400°F.

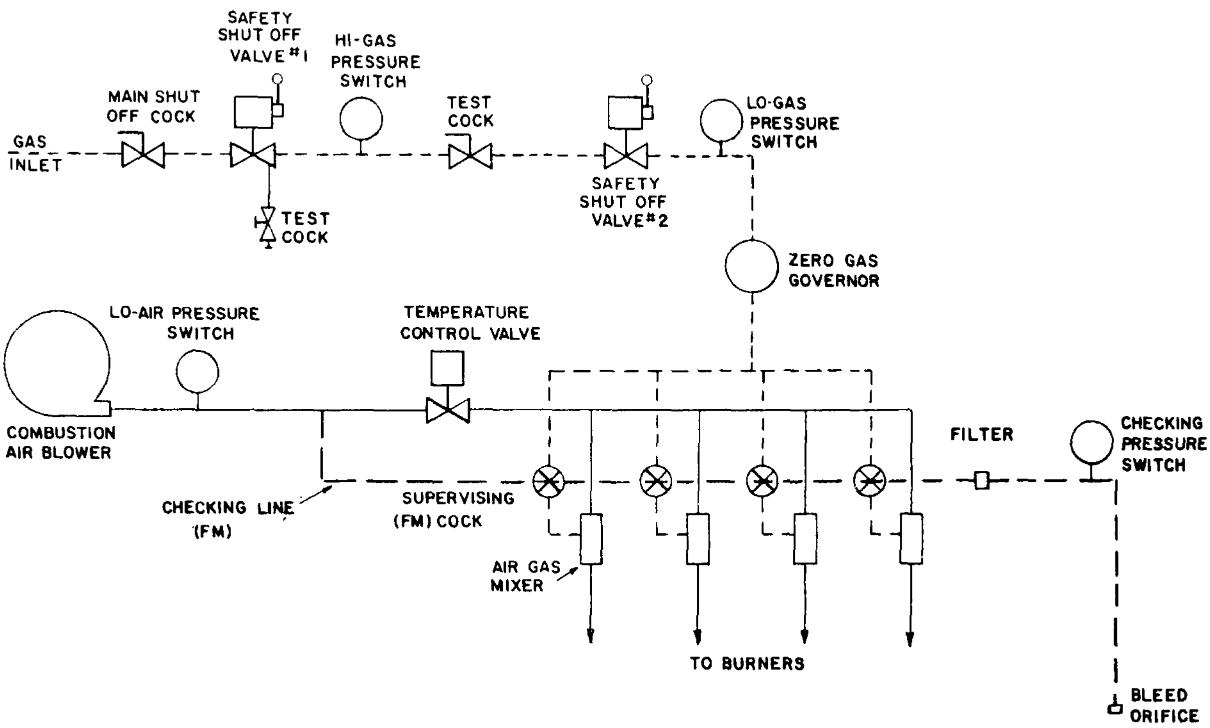


Figure 4-6.4.2(a) Piping.

NOTE: A method of assuring closure of all individual fuel gas burner cocks before the main burner fuel gas safety shutoff valve can be opened is the supervising cock and fuel gas safety control system. A typical piping and wiring arrangement using the pneumatic-type supervising cock is illustrated in Figure 4-6.4.2(a) (*See Section 1-4, Supervising Cock.*) The number and location of pressure switches, arrangement of tubing and other details will vary with the individual installation, the main burner safety shutoff valve cannot be opened until the supervising cocks are closed, combustion air pressure is normal, and normal fuel gas pressure present in the pilot burner manifold. Power failure, loss of combustion air, and/or gas pressure failure during normal firing will shut and lock out the main burner and pilot safety shutoff valves. Once the initial check has been completed and the main burner safety shutoff valve is opened, the low fuel gas pressure switch downstream from the safety shutoff valve shunts the checking pressure switch so that, after lighting the pilots, the supervising cocks can be opened to light-off.

A typical piping and wiring arrangement for the electric interlocking-type supervising cock is also illustrated in Figure 4-6.4.2(b). The main burner safety shutoff valve cannot be opened until all supervising cocks are closed (cock switch contacts in series are all closed), ventilation fans operating, preventilation purge completed and other interlocks satisfied.

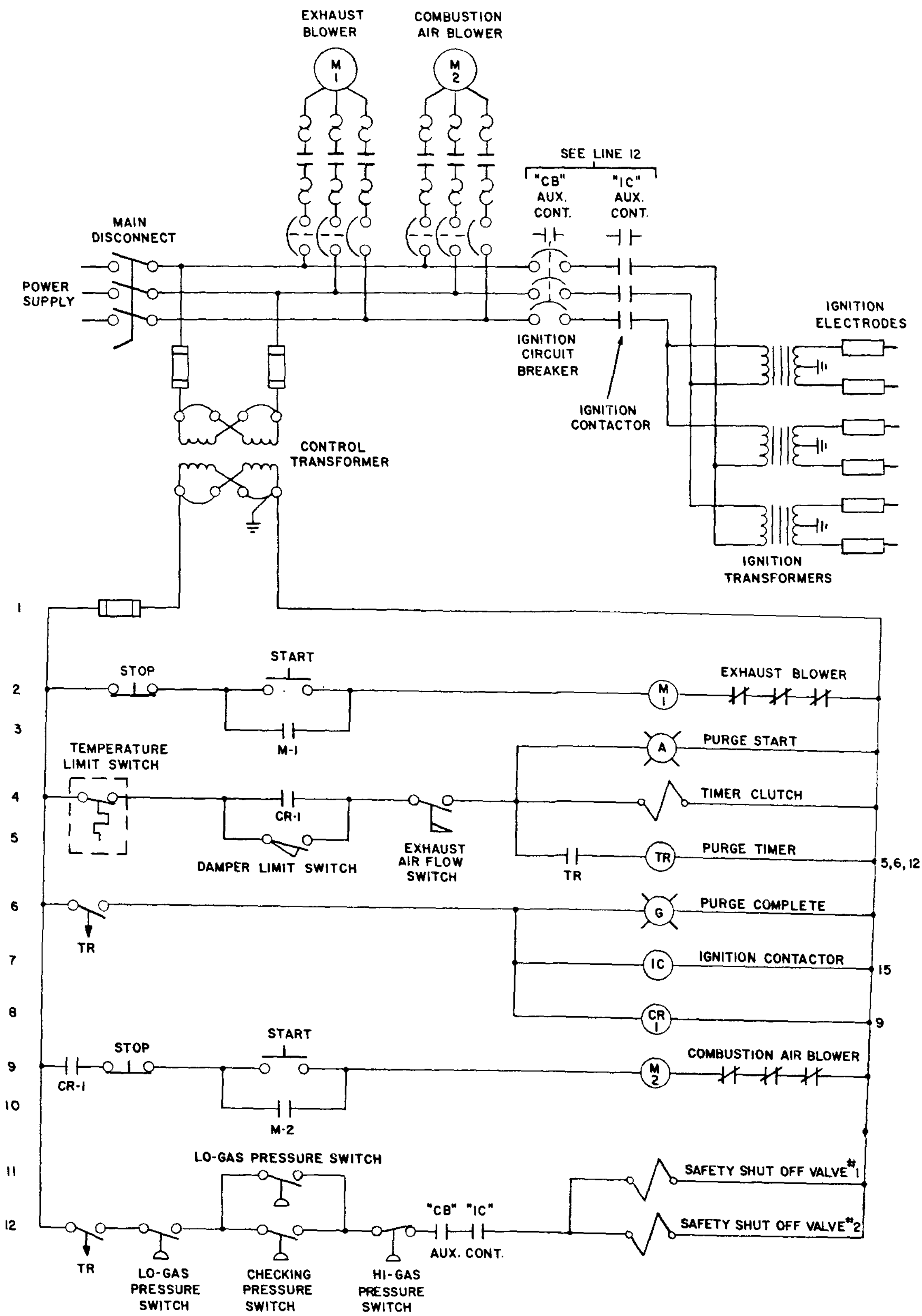


Figure 4-6.4.2(a) Electrical.

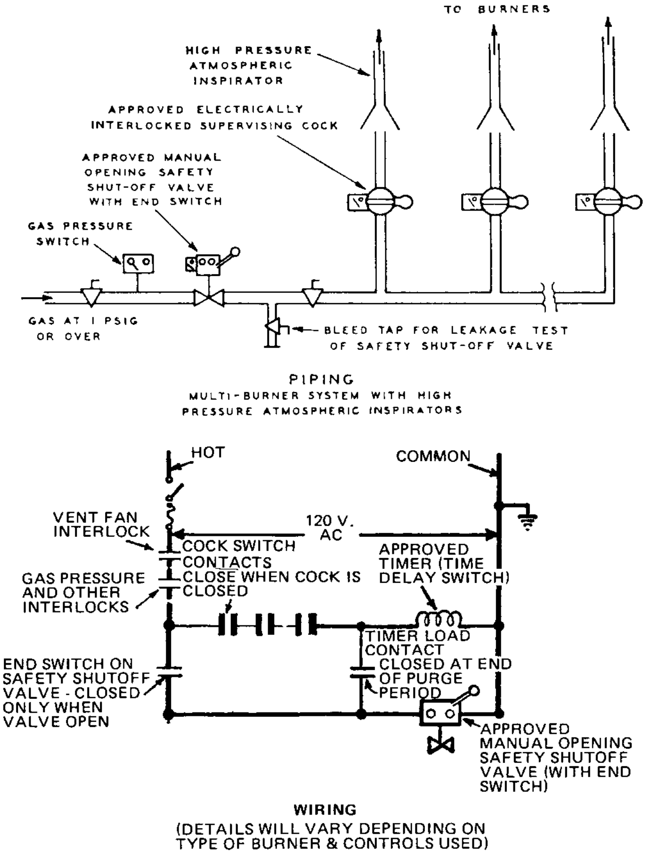
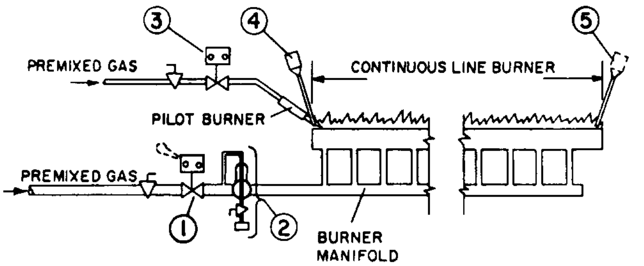


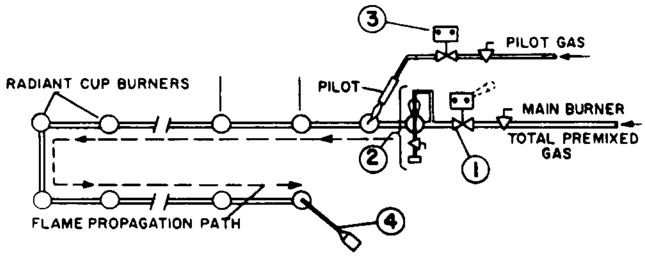
Figure 4-6.4.2(b) Examples of a Safety Control System Piping and Wiring, Electric Interlock-Type Supervising Cock.

4-6.4.2.1 Line burners, pipe burners, and radiant burners, when installed immediately and adjacent to one another or connected with suitable flame propagating tubes/devices, shall have at least one approved flame safeguard installed so as to sense flame presence at the furthest end of assembly from source of ignition within the trial-for-ignition period. (*See also 4-6.4.3.*)



1. Approved main gas safety shutoff valve. Manual-opening automatic-closing valve or automatic-opening automatic-closing valve, to suit firing method used.
2. Permanent and ready means for making periodic checks of main gas safety shutoff valve.
3. Approved pilot gas safety shutoff valve.
4. Pilot flame-sensing element.
5. Main flame-sensing element.

Figure 4-6-4.2.1(a) Example of Application of an Approved Combustion Safeguard Supervising a Pilot for a Continuous Line Burner During Lighting and the Main Flame Alone During Firing.



1. Approved main gas safety shutoff valve. Manual-opening automatic-closing valve or automatic-opening automatic-closing valve, to suit firing method used.
2. Permanent and ready means for making periodic tightness checks of main gas safety shutoff valve.
3. Approved pilot gas safety shutoff valve.
4. Main flame-sensing element.

Figure 4-6-4.2.1(b) Example of Application of an Approved 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.

4-6.4.3 Automatic relight after unintentional flame failure shall be prohibited.

4-6.4.4 Trial-for-ignition of pilots or main burners shall not exceed 15 seconds.

Exception: Longer time, up to a maximum of 60 seconds, may be permitted for ignition provided:

(a) Written request for extension of trial-for-ignition is filed with the authority having jurisdiction, and

(b) It is determined that 25 percent of the lower explosive limit will not be exceeded in the extended time.

4-6.5 Fuel Oil Atomization, other than Mechanical Atomization.

4-6.5.1 Adequate pressure/flow of the atomizing medium shall be proven to exist before the fuel oil enters the burning zone.

4-6.5.2 If a low pressure switch is used to sense/supervise the atomizing medium, consideration shall be given to locating it downstream from all cocks, valves, and other obstructions which can shut off flow or cause excessive pressure drop of atomization medium.

4-6.6 Low Fuel Oil Temperature Limit Devices.

4-6.6.1 A low fuel oil temperature limit device shall be provided and interlocked to de-energize the oil safety shutoff valve(s) whenever fuel oil temperature falls below a safe predetermined level and under the following conditions:

(a) Whenever the temperature of the fuel oil can drop below a safe level for proper atomization;

(b) When a fuel oil preheater is used;

(c) With No. 2 or No. 4 fuel oil when its temperature may reach the congealing point, whether or not preheaters are used.

4-6.7 Multiple-fuel systems require safety devices for the secondary fuel(s) that are equivalent to those devices used for the primary fuel; i.e., the fact that oil or gas may be considered to be a standby fuel for a dual-fuel burner system shall not lessen the safety requirements for that portion.

4-6.7.1 When dual-fuel burners are used, positive provision shall be made to prevent simultaneous introduction of both fuels.

NOTE: Not applicable to combination burners.

4-7 Fuel Gas-Mixing Machines. Safety equipment and installation shall comply with NFPA 54, *National Fuel Gas Code.*

4-8 Ignition of Main Burners — Fuel Gas or Oil.

4-8.1 Burners shall be ignited by a manual torch or by a continuous, intermittent, or interrupted pilot burner or by direct electrical means.

4-8.1.1 Sufficient energy shall be provided for safe and proper ignition of the burners.

4-8.1.2 If any specific input, or a limited range of inputs is required for safe ignition, the fuel control valve shall be properly positioned and interlocked prior to each and every attempt at ignition.

4-8.2 Electrical ignition energy for direct spark ignition systems shall be terminated after the main burner trial-for-ignition period.

Exception No. 1: Repetitive operation of a direct spark igniter for multiple burners is allowed where the input per burner does not exceed 150,000 Btu/hr (44 kw).

Exception No. 2: Repetitive operation of a direct spark igniter for radiant tubes is allowed.

4-8.3 Line burners, if used as runner pilots for multiple main burners, shall be single path and proven ignited, end-to-end, prior to main burner ignition attempt.

4-8.4 If one or more main burners is/are to be ignited from another main burner, the burden for proof of reliability shall rest with the equipment manufacturer.

4-9 Excess Temperature Limit Controller.

4-9.1 An excess temperature limit controller shall be used on any heating unit where it is possible for the controlled temperature to exceed a safe limit.

Exception: A single/multipoint recorder with excess temperature switch capability may be used as an excess temperature controller but shall not be used as primary temperature controller. This instrument shall not have a switch that can avoid the high limit contact.

4-9.1.1 The thermal element of the excess temperature limit controller shall be suitable for the atmosphere to which it will be exposed.

4-9.2 The excess temperature limit controller shall be interlocked with the safety circuit to cut off the source of heat when safe temperature is exceeded and require operator attention before startup of the furnace or affected furnace zone.

4-9.3 The thermal element of the excess temperature limit controller within the heating system shall be located to supervise that temperature most critical to proper operation.

4-9.4 The operating temperature controller and/or its thermocouple shall not be used as an excess-temperature limit.

4-10 Auxiliary Interlocks.

4-10.1 Conveyor interlocks shall be provided for ovens processing flammable volatiles.

4-10.2 Interlocks shall be provided for protection of the furnace. Among those to be considered are:

(a) Water-cooled walls, rolls, fan bearings, etc.

(b) Conveyors

(c) Doors.

4-10.3 An audible and/or visible alarm shall be provided in the safety circuit to give warning of unsafe conditions or interruption of the safety circuit.

4-11 Electrical Power.

4-11.1 Safety control circuits shall be single phase, one side grounded, with all breaking contacts in the "Hot" ungrounded, fused (or circuit breaker) protected line, which shall not exceed 120-volt potential.

NOTE 1: This control circuit and its "nonfurnace or oven-mounted control and safety components" should be housed in a panel or cabinet, protected by partitions or secondary barriers or separated by sufficient spacing from electrical controls employed in the higher voltage furnace or oven power system. Related instruments may or may not be installed in the same control cabinet.

NOTE 2: The door providing access to this control enclosure may include means for mechanical interlock with the main disconnect device required in the furnace power supply circuit.

NOTE 3: 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 as may be employed in the control circuit.

4-12 Safety Control Application for Electrical Heating Systems.

4-12.1 General. Safety control application for electrical heating systems shall provide protection from excess temperatures, loss of secondary systems (cooling, material handling, etc.) essential to normal operation of the furnace.

4-12.2 Electric Heating Equipment Controls.

4-12.2.1 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 disconnecting device(s) shall be capable of interrupting maximum fault current as well as rated load current. (*See NFPA 70, National Electrical Code.*)

NOTE 1: Abnormal conditions which may occur and require automatic or manual de-energization of affected circuits are as follows:

(a) A system fault (short circuit) not cleared by normally provided branch-circuit protection. (*See NFPA 70, National Electrical Code.*)

(b) Occurrence of excess temperature in a portion of the furnace which has not been abated by normal temperature controlling devices.

(c) A failure of any normal operating controls when such failure can contribute to unsafe conditions.

(d) A loss of electric power which can contribute to unsafe conditions.

NOTE 2: Drives for equipment such as conveyors, ventilation or recirculating fans, cooling components, etc., should not be stopped when interruption of heating energy is adequate to provide protection to other components of the equipment. (*See 4-9, 4-12.2.2 and Section 4-13*).

4-12.2.2 Automatic versus supervised operation of the "main heating system disconnect" shall be governed by the furnace size, design characteristics, and the potential hazards involved.

NOTE: When operation of a multiple phase "main disconnect" is to be manually supervised, each phase of the power supply circuit should be equipped to show electrical potential on the protected or load side, as an indication of intended operation, and partial or complete loss of power.

4-12.2.3 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 when fully equipped for the location and type of service proposed.

NOTE: This may require derating some components as listed by manufacturers for other types of industrial service, motor control, etc. and shown in Table 4-12.2.3.

Table 4-12.2.3

	Resistance-Type Heating Devices		Infrared Lamp and Quartz Tube Heaters	
Control Device	**Rating in % of Actual Load**	**Permissible Current in % of Rating**	**Rating in % of Actual Load**	**Permissible Current in % of 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: The above applies to "maximum load" or open ratings for safety switches, circuit breakers, and industrial controls approved under current NEMA standards.

4-12.2.4 All controls, using thermal protection or trip mechanisms, shall be so located or protected as to preclude faulty operation due to normal temperatures.

4-12.2.5 Equipment using solid-state power controllers (SCRs) shall have warning signs attached stating that the main line disconnect switch and/or heater circuit breaker shall be turned "off" whenever the equipment is shut off or being serviced.

4-13 Excess Temperature Limit Controller.

4-13.1 An excess temperature limit controller shall be used on any heating unit where it is possible for the controlled temperature to exceed a safe limit.

Exception: A single/multipoint recorder with excess temperature switch capability may be used as an excess temperature controller but shall not be used as primary temperature controller. This instrument shall not have a switch that can avoid the high limit contact.

4-13.1.1 The thermal element of the excess temperature limit controller shall be suitable for the atmosphe. to which it will be exposed.

4-13.2 The excess temperature limit controller shall be interlocked with the safety circuit to cut off the source of heat when safe temperature is exceeded and require operator attention before startup of the furnace or affected furnace zone.

4-13.3 The location of thermal element of the excess temperature limit controller within the heating system shall supervise that temperature most critical to safe operation.

4-13.4 The operating temperature controller and/or its thermocouple shall not be used as an excess-temperature limit.

4-14 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*.

Chapter 5 Safety Ventilation for Class A Ovens

5-1 Scope. Ventilation requirements for solvent evaporation ovens, flammable process vapors, and for fusing organic powders, are of prime importance. Proper ventilation within the scope of this chapter means a sufficient supply of fresh air and proper exhaust to a safe location with a sufficiently vigorous and properly distributed air circulation to ensure that the flammable vapor concentration in all parts of the oven or dryer enclosure shall be below the lower explosive limit at all times. For low-oxygen atmosphere oven application, refer to Chapter 6.

5-1.1 The determination of safe oven ventilation shall be based on:

(a) The volume of combustion products (if any) entering the oven heating chamber.

(b) The weight of flammable constituents, from organic powder or liquid coatings, released during the heating process.

(c) Design of the oven heating and ventilation system as to:

1. Materials to be processed.
2. Temperature to which these materials will be raised.
3. Method of heating as to direct or indirect venting of combustion products vs. alternate use of steam or electrical energy.
4. General design of oven as to continuous or batch-type operation.
5. Type of fuel and chemicals to be used and consequent by-products that may be generated in the heating chamber during normal or excessive temperature cycles.

NOTE: Ovens used to fuse organic powders will require safety ventilation on the same basis as ovens used to evaporate flammable solvents, when expressed in terms of cu ft (m^3) of standard

70°F (21°C) (at sea level) air required per lb (kg) of the various organic materials being released.

5-1.2 Safety ventilation shall be continuous until all flammable vapors are removed or have been released from the oven and other associated equipment.

5-1.3 Consideration shall be given to the hazard of blockage of heat recovery devices installed in the oven exhaust system. These devices may cause reduction or loss of safety ventilation, i.e., due to condensation of flammable volatiles, foreign materials, etc.

5-1.4 Careful consideration shall be given to the safe removal, dilution, or other disposal of flammable vapors or vapor-air mixtures. To do this, all necessary consideration shall be given to temperatures of operation, periods of dripping and predrying, speed of conveyor travel, safe disposal of flammable drippings, safe escape of flammable vapors or gases, safe control of combustion and the safety of chains, carrier belts, hoods, racks and carts.

5-1.5 The consideration of all these factors and their evaluation, the selection of the equipment and its design, including arrangement to meet all requirements for proper operation and adequate ventilation, shall be done by a qualified person familiar with oven design and basic rules of safety.

5-1.6 In general, the need for and type of ventilation required for safety in ovens covered by this standard is as follows:

(a) Ovens in which flammable or toxic vapors are liberated shall be mechanically ventilated to outdoor atmosphere regardless of the type of heating equipment employed.

(b) The safe disposal of the products of combustion shall be a part of the engineering consideration.

5-1.7 General basic requirements for oven ventilating systems handling flammable or toxic vapors are as follows:

(a) Exhaust duct openings shall be located in the area of greatest concentration of vapors.

(b) Exhaust duct openings shall be placed and sized so that they will gather and discharge vapors to the outdoor atmosphere as directly as practical in accordance with applicable local, state, and federal regulations, such as those of the Environmental Protection Agency (EPA).

(c) All exhaust shall be by mechanical means, using power-driven fans.

NOTE: Each oven should be equipped with an individual exhaust system not connected to an exhaust system serving other equipment.

(d) Manifold exhaust systems shall be designed so that the failure or nonoperation of one or more exhausts shall not adversely affect the remaining exhausts, and that the operating units will not create a hazard in the failed or nonoperating unit(s).

NOTE: Groups of ovens or ovens divided into several compartments may be exhausted by a common exhaust fan or individual oven exhaust fans connected to a common exhaust system.

(e) Ovens in which the temperature is controlled by dampers (manual or automatic) which affect the volume of hot air admitted to the oven shall be designed so that a reduction in the volume of hot air supplied does not result in a reduction of the volume of fresh air supplied to meet the requirements for safety ventilation.

NOTE 1: It is recommended that a separate draft fan, not connected with the oven ventilation, be used for exhausting the products of combustion from indirect gas- or oil-fired air heaters.

NOTE 2: On small indirect-fired installations, subject to the approval of the authority having jurisdiction, it may be permissible to connect the heater exhaust to the oven exhaust system, provided that: the temperature of the products of combustion should be reduced (when necessary) by the addition of fresh air to a point where it will prevent ignition of any combustible fumes in the oven exhaust system.

(f) 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.

NOTE: For unacceptable safety ventilation systems, see Figure 5-1.7.

5-1.8 When ventilation is required for ovens and furnaces, the following shall be complied with:

(a) Interlocks. (*See Sections 4-2 and 4-4.*)

1. Interlocks actuated by devices such as airflow or pressure switches shall be provided.

2. Electrical interlocks obtained through interconnection with a motor starter shall be provided.

(b) Fresh Air Supply.

1. Ovens in which flammable vapors are being liberated shall be assured of receiving the full required amount of fresh air for safe dilution of vapors. (*See Sections 5-2 and 5-3.*)

2. Ovens heated by electric resistance heaters or by combustion of any fuel shall have the air supply fans electrically or mechanically interlocked in such a manner as to prevent operation of the heating units unless the air supply fans are running.

3. Volume control dampers in the ducts which affect the volume of fresh air admitted to and vapors or gases exhausted from the oven shall be designed so that when in closed position they will pass the volume required for safe ventilation.

(c) Exhaust.

1. Ovens in which flammable vapors are being produced or into which the products of combustion of fuels are permitted to enter shall be assured of having the required amount of exhaust for safe ventilation. (*See Sections 5-2 and 5-3.*)

2. Ovens heated by electric or infrared lamps or by combustion of any fuel shall have the exhaust fans electrically and mechanically interlocked in such a manner as to prevent operation of the heating units unless the exhaust fans are running.

3. Volume control dampers in the ducts which affect the volume of fresh air admitted to and vapors or gases exhausted from the oven shall be designed so that when in closed position they will pass the volume required for safe ventilation.

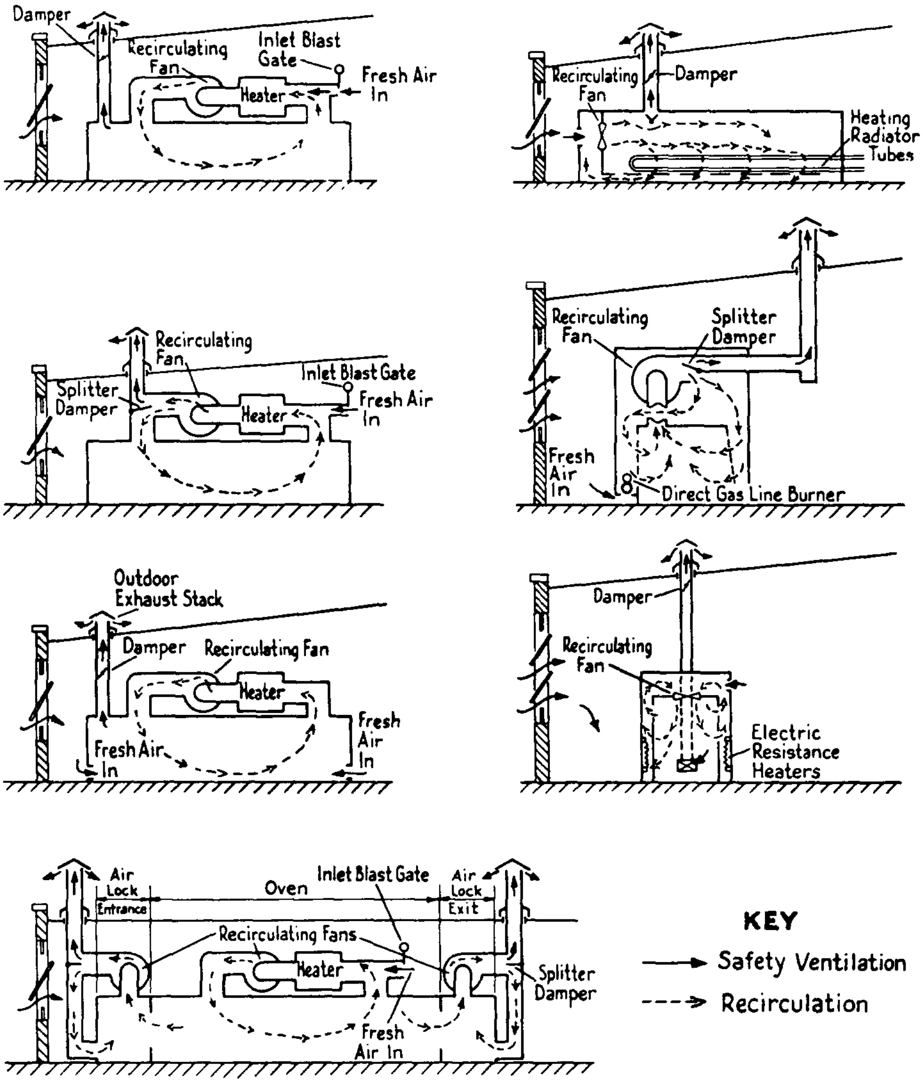


Figure 5-1.7 Unacceptable Safety Ventilation Systems Using Dual-Purpose Fans Alone (Recirculation Combined with Spill Exhaust).

(d) Purging Interval. Purging cycle or preventilation shall be in accordance with Section 4-2.

5-1.9 Forced Ventilation.

5-1.9.1 Ventilation requirements shall be entirely independent of and in addition to (a) recirculation within the oven enclosure, and (b) exhaust for removal of products of combustion, in an indirect heating system in accordance with 5-1.9.2 and 5-1.9.3.

5-1.9.2 Mechanical means for reliable and adequate ventilation of ovens shall be provided.

5-1.9.3 On the completion of an oven installation, airflow tests shall be conducted on the ventilation systems under operating conditions of the oven, with adjustable dampers at minimum opening. Tests of safety devices shall be made to assure proper ventilation and operation of the system. These tests shall be repeated periodically.

NOTE: The user should make arrangements to have these tests conducted by qualified personnel if the user is not equipped to do so.

5-1.10 Natural ventilation shall not be used on Class A ovens when flammable volatiles or toxic fumes are given off from the work in process.

5-1.11 Temperature Corrections. Temperature conversion factors shall be taken into consideration in the application of the following requirements, since the volume of gas varies in direct proportion to its absolute temperature [0°F (-18°C) equivalent to 460° R (256°K)]. (*See Table 5-1.11.*)

NOTE: English Units: For example, in order to draw 9200 cfm of fresh air referred to 70°F (530°F absolute) into an oven operating at 300°F (760°F absolute), it is necessary to exhaust 760/530 × 9200 = 13,150 cfm of 300°F air.
SI Units: For example, in order to draw 260 m^3/minute of fresh air referred to 21°C (294°K absolute) into an oven operating at 149°C (422°K absolute), it is necessary to exhaust 422/294 × 260 = 373 m^3/minute of 149°C air.

Table 5-1.11 Temperature-Volume Conversion Table (At Sea Level)

Temp. °F (°C)	Factor	Temp. °F (°C)	Factor	Temp. °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				

5-1.12 Dilution of Vapors. Ventilation shall be arranged in an oven enclosure in such a way that there are no zones in which circulation does not take place. In compliance with this requirement, due consideration shall be given to the proportioning of fresh air and recirculated air inlets and exhaust outlets in such a way that maximum dilution is obtained at points of maximum solvent evaporation, and also to the specific gravity of the solvent vapor and fuel gas.

NOTE: 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 Table 5-2)*. Liquefied petroleum gases are heavier than air and other fuel gases are lighter than air. *(See NFPA 325M, Fire Hazard Properties of Flammable Liquids, Gases and Volatile Solids.)*

5-1.13 Air Drying or Dripping. In areas outside of the oven where volatiles are given off by material prior to entering the oven, adequate provisions shall be made to exhaust vapors to the atmosphere in accordance with applicable local, state, and federal regulations.

5-1.14 Methods for Calculation of Ventilation for Continuous and Box- or Batch-Ovens.

NOTE 1: This contains explanatory material relative to the methods for calculating ventilation in continuous and box- or batch-type ovens. The air delivered into an oven by the supply system to do the work required may be all fresh air (from a source outside the oven), or it may be partly fresh air and partly recirculated air from the oven. A volume of air equivalent to the fresh air supplied must be exhausted from the oven to keep the system in balance. It is this portion of the air supplied to the oven which provides the ventilation.

The minimum amount of fresh air delivered into the oven for ventilation is based on the amount of solvent vapor which is liberated from the work in process. The method for determining the minimum volume of fresh air required for ventilation is demonstrated by the following example:

NOTE 2: Measurement of Quantity of Air Exhausted from an Oven.

The amount of air discharged from an oven by the exhaust system is generally a fair indication of the safety ventilation, assuming that supply and exhaust are properly designed.

A simple method may be used to determine the quantity of air being exhausted from an oven. Establish the velocity of the air through the discharge duct by means of a velometer, anemometer, pitot tube, or other suitable means, and calculate the cu ft (m^3) of air per minute by multiplying the velocity in lineal ft (m) per minute by the cross-sectional area of the exhaust duct in sq ft. The temperature of the exhaust air should also be read and the volume referred 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 of the continuous type, the exhaust ducts have been incorrectly placed in a location which permits air from the outside of the oven to enter the exhaust system together with the ventilation air exhausted from the oven. It is necessary that only the ventilation air exhausted from the oven be considered in calculating the safety volume.

The temperature of air discharged from the exhaust will be the average of the temperature of the air exhausted from the oven and the air exhausted from the space outside the oven in proportion to their volumes. Temperature readings should be noted within the oven in the area of the exhaust, outside the oven in the area of the exhaust, and at the fan discharge. From these temperatures the proportion of oven air and outside air can be determined with a fair degree of accuracy.

Only the air exhausted from the oven should be considered. For example, Continuous Oven:

Temperature reading of mixed air in exhaust duct of oven: 242.5°F (117°C).

Temperature of air in oven within exhaust area: 300°F (149°C).

Temperature of air outside of oven exhaust system, short-circuited into oven: 70°F (21°C).

Problem:
How many parts of air at 300°F (149°C) and at 70°F (21°C), when mixed, will produce a resultant temperature of 242.5°F (117°C)?

English	SI
X = parts @ 300°F	X = parts @ 149°C
y = parts @ 70°F	y = parts @ 21°C
$242.5(x+y) = 300x + 70y$	$117(x+y) = 149x + 21y$
$242.5x + 242.5y = 300x + 70y$	$117x + 117y = 149x + 21y$
$172.5y = 57.5x$	$96y = 32x$
$3y = x$	$3y = x$

Therefore,
3 parts @ 300°F (149°C) + 1 part @ 70°F (21°C) = 4 parts total.

Therefore, 75 percent of the air being discharged by the exhaust fan in this example is from inside the oven. Correcting this volume for 70°F (21°C), we have the actual amount of ventilation air being exhausted, or the equivalent amount of fresh air being admitted into the oven.

In case all of the fresh air is admitted to the oven through an opening or openings where it can be measured directly, it will not be necessary to go through the preceeding exhaust calculations.

NOTE 3: Theoretical Determination of Required Ventilation.

1. Determine the number of gallons (dm^3) of paint or coating which will be baked in oven per hr (for example, 10 gal = 37.9 dm^3).
2. Determine the total percentage of solvent in coating [for example, 60 percent = 6 gal (22.7 dm^3)].
3. Determine air volume rendered barely explosive by vapor from one gal (3.79 dm^3) of solvent.
   a. The lower explosive limit (LEL) = 1.2 percent by volume in air. *(See Table 5-2.)* As given, this value for the lower explosive limit is at the ordinary ambient temperature, approximately 70°F (21°C).
   b. The specific gravity of this liquid (Sp Gr) = 0.9 (water = 1.0).
   c. The vapor density = 3.1 (air = 1.0).
   d. The weight per cu ft of dry air at 70°F (21°C) and 29.9 in. (0.76 m) Hg = 0.0756 lbs (1.20 kg/m^3).
   e. One gal (3.79 dm^3) of water weighs 8.33 lbs (0.998 kg) at 70°F (21°C).

English

To determine the ft^3 of vapor per gal of solvent, use the following formula:

$$\frac{8.33 \times SpGr}{0.075 \times VD} = ft^3 \text{ per gal @ } 70°F$$

For this example,

$$\frac{8.33 \times 0.9}{0.075 \times 3.1} = 32.2 \text{ ft}^3$$

The LEL being 1.2 percent the ft^3 of air rendered explosive, one gal of (toluene) is:

$$\frac{(100 - 1.2) \times 32.2}{1.2} = 2651 \text{ cu ft @ } 70°F$$

This 70°F volume, if handled at a higher temperature, must be corrected for the higher temperatures by the use of an expansion factor in which t = the exhaust temperature. Assume the exhaust temperature to be 300°F.

For example,

$$\frac{t\,°F + 460}{70°F + 460} = \frac{300 + 460}{70 + 460} = 1.43 = \text{ratio of absolute temperatures at } 70° \text{ and } 300°F$$

At oven exhaust temperature, the volume of air rendered barely explosive by vapor from one gal of toluene is:

$2{,}651 \times 1.43 = 3{,}790$ ft³ per gal of solvent at 300°F

SI Units

To determine the m³ of vapor per dm³ of solvent, use the following formula:

$$\frac{0.998 \times SpGr}{1.20 \times VD} = m^3/dm^3 \ @ \ 21°C$$

For this example,

$$\frac{0.998 \times 0.9}{1.20 \times 3.1} = 0.24 \ m^3/dm^3$$

The LEL being 1.2 percent, the m³ of air rendered explosive by one dm³ of toluene is:

$$\frac{100 - 1.2}{1.2} \times 0.24 = 19.8 \ m^3 \ @ \ 21°C$$

This 21°C volume, if handled at a higher temperature, must be corrected for the higher temperatures by the use of an expansion factor in which t = the exhaust temperature. Assume the exhaust temperature to be 149°C.

For example,

$$\frac{t\,°C + 273}{21°C + 273} = \frac{149 + 273}{21 + 273} = 1.43 = \text{ratio of absolute temperature at } 21° \text{ and } 149°C$$

At oven exhaust temperature, the volume of air rendered barely explosive by vapor from one dm³ of toluene is:

$19.8 \times 1.43 = 28.3$ m³/dm³ of solvent at 149°C.

NOTE 4: Another Method of Computation.

For this example, use xylene as the solvent.

SpGr = 0.9

Then:

English

Weight of 1 gal liquid = 8.33 × 0.9 = 7.5 lbs
Molecular weight of $C_6H_4(CH_3)_2$ = 106

If the vapor density is not known, the volume of the vapor can be determined from the molecular weight. The molecular weight in pounds of any gas or vapor occupies 388 cu ft at 70°F and 29.9 in. of mercury.

The volume of one gal of xylene, when vaporized, is, therefore:

$$\frac{7.5 \times 388}{106} = 27.5 \ ft^3 \ @ \text{ standard conditions}$$

LEL for xylol = 1.0 percent by volume

$$\frac{(100 - 1.0) \times 27.5}{1.0} = 2{,}723 \ ft^3 \text{ per gal @ } 70°F \text{ at LEL}$$

For a higher exhaust temperature, t, this 70°F volume must be corrected by an expansion factor. Assume t = 300°F.

$$\text{Expansion factor} = \frac{300 + 460}{70 + 460} = 1.43 = \text{ratio of absolute temperature at } 70° \text{ and } 300°F$$

Then:

2,723 × 1.43 = 3,894 ft³ of air rendered barely explosive per gal of solvent at 300°F.

SI Units

Weight of one dm³ liquids 0.998 × 0.9 = 0.90 kg/dm³
Molecule weight of $C_6H_4(CH_3)_2$ = 106

If the vapor density is not known, the volume of the vapor can be determined from the molecule weight. The molecular weight in grams of any gas or vapor occupies 24.2 dm³ at 21°C and 101 kPa. The volume of one dm³ of xylene when vaporized, is, therefore:

$$\frac{0.9 \times 24.2}{106} = 205 \ dm^3 \ @ \text{ standard conditions}$$

LEL for xylene = 1.0 percent by volume

$$\frac{(100 - 1.0) \times 205}{1.0} = 20.3 \ m^3 \text{ per } dm^3 \ @ \ 21°C \text{ at LEL}$$

For a higher exhaust temperature, t, this 21°C volume must be corrected by an expansion factor. Assume t = 149°C.

$$\text{Expansion factor} = \frac{149 + 273}{21 + 273} = 1.43 = \text{ratio of absolute temperature at } 21° \text{ and } 149°C$$

Then:

20.3 × 1.43 = 29.0 m³ of air rendered barely explosive per dm³ of solvent at 149°C.

5-2 Continuous Process Oven.

5-2.1 Rate of Ventilation. In continuous process ovens, the safety ventilation rate shall be designed and maintained to prevent the vapor concentration in the oven from exceeding 25 percent of the lower explosive limit.

Exception: The safety ventilation rate may be decreased when a continuous vapor concentration indicator and controller is provided (see Section 5-4). For such installation, the continuous vapor concentration indicator and controller shall be arranged to alarm and shut down the oven heating systems or operate additional exhausters at a predetermined vapor concentration not to exceed 50 percent of the lower explosive limit.

NOTE: The recirculation and exhaust fans and other devices should be operated in such a manner that the vapor concentration is maintained at or less than the safe predetermined concentration.

5-2.2 Estimated Rate of Ventilation Method. In continuous process ovens the rate of safety ventilation shall be not less than 10,000 cu ft (283 m³) of fresh air referred to 70°F (21°C) (at sea level) per gal of solvent evaporated in the oven, except as permitted in 5-2.3.

NOTE: The basis for the above general rule is that 1 gal of common solvent produces a quantity of flammable vapor which will diffuse in air to form roughly 2,500 cu ft (71 m³) of the leanest explosive mixture. (*See calculation 5-2.3.*)

Since a considerable portion of the ventilating air may pass through the oven without traversing the zone in which vapors are given off and on account of a possible lack of uniform distribution of the ventilation air, and also to provide a margin of safety, four times this amount of air, or 10,000 cu ft (283 m³) referred to 70°F (21°C), for each gallon of solvent evaporated, should be allowed.

Warning: It should be noted that with certain solvents, when the volume of air rendered barely explosive exceeds 2,500 cu ft (71 m³) (Column J, Table 5-2), the factor of safety in this estimation method decreases in proportion.

The total volume of air, in cu ft (m^3) per minute required for ventilation of the oven is obtained by multiplying the cu ft (m^3) of air required per gal (m^3) of solvent by the gal (m^3) of solvent per minute.

5-2.3 Calculated Rate of Ventilation Method. In continuous process ovens, when the rate of ventilation is calculated, the following method shall be used.

English:

NOTE 1: This method is usually applied when an oven is designed to operate with a particular solvent and when ventilating air may be accurately controlled.

$$\text{Required ventilation} = \frac{444 \times \text{SpGr} \times (100 - \text{LEL})}{\text{VD} \times \text{LEL}} \text{ cu ft of air}$$

referred to 70°F (21°C) per gallon solvent evaporated, where:
SpGr = Specific gravity of solvent (water = 1)
VD = Vapor density of solvent vapor (air = 1)
LEL = Lower explosive limit expressed in percent by volume. (For example, LEL of gasoline written 1.3, not .013.)

NOTE 2: The derivation of the above formula is as follows:

$$\text{One gallon of solvent produces } \frac{8.33 \times \text{SpGr}}{.075 \times \text{VD}} \text{ cu ft of flammable vapor}$$

where:
8.33 = Weight of 1 gal of water in lbs
.075 = Weight of 1 cu ft of air in lbs

The volume of air required to render this amount of vapor barely explosive is $\frac{(100 - \text{LEL})}{\text{LEL}}$ × this figure, or 1 gal of solvent will form

$$\frac{8.33 \times \text{SpGr} \times (100 - \text{LEL})}{.075 \times \text{VD} \times \text{LEL}} \text{ cu ft of the barely explosive mixture.}$$

Providing a factor of safety of 4 (maintaining an average concentration of 25 percent of the lower limit) then the equation becomes:

$$4 \times \frac{8.33 \times \text{SpGr} \times (100 - \text{LEL})}{.075 \times \text{VD} \times \text{LEL}} \text{ or } \frac{444 \times \text{SpGr} \times (100 - \text{LEL})}{\text{VD} \times \text{LEL}}$$

The total volume of air, in cu ft per minute, required for ventilation of the oven is obtained by multiplying the cu ft of air required per gal of solvent by the gal of solvent per minute entering the oven. *(See 5-1.14 and 5-2.4 for calculation examples.)*

SI Units:

$$\text{Required ventilation} = \frac{3.33 \times \text{SpGr} \times (100 - \text{LEL})}{\text{VD} \times \text{LEL}} \text{ m}^3 \text{ of air}$$

referred to 21°C per dm^3 solvent evaporated, where:
SpGr = Specific gravity of solvent (water = 1)
VD = Vapor density of solvent vapor (air = 1)
LEL = Lower explosive limit expressed in percent by volume. (For example, LEL of gasoline written 1.3, not .013.)

NOTE 2: The derivation of the above formula is as follows:

$$\text{One dm}^3 \text{ of solvent produces } \frac{0.998 \times \text{SpGr}}{1.20 \times \text{VD}} \text{ m}^3 \text{ of flammable vapor}$$

where:
0.998 = Weight of one dm^3 of water in kg
1.20 = Weight of 1 m^3 of air in kg

The volume of air required to render this amount of vapor barely explosive is $\frac{100 - \text{LEL}}{\text{LEL}}$ × this figure, or 1 dm^3 of solvent will form

$$\frac{0.998 \times \text{SpGr} \times (100 - \text{LEL})}{1.20 \times \text{VD} \times \text{LEL}} \text{ m}^3 \text{ of the barely explosive mixture}$$

Providing a factor of safety of 4 (maintaining an average concentration of 25 percent of the lower limit) then the equation becomes

$$4 \times \frac{0.998 \times \text{SpGr} \times (100 - \text{LEL})}{1.20 \times \text{VD} \times \text{LEL}} \text{ or } \frac{3.33 \times \text{SpGr} \times (100 - \text{LEL})}{\text{VD} \times \text{LEL}}$$

The total volume of air, in m^3 per minute, required for ventilation of the oven is obtained by multiplying the m^3 of air required per dm^3 of solvent by the dm^3 of solvent per minute entering the oven. *(See 5-1.14 and 5-2.4 for calculation examples.)*

A convenient listing of the properties and approximate volumes of air required to render 1 gal of common solvents barely explosive appears in data tables found in Table 5-2.

5-2.4 In continuous process ovens, including powder coating, when a direct-fired combustion system (within the oven chamber or remote) is used, the volume of combustion products from burners shall be determined for stoichiometric operation by the formula:

English:

$$\frac{\text{Btu/hr (Total Burner Rating)}}{95 \times 60} = \text{Cu ft of air per min (SCFM) referred to 70°F (21°C) (standard density)}$$

SI Units:

$$\frac{\text{W (Total Burner Rating) 60 sec/min}}{3.54 \text{ MJ/m}^3} = \text{cu m of air per minute referred to 21°C}$$

Where 95 Btu/cu ft = the approximate heat content of an air mixture with slight excess air.

Btu = 1,056 J; cu ft = 0.028 m^3

When this calculation for 70°F (21°C) equivalent volume is greater than one-third (⅓) of the volume determined for removal of chemical by-products (from 5-2.1, 5-2.2 or 5-2.3), the minimum exhaust volume for the oven will be the sum of the two computations, adjusted for thermal expansion as per 5-1.11. When the combustion products are less than one-third of the volume determined for removal of chemical by-products, the minimum exhaust volume for the oven shall be based on the volume for removal of chemical by-products only, with adjustment for thermal expansion as per 5-1.11.

NOTE 1: Example for a Continuous Liquid Solvent Paint Oven. This direct gas-fired oven has a 2¼-million Btu/hr (2,376 MJ/hr-) burner system and the heating process is intended to evaporate 14 gal (0.053 m^3) per hr of toluene from a dipped liquid finish on sheet steel products being baked at 400°F (204°C).

English:

(a) The exhaust indicated for combustion products is (see 5-2.4):

$$\frac{2{,}250{,}000}{95 \times 60} = 395 \text{ SCFM [70°F (21°C)] condition}$$

(b) Ventilation for solvent vapors is (see 5-2.2):

$$\frac{14 \text{ gph} \times 10{,}000}{60} = 2{,}331 \text{ SCFM}$$

(c) The adjustment for thermal expansion is based on item "b" only:

2,331 × 1.62 = 3,776 CFM (at 400°F)

SI Units:

(a) The exhaust indicated for combustion products is (see 5-2.4):

$$\frac{659\text{KW} \times 60 \text{ sec/min}}{3.54 \text{ MJ/m}^3} = 11.17 \text{ m}^3\text{/min (21°C)}$$

Table 5-2
Table of Properties of Commonly Used Flammable Liquids In English Units

The data in this table have been obtained from NFPA 325M, *Fire Hazard Properties of Flammable Liquids, Gases, and Volatile Solids* Available figures from numerous sources will be found to 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 figures presented are for information and general guidance only and are not to be regarded as official standards

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 multicomponent preparations may contain several solvents with widely different values of "lower explosive limit," "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 Corrections and factors of safety for final ventilation values are to be applied as indicated in the footnotes

	A	B	C	D		E	F	G	H	I		J
	Molecular Weight	Flash Point Deg F	Ign Temp Deg F	Explo Limits % by Volume		Specif Gravity (Water = 1)	Vapor Density (Air = 1)	Boiling Point Deg F	Lbs Per Gal	Cu Ft of Vapor		*Approximate Cu Ft of Air rendered barely explosive per gal of Solvent
				Lower	Upper					Per Gal Liquid	Per Lb Liquid	
Acetone	58	- 4	869	2 15	13	0 8	2 0	133	6 7	44 4	6 63	2020
Amyl Acetate n	130	60	680	1 1	7 5	0 9	4 5	300	7 3	22 2	3 04	2000
Amyl Acetate iso	130	89				0 9	4 5	249	7 2	22 2	3 09	
Amyl Alcohol	88	91	572	1 2	10 0 @212	0 8	3 0	280	6 8	29 6	4 36	2440
Benzine (Petroleum Ether)	Mix	< 0	550	1 1	5 9	0 6	2 5	95-140	5 4	26 7	4 94	2400
Benzene (Benzol)	78	12	928	1.3	7 1	0 9	2 8	176	7 3	35 7	4 89	2710
Butyl Acetate n	116	72	797	1 7	7 6	0 9	4 0	260	7 3	25 0	3 42	1450
Butyl Alcohol n	74	84	650	1 4	11 2	0 8	2 6	243	6 7	34 2	5 10	2410
Butyl Alcohol	74	75	761	1 7 @212	9 8 @212	0.8	2.6	201	6 7	34 2	5 10	1980
Butyl Cellosolve (Glycol monobutyl Ether)	118	148	472			0 9	4.1	340	7 5	24 4	3 25	
Butyl Propionate	130	90	799			0 9	4 5	295	7 3	22 2	3 04	
Camphor (2-Camphonone)	152	150	871	0.6	3.5	1 0	5 2	399	8 2	21 2	2 58	
Carbon Disulphide	76	- 22	194	1 3	50 0	1 3	2 6	115	10 5	55 5	5 29	4210
Cellosolve (Ethylene Glycol Monoethyl)	90	106	460	2 6	15 7	0.9	3 1	275	7 8	32 2	4 13	1210
Cellosolve Acetate (Ethylene Glycol Monoethyl Ether Acetate)	132	126	715	1 7		0 97	4 7	311	8 1	22 8	2 82	1320
Chlorobenzene-mono	113	84	1099	1 3	9 6	1 1	3 9	270	9 2	31 3	3.41	2380
Cottonseed Oil Refined	Mix	486	650			0 9			7 7			
Cresol m or p	108	187	1038	1 1 @302		1.0		395	8 6	29 2	3 40	2620
Cyclohexane	84	- 4	473	1 3	8	0 8	2.9	179	6.5	30 6	4 71	2320
Cyclohexanone	98	111	788	1 1 @212	9 4	0 9	3 4	313	7 9	29 4	3 72	2640
Cymene-para	134	117	817	0.7 @212	5.6	0 9	4 6	349	7 2	21 7	3 02	3080
Denatured Alcohol	Mix	60	750			0.8	1.6	175	6 7	55 5	8 29	
Dibutylphthalate o	278	315	757	0 5 @456		1 04		644	8 7			
Dichlorobenzene ortho	147	151	1198	2 2	9 2	1 3	5 1	356	10 9	28 3	2 60	1260
Diethyl Ketone	86	55	842	1 6		0 8	3 0	217	6 8	29 6	4 36	1820
Dimethyl Formamide	73	136	833	2 2 @212	15 2	0 9	2 5	307	7 8	40 0	5 13	1780
Dioxane P (Diethylene Dioxide)	88	54	356	2 0	22	1 0 +	3 0	214	8 97	37 0	4 13	1810
Ethyl Acetate	88	24	800	2 0	11 5	0 9	3 0	171	7 5	33 3	4 44	1630
Ethyl Alcohol	46	55	685	3 3	19	0 8	1 6	173	6 6	55 5	8 41	1630
Ethyl Ether	74	- 49	320	1 9	36	0 7	2 6	95	5 9	29 9	5 07	1540
Ethyl Lactate	118	115	752	1 5 @212		1 0 +	4 1	309	8 5	27 1	3 19	1780
Ethyl Methyl Ether	60	- 35	374	2 0	10 1	0 7	2 1	51	6 1	37 0	6 06	1810
Ethyl Propionate	102	54	824	1 9	11	0 9	3 5	210	7 4	28 6	3 86	1480
Ethylene Dichloride	99	56	775	6 2	16	1 3	3 4	183	7 4	42 5	5 74	640
Gasoline	Mix	- 45	495	1 4	7 6	0 8	3 4	100-400	7 0	25 4	3 63	1790
Hexane n	86	- 7	437	1 1	7 5	0 7	3 0	156	5 5	25 9	4 71	2330
Kerosene (Fuel Oil No 1)	Mix	110 162	410	0 7	5	< 1		304-574	7 5			
Linseed Oil Raw	Mix	432	650			0 9		600 +	7 7			
Methyl Acetate	74	14	850	3 1	16	0 9	2 8	140	7 7	35 7	4 64	1120
Methyl Alcohol	32	52	725	6 0	36	0 8	1 1	147	6 6	80 8	12 2	1270
Methyl Carbitol (Diethylene Glycol Methyl Ether)	120	188				1 02	4 14	345	8 5	27 4	3 22	
Methyl Cellosolve	76	105	551			0 97	2 6	255	8 1	40 9	5 08	
Methyl Cellosolve Acetate (Ethylene Glycol Methyl Ether Acetate)	118	56		1 7	8 2	1 0	4 07	292	8 3	27 3	3 29	
Dimethyl Ether	46	Gas	662	3 4	27 0	0 7	1 6	- 11	5 5	48.6	8 84	
Methyl Ethyl Ketone (Butanone)	72	16	759	1 7 @200	11 4 @200	0 8	2 5	176	6 7	35 5	5 30	2050
Methyl Lactate	104	121	725	2.2 @212		1 1	3 6	293	9 1	33 9	3 73	1510
Mineral Spirits No 10	Mix	104	473	0 8 @212		0 8	3 9	300	6 7	22 8	1 72	2830
Naptha (V M & P Regular)	Mix	28	450	0 9	6 0	0 8	3 7	212 320	6 2	24 0	3 87	
Naphthalene	128	174	979	0.9	5 9	1 1	4 4	424	9 7	27 8	2 86	3060
Nitrobenzene	123	190	900	1 8 @200		1 2	4 3	412	10 0	31 0	3 10	1690
Nitroethane	75	82	778	3 4		1 1	2 6	237	8 7	47 0	5 40	1340
Nitromethane (a)	61	95	785	7 3		1 1	2 1	214	9 4	58 2	6 19	740
Nitropropane 1	89	96	789	2 2		1 0	3 1	268	8 3	35 8	4 32	1590
Nitropropane 2	89	75	802	2 6	11 0	1 0	3 1	248	8 2	35 8	4 37	1340
Paraffin Oil	Mix	444							7 1 7 5			
Petroleum Ether	Mix	< 0	550	1 1	5 9	0 6	2 5	95 140	5 4	26 7	4 94	2400
Propyl Acetate iso	102	55	842	1 7 @100	8	0 9	3 5	215	7 5	28 6	3 81	1650
Propyl Alcohol n	60	74	775	2 1	13 7	0 8	2 1	207	6 7	42.3	6 32	1970
Propyl Alcohol iso	60	53	750	2 0	12 0	0 8	2 1	176	6 6	42 3	6 41	2070
Propyl Ether iso	102	70	419			0 75	3 53	194	6 1	23 6	3 87	
Pyridine	79	68	900	1 8	12 4	1 0 -	2 7	239	8 2	41 1	5 02	2240
Rosin Oil	Mix	266	648			1 0		> 680	8 2			
Soy Bean Oil	Mix	540	833			0 9			7 7			
Perchloroethylene	106	None				1 63	5 8	429	13 6			
Toluene	92	40	896	1 2	7 1	0 9	3 1	231	7 2	32 2	4 48	2650
Turpentine	136	95	488	0 8		< 1	4 8	300	7 2			
Vinyl Acetate	86	18	756	2 6	13 4	0 9	3 0	161	7 7	33 3	4 33	1250
O-Xylene	106	90	867	1 0	6 0	0 9	3 7	292	7 3	27 0	3 70	2670

Note Column J gives the cubic feet of air rendered barely explosive by 1 gallon of solvent However, for most practical calculations, this value is close enough to the actual volume of the vapor air mixture

*For final required safety ventilation values in each particular oven operation these figures are multiplied by the following factors as they apply

(1) Temperature Volume Conversion (see Table 5 1 11).

(2) Standard factor of safety of 4 for continuous process ovens (see 5 2 1)

(3) L E L Correction factor for batch ovens between 250°F and 500°F multiply by 1 4 (see 5 3 3)

(4) The maximum number of gallons of solvent evaporated per unit of time on the basis of maximum possible loadings

(a) Classified as a potentially explosive chemical

Table 5-2
Table of Properties of Commonly Used Flammable Liquids In Metric Units

The data in this table have been obtained from NFPA 325M, *Fire Hazard Properties of Flammable Liquids, Gases, and Volatile Solids* Available figures from numerous sources will be found to 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 figures presented are for information and general guidance only and are not to be regarded as official standards

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 multicomponent preparations may contain several solvents with widely different values of "lower explosive limit," "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 Corrections and factors of safety for final ventilation values are to be applied as indicated in the footnotes

	A Molecular Weight	B Flash Point Deg C	C Ign Temp Deg C	D Explo Limits % by Volume Lower	D Upper	E Specif Gravity (Water = 1)	F Vapor Density (Air = 1)	G Boiling Point Deg C	H Kg Per dm³	I Cu Meters of Vapor Per dm³ Liquid	I Per Kg Liquid	J Approx . Cu Meters of Air rendered barely explosive per dm³ of Solvent
Acetone	58	- 20	465	2 15	13	0 8	2 0	56	0 823	0 333	0 404	15 16
Amyl Acetate n	130	16	360	1 1	7 5	0 9	4 5	149	0 875	0 166	0 190	14 92
Amyl Acetate iso	130	32				0 9	4 5	121	0 863	0 166	0 193	
Amyl Alcohol	88	33	300	1 2	10 0 @100	0 8	3.0	138	0 815	0 222	0.272	18 28
Benzine (Petroleum Ether)	Mix	< - 18	288	1 1	5 9	0 6	2 5	35-60	0 647	0 200	0 309	17 98
Benzol (Benzene)	78	- 11	498	1 3	7 1	0 9	2 8	80	0 875	0 267	0 306	20.27
Butyl Acetate n	116	22	425	1 7	7 6	0 9	4 0	127	0 875	0 187	0 214	10 81
Butyl Alcohol n	74	29	343	1 4	11 2	0 8	2.6	117	0 803	0 256	0 314	18 03
Butyl Alcohol	74	24	405	1 7 @100	9 8 @100	0 8	2 6	94	0.803	0 256	0 319	14 80
Butyl Cellosolve (Glycol Monobutyl Ether)	118	64	244			0 9	4 1	171	0 844	0 183	0 203	
Butyl Propionate	130	32	426			0 9	4 5	146	0 875	0 166	0 190	
Camphor (2 Camphonone)	152	66	466	0 6	3 5	1 0	5 2	204	0 982	0 160	0 163	26 51
Carbon Disulphide	76	- 30	90	1 3	50 0	1 3	2 6	46	1 258	0 416	0 331	31 58
Cellosolve (Ethyl Cellosolve) (Ethylene Glycol Monoethyl)	90	41	238	2 6	15 7	0 9	3 1	135	0 934	0 241	0 259	9 51
Cellosolve Acetate (Ethylene Glycol Monoethyl Ether Acetate)	132	52	380	1 7		0 97	4 7	156	0 970	0 172	0 177	9 95
Chlorobenzene mono	113	29	593	1 3	9 6	1 1	3 9	132	1 102	0 235	0 213	17 86
Cottonseed Oil (Refined)	Mix	252	343			0 9			0 922			
Cresol m or p	108	86	558	1 1 @150		1 0		201	1 030	0 223	0 223	20 04
Cyclohexane	84	- 20	245	1 3	8 0	0 8	2 9	82	0 779	0 229	0 295	17 39
Cyclohexanone	98	44	420	1 1 @100	9 4	0 9	3 4	156	0 946	0 220	0 233	19 78
Cymene-para	134	47	436	0 7 @100	5 6	0 9	4 6	176	0 862	0 163	0 189	23 12
Denatured Alcohol	Mix	16	399			0 8	1 6	79	0 803	0 416	0 518	
Dibutylphthalate o	278	157	402	0 5 @235		1 0		340	1 042			
Dichlorobenzene-ortho	147	66	648	2 2	9 2	1 3	5 1	180	1 306	0 212	0 162	9 42
Diethyl Ketone	86	13	450	1 6		0 8	3 0	103	0 815	0 222	0 272	13 65
Dimethyl Formamide	73	58	445	2 2 @100	15 2	0 9	2 5	153	0 934	0 299	0 321	13 29
Dioxane P (Diethylene Dioxide)	88	12	180	2 0	22	1 0	3 0	101	1 075	0 277	0 258	13 57
Ethyl Acetate	88	- 4	426	2 0	11 5	0 9	3 0	77	0 899	0 250	0 278	12 25
Ethyl Alcohol	46	13	363	3 3	19	0 8	1 6	78	0 790	0 416	0 526	12 19
Ethyl Ether	74	45	160	1 9	36 0	0 7	2 6	35	0 707	0 224	0 317	11 57
Ethyl Lactate	118	46	400	1 5 @100		1 0	4 1	154	1 018	0 203	0 199	13 33
Ethyl Methyl Ether (See Methyl Ethyl Ether)	60	- 37	190	2 0	10 1	0 7	2 1	11	0 730	0 277	0 380	13 57
Ethyl Propionate	102	12	440	1 9	11	0 9	3 5	99	0 886	0 214	0 241	11 05
Ethylene Dichloride	99	13	413	6 2	16	1 3	3 4	84	0 886	0 318	0 359	4 81
Gasoline	Mix	43	257	1 4	7 6	0 8	3 4	38-204	0 839	0 190	0 227	13 38
Hexane n	86	22	223	1 1	7 5	0 7	3 0	69	0 659	0 194	0 294	17 44
Kerosene	Mix	43 72	210	0 7	5	< 1		151 301	0 899			
Linseed Oil Raw	Mix	222	343			0 9		316	0 922			
Methyl Acetate	74	- 10	454	3 1	16	0 9	2 8	60	0 922	0 267	0 290	8 35
Methyl Alcohol	32	11	385	6 0	36	0 8	1 1	64	0 790	0 605	0 766	9 18
Methyl Carbitol (Diethylene Glycol Methyl Ether)	120	87				1 02	4 14	174	1 018	0 205	0 201	
Methyl Cellosolve	76	41	289			0 97	2 6	124	0 970	0 310	0 320	
Methyl Cellosolve Acetate (Ethylene Glycol Methyl Ether Acetate)	118	56		1 7	8 2	1 0	4 07	144	0 994	0 204	0 206	
Dimethyl Ether	46	Gas	350	3 4	27 0	0 7	1 6	21	0 659	0 364	0 552	
Methyl Ether Ketone (Butanone)	72	9	404	1 7 @93	11 4 @93	0 8	2 5	80	0 803	0 266	0 331	15 38
Methyl Lactate	104	49	385	2 2 @100		1 1	3 6	145	1 090	0 254	0 233	11 29
Mineral Spirits No 10	Mix	40	245	0 8 @100		0 8	3 9	149	0 803	0 171	0 212	21 20
Naptha (V M & P Regular)	Mix	2	232	0 9	6 0	0 8	3 7	100 160	0 743	0 180	0 242	19 82
Naphthalene	128	79	526	0 9	5 9	1 1	4 4	218	1 162	0 208	0 179	22 90
Nitrobenzene	123	88	482	1 8 @93		1 2	4 3	211	1 198	0 232	0 194	12 66
Nitroethane	75	28	414	3 4		1 1	2 6	114	1 042	0 352	0 337	10 00
Nitromethane (a)	61	35	418	7 3		1 1	2 1	101	1 126	0 436	0 387	39 20
Nitropropane 1	89	36	421	2 2		1 0	3 1	131	0 994	0 268	0 270	11 91
Nitropropane 2	89	24	428	2 6	11 0	1 0	3 1	120	0 982	0 268	0 273	10 04
Paraffin Oil	Mix	229							0 850 | 0 899			
Petroleum Ether	Mix	< - 18	288	1 1	5 9	0 6	2 5	35 60	0 647	0 200	0 309	17 98
Propyl Acetate iso	102	13	450	1 7 @38	8 0	0 9	3 5	102	0 899	0 214	0 238	12 37
Propyl Alcohol n	60	23	412	2 1	13 7	0 8	2 1	97	0 803	0 317	0 395	14 78
Iso Propyl Alcohol	60	12	399	2 0	12 0	0 8	2 1	80	0 791	0 317	0 401	15 53
Propyl Ether iso	102	21	215			0 75	3 53	90	0 731	0 177	0 242	
Pyridine	79	20	482	1 8	12 4	1 0	2 7	115	0 982	0 308	0 314	16 80
Rosin Oil	Mix	130	342			1 0		>360	0 982			
Soy Bean Oil	Mix	282	445			0 9			0 922			
Perchloroethylene	106	None				1 63	5 8	220	1 629	0 234	0 143	
Toluene	92	4	480	1 2	7 1	0 9	3 1	111	0 863	0 211	0 280	19 84
Turpentine	136	35	253	0 8		<1	4 8	149	0 863	0 173	0 200	21 45
Vinyl Acetate	86	8	402	2 6	13 4	0 9	3 0	72	0 922	0 250	0 271	9 37
O Xylene	106	32	463	1 0	6 0	0 9	3 7	144	0 875	0 202	0 231	20 00

Note Column J gives the cubic meters of air rendered barely explosive by 1 liter of solvent However, for most practical calculations, this value is close enough to the actual volume of the vapor air mixture.

*For final required safety ventilation values in each particular oven operation these figures are multiplied by the following factors as they apply

(1) Temperature Volume Conversion (see Table 5 1 11)

(2) Standard factor of safety of 4 for continuous process ovens (see 5 2 1)

(3) L E L Correction factor for batch ovens between 121° C and 260° C, multiply by 1 4 (see 5-3 3).

(4) The maximum number of liters of solvent evaporated per unit of time on the basis of maximum possible loadings

(a) Classified as a potentially explosive chemical

(b) Ventilation for solvent vapors is (see 5-2.2):

$$\frac{0.053 \text{ m}^3/\text{hr} \times 74660 \text{ m}^3/\text{min}}{60 \text{ min/hr}} = 66.0 \text{ m}^3/\text{min}$$

(c) The adjustment for thermal expansion is based on item "b" only:

$66.0 \times 1.62 = 106.9$ m³/min at 204°C

5-2.5 Calculated Rate of Ventilation Method for Powder Fusing or Curing Ovens. In continuous process ovens when the rate of ventilation for powder fusing or curing is calculated, the following method shall be used.

Dilution of the powder constituents released at theoretical minimum explosive condition shall require ventilation of:

English:

$W \times R \times 360$ = cu ft per hr referred to 70°F (21°C) (standard density)

Provide a factor of safety of 4 and convert to cu ft per minute, the equation above becomes:

$$\frac{W \times R \times 360 \times 4}{60} = \text{SCFM (standard density)}$$

Determine the weight of powder for use in the above calculation, as follows:

$$W = \frac{S \times T}{C} = \text{Weight of powder in lbs entering oven per hr}$$

Where:

W = Maximum intended hourly rate of powder delivery into the oven

R = Percent of powder constituents released during oven cure cycle

(A generally accepted value for characteristic powder and operating conditions is 9 percent based on experimental determination.)

360 = Cu ft of air rendered barely explosive per lb of powder constituent released (based on xylol — see Table 5-2)

S = Surface area of parts to be coated in sq ft per hr

T = Maximum powder coating thickness in mils

C = Manufacturer's recommended coverage in sq ft per lb for one mil thickness (135 typical)

SI Units:

$Wm \times Rm \times 22.46 = \text{m}^3/\text{hr}$ at 21°C

Provide a factor of safety of 4 and convert to m³/min, the equation above becomes:

$$\frac{Wm \times Rm \times 22.46 \times 4}{60} = \text{m}^3/\text{min}$$

Determine the weight of powder for use in the above calculation, as follows:

$$W = \frac{S \times T}{C} = \text{weight of powder in kg entering oven per hr}$$

Where:

Wm = Maximum intended hourly rate of powder delivery into the oven

Rm = Percent of powder constituents released during oven cure cycle

(A generally accepted value for characteristic powders and operating conditions is 9.0 percent based on experimental determination.)

22.46 = m³ of air rendered barely explosive per kg of powder constituent released (based on xylol — see Table 5-2)

S = Surface area of parts to be coated in m²/g per hr

T = Maximum powder coating thickness in mm

C = Manufacturer's recommended coverage in m²/g for one mm thickness (12.5 m² × 0.56 mm/kg = 7.0 typical)

NOTE 1: Example 1. For a Continuous Powder Coating Oven. This direct gas-fired oven has a 2,000,000-Btu/hr (586.2-kW) burner system being used to fuse an organic powder finish on steel products at 450°F (232°C). Seven thousand sq ft [7,000 sq ft (650 m²)] of surface is to be covered hourly to a depth of 3 mils (0.075 mm) with a powder intended to provide 135 sq ft (12.5 m²) of 1 mil coating per lb (0.056 mm/kg).

English:

(a) The exhaust indicated for combustion products is (see 5-2.4):

$$\frac{2{,}000{,}000}{95 \times 60} = 351 \text{ SCFM}$$

(b) The amount of powder to enter the oven is:

$$\frac{7000 \times 3}{135} = 156 \text{ lb per hr}$$

(c) Ventilation for constituents released from powders will be (see 5-2.5):

$$\frac{156 \times 0.09 \times 360 \times 4}{60} = 337 \text{ SCFM}$$

(d) The adjustment for thermal expansion is based on item (a) only:

$351 \times 1.72 = 604$ CFM (at 450°F)

SI Units:

(a) The exhaust indicated for combustion products is (see 5-2.4):

$$\frac{586.2 \text{ kW} \times 60 \text{ sec./min}}{3.54 \text{ MJ/m}^3} = 9.94 \text{ m}^3/\text{min (21°C)}$$

(b) The amount of powder to enter the oven is:

$$\frac{650 \times 0.762}{12.5 \times 0.56} = 70.7 \text{ kg/hr}$$

(c) Ventilation for constituents released from powders will be (see 5-2.5):

$$\frac{70.7 \times 0.09 \times 22.46 \times 4}{60} = 9.53 \text{ m}^3/\text{min}$$

(d) The adjustment for thermal expansion is based on item (a) only:

$9.94 \times 1.72 = 17.1$ m³/min at 232°C

NOTE 2: Example 2. For a Continuous Powder Coating Oven. This 450°F (232°C), electrically heated oven is required to cure 156 lbs (70.7 kg) of powder per hr as in Example 1. However, there are no combustion products to be considered. Accordingly, the ventilation rate for constituents released from powders will be:

English:

(a) $\frac{156 \times 0.09 \times 360 \times 4}{60} = 337$ SCFM

(b) The adjustment for thermal expansion will be:

$337 \times 1.72 = 580$ CFM (at 450°F)

SI Units:

(a) $\frac{70.7 \times 0.09 \times 22.46 \times 4}{60} = 9.53$ m³/min

(b) The adjustment for thermal expansion will be:

$9.53 \times 1.72 = 16.4$ m³/min at 232°C

If this is adequate to avoid undesirable fume spill at oven work openings, no additional ventilation will be required.

5-3 Batch Process Ovens.

5-3.1 Estimated Rate of Ventilation Method. In batch ovens for coated sheet metal-type work, the safety ventilation rate shall be designed and maintained to provide at least 380 cfm of ventilation air per minute referred to

70°F per gal of flammable volatiles (2.841 m^3/min per dm^3) except as permitted in 5-3.2.

NOTE 1: Industrial experience indicates that the nature of the work being baked is the main factor in determining the ventilation rate. Different types of work produce different evaporation rates, while baking and field tests show that sheet metal or metal parts coated by dipping produce the highest evaporation rates ordinarily encountered. Tests and years of experience have shown that 380 cu ft (2.841 m^3/min per dm^3) of ventilation air per minute referred to 70°F (21°C) per gal of flammable volatiles in the batch is reasonably safe for dipped metal.

NOTE 2: Tests of dipped sheet metal in batch process ovens show that in typical 1-hr bakes, practically all the solvent is evaporated in the first 20 minutes. Further, the peak evaporation rate occurring from 4 to 8 minutes after loading is about 3 times the 20-minute average. With 1 gal (3.77 dm^3) of solvent in the batch, the 20-minute average evaporation rate is $\frac{1}{20}$ gpm (0.00019 m^3/min) and the peak rate 3 times this or $\frac{3}{20}$ gpm (0.057 dm^3/min). Using 1 gal of solvent whose vapor requires approximately 2,500 cu ft (18.7 m^3 per dm^3) of air referred to 70°F (21°C) to keep the mixture barely below the lower explosive limit, the rate of ventilation required in order to be safe under the worst condition would be $\frac{3}{20}$ × 2,500 or approximately 380 cfm (2.84 m^3/min air per dm^3) referred to 70°F (21°C).

5-3.2 Calculated Rate of Ventilation Method. In batch ovens processing other than coated sheet metal-type work, the figure of 380 cfm per gal (2.84 m^3/min per dm^3) of flammable solvent referred to 70°F (21°C) shall be used unless the required ventilation rates can be calculated on the basis of reliable previous experience or the maximum evaporation rate determined in tests run under actual oven operating conditions. On the basis of the maximum evaporation rate determined by test, sufficient ventilation shall be furnished to prevent the vapor concentration in the oven from exceeding 25 percent of the lower explosive limit.

Exception No. 1: The safety ventilation rate may be decreased when a continuous vapor concentration indicator and controller is provided. For such installations the continuous vapor concentration indicator and controller shall be arranged to alarm, shut down the oven heating system, and operate additional exhausters at a predetermined vapor concentration not to exceed 50 percent of the lower explosive limit.

NOTE: The recirculation and exhaust fans and other devices should be operated in such a manner that the vapor concentration is maintained at or less than the safe predetermined concentration.

Exception No. 2: All types of work. If the maximum number of gal (dm^3) evaporated during any 1 hr of the total heating period is known, this figure may be used to calculate the required amount of ventilation as follows:

The required amount of ventilation air in cu ft per minute (m^3/min) referred to 70°F (21°C) shall be at least equal to the gal (3.77 dm^3) of solvent evaporated during the maximum hour multiplied by the volume of air referred to 70°F (21°C), computed as rendered flammable at the lower explosive limit (per formula in 5-2.3) then multiplied by an empirical factor of 10 and divided by 60.

Warning: Use caution in applying this method to work of low mass which will heat up quickly (such as paper, textiles) or work coated with materials containing highly volatile solvents. Either condition may give too high a peak evaporation rate for this method.

NOTE 1: Application of Examples for Box- or Batch-Ovens.

(a) Coated Metal.

A batch oven takes a load of dipped metal at 300°F (149°C). There are 3 gal (11.4 dm^3) of volatiles, mostly xylene, contained in the paint used in the load. The ventilation required in 5-3.1 and 5-3.3 is figured as follows:

English:

Required Ventilation cfm referred to 70°F = 380 × 3 (gal of xylene) × 1.4 (LEL correction factor, see 5-3.3) = 1596 cfm referred to 70°F. The Required Ventilation at the oven temperature of 300°F would be:

$$1{,}596 \times \frac{300 + 460}{70 + 460} = 2{,}290 \text{ cfm of air at } 300°F$$

SI Units

Required Ventilation m^3/min referred to 21°C = 2.84 m^3/min per dm^3 × 11.4 (dm^3 of xylene) × 1.4 (LEL correction factor) = 45.3 m^3/min referred to 21°C or Required Ventilation at the oven temperature of 149°C would be:

$$45.3 \times \frac{149 + 273}{21 + 273} = 65.0 \text{ m}^3 \text{ of air at } 149°C$$

(b) Types of Work other than Coated Metal where Evaporation Rate Tests have been made.

A batch oven operates at 255°F (124°C) with load of small transformer coils impregnated with material containing 4.8 gal (18.2 dm^3) of volatiles, mostly toluene. Tests under plant operating conditions indicate that over 5 hrs were required to evaporate all volatiles and that the peak evaporation rate occurring in the first 5 minutes after loading was 0.06 gal per min (0.227 dm^3/min). The ventilation, required in 5-3.2 would be figured as follows:

English:

Required Ventilation cfm referred to 70°F = Peak evaporation rate gpm (determined by test) × cu ft of air to form a barely explosive mixture per gal of toluene (*see 5-1.14, Note 3*) × Factor of 4 (to prevent vapor concentration exceeding 25 percent LEL) × LEL Correction Factor (*see 5-3.3*) or = 0.06 × 2,268 (from 5-1.14, Note 3) × 4 × 1.4 = 762 cfm referred to 70°F, or Required Ventilation at the oven temperature would be:

$$762 \times \frac{255 + 460}{70 + 460} = 1{,}029 \text{ cfm of air at } 255°F$$

SI Units:

Required Ventilation cfm referred to 21°C = Peak evaporation rate gpm (determined by test) × m^3 of air to form a barely explosive mixture per dm^3 of toluene × Factor of 4 (to prevent vapor concentration exceeding 25 percent LEL) × LEL Correction Factor (*see 5-3.3*)

or = 0.227 dm^3/min (from 5-1.14, Note 3) × 16.9 m^3 × 4 × 1.4 = 21.5 m^3/min referred to 21°C

or Required Ventilation at the oven temperature would be:

$$21.5 \times \frac{124 + 273}{21 + 273} = 29.0 \text{ m}^3/\text{min at } 124°C$$

(c) Alternate Estimation of Ventilation — All Types of Work.

A batch oven cures at 480°F (249°C) a load of asbestos rings impregnated with thinned asphalt, the volatiles being mostly Mineral Spirits No. 10. It is known from weight tests of samples removed progressively throughout the cure that the maximum amount of volatiles evaporated in any 1 hr is 2.3 gal (8.7 dm^3), and the total loss of weight throughout the cure is equivalent to 6.6 gal (25.0 dm^3). The estimated ventilation, required in 5-3.2., Exception No. 2, is figured as follows:

English:

Estimated Ventilation cfm referred to 70°F per gal of solvent evaporated during maximum hr × cu ft of air rendered barely explosive per gal of Mineral Spirits No. 10 (*see Table 5-2*) × empirical factor of 10 × LEL Correction Factor (*see 5-3.3, Note 2*) or = 2.3 × 2,802 × 10 × 1.4 = 1,504 cfm referred to 70°F or Estimated Ventilation at the oven temperature of 480°F would be:

$$1{,}504 \times \frac{480 + 460}{70 + 460} = 2{,}667 \text{ cfm at } 480°F$$

SI Units:

Estimated Ventilation m^3/minute referred to 21°C = dm^3 of solvent evaporated during maximum hr × m^3 of air rendered barely explosive per dm^3 of Mineral Spirits No. 10 (*see Table 5-2*) × empirical factor of 10 × LEL Correction Factor (*see 5-3.3, Note 2*)

$$\text{or} = \frac{8.7 \times 20.96 \times 10 \times 1.4}{60} = 42.5\ m^3/\text{min at } 20°C$$

or Estimated Ventilation at the oven temperature of 249°C would be:

$$42.5 \times \frac{249 + 273}{21 + 273} = 75.5\ m^3/\text{min at } 249°C$$

NOTE 2: Important Suggestions for Securing Data.

Rate of Evaporation

(a) The maximum number of gallons of solvent evaporated per unit of time in ovens must be figured on the basis of maximum possible loadings; i.e., if the baking cycle is 20 minutes and 2 gal (7.6 dm^3) of solvent enters the oven in this period, then the number of gal (dm^3) of solvent per hr for purposes of figuring fresh air for safe ventilation must be assumed to be 6 gal (22.7 dm^3) per hr, whether actual loadings are continued for the entire hour or not.

(b) It has been shown in the foregoing examples that the volume of air in cu ft per lb (m^3/kg) of air increases with rise in temperature and that correction must be made for this increase in order to provide the required volume at 70°F (21°C).

(c) Air also increases in volume at elevated altitudes due to lower barometric pressures, even though the temperatures are constant. While no correction is ordinarily made at altitudes in the lower levels [up to about 1000 ft (305 m) above sea level], such a correction is necessary at higher altitudes. The correction figure may be obtained from available tabulated data.

(d) Every effort should be made to obtain the information on the exact solvents, and their characteristics, to be used in a proposed coating operation. When a combination of solvents is used, that solvent which requires the greatest amount of air per gal (dm^3) for ventilation should be used as the basis for calculation.

5-3.3 Volumes of air specified or calculated as per 5-3.1 or 5-3.2, corrected for operating temperature, shall apply for oven temperatures up to 250°F (121°C). For batch ovens operating at temperatures over 250°F (121°C), the volume shall be increased by a multiplier of 1.4 and the temperature corrected as outlined in 5-1.11.

NOTE 1: The 1.4 multiplier is not required on continuous process ovens.
NOTE 2: Extensive tests have been conducted by Underwriters Laboratories Inc. to obtain data as to the effect of elevated temperatures on the LEL of many of the solvents commonly used in connection with ovens. These tests show that the LEL of all solvents tested decreases as the temperature increases, the conclusion being that more air [referred to 70°F (21°C)] is required for safety per gal (dm^3) of solvent as the oven temperature increases. The actual figures vary considerably with different solvents, but for the sake of simplicity the preceding requirement applies.

5-4 Vapor Concentration Indicators and Controllers.

5-4.1 Continuous flammable vapor concentration indicators and controllers are devices which measure and indicate, directly or indirectly in percentage of the lower explosive limit, the concentration of a flammable vapor-air mixture.

NOTE: They may be of the portable or fixed-location continuous-operating type. The continuous indicators are mostly used throughout the period of operation of a process wherein flammable vapor is evolved. In addition to indicating or recording concentrations to aid in safe and efficient process control, they can be arranged through suitable controls to automatically sound an alarm, open or close dampers, and start or stop motors, conveyors, and ventilating fans when the concentration of a flammable vapor-air mixture has reached a predetermined dangerous level.

These devices are ordinarily used with continuous process ovens and dryers, or coating machines evaporating relatively large amounts of flammable liquids where the character of the process is such that evaporation rates may fluctuate widely or where the normal working vapor concentration level is unusually high. Ovens connected to solvent recovery systems are frequently equipped with these instruments.

Only approved devices should be used and plans covering the application of the instrument to the process in question should be submitted to the authority having jurisdiction.

5-4.2 Flammable vapor concentration indicators shall be used to test flammable vapors having a flash point below 70°F (21°C) unless it is possible to maintain the sampling line and measuring assembly at the temperature of the vapors, so that condensation will not occur.

5-4.3 Maintenance of continuous flammable vapor indicators and controls shall be done periodically, through a maintenance service by the instrument manufacturer or equivalent. Properly trained personnel, competent to make necessary daily adjustments in accordance with the manufacturer's exact instructions or equivalent, shall be made responsible for reliable operation.

NOTE: A reliable auxiliary means for frequently checking indicator calibrations is imperative. It should be noted that some flammable vapor indicators are designed for use on specific materials, and that new calibrations must be made for each change in material tested. Maintaining sampling lines clean and airtight and prompt renewal of filaments when necessary are essential.

Chapter 6 Low-Oxygen Atmosphere Class A Ovens with Solvent Recovery

(*See Figure 6-1 for an example*)

6-1 Scope. Safety requirements for low-oxygen atmosphere ovens designed to evaporate flammable solvents are of prime importance. These ovens normally operate at high solvent levels and can operate safely in this manner by limiting the oxygen concentration within the oven enclosure. (*See Table 6-1.*) This chapter does not include the solvent recovery system associated with this type of oven.

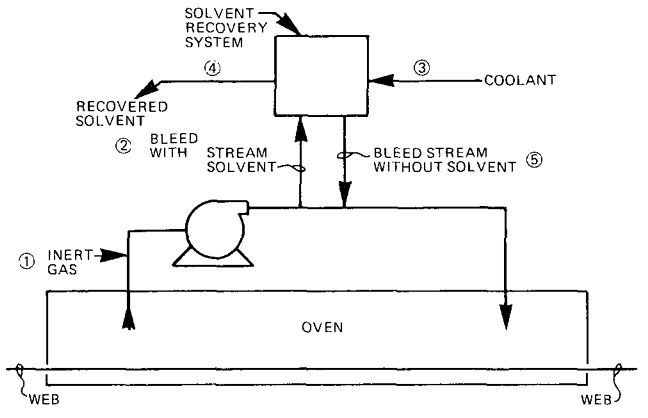


Figure 6-1 An Example of a Low-Oxygen Oven with a Solvent Recovery System.

NOTE: As in the conventional case, the treated product passes into and out of the oven enclosure through the oven openings. The oven atmosphere consists of an inert carrier gas which is continuously recirculated through the oven enclosure (line 1). Solvents evolve from the treated product and build up to an equilibrium vapor level which is much higher than the allowable levels in an air atmosphere. A bleed stream (line 2), which is typically 1 percent of the recirculation flow, is processed by a solvent recovery system. A liquid (line 3), which provides cooling through vaporization, acts to condense the solvents which are pumped to storage (line 4). After solvents are stripped from the inert gas stream, it is returned directly to the oven enclosure (line 5) to resume its role as a solvent vapor carrier.

Table 6-1 Maximum Permissible Oxygen Percentage to Prevent Ignition of Flammable Gases and Vapors Using Nitrogen and Carbon Dioxide for Inerting.

	N-Air		CO_2-Air	
	O_2 Percent Above Which Ignition Can Take Place	Maximum Recommended O_2 Percent	O_2 Percent Above Which Ignition Can Take Place	Maximum Recommended O_2 Percent
Acetone	13.5	11	15.5	12.5
Benzene (Benzol)	11	9	14	11
Butadiene	10	8	13	10.5
Butane	12	9.5	14.5	11.5
Butene-1	11.5	9	14	11
Carbon Disulfide	5	4	8	6.5
Carbon Monoxide	5.5	4.5	6	5
Cyclopropane	11.5	9	14	11
Dimethylbutane	12	9.5	14.5	11.5
Ethane	11	9	13.5	11.0
Ether	–	–	13	10.5
Ether (Diethyl)	10.5	8.5	13	10.5
Ethyl Alcohol	10.5	8.5	13	10.5
Ethylene	10	8	11.5	9
Gasoline	11.5	9	14	11
Gasoline 73 100				
Octane	12	9.5	15	12
100-130 Octane	12	9.5	15	12
115-145 Octane	12	9.5	14.5	11.5
Hexane	12	9.5	14.5	11.5
Hydrogen	5	4	6	5
Hydrogen Sulfide	7.5	6	11.5	9
Isobutane	12	9.5	15	12
Isopentane	12	9.5	14.5	11.5
JP-1 Fuel	10.5	8.5	14	11
JP-3 Fuel	12	9.5	14	11
JP-4 Fuel	11.5	9	14	11
Kerosene	11	9	14	11
Methane	12	9.5	14.5	11.5
Methyl Alcohol	10	8	13.5	11
Natural Gas				
(Pittsburgh)	12	9.5	14	11
Neopentane	12.5	10	15	12
n-Heptane	11.5	9	14	11
Pentane	11.5	9	14.5	11.5
Propane	11.5	9	14	11
Propylene	11.5	9	14	11

Notes to Table

1. Data in this Table were obtained from publications of the US Bureau of Mines.
2. Data were determined by laboratory experiments conducted at atmospheric temperature and pressure. Vapor-air inert-gas samples were placed in explosion tubes and exposed to a small electric spark or open flame.
3. In the absence of reliable data, the US Bureau of Mines or other recognized authority should be consulted.
4. The "Maximum Recommended O_2 Percent" applies only to maintaining an inert atmosphere for protection against unexpected or unlikely sources of ignition. Much higher factors of safety are required for conditions where sources of ignition are deliberately applied such as hot work.

NOTE: This Table was extracted from NFPA 69-1978, *Standard on Explosion Prevention Systems*, Table 1, Appendix B.

6-2 Purpose. High solvent concentrations in oven atmospheres require careful operational and design considerations not normally addressed in conventional solvent evaporation ovens.

6-3 Application. The oven design shall accommodate the following basic requirements for system operation:

(a) Safe operational procedures.

(b) Start oven and purge with inert gas to lower the oxygen content to a predetermined safe level.

(c) Heat the recirculating oven atmosphere to the required process temperature.

(d) Introduce coated substrate to the oven enclosure.

(e) Safe shutdown procedures.

(f) Emergency shutdown procedures.

6-4 Oven Construction and Location.

6-4.1 The following requirements are in addition to those described in Chapter 2, Location and Construction.

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

6-4.2 The oven atmosphere recirculation system shall be designed to provide circulation throughout the entire oven enclosure.

6-4.3 The oven enclosure and any ductwork from the enclosure shall be essentially gastight, preferably all welded. All access doors shall be gasketed and have positive latches to minimize leakage.

6-4.4 The oven and oven end openings shall be designed to restrict the entrance of air and the exit of solvent vapors.

6-5 Inert Gas Storage Systems.

6-5.1 General.

6-5.1.1 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 temperatures. NFPA standards that are applicable shall be followed.

6-5.1.2 Vessels, controls, and piping shall be provided which will maintain their integrity at the maximum/minimum design pressures and temperatures.

6-5.1.3 ASME tank relief devices shall be provided and sized, constructed and tested in accordance with ASME *Boiler and Pressure Vessel Code*, Section 8, Division 1.

6-5.1.4 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.

6-5.1.5 Bulk storage systems shall be rated and installed so as to provide assured and uninterrupted flow of inert gas to the user equipment as required.

6-5.1.6 Where inert gases are used as safety purge media, the volume stored shall always be sufficient to purge all connected low-oxygen atmosphere ovens with a minimum of 5 oven volumes. (*See 6-5.2.3.*)

Exception: The required purge volume is a function of the operating oven solvent concentration. The stored volume may be reduced if the oven solvent concentration is low. A greater volume may be required if the initial concentration is high or mixing is poor. The essential requirement is that the stored inert gas volume be sufficient to reduce the concentration in the oven to below the LEL.

6-5.2 Vaporizers Used for Liquified Purging Fluids.

6-5.2.1 Vaporizers utilized to convert cryogenic fluids to the gas state shall be ambient air heated units, so that their flow is unaffected by the loss of power.

Exception: Use of powered vaporizers shall be permissible, provided:

(a) The vaporizer has reserve heating capacity sufficient to continue vaporizing at least 5 furnace volumes at the required purge flow rate immediately following power interruption, or

(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 5 furnace volumes at the required purge flow rate.

(c) Purge gas is available from an alternate source that fulfills the requirements of 6-5.1.5, 6-5.1.6, 6-5.2.2 and 6-5.2.4.

6-5.2.2 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. Wintertime temperature extremes in the locale shall be taken into consideration by the agency responsible for rating them.

6-5.2.3 It shall be the user's responsibility to inform the industrial gas supplier of additions to the plant which will materially increase inert gas consumption rate, so vaporizer and storage capacity may be enlarged in advance of expansion.

6-5.2.4 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.

NOTE: A flow limiting device such as a critical flow metering orifice, sized to limit the flow at the maximum inlet pressure, may fulfill this requirement.

6-5.2.5 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 may begin corrective actions in advance of the flow stoppage.

6-6 Inert Gas Flow Rates.

6-6.1 Inert gas shall be required to "dilute the air infiltration" which may otherwise result in the creation of a flammable gas-air mixture within the oven. The flow rate may be varied during the course of the process cycle.

6-6.2 Reliable means shall be provided for metering and controlling the flow rate of the inert gas.

6-6.3 The flow control equipment may be installed at the oven, generator, or in a separate flow control unit. In all cases, it shall be accessible and in an illuminated area so that an operator can readily monitor its operation.

6-6.4 An inert gas flow control unit equipped with an automatic emergency inert purge mode shall also have a manually operated switch located prominently on the face of the unit, and a remote switch, which will activate the purge.

6-6.5 The pressure of the inert gas system shall be regulated so as to not overpressure components in the system such as glass tube flowmeters.

6-7 Inert Gas Piping System.

6-7.1 The piping system for inert gas shall be sized to permit the full flow of inert gas to all connected ovens at the maximum demand rates.

6-7.2 Lead-containing solders shall not be used to join pipes, except to join process water pipes.

6-8 Safety Equipment and Application.

6-8.1 Each zone of an oven shall be continuously analyzed and controlled for oxygen content. In addition a second analyzer system shall be provided to actuate an inert gas safety purge.

6-8.2 Emergency standby power generator shall be provided for emergency shutdown during a power failure.

Exception: This equipment is not required if alternate safety shutdown procedures for power failure are employed (see Appendix C).

6-8.3 Provisions shall be made to restrict entry into the oven when the oxygen atmosphere may be injurious to human health. See Chapter 9 and Appendix C, Inspection and Maintenance.

6-9 Inert Gas Introduction, and Starting the Production Line.

6-9.1 The following items shall be accomplished for inert gas introduction and starting the production line.

(a) Operator will make sure that all personnel are out of oven enclosure, all guards in place, doors closed.

(b) 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.

(c) The solvent recovery system interfaced with the oven must be operational and prepared to receive solvent-laden gas prior to starting production.

(d) Start the recirculation fans in the oven enclosure prior to introduction of inert gas. This ensures that effective oxygen purging will occur once inert gas enters the enclosure.

(e) Purge the oven enclosure with inert gas until the enclosure oxygen concentration is 3 percentage points below the minimum oxygen concentration that will support combustion of the solvents used. (*See Table 6-1.*)

6-9.2 Heat the recirculating oven gas to the required operating temperature.

6-9.3 Start the production line.

6-10 Production Running.

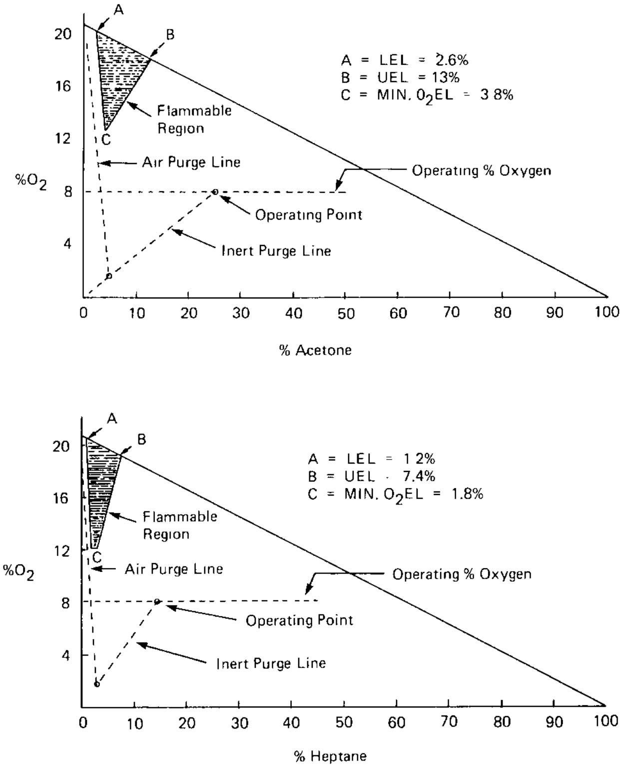
6-10.1 Oven enclosure oxygen levels shall be maintained at least 3 percentage points below the flammability level of the solvent during normal operation. (*See Table 6-1.*)

6-10.2 The oven temperature shall not be permitted to approach the solvent dew point temperature in the enclosure, so that solvent vapors will not condense in the oven enclosure.

6-11 Shutting Down the Production Line and Access to the Oven Interior.

6-11.1 Stop production line.

6-11.2 Continue flow to and from the solvent recovery system and purge with inert gas as is required until the solvent vapor concentration in the oven enclosure is no greater than the solvent concentration at the point of minimum oxygen for flammability. (*See Figure 6-11.2*).



NOTE: To purge from any operating point on the 8 percent oxygen operating line, purge with inert gas to reach the solvent concentration at "C" (flammability limit at minimum oxygen), then purge with air. This avoids passing through the flammability region by a comfortable margin.
Reference: Bureau of Mines Bulletin 627 pp. 32, 77.

Figure 6-11.2 Example of Purging Requirements.

6-11.3 Discontinue flow to and from the solvent recovery system and de-energize oven heaters.

6-11.4 Introduce air to the oven enclosure until the oxygen level reaches a minimum of 19 percent, at which point it can sustain human life. Once this level has been reached, enclosure access is permitted.

NOTE: Check for presence of toxic fumes prior to entry.

6-12 Emergency Procedures.

6-12.1 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 is not required if alternate safety procedures for power failures are employed.

6-12.2 The production line shall shut down automatically when the emergency purge cycle is initiated. The oxygen analyzer which initiates the emergency purge cycle shall be hard wired to bypass all other process control instrumentation.

6-12.3 The oven enclosure shall have an adequate vent line which opens automatically when the emergency purge cycle is initiated. This is necessary to avoid pressurizing of the oven enclosure.

6-13 Special Operator Training and Maintenance.

6-13.1 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 9, Inspection and Maintenance.

6-14 Personnel Entry.

6-14.1 See Appendix C for oven entry procedure and asphyxiation warnings.

Chapter 7 Fume Incinerators (Afterburner Systems) for Class A Ovens

7-1 General.

7-1.1 Fume incinerators or afterburners are systems intended to control atmospheric hydrocarbon emissions by direct thermal oxidation at or near 1400°F (760°C).

7-1.2 Design and operation of combustion systems and controls shall comply with all parts of this standard pertaining to direct-fired ovens.

7-1.3 Interlocks shall be provided to ensure that proper operation is maintained in conjunction with the fume generating process and that sufficient operating temperatures are sustained for acceptable thermal destruction of fumes.

NOTE: Afterburner or fume incinerator systems may or may not employ catalysts and/or various heat exchange devices to reduce fuel usage.

7-1.4 Where the relative location of equipment and/or the type of fumes generated are such that combustible liquids or solids may condense between the generating process and the afterburner, special precautions shall be taken to reduce the fire hazards.

7-1.5 Various forms of excess temperature protection shall be provided to prevent uncontrolled temperature rise from heat of combustion released by burning hydrocarbon emissions. Forms of protection may include one or more of the following:

1) Excess temperature limit switches
2) Interruption of the fume generating process
3) Dilution of hydrocarbon concentration with fresh air
4) Partial emission stream by-pass of heat exchanger.

NOTE: Structural supports, thermal expansion joints, and protective insulation for afterburner housings, stacks, related ductwork and/or heat recovery systems utilizing afterburner exhaust gases should be designed for high operating temperatures ranging from 800° to 1500°F (427° to 816°C).

7-1.6 When heat recovery systems are employed and portions of the afterburner 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. An adequate supply of fresh air shall be introduced into the system to provide the oxygen necessary for combustion of hydrocarbons as well as primary burner fuel.

7-2 Catalyst Afterburners and Catalytic Fume Incinerators (*see Figure 7-2*).

7-2.1 General. Catalyst afterburners or catalytic fume incinerators are also systems to control atmospheric hydrocarbon emissions by thermal oxidation. Using a catalyst element, oxidation occurs at or near the autoignition temperature of the contaminants, thus ranging from 450° to 950°F (232° to 510°C).

7-2.2 Design and operation of combustion systems and controls shall comply with all parts of this standard pertaining to direct-fired oven heaters and direct thermal afterburners.

NOTE 1: Catalyst elements utilize various types and forms of substrates such as (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, etc. 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 the substrates listed above.
NOTE 2: Catalyst elements may be employed to directly burn fuel gases where radiation to the oven product chamber represents significant portions of the energy released, similar to direct-fired internal burners. For atmospheric pollution control, catalyst materials are frequently 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.
NOTE 3: Applications for catalysts must recognize inherent limitations associated with these materials, such as the inability to oxidize silicone and chlorinated compounds as well as metallic vapors such as tin, lead and zinc. These materials can destroy catalyst activity, whereas various inorganic particulates (dust) may mask the catalyst elements and retard activity, thus requiring specific maintenance procedures. Consultation with qualified suppliers and equipment manufacturers is recommended prior to installation.

7-2.3 All special design features and control instrumentation applicable to direct thermal afterburners shall also be applicable to catalyst afterburners.

7-2.4 An excess temperature limiting device shall be located downstream from the discharge of the catalyst bed for thermal protection of both afterburner equipment as well as the catalyst elements. When actuated, the process burners and material handling feed shall be shut down.

7-2.5 Oxidation of combustibles within the catalyst bed will produce a temperature rise therein and consideration shall be given to measuring the temperature differential (ΔT).

NOTE: Separate temperature indicating instruments or controllers may be used to arithmetically determine the ΔT. Control of fuel or electrical energy for preheating the fume stream entering the catalyst can utilize temperature measuring instruments at the catalyst inlet, discharge, or an interrelationship between instruments in each location. Maximum permissible afterburner temperature should be monitored only at the catalyst bed exit. The ΔT through the catalyst bed indicates the energy release and should be limited to values nondestructive to the catalyst material.

7-2.6 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 and for this latter reason, to indicate maintenance requirements, differential pressure measurements shall be made.

7-2.7 Sufficient process exhaust ventilation shall be provided to maintain vapor concentrations that will not generate temperatures at which thermal degradation of the catalyst will occur. Concentrations at 25 percent LEL can produce a temperature rise near 600°F (316°C), that, when added to the required inlet temperature, will result in temperatures generally considered to be in a range where thermal degradation occurs.

7-2.8 Where directly integrated with the process oven generating the vapors, the housing enclosing the catalyst bed shall conform to the requirements of 2-2.3, Explosion Vents.

7-2.9 For direct heat recovery applications, sufficient fresh air shall be induced into the system to purge the process oven of flammable vapors and to provide adequate oxygen for combustion in both the oven and afterburner.

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

7-2.10 Where catalysts are utilized with direct heat recovery, a rigid 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.

NOTE 1: Alternately, catalytic heaters may be installed in the oven exhaust stream to release heat from evaporated oven by-products with available energy being returned via heat exchange and recirculation to the oven processing zone (*see Section 1-4, Heater, Direct-Fired External*). [*See Figures 7-2(a), (b), (c), and (d).*]

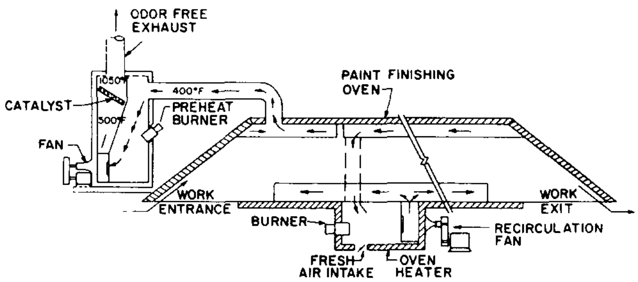


Figure 7-2(a) Catalyst System Independent of Oven Heater for Air Pollution Control.

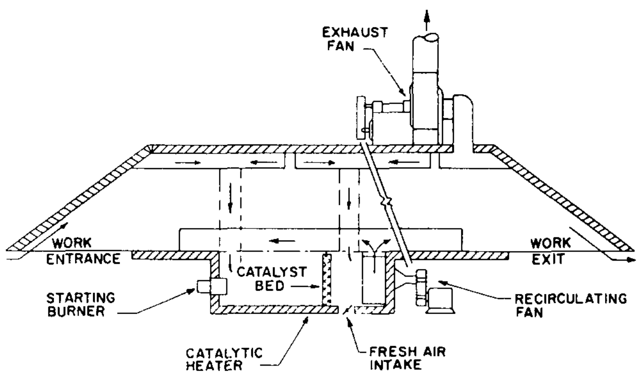


Figure 7-2(b) Direct-Type Catalytic Oven Heater for Partial Air Pollution Control.

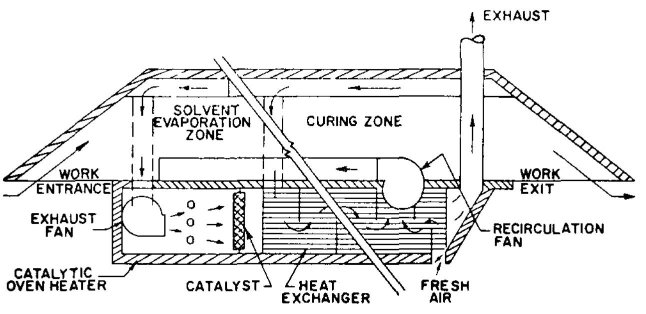


Figure 7-2(c) Indirect-Type Catalytic Oven Heater for Full Air Pollution Control.

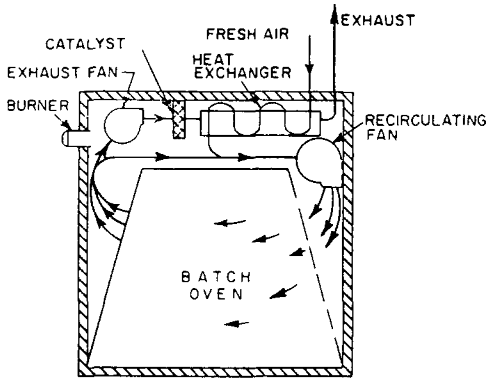


Figure 7-2(d) Batch Oven Catalytic Heater for Full Air Pollution Control.

NOTE 2: Three basic types of catalytic combustion elements are available. One is a mat of all metal construction available in various dimensions for use as a fuel-fired radiant heater or alternately for oxidation of combustible materials in fume-air mixtures. The second type consists of ceramic or porcelain construction arranged in various configurations for fuel gas or fume oxidation with catalyst media, including a variety of "rare earth" elements, platinum, or metallic salts. Both of these types are classified as "fixed bed" catalysts since they are normally held rigidly in place by clamps, cement, or other means. A third type consists of a bed of pellets or granules supported or retained between screens in essentially a fixed position, but with the individual members free to migrate within the bed.

Chapter 8 Safety Devices for Arc Melting Furnaces

8-1 General. Arc melting furnaces shall require controls normally not found on other types of electrically heated furnaces. 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 so as to be accessible at all times.

8-2 Safety Devices.

8-2.1 The furnace main disconnect shall be either a circuit breaker or fused switch equipped with the following appropriate accessories:

(a) Overcurrent relays with inverse time and instantaneous trips;

(b) Overcurrent ground fault relays with inverse time and instantaneous relays;

(c) Undervoltage trip relay;

(d) Surge protection;

(e) Local and remote "Close/Trip" switches to be interlocked by a common key such that only one location may be operated at any time.

8-2.2 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 run entirely separately from any other wiring. It shall provide a positive lockout and isolation of 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 be free when in the "OFF" position. This key shall be kept under the supervision of the authorized operator.

8-2.3 Interlocks shall be provided to ensure that the following conditions are satisfied before the main disconnect can be closed:

(a) Furnace transformer heat exchangers operating;

(b) Oil flowing to furnace heat exchangers (if fitted);

(c) Water flowing to furnace transformer heat exchangers (flow or pressure proving switch);

(d) Transformer tap changer on "tap" position (if off-load tap changer fitted);

(e) Furnace transformer oil temperature normal;

(f) Furnace transformer winding temperature normal;

(g) Gas detector registering "no gas" in transformer tank;

(h) Furnace electrode drive control gear "on";

(i) All supply voltages "on" and normal;

(j) Furnace roof and electrode swing normal;

(k) Furnace within specified limits of forward and backward tilt;

(l) Master lockout switch "on."

8-2.4 The main furnace structure shall be interlocked when 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:

(a) Roof is down;

(b) Limit switches are at forward and backward limits of travel.

Interlocks to be fitted to prevent swinging the roof and electrodes unless:

(a) Electrode arms are up clear of shell;

(b) Furnace tilt platform is normal and locked (if fitted);

(c) Roof is raised.

8-2.5 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."

Chapter 9 Inspection and Maintenance

(*See Appendix C*)

9-1 Responsibility of the Manufacturer and of the User. The equipment manufacturer shall inform the user regarding the need for adequate operational checks and maintenance and shall provide complete and clear maintenance instructions. The final responsibility for establishing a maintenance program which ensures that the equipment is in proper working order shall rest with the user.

NOTE 1: When the original equipment manufacturer no longer exists, plant personnel shall develop adequate operational checks and maintenance procedures.

NOTE 2: An essential safety aid is an established maintenance program which ensures that the equipment is in proper working order.

9-2 Equipment Entry (*see Appendix C*). The user's operational and maintenance program shall include procedures that are applicable to the proper entry into the equipment.

9-3 Checklist (*see Appendix C*). The user's operational and maintenance program shall include all listed procedures that are applicable to the equipment. An operational maintenance checklist shall be maintained and is essential to safe operation of the equipment.

NOTE: The user should review recommendations from the insurance underwriter and the equipment supplier and, where applicable, include these recommendations in the maintenance program.

9-4 Cleaning. Foreign material, parts, and residue shall be removed from recirculation blowers, exhaust blowers, burner and pilot ports, combustion blowers, ductwork and equipment interiors. Ductwork shall be checked for obstructions (i.e., improperly adjusted dampers).

9-5 Tension and Wear. Recirculation and exhaust system blowers that are V-belt driven shall be checked for proper belt tension and excessive belt wear.

9-6 Combustible/Flammable Loading. It shall be the user's responsibility to periodically check the furnace to determine that the combustible/flammable loading does not exceed the design capacity.

Chapter 10 Fire Protection

10-1 Basic Fire Protection.

10-1.1 Ovens containing or processing sufficient combustible materials to sustain a fire shall be equipped with automatic sprinklers, as required by the authority having jurisdiction. This shall include sprinklers in the exhaust ducts, when necessary. Plans showing the arrangement of the sprinkler installation shall be submitted to the authority having jurisdiction for review and approval before the installation is started.

NOTE: The extent of protection required will depend upon the construction and arrangements of the oven as well as the materials handled. Fixed protection should extend as far as necessary in the enclosure if combustible material is processed or if trucks or racks used are combustible, or subject to loading with excess finishing material, and also if an appreciable amount of flammable drippings of finishing materials accumulates within the oven.

10-1.2 Dip tanks and drainboards included in the oven enclosure shall be protected in accordance with NFPA 34, *Standard for Dipping and Coating Processes Using Flammable or Combustible Liquids.*

10-1.3 Automatic Sprinkler Systems.

10-1.3.1 Automatic sprinkler installations shall conform to NFPA 13, *Standard for the Installation of Sprinkler Systems.*

NOTE 1: When oven temperatures are over 465°F (241°C) or where flash fire conditions may exist, an open sprinkler system, supplied by an approved deluge valve equipped with a hand-pull for manual operation, and controlled by heat-actuated devices, is recommended within the oven; otherwise automatic sprinklers of proper rating may be used.
NOTE 2: When rapid temperature changes may be anticipated that will result in premature operation of rate-of-rise release equipment, fixed temperature controls should be used.

10-1.4 Water Spray Systems.

10-1.4.1 Water spray systems shall be fixed systems, automatic in operation and conforming to NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection.*

NOTE: Protection systems utilizing the application of water in finely divided form may be provided to protect oven enclosures.

10-1.4.2 Water spray systems shall be operated by deluge valves actuated by either fixed temperature or rate-of-rise equipment, as approved by the authority having jurisdiction. Manual operation of the deluge valve by hand-pulls shall be provided in all cases.

10-1.4.3 Where fire in an oven may involve other equipment as may be the case in "in line" coating or finishing operations, water spray systems actuated by high-speed detection devices shall be provided to protect the oven work openings. Manual controls for these systems shall also be provided. Plans showing the arrangement of such protection shall be submitted to the authority having jurisdiction before the installation is started.

10-2 Supplementary Fire Protection.

10-2.1 Plans showing the arrangement of supplementary protection shall be submitted to the authority having jurisdiction for review and approval before the installation is started.

NOTE: If desired, permanently installed supplementary protection of an approved type such as carbon dioxide, foam, dry chemical, etc., may be provided. Such protection is not a substitute for automatic sprinklers.

10-2.2 Carbon Dioxide Extinguishing Systems.

10-2.2.1 Carbon dioxide equipment shall be installed in accordance with NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems.*

NOTE: These systems will provide good protection for ovens and dryers containing materials or deposits that would produce surface burning fires, principally those involving flammable liquids.

10-2.3 Foam Extinguishing Systems.

10-2.3.1 Foam equipment shall be installed in accordance with NFPA 11, *Standard for Low Expansion Foam and Combined Agent Systems.*

NOTE: Foam protection can be a valuable supplement to the required automatic sprinkler protection in ovens which contain dip tanks and drip boards, and should be automatic.

10-2.4 Dry Chemical Systems.

10-2.4.1 Dry chemical extinguishing equipment shall be installed in accordance with NFPA 17, *Standard for Dry Chemical Extinguishing Systems.*

NOTE: These systems will provide good protection for ovens and dryers containing materials or deposits that would produce surface fires, principally those involving flammable liquids.

10-2.5 Steam Extinguishing Systems.

NOTE: The use of steam in ovens and dryers is not generally recommended. However, where steam flooding is the only alternative, see Appendix F for details.

10-3 Portable Protection Equipment.

10-3.1 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.*

10-3.2 Hose Connections. Hose connections shall be installed in accordance with NFPA 14, *Standard for the Installation of Standpipe and Hose Systems.*

10-3.3 Means of Access. Doors or other effective means of access shall be provided in ovens and ductwork so that portable extinguishers and hose streams may be used effectively in all parts of the equipment.

NOTE: Such access doors are also of great value for periodic cleaning and inspection.

Exception: Not required on heat-treating furnaces.

10-4 Maintenance of Fire Protection Equipment.

10-4.1 Inspection. All fire protection equipment shall be inspected and maintained at regular intervals, in accordance with applicable NFPA standards.

10-4.2 Records of inspection and tests shall be kept on forms prepared for this purpose and brought to the attention of management.

10-4.3 Testing shall be done by responsible personnel familiar with the operation and maintenance of this type of fire protection equipment.

10-4.4 Outlets. Sprinkler heads and outlets of other extinguishing equipment shall be kept clean and free of deposits under a regular inspection program.

Chapter 11 Referenced Publications

11-1 The following documents or portions thereof are referenced within this standard and shall be considered part of the requirements of this document. The edition indicated for each reference is current as of the date of the NFPA issuance of this document. These references