Report of Committee on Ovens and Furnaces

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NOTE: Industrial Risk Insurers have one voting alternate, but no principal representative.

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The report of the Committee on Ovens and Furnaces is in two parts.

Part I proposes for official adoption a complete revision of NFPA 86A–1973, Ovens and Furnaces. This Standard was prepared by the Sectional Committee on Class A Ovens and Furnaces.

Part I has been submitted to letter ballot of the Sectional Committee which consists of six voting members, of whom five have voted affirmatively, and one has voted negatively. Mr. McCreery has voted negatively.

Part I has also been submitted to letter ballot of the Ovens and Furnaces Committee which consists of 29 voting members, of whom 20 have voted affirmatively, eight negatively and one has asked to be recorded as not voting. Messrs. Bayer, Benedict, McCreery, H. E. Parker, W. F. Parker, Willan, Rademacher, and Talbot have voted negatively, and Mr. Gunow has asked to be recorded as not voting.

Part II proposes for official adoption the addition of a chapter covering Molten Salt Bath Furnaces to NFPA 86C–1974, Industrial Furnaces Using a Special Processing Atmosphere. This chapter was prepared by the Sectional Committee on Class C Furnaces.

Part II has been submitted to letter ballot of the Sectional Committee which consists of six voting members, of whom four have voted affirmatively and two have voted negatively. Messrs. Bayer and Wingate have voted negatively.

Part II has also been submitted to letter ballot of the Ovens and Furnaces Committee which consists of 29 voting members, of whom 23 have voted affirmatively, four negatively, and two have not returned ballots. Messrs. Bayer, McCreery, Wingate, and Rademacher have voted negatively, and Messrs. Hixson and Nabors have not returned ballots.
Foreword

Explosions and fires in fuel-fired steam and electric heat utilization equipment constitute a loss potential in life, property, and production. This standard is a compilation of guides, 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 ovens and 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).

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 the location, design, and construction of ovens and furnaces is set forth under classifications as follows:

Class A ovens or furnaces are heat utilization equipment operating at approximately atmospheric pressures and temperatures below 1400°F (760°C) where there is an explosion hazard from either, or a combination of, the fuel in use of, flammable volatiles from material in the oven or catalytic combustion system; i.e., flammable volatiles from paints, and other finishing processes such as dipped or sprayed material, impregnated material, coated fabrics, curing applications, drying, water dry off, etc.

Class B ovens or furnaces are those operating at or above atmospheric pressure and temperatures exceeding 1400°F (760°C).

Class C furnaces are those in which there is an explosion hazard due to a flammable special atmosphere being used for treatment of material in process. This type of furnace may use any type of heating system and includes the atmosphere generator.

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

Notes in this standard are for informational purposes only, and are not mandatory.
Air Flow Switch means a device actuated by the flow of air in a duct system.

NOTE 1: Vane-type air flow switches consist of a vane or paddle mounted on a movable arm. The vane is so located that a differential pressure or air flow against the vane will cause the vane arm assembly to move and actuate a switch contact.

NOTE 2: Diaphragm-type air flow switches consist generally of a diaphragm with one side open to room pressure and the other connected to the exhaust or ventilation duct. Movement of the diaphragm by a pressure differential will actuate switch contact.

Air-Gas Mixer means a device into which the fuel gas and the primary combustion air are introduced, mixed, and then delivered to the burner nozzle(s).

NOTE: The kinetic energy of the gas under pressure may be used to inject part or all of the air required for combustion as primary air. Conversely, all or part of the primary combustion air may be pressurized, as by a centrifugal blower, and used to cause injection of the fuel gas.

Atmospheric (Venturi) Inspirator means 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 (see Figure 1-4.1).

NOTE: "Low pressure inspirators" operate at about 1 psig gas pressure, or less, and cannot inject 100 percent combustion air. "High pressure inspirators" operate in the approximate range of 1 to 30 psig gas pressure, and may or may not inject 100 percent primary air.

Air Jet Mixer means a device which utilizes air under pressure, to entrain all or part of the fuel gas which may be supplied at, or below, or above atmospheric ("zero") pressure.

NOTE: Air jet mixers have internal or external means for varying the flow of primary combustion air. In addition and simultaneously, provision is made for corresponding flow control of the fuel gas.

Branch Circuit — Individual means a branch circuit that supplies only one utilization equipment.

Burner (or Nozzle) means a device through which combustion air and fuel are released into the combustion zone.

NOTE: 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.

Atmospheric Burner means a burner used in the low pressure gas or "Atmospheric" system which requires secondary air for complete combustion.

Blast Burner means a burner delivering a combustible mixture under pressure, normally above 0.3 in. w.c. to the combustion zone.

Blast Tip means a small metallic or ceramic burner nozzle so made that flames will not blow away from it, even with high mixture pressures.

Burner Turndown means the ratio of maximum to minimum burner fuel-input rates.

Combination Gas and Oil Burner means a burner which can burn either gas or oil or both together.

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

Dual Fuel Burner means a burner designed to burn either gas or oil, but not both together.

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

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Figure 1-4.1 Atmospheric Inspiring Burner Mixer.
Excess Air Burner means a nozzle mixing burner delivering a fixed volume of air and a variable volume of gas such that complete combustion of gas occurs at all rates of firing, to provide a relatively uniform flow of air and products regardless of firing rates.

Flame Retaining Nozzle means any burner nozzle with built-in features to hold the flame at high mixture pressures.

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

Line Burner means a burner whose flame is a continuous “line” from one end to the other. (Normally applied to a blast burner.)

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

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

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

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

NOTE: These openings are of various shapes — round, square, clover-leafed, etc. Combustion air may be supplied by natural, induced, or forced draft. Complete assemblies combining burner, refractory plate, wind box, blower, and controls are generally known as forced draft boiler burners.

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

Nozzle Mixing Burner means a burner in which the gas and air are kept separate until discharged from the burner into the combustion chamber or tunnel.

NOTE: Generally used with low pressure gas (up to \( \frac{1}{2} \) psig or 14 in. w.c.) and low pressure air (up to 3 psig).

Open Port Burner means 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.

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

Power Burner means a gas burner in which either gas or air, or both, are supplied at pressure exceeding, for gas, the line pressure, and for air, atmospheric pressure. (This added pressure is applied at the burner.)

NOTE: Examples are gas burners having zero governor inspirator mixers, those supplied by blower mixers or approved gas-mixing machines, and those supplied with air by a blower, compressor, or forced-draft fan.

Premixed Burner means a burner that utilizes a positive and dependable air-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.

NOTE: The zero governor inspirator mixer, high-pressure (gas pressure 1.0 psig or higher) atmospheric inspirator mixer, blower mixer, and the approved gas-mixing machine are illustrative of such a mixer.

Pressure Burner. Same as Blast Burner.

Radiant Burner means 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.

Radiant Tube Burner means a burner of either the atmospheric or nozzle mixing type specially designed to provide a long flame within a tube of given length to assure substantially uniform radiation from the tube surface.

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

Ring Burner means a form of atmospheric burner made with one or more concentric rings.

NOTE: Combustion air may be supplied by natural, induced, or forced draft.

Self-piloted Burner means a burner where the pilot fuel is issued from the same ports as main flame and/or merge with the main flame to form a common flame envelope with a common flame base.

NOTE: In effect, the pilot flame is simply enlarged to become the main flame.

Single Port Burner means a burner having only one discharge opening or port.

Tunnel Burner means 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.
Catalytic Combustion System (Direct or Indirect Heater) means an oven heater of any construction that employs catalysts to accelerate the oxidation or combustion of fuel-air or fume-air mixtures for eventual release of heat to an oven process.

Combustion Safeguard means 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.

Commercial Manufactured Gas means 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 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, called carbureted water gas, is sometimes mixed with coke-oven gas.
(d) Oil gas, made by “cracking” petroleum oils, is used occasionally in manufactured gases.

Continuous Vapor Concentration Indicators and Controllers means devices which measure and indicate, directly or indirectly in percentage of the lower explosion 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 automatically to sound an alarm, open or close dampers, start or stop motors, conveyors, and ventilating fans, when the concentration of a flammable vapor-air mixture has reached a predetermined dangerous level.

Dielectric Heater means a heater similar to an induction heater, but the frequencies used are generally higher (in the order of three megacycles or more) than those in induction heating.

NOTE: This type of heater is useful for heating materials which are commonly thought of as being nonconductive.

Examples: Heating plastic preforms before molding, curing glue in plywood, drying rayon cakes, and for many similar applications.

Direct Fired means any heating system where the products of combustion enter the oven chamber and come in contact with the work in process (see Figures 1-4.2, 1-4.3, 1-4.4, and 1-4.5).

Direct Fired External Heater means 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. There are two classes of these heaters as follows:

Direct Fired External Nonrecirculating Heater means any direct fired external heater so arranged that products of combustion without any return or recirculation from the oven chamber are discharged into the oven chamber (see Figure 1-4.3).

Direct Fired External Recirculating Heater means a direct fired external heater so arranged that oven atmosphere is recirculated to the oven heater and in contact with the burner flame (see Figure 1-4.4).

NOTE 1: A heating system so constructed that the oven atmosphere circulated through a blower with products of combustion admitted to the recirculating duct work, but without the oven atmosphere actually passing through the combustion chamber, is designated as “direct fired external, recirculating not through heater” (see Figure 1-4.5).

NOTE 2: A combustion chamber of a recirculating oven heater may be built within an oven chamber but substantially separated from the oven atmosphere by gas-tight construction. This type of heater is classed as direct fired external and may be either nonrecirculating or recirculating.

NOTE 3: Attention is called to some advantages of direct fired external heaters either recirculated or nonrecirculated for ovens which are to be direct fired because of the use of a single burner for each heater.

NOTE 4: The type of operation permits the installation of a single combustion safeguard for each heater, usually a less complicated and less expensive installation than can be secured in any design using multiple burners, particularly those designs making use of multiple line burners where it is not ordinarily possible to secure ignition over the entire length of each burner by reliable automatic controls. In general, any design which makes use of the smallest possible number of burners is preferred to multiple burner installations.

Direct Fired Internal Heater means any oven heating system in which the burners are within the oven chamber and in contact with the oven atmosphere.

Dustproof means so constructed or protected that dust will not interfere with its successful operation.
Electrical Ventilation Interlocking means a fan that is motor driven by direct shaft or at least two "V" belts which is interlocked with the safety control circuit by energizing the circuit from the load side of an overcurrent protected starter for the fan motor, through an extra contact of the starter or a suitable relay or transformer.

Explosive Range (Limits of Flammability) means the range of concentration of a flammable gas in air within which flame is propagated.

NOTE: The lowest flammable concentration is the lower explosive limit. Within the range, the maximum rate of flame propagation occurs when the combustible gas and air are mixed in proportions for complete combustion or often with the gas at a slightly higher concentration (see Table 1-4.1).

Flame Detection Device means a device which will detect the presence or absence of flame and will cause automatic shutoff of the fuel supply in event of flame outage.

NOTE: Flame detection devices may be based on:
(a) Flame rectification.
(b) Ultra-violet radiation produced by burning gases.
(c) Infrared radiation produced by burning gases.
### Table 1-4.1 Properties of Typical Commercial Gases

<table>
<thead>
<tr>
<th>Gas</th>
<th>Limits of Explosive Range Per cent in Air by Volume Compared to Air—1.0 Cu. Ft. of Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Btu Per Cu. Ft. Lower</td>
</tr>
<tr>
<td>Natural (High Btu type)</td>
<td>1115</td>
</tr>
<tr>
<td>Natural (High methane type)</td>
<td>960</td>
</tr>
<tr>
<td>Natural (High inert type)</td>
<td>1000</td>
</tr>
<tr>
<td>Coke Oven</td>
<td>575</td>
</tr>
<tr>
<td>Carbureted Water (Heavy oil with blow run)</td>
<td>530</td>
</tr>
<tr>
<td>Carbureted Water (Gas oil)</td>
<td>530</td>
</tr>
<tr>
<td>Oil Gas (Pacific Coast)</td>
<td>496</td>
</tr>
<tr>
<td>Coal Gas</td>
<td>536</td>
</tr>
<tr>
<td>Water Gas (Blue gas)</td>
<td>287</td>
</tr>
<tr>
<td>Producer Gas (Anthracite)</td>
<td>136</td>
</tr>
<tr>
<td>Producer Gas (Bituminous)</td>
<td>153</td>
</tr>
<tr>
<td>Propane</td>
<td>2500</td>
</tr>
<tr>
<td>Butane</td>
<td>3200</td>
</tr>
</tbody>
</table>

**Flame Propagation (Rate of)** means the speed at which a flame progresses through a combustible gas-air mixture under pressure, temperature, and mixture conditions existing in the combustion space, burner, or piping under consideration (see Figure 1-4.7).

**NOTE:** The rate of flame propagation has practical significance in the design and operation of premixing gas burners. If the velocity of the mixture at the burner diminishes, the tendency of the flame to flash back into the burner body is increased. Conversely, if the gas velocity leaving the burner is much greater than the rate of flame propagation, the flame may be blown away from the burner. For this reason, a burner which has been used on a manufactured gas, with a relatively high rate of flame propagation, may not be suitable for natural gas or butane which has a low rate. Fortunately, the relation between burner discharge velocity and flame propagation rate is not critical, so that neither variation in the rate of flow nor changes in mixture adjustment over a fairly-wide range will cause the flame to blow away from the burner or to flash back.

**Flame Rod** means 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, and the electrical current passing through the flame is rectified and this rectified current is detected and amplified by the combustion safeguard.

**Fuel Oil** means Nos. 2, 4, 5 or 6 in accordance with Specifications for Fuel Oils, ASTM D-396-73.

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

**Gas Pressure Regulator** means a diaphragm-operated valving device that attempts to maintain a constant outlet pressure despite varying flow.

**NOTE:** A “zero governor” is a special type of gas regulator that has an outlet pressure at, or near, atmospheric.

![Theoretical Ignition Velocity Curves for Various Gases](image-url)
Guarded means covered, shielded, fenced, enclosed or otherwise protected, by means of suitable covers or casings, barriers, rails or screens, mats or platforms, to remove the liability of dangerous contact or approach by persons or objects to a point of danger.

High Pressure Air System (air pressure 5 psig or higher) means a system using the momentum of a jet of high pressure air to entrain gas, or air and gas, to produce a combustible mixture.

High Pressure Gas System (gas pressure 1 psig* or higher) means a system using the momentum of a jet of high pressure gas to entrain from the atmosphere all, or nearly all, of the air required for combustion.

Ignition Temperature means the lowest temperature at which a gas-air mixture may ignite and continue to burn.

NOTE: This is also referred to as the auto-ignition temperature. When burners supplied with a gas-air mixture in the flammable range are heated above the auto-ignition temperature, flash backs may occur. In general, such temperatures range from 870°F to 1300°F. 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 is needed and for natural gas a temperature of about 1400°F is needed.

Ignition Systems.

Automatic-ignited Burner means a burner ignited by direct electric ignition, or by an electric-ignited or continuous pilot.

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

NOTE: Firing of the main burner(s) may be high-low, modulated to off, or on-off.

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

Manual-ignited Burner means a burner ignited by a portable gas- or oil-burner torch or by an oil-soaked swab torch, placed in proximity to the burner nozzle by the burner man.

Manual-lighted Industrial Heating Equipment means gas- or oil-fired equipment such as a furnace or oven 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 burner man (see Manual-ignited Burner and Semiautomatic-ignited Burner).

NOTE: Once ignited, firing of the main burner(s) may be high-low or modulated.

Proved Low-fire-start Interlock means a burner start in which a control sequence ensures that a high-low or modulated burner is in the low-fire (firing rate not exceeding 33 percent of the maximum) 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 means a burner ignited by direct electric ignition or by an electric-ignited pilot, electric ignition being manually activated.

Semiautomatic-lighted Industrial Heating Equipment means 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 burner man (see Manual-ignited Burner and Semiautomatic-ignited Burner).

NOTE: Once ignited, firing of the main burner(s) may be high-low, modulated to off, or on-off.

Indirect Fired External Heater means 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. These heaters may be of three types as follows:

Indirect Fired, External Heater, Recirculating, not Through Heater means 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 (see Figure 1-4.9).

Indirect Fired, External Heater, Recirculating means a system in which oven atmosphere is recirculated through radiators outside the oven chamber (see Figure 1-4.10).

Indirect Fired, External Heater, Internal Radiator means a system in which products of combustion from a heater located outside the oven chamber are circulated through radiator tubes located within the oven (see Figure 1-4.11).

NOTE: Heaters of these types are well adapted to low temperature drying operations and practically eliminate the possibility of explosion in the oven or dryer from fuel gases, but do not in any way reduce the possibility of explosion from vapors given off by the work being dried.

*Equipment will not function satisfactorily at pressures less than 1 psig.
Indirect Fired Heating System means a system so arranged that the products of combustion do not enter the work chamber, heating being accomplished by radiation or convection from tubes or muffs.

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

Explosion Resisting means an indirect fired internal heater so constructed as to withstand explosion pressure from ignition of a gas-air mixture in the radiators (see Figure 1-4.6).

Nonexplosion Resisting means an indirect fired internal heater with gas-tight radiators which, however, are not designed to withstand an internal explosion (see Figure 1-4.8).

Muffles means 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.

NOTE: Burners may be used for direct-firing of the space within the furnace but outside the muffle, or heating of the muffle may be by indirect means using radiant tubes or external furnace heaters (see Figure 1-4.12).

Radiant Tubes means tubular elements open at one or both ends, constructed gas-tight of suitable heat-resistant material, and capable of withstanding explosion pressure from ignition of fuel-air mixtures.

NOTE: 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 (see Figure 1-4.13).

Induction Heater means 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 70-1978.)

Infrared Lamp and Tubular Heaters means 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.
Limit Switch (for use on oven doors or ventilation system dampers) means a device consisting of a lever and suitable connecting mechanism to a switch contact.

NOTE: By swinging the door or damper to a predetermined position, usually wide open, where it moves the lever, the switch contact is made. Limit switches are used mostly for safe lighting-off sequence to ensure the doors or dampers will be wide open or positioned for ventilation before electric-ignition or fuel will be made available for lighting up burners, or power is available for energizing electric-heaters.

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

NOTE: The composition of liquefied petroleum gases varies, but in all the established grades the predominant compounds are propane and butane (iso-butane and normal butane). Under moderate pressure, the gases liquefy, but upon relief of the pressure are readily converted into the gaseous phase. Advantage of this characteristic is taken by the industry, and for convenience, the gases are shipped and stored under pressure as liquids. When in the gaseous state, these gases present a hazard comparable to any flammable natural or manufactured gas, except that being heavier than air, ventilation requires added attention. The range of combustibility is slightly narrower and lower than that of natural gas. When below 30° F, butane is a liquid and the hazard is similar to that of a flammable liquid.

Low Pressure Air System (air pressure up to 5 psig) means a system using the momentum of a jet of low pressure air to entrain 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.

Low Pressure Gas or “Atmospheric” System (gas pressure less than 0.5 psig) means a system using the momentum of a jet of low pressure gas to entrain from the atmosphere a portion of the air required for combustion.

Mechanical Mixer means a mixer using mechanical means to mix gas and air, neglecting entirely any kinetic energy in the gas and air, and compressing the resultant mixture to a pressure suitable for delivery to its point of use.

NOTE: 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 gas 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/gas ratio as rates of flow are changed.

Mechanical System means a system which proportions air and gas and mechanically compresses the mixture for combustion purposes.

NOTE: A central mixing unit may be used or individual appliances may have their own mixer.

Mixing Blower means a motor-driven blower to produce air-gas mixtures for combustion through one or more gas burners or nozzles on a single zone industrial heating appliance or on each control zone of a multi-zone installation.

Natural Gas means 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 the distribution system.

Oil Burner Types.

Air or Steam Atomizing means oil divided into a fine spray by an atomizing agent, such as steam or air.
Rotary means oil atomized by centrifugal force, such as applied by a whirling cone or plate.

Pressure Atomizing means oil under high pressure forced through small orifices.

Vapor means oil vaporized by heat.

Operator means the individual responsible for the light-up, operation, shutdown, and emergency handling of the specific installation, consisting of the oven and the associated equipment.

Oven means any heated enclosure operating at approximately atmospheric pressure used by industry for the processing of materials. (Except where specifically stated, the words ovens and furnaces are used interchangeably.)

Batch Process Ovens means ovens into which the work charge is introduced all at one time so that the evaporation of flammable volatiles within the oven is not at a constant rate.

Continuous Process Ovens means ovens into which the work charge is more or less continuously introduced, as by a conveyor, so that the evaporation of flammable volatiles within the oven approaches a constant rate.

Photoelectric, Infrared and Ultraviolet Detecting Device means a detector based on the radiant energy of specific wave lengths of the flame, and 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 shut-off valves.

Pilot means a flame that is issued to light the main burner.

Continuous Pilot means a pilot that burns without turndown throughout the entire period that the heating equipment is in service whether or not the main burner is firing.

Expanding Pilot means 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.

Intermittent Pilot means a pilot which burns during lighting-off and while the main burner is firing, and which is shut off with the main burner.

Interrupted Pilot means 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.

Proved Pilot means 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.

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

Pressure Switch.

Bellow-Operated Pressure Switch means a pressure switch used for higher pressures, and generally similar in operating principle to the diaphragm type, except that a flexible metal bellows replaces the diaphragm.

High Fuel Pressure Switch means a pressure activated device arranged to effect a safety shutdown of the burner or burners or prevent the burner or burners from starting in the event of abnormally high fuel pressures.

Low Fuel Pressure Switch means a pressure activated device arranged to effect a safety shutdown of the burner or burners or prevent the burner or burners from starting in the event of abnormally low fuel pressure.

Atomizing Medium Pressure Switch means a pressure activated device arranged to effect a safety shutdown or to prevent the oil burner or burners from starting in the event of inadequate atomizing medium pressure.

Combustion Air Pressure Switch means a pressure activated device arranged to effect a safety shutdown or to prevent the burner or burners from starting in the event the combustion air supplied to the burner or burners falls below that recommended by the burner manufacturer.

Diaphragm-operated Pressure Switch means a pressure switch used for low pressures, generally not exceeding several pounds per square inch.

NOTE: The diaphragm suitable for the fluid being handled bears against a lever controlling a switch contact. A spring, with tension adjustment for pressure setting, provides counterthrust to the diaphragm.

Preventilation Time Delay Relay means a switch which is closed automatically after a preset time interval usually measured by a timing device.

NOTE: Such a relay should be arranged to reset instantly to the starting position when the current supply is interrupted.
**Primary Air** means all air supplied through the burner, including atomizing and combustion air.

**Producer Gas** means any gas formed by blowing air through incandescent coal, coke, or charcoal.

NOTE: Such gases often contain solid particles and carry liquids which cause difficulty in burner operation. Special design is needed and automatic control is often difficult.

The use of producer gas for heating systems should be restricted to equipment under constant supervision of a qualified operator. Plans for producer gas equipment, distribution systems and oven heating systems should be submitted to the authority having jurisdiction for approval.

The use of other types of gases is recommended.

**Proper Ventilation** means a sufficient supply of fresh air and proper exhaust to outdoors with a sufficiently vigorous and properly distributed air circulation to ensure that the flammable vapor concentration in all parts of the oven or dryer enclosure will be safely below the lower explosive limit at all times.

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

**Proportioning Mixer** means a mixing device comprised of an inspirator which, when supplied with air, will draw into the air stream all the gas necessary for combustion and a gas governor, zero regulator, or ratio valve which reduces incoming gas pressure to approximately atmospheric (see Figure 1-4.14).

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

NOTE: Similar devices with additional controls to permit operation with control devices between burner and proportioning device are governed by 3-3.6.3.

**Resistance Heater** means any electric heater in which heat is produced by current flow through a resistive conductor.

NOTE: Resistance heaters may be of "open" type with bare heating conductors or "insulated sheath" type with heater conductors covered by a protecting sheath which may be filled with electrical insulating material.

**Rotational Switch** (for ventilation interlocking) is a device which is usually driven directly by the fan wheel or fan motor shaft, and when the speed of the fan shaft or drive motor reaches a certain predetermined rate, which will give a safe minimum air flow, a switch contact closes.

**Safe-start Check** means 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.

**Safety Shutoff Valve** means a normally closed (closed when de-energized) automatic valve installed in the fuel piping to shut off the fuel in the event of unsafe conditions or during shutdown periods.

**Electric, Manual-opening, Automatic Closing Safety Shutoff Valve** means a valve which can be opened only after the valve solenoid coil is energized and must be opened manually by means of a suitable "free-handle" and de-energizing the valve solenoid coil automatically closes the valve.

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

**Mechanical, Pressure-operated Safety Shutoff Valve** means a valve which must be opened manually but automatically shuts off the fuel supply if the fuel and/or air pressure necessary for proper atomization or combustion falls below predetermined values.
NOTE: These pressure settings are usually the minimum values for stable combustion and safe operation. These valves must be reopened manually but will reclose when the hand is removed unless the fuel and/or air pressure has been restored to above the set point.

Secondary Air means all of the air that is intentionally allowed to enter the furnace, but which does not pass through the burner nozzle.

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

Supervised Flame means a flame whose presence or absence is detected by a combustion safeguard.

Supervising Cock means 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 burners supervising cocks must be in the full closed position.

Electric Interlocking Type of Supervising Cock means 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 (see Figure 1-4.15). 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.

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

NOTE: The key way width is narrow enough in respect to the size and proportions of the main gas ports to ensure positive closure of the main gas way before opening the side outlets. This particular type of supervising cock is not suitable for fuel oil (see Figure 1-4.16).

Temperature Controller means a device which measures the temperature automatically and controls the heat input of the burner.

Excess Temperature Controller means a similar unit designed to cut off the source of heat if the temperature controller fails to operate properly on failure of the primary sensing element.
Trial-for-ignition Period \textit{(Flame-establishing Period)} means 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 System means a system using separate control of air and gas, both of which are under pressure.

NOTE: The valves controlling the air and gas flows may or may not be interlocked.

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

Ventilation Controls means devices such as flow switches, pressure switches, fan shaft rotation detectors, dampers, position limit switches, time delay relays 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.

Zero Governor, also called “atmospheric regulator,” means a diaphragm-type regulator that maintains the fuel-gas pressure at atmospheric or zero gage pressure.

1-5 Approvals, Plans, and Specifications.

1-5.1 Before new equipment is installed or existing equipment remodeled, complete plans and specifications shall be submitted for approval to the authority having jurisdiction. Plans shall be drawn to an indicated scale, and show all essential details as to location, construction, ventilation duct work, volume of fresh air at 70°F introduced for safety ventilation, heater equipment, fuel piping, heat input, and safety control wiring diagrams. The plans shall include a list of all equipment giving manufacturer and type number.

NOTE: For illustration purposes only and not to show sequencing of devices.

1-5.2 Wiring diagrams and sequence of operations for all safety controls including “ladder type” schematic drawings shall be provided (see Figure 1-5.2).

1-5.3 All wiring in and around ovens shall be in accordance with the National Electrical Code (NFPA 70-1978) and as described hereafter.

1-5.4 Any material deviation from this standard will require special permission from the authority having jurisdiction.

1-6 Operator Training.

1-6.1 New operators shall be thoroughly instructed and shall demonstrate an adequate understanding of the equipment and its operations.

NOTE: It is fully recognized that the most essential safety consideration is the selection of alert and competent operators. Their knowledge and training are vital to continued safe operation.

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

Figure 1-5.2 Typical “Ladder Type” Schematic Diagram.
1-6.3 Operators shall have access to operating instructions at all times.

1-6.4 Operating instructions shall be provided by the equipment manufacturer. These instructions shall include schematic piping and wiring diagrams. Light-up, shutdown, and emergency procedures shall be available in a suitable location near the facility.

1-6.5 Operator training shall include:
(a) Combustion of air-gas mixtures.
(b) Explosion hazards.
(c) Sources of ignition and ignition temperature.
(d) Functions of control and safety devices.

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

1-7.1 A suitable, clearly worded, and prominently displayed oven safety design data form shall be provided by the builder of each oven stating the safe operating conditions for which the oven was designed and built, and disregard of which may put the apparatus in jeopardy of failure to function safely, and cause it to become liable to destruction by fire or explosion.

1-7.2 Data shall be furnished on approved forms similar to Figure 1-7.2. They shall be prepared in quintuplicate, the original to be on a good quality lightweight card which is to be inserted in a metal frame fastened to the equipment and protected either with a glass or clear plastic cover. The other four sheets, which are to be exact duplicates and serve as file copies of the original, may be a lightweight paper of sufficiently good quality to preserve as a record.

Figure 1-7.2 Typical Safety Design Form

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.
Chapter 2 Location and Construction

2-1 Location.

2-1.1 General.

NOTE: Ovens, oven heaters, and related equipment should be located with consideration to the possibility of fire resulting from overheating or from the escape of fuel and the possibility of building damage and personal injury resulting from an explosion.

2-1.2 Grade Location.

2-1.2.1 Special consideration shall be given to the location of Class A equipment processing flammable materials or when using fuels with a specific gravity greater than air.

NOTE: Class A ovens and furnaces should be located at or above grade to make maximum use of natural ventilation and to minimize restrictions to adequate explosion relief. However, Class A equipment may be located in basements where additional consideration has been given to ventilation and the ability to safely provide the required explosion relief. (See NFPA 68-1974, Explosion Venting Guide.)

2-1.3 Structural Members of the Building.

2-1.3.1 Ovens and 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 members passing through ovens having an operating temperature less than 500°F shall be of noncombustible material and fireproofed.

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

2-1.4.1 Valuable Stock.

NOTE: Ovens and 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 oven or furnace.

2-1.4.2 Personnel. Furnaces and ovens 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 Finishing Operations.

2-1.4.3.1 Industrial ovens and furnaces (except those heated by steam) shall be safely located and protected from exposure to dip tanks, spray booths, storage and mixing rooms for flammable liquids, or storage areas used for readily flammable materials, or exposure from or to the diffusion of flammable vapor air mixtures.

NOTE 1: The hazard is particularly severe when vapors from dipping operations may flow by gravity to heating units at or near the floor level. (See NFPA 30-1976, NFPA 33-1973, and NFPA 34-1974.)

NOTE 2: The use of combined dipping and baking, and spraying and baking, units is permissible when adequately ventilated.

2-1.4.3.2 The room in which flammable vapors are produced shall be ventilated in such a manner that the atmosphere in the vicinity of painting operations will be kept well below the lower explosive limit. Flow of ventiling air from paint room or area shall be away from the ovens or heaters.

2-1.5 Floors and Clearances.

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

2-1.5.2 If oven 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 long-time heat exposure.

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

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

(b) If the combustible floor is not removed, provide hollow tile or steel tunnels on top of floor extending to oven outline and laid to form continuous air channels parallel with short axis of the oven wherever possible, open at both ends, for air movement so that the surface temperature of the floor will not exceed 160°F. If the temperature at the combustible floor surface exceeds 160°F, 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, the oven floor shall be further insulated with suitable material equivalent in insulating value to that used for oven walls and roof, and suitably
enclosed or covered for protection against mechanical damage or abrasion. The external temperature of the floor near the oven should not exceed 250°F.

NOTE: Insulating cement for 700°F oven heat may be diatomaceous earth or its equivalent mixed with cement, and the thicknesses used should be:

- 2 in. for 300°F oven heat
- 3 in. for 400°F oven heat
- 4 in. for 500°F oven heat
- 5 in. for 600°F oven heat
- 6 in. for 700°F oven heat

(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 the National Electrical Code (NFPA 70–1978).

(e) Combustible floors in immediate area of oil burners shall be covered with noncombustible material in such a manner that the floor cannot become oil soaked. (See the building code having jurisdiction.) Adequate protection from heat and from fuel spillage shall be provided for combustible floors under heaters.

2-1.5.4 Where oven ducts or stacks pass through combustible walls, floors or roofs, adequate insulation and clearances shall be provided to prevent surface temperatures of combustible materials exceeding 160°F.

2-1.5.5 Combustible work benches and other combustible equipment shall not be located within two feet of an oven, oven heater, or ductwork.

2-2 Construction.

2-2.1 General.

2-2.1.1 Ovens and related equipment shall be built in a substantial manner with due regard to the fire hazard inherent in equipment operating at elevated temperatures, the hazard to operators from high temperatures, open flames and mechanical equipment and the need of ensuring reliable, safe operation over the expected maximum life of the equipment.

2-2.2 Materials.

2-2.2.1 Ovens and furnaces 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.

2-2.3 Adequate facilities for access shall be provided to permit proper inspection and maintenance.

2-2.4 Burners and heating elements of all types shall be substantially constructed or guarded to resist mechanical damage.

2-2.5 Where refractory materials are used, they shall be adequately supported.

2-2.6 Corrosion Resistance. Where subject to corrosion, metal parts shall be protected.

2-2.7 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 panel shall be so located that all necessary observation, and adjustment may be readily made.

2-2.8 All parts of equipment operating at elevated temperatures shall be installed in accordance with 2-1.5.

2-2.8.1 Where impractical to guard, warning signs or permanent floor markings shall be provided or mounted 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.

2-2.9 Properly located observation ports shall be provided to permit the operator to observe the lighting of individual burners.

2-2.10 Devices such as relief valves, open sight drains, and water flow switches from water cooling systems shall be designed and installed for ready observation by operator.

2-2.11 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 ignited materials such as cotton unless for controlled exposure time, as in continuous processes where further automatic provisions and/or arrangement of guard baffles preclude the possibility of ignition.

2-2.12 The metal frames of ovens shall in all cases be electrically grounded throughout for the safe removal of static
electric charges. (See Recommended Practice on Static Electricity, NFPA 77–1972.)

2-2.3 Explosion Vents.

2-2.3.1 Ovens which may contain flammable liquids, vapors, or gases shall be equipped with unobstructed relief vents for freely relieving internal explosion pressures, and constructed in accordance with NFPA 68–1974.

2-2.3.2 Explosion relief panels shall be proportioned in the ratio of their area in square feet to the explosion-containing volume of the oven, due allowance being made for openings or hinged panels or access doors equipped with approved explosion-relieving hardware.

NOTE: The preferred ratio is 1:15, i.e., one square foot of relief panel area to every fifteen cubic feet of oven volume. For those fuel-fired ovens in which there is no flammable or explosive solvent hazard, equipped with all recommended fuel safety devices, an explosion venting ratio of 1:30, i.e., one square foot of vent ratio to every thirty cubic feet of oven volume should be permitted.

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. In installation, care shall be taken to make sure that the operation of relief vents to their full capacity is not obstructed by low ceilings, piping, building columns, or walls, instrument panels, or other fixed equipment.

NOTE 1: These vents should preferably be provided in the form of gravity retained roof panels designed to afford adequate insulation and possess the necessary structural strength.

NOTE 2: Guard rails may be needed to prevent movable equipment from being placed so as to obstruct such vents.

NOTE 3: Explosion relief vents, where possible, should be placed in the top of the oven or in side walls and located so that employees will not be exposed to injury.

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

2-2.3.3.3 See NFPA 68–1974, Explosion Venting Guide.

2-2.4 Duct Work.

2-2.4.1 Whenever oven 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.

NOTE: The oven location should permit the shortest and most direct path for ducts (exhaust or relief) to discharge to atmosphere.

2-2.4.2 Ducts shall be constructed entirely of sheet steel or other noncombustible material, and 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 air 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 gage 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 oven 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 oven 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 feet of the building floor shall be protected to prevent injury to personnel (temperature not to exceed 160°F).
2-2.4.12 Exhaust ducts shall not discharge near doors, windows, or other air intakes in a manner that will permit re-entry of vapors into the building.

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

2-2.4.13 All external exhaust duct work shall conform to NFPA 91–1973, Blower and Exhaust Systems.

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.

NOTE: When such openings are intended to permit persons to climb inside for inspection and cleaning, there should be provided such additional equipment as ladders, steps, and grab-rails to permit safe and easy access and egress.

2-2.5.2 Mountings for auxiliary equipment shall provide for rigid mounting of control instruments and safety devices protected against injury by heat, vibration, and mechanical equipment.

2-2.5.3 Where ladders or steps are needed to reach 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 When petroleum oils or other combustible fluids must be used for door operation, lifts for work loads, and conveyor systems, the hydraulic system shall be designed to minimize the possibility of fluid release which may result in a fire or explosion.

NOTE: The use of fire resistant fluids is recommended.

2-2.6.2 All components of the hydraulic system shall conform to the standards of the National Fluid Power Association and/or ANSI standards in the B93 series.


2-2.7 Fans.

2-2.7.1 Any fan not directly connected to the motor shall be multiple V-belt driven, suitably interlocked as described in Chapter 5.

2-2.7.2 All moving parts shall be guarded from mechanical accidents or possibility of causing personal injury.

Chapter 3 Heating Systems

3-1 Scope.

(a) For the purposes of this standard, the term "heating system" shall include the heating source (and associated piping/wiring) and the circulating fans (and associated ductwork) used to convey heat to the furnace and for the work therein. Exhaust systems and ductwork are not included.

(b) The source of heat may be either internal (within the unit) or external (outside the unit). The unit may be direct fuel fired (where the products of combustion contact the work) or indirect fuel fired (where the products of combustion do not contact the work).

(c) The transfer of heat into and throughout the unit may be by convection, conduction or radiation; or by combinations of these.

(d) Coal (or other solid fuel) firing systems and hot liquid circulating systems are not included in this standard.

3-2 Electrical Wiring. All electrical wiring, and applicable electrical components, shall be in accordance with NFPA 70-1978, National Electrical Code, and as described hereafter.

3-3 Gas Fired Units.

3-3.1 General.

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

(b) For fuel gas data and properties, see Table 1-4.1.

(c) Additional safety considerations which are beyond the scope of this standard shall be given to dirt-laden gases, sulfur-laden gases, high-hydrogen gases, low Btu waste gases, etc., 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 Gas Supply Piping.

3-3.3.1 Piping from the point of delivery to the burner system shall comply with NFPA 54-1974, *National Fuel Gas Code*.

3-3.3.2 Installation of LPG storage and handling systems shall comply with NFPA 58-1976, *Standard for Liquefied Petroleum Gases*.

3-3.3.3 Emergency Shut-off Valves. Valves shall be provided to permit turning off the fuel in an emergency and shall be located so that fires, explosions, etc., at ovens/furnaces will not prevent access to these valves.

3-3.3.4 Manual Shut-off Valves and cocks shall be provided for shut-off of the fuel to the pilot and/or burner for extended periods of shut down.

3-3.3.5 Valves and cocks shall be maintained in accordance with the manufacturer's instructions.

3-3.3.6 Consideration shall be given to the use of quarter turn valves.

3-3.3.7 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 valves port.

3-3.4 Gas Train Piping.

3-3.4.1 Gas train piping is defined as that piping which connects from the user's gas supply piping (see 3-3.3.1 and 3-3.3.2) to the air-gas mixing device (or to the burner, if nozzle-mixing).

3-3.4.2 Material. Material for pipe and fittings shall comply with the *National Fuel Gas Code* (NFPA 54-1974).

3-3.4.3 Sizing. Pipe, fittings and valving equipment shall be sized to prevent excessive pressure losses at the maximum rate of flow.

3-3.4.4 Main Gas Cock. A main gas shut-off cock shall be located upstream from all other gas line train components to shut off all flow of gas for servicing and for other shutdowns.

3-3.4.5 Pressure Regulator.

3-3.4.5.1 A pressure regulator shall be furnished whenever the plant supply pressure exceeds that required for proper burner operation or whenever the plant supply pressure is subject to excessive fluctuations.

NOTE: A zero governor is a special type of regulator, the primary difference being in the outlet pressure delivered.

3-3.4.5.2 Regulators shall be vented to outdoors or other safe location, with terminating end protected against water entry and bug screened. Vent pipe shall be of adequate size to not lengthen response time.

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

3-3.4.5.3 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.

NOTE 1: Vents from gas pressure switches, but from no other devices, may be vented into the regulator vent lines provided that switch failure cannot backload regulator.

NOTE 2: 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.

3-3.4.5.4 The gas vent line connected to the normally open vent valve, located between the two safety shut-off valves (refer to 5-5.2.5), shall be piped separately into atmosphere.

3-3.4.5.5 Positive shut-off devices shall not be used in the impulse line to the regulator.

3-3.5 Gas Burners.

3-3.5.1 All burners shall maintain a stable flame, with neither flash back nor blow-off, over the entire range of turndown that will be encountered during operation when supplied with combustion air and the designed fuel gases in the proper proportions and in the proper pressure ranges.

NOTE: Burner operation may be adversely affected with other than the designed fuel gases.

3-3.5.2 Multiple-port Burners. Line, ribbon, pipe, ring, radiant and diaphragm type burners shall perform in accordance with the provisions of 3-3.5.1. In addition, they shall maintain flame stability throughout their entire length (and/or surface) under all operating conditions that will be encountered.
3-3.5.3 Burner Ignition. Burners shall ignite completely, smoothly, and reliably from the ignition source provided. If a burner cannot be safely ignited at all firing rates encountered, positive provision shall be made to assure a firing rate suitable for safe light-off at the time of ignition (low fire start).

NOTE: Safety Warning: Multiple small burners manifolded together and mounted on a single heater are usually spaced too far apart to flash across from burner to burner from a single ignition source, and require that extreme caution be exercised — especially at light-off.

3-3.5.4 Secondary Air Adjustment. If provided, adjustment shall include a locking device to prevent unintentional change in setting.

3-3.6 Air-Gas Mixers.

NOTE: Certain burner/nozzle designs utilize a full (stoichiometric) or a partial (gas-rich) mixture of air and gas. An appropriate device is then used to mix the air and gas for subsequent delivery to the nozzle(s) or to the mixture piping connecting to the nozzle(s).

3-3.6.1 Air-Gas Mixture Piping.

3-3.6.1.1 In the design, fabrication and utilization of mixture piping, continuous consideration shall be given to the fact that the mixture is in the flammable (i.e., explosive) range and all due precautions shall be exercised.

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 (H₂).

3-3.6.3.4 Mixing blowers shall not be utilized where 10 in. w. c. 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 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 whether under positive, negative or atmospheric pressure, the quality and quantity of the combustion air shall be equal to, or better 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.
3-3.9 Gas Mixing Machines.

3-3.9.1 General. Any combination of proportioning control devices, blowers, or compressors which supply mixtures of 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: The essential difference between the mixing devices used with air-gas mixers (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.

A gas mixing machine usually comprises a pressure regulator or "zero governor" which reduces the gas supply pressure to atmospheric and a proportioning valve and compressor. 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 flash backs occurring in piping containing the flammable mixture, or to prevent damage if flash back 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 cut-off room, explosion vents shall be provided in the ratio of 1 sq. ft. of vent area to each 20 cu. ft. of room volume (see NFPA 68-1974, Guide for Explosion Venting).

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) and (c) 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 of the manually opening automatic closing type in the gas supply connection to each machine arranged to automatically shut off the gas supply in event of air and/or gas supply failure (see Chapter 3).

3-3.10 Fuel Ignition.

3-3.10.1 Whenever filling of the combustion chamber with flammable (i.e., explosive) air-fuel mixture can result in an unsafe
condition, the length of time allotted for flame ignition and the
rate of fuel input at ignition shall be correlated so that the LEL,
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 safely
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.

3-3.10.3.1 Special precautionary measures shall be taken
with large capacity pilot systems in the range of 400,000 Btu/each
hour and upward, as directed by the manufacturer and/or the
authority having jurisdiction.

NOTE: Pilot capacities are generally in the range of 5,000 to 50,000 Btu/each
hour.

3-3.10.4 Pilot Mixers. If pilot mixers are used, the pro-
visions 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 manu-
facturer.

3-3.10.6.2 The pilot shall be so mounted to prevent un-
tentional 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 ovens/
furnaces fired with No. 2, No. 4, No. 5, and No. 6 industrial fuel
oils as specified by ASTM D-396-73, Specifications for Fuel Oils.
It also includes the oil-burning portions of dual-fuel and combina-
tion burners.

(b) Additional safety 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 Special Safety Considerations. In the design of, and
the use of, oil-fired units, continuous considerations shall be given
to the following facts:

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

(b) Fuel oil must be vaporized prior to combustion. Heat
generated by the combustion is commonly utilized for this pur-
pose, 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 re-vaporize whenever the
temperature rises to a certain undeterminate point.

(d) Therefore, oil in a cold oven can lead to a hazardous con-
dition; for it cannot be purged out as gas can, but it may vaporize
(to become a gas) when, or because, oven operating temperature is
reached.

(e) Unlike water, for example, there is no published relation-
ship between temperature and vapor pressure for fuel oil. For pur-
poses of comparison, a gallon of fuel oil is equivalent to 140 cu. ft.
of natural gas (hence 1 oz. equals approximately 1 cu. ft.).

3-4.3 Burner System Selection. Burners, along with asso-
ciated 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 tank and installation shall comply with

3-4.4.2 Piping materials shall be wrought iron, steel, brass
or copper. Pipe shall be connected with standard fittings, tubing
with listed fittings. Connectors made of oil 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 Oil pump, if not an integral part of the burner, shall be:
(a) Of the positive displacement type which automatically shuts off the fuel when stopped.

(b) Listed or approved by the authority having jurisdiction.

(c) Equipped with an integral safety relief valve, or with an external remote safety relief valve connected upstream from all shut-off valves in the discharge line and arranged to return surplus oil to the suction side of the pump or to the storage tank.

3-4.4.4 Manual Shut-off Valves and Cocks.

3-4.4.4.1 Manual shut-off valves shall be installed where required to avoid oil spillage during servicing of supply piping and associated components.

3-4.4.4.2 Manual shut-off valves and cocks shall be provided for shut-off of the fuel to the pilot and/or burner for extended periods of shutdown.

3-4.4.4.3 Valves and cocks shall be maintained in accordance with the manufacturer’s instructions.

3-4.4.4.4 Consideration shall be given to the use of quarter turn valves.

3-4.4.4.5 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.

3-4.4.5 Emergency Shut-off Valves. Valves shall be provided to permit turning off the fuel in an emergency and shall be located so that fires, explosions, etc., at ovens/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.

3-4.4.6 Full consideration shall be given to the necessity to initially purge all air from the supply and return piping, and to the safety advantages of minimizing air entrainment in the oil. The inherent advantages of a long circulating loop, consisting of a supply leg, a back-pressure regulating valve, and a return line back to the storage tank, shall not be overlooked.

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

3-4.4.7 Suction, supply and return piping shall be adequately sized with respect to oil pump capacity.

3-4.4.7.1 Oil shall be supplied to the oven/furnace site properly conditioned (pressure, temperature, filtered, air-free, water-free) as directed by the equipment manufacturer.

3-4.4.8 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 (100 psig with a 100 ft lift will net only 63 psig). When going down, pressure will be added (100 psig with a 100 ft drop will net 137 psig). 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 3-4.4.8).

Table 3-4.4.8 Useful Conversion Data

<table>
<thead>
<tr>
<th>FROM</th>
<th>TO PSIG</th>
<th>*HG</th>
<th>FT H2O</th>
<th>FT .85 SG OIL</th>
</tr>
</thead>
<tbody>
<tr>
<td>One PSIG =</td>
<td>1</td>
<td>2.04</td>
<td>2.31</td>
<td>2.71</td>
</tr>
<tr>
<td>One * HG =</td>
<td>0.49</td>
<td>1</td>
<td>1.13</td>
<td>1.33</td>
</tr>
<tr>
<td>One FT H2O =</td>
<td>0.43</td>
<td>0.88</td>
<td>1</td>
<td>1.18</td>
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<tr>
<td>One FT .85 SG OIL =</td>
<td>0.37</td>
<td>0.75</td>
<td>0.85</td>
<td>1</td>
</tr>
</tbody>
</table>

NOTE: 14.7 psig & 29.92 in. HG are sea level figures.

3-4.5 Branch Circuit Oil Piping.

3-4.5.1 Branch circuit oil piping means that piping which connects from the supply leg of the circulating loop to one or more 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 shut-off valves (refer to 3-4.4.4, 3-4.4.5 and 3-4.4.8).

3-4.6 Oil Train Piping.

3-4.6.1 Oil train piping means that piping which connects from the branch circuit 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 Shut-off Valve. A manual shut-off 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 shut-downs.

3-4.6.4 Pressure Regulator.

3-4.6.4.1 A 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.

3-4.6.4.2 Regulator shall be suitable for the service.

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.

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

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 burner and valving protection.

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 as may be required for inspection, cleaning, repair, replacement, and other maintenance.

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 a firing rate suitable for safe light-off at the time of ignition (low-fire start).

NOTE: Safety warning multiple small burners manifolded together are usually spaced too far apart to flash across from burner to burner from a single ignition source, and require that extreme caution be exercised — especially at light-off.

3-4.7.4 Burner Shut-down. If clearance of oil passages upon normal termination of a firing cycle is required, it shall be done prior to safety shut-down with the initial ignition source (pilot flame) 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, and whether under positive, negative or atmospheric pressure, the quality and quantity of the air shall be equal to, or better 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 Special precautions shall be taken, when necessary, to prevent insufficiently diluted products of combustion from short-circuiting back into the combustion air inlet of the mixer.

3-4.9.4 Combustion Air. When provided mechanically, air pressure and/or volume shall be proven electrically and/or pneumatically, and interlocked with the safety shut-off 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. The quantity of the combustion air for combustion shall be adequate for proper burner performance.

3-4.10 Units Heated with 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 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 Definitions. The following definitions apply to the several types of electrical heating systems included in 3-5.

Resistance Heater means any electric heater in which heat is produced by current flow through a resistive conductor. Resistance heaters may be of "open" type with bare heating conductors or "insulated sheath" type with heater conductors covered by a protecting sheath which may be filled with electrical insulating material.

Infrared Lamp and Tubular Heaters means 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.

Induction Heater means a heating system by which a current-carrying conductor induces the transfer of electrical energy to the work by eddy currents. (See Article 665 of NFPA 70-1978.)

Dielectric Heater means a heater similar to an induction heater, except that the frequencies used are generally higher (in the order of three megacycles or more) than those in induction heating.

NOTE: This type of heater is useful for heating materials which are commonly thought of as being nonconductive, such as heating plastic preforms before molding, curing glue in plywood, drying rayon-cakes, and for many similar applications.

3-5.1.3 Safety Equipment. Safety equipment including air flow interlocks, time relays, and temperature switches shall be in accordance with Chapter 5.

3-5.1.4 Electrical Installation. All parts of the electrical installation shall be in accordance with the National Electrical Code, NFPA 70-1978.

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 (quartz, ceramic, and tubular glass types).

NOTE: Resistance heating systems are suitable for Class A ovens but as the surfaces of all types of resistance heaters operate above ignition temperatures of most finishing materials, the fire and flammable vapor hazards are comparable to that of direct fuel fired heating systems.

3-5.2.2 Enclosure.

3-5.2.2.1 When used with flammable vapors, the use of an enclosed oven shall be considered. (See 3-7, Unenclosed Heating Systems.)

3-5.2.2.2 All parts of heaters operating within an oven at elevated temperatures and all energized parts shall be protected to prevent contact by persons and also to prevent accidental contact by work in process and metal objects as by drippage from work going through the oven.

3-5.2.2.3 External electric heating systems shall have the electric elements encased in a sufficiently insulated chamber to prevent injury to personnel and property.

3-5.2.2.4 The heater housing shall be so constructed as to provide easy accessibility to heating elements and wiring.

3-5.2.2.5 Heating elements shall be fastened securely to a supporting frame and the frame shall be grounded.

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. Neither shall they be located directly over readily ignited materials, such as cotton, unless for controlled exposure time, as in continuous processes, where further automatic provisions
3-5.2.3.2 Parts of oven heaters which operate at temperatures in excess of 160°F or which are energized at potentials in excess of 20 volts 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 Resistance heaters of all types shall be constructed to resist, or protect against damage from falling work, or other mechanical hazards.

3-5.2.4.2 Where insulators are used, they shall be supported so they will resist falling out of place.

3-5.2.4.3 Corrosion Resistance. Where subject to corrosion, metal parts shall be protected.

3-5.2.4.4 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 5.

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 70–1978, 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 10kHz.

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 70–1978.)

3-5.3.3 Construction.

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

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

3-5.3.3.3 Protection shall be installed to prevent overheating of any part of the equipment, in accordance with NFPA 70-1978.

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 water flow 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 Rules for the Installation of Heating Furnaces, Boilers, and Fire Boxes of Power Boilers, and by any applicable local or state regulations. Burners and controls for boilers using gas, oil, or pulverized coal are covered by NFPA Standards for Oil Burning Equipment (No. 31), and Pulverized Fuel Systems (No. 60), 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 B31.1–1967. Suitable relief valves shall be provided where needed in this system.
3-6.2.2 Enclosures or duct work 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 5 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.

3-7 Unenclosed Heating Systems...

3-7.1 The use of "oven-less" or unenclosed heating systems employing lamps, resistance-type electric elements, or gas-fired infrared heaters in processes responsible for the vaporization of flammable, toxic or corrosive liquids and their thermal decomposition products shall be subject to the approval of the authority having jurisdiction.

3-7.2 To avoid the escape of flammable, toxic, or corrosive vapors into the general area, an oven enclosure shall be considered as ventilation and personnel safeguards can be more readily applied.

Exception: Heating systems having an energy input of under 400,000 Btu/hr, or 100 KW are excluded if adequate area ventilation is provided.

4-1 Scope. The proper ventilation of ovens is of prime importance. Proper ventilation within the scope of this chapter means a sufficient supply of fresh air and proper exhaust to outdoors with a sufficiently vigorous and properly distributed air circulation to ensure that the flammable vapor concentration in all parts of the oven or dryer enclosure shall be safely below the lower explosive limit at all times.

4-1.1 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 cubic feet of standard 70°F air required per pound of the various organic materials being released.

4-1.2 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 dripings, safe escape of flammable vapors or gases, safe control of combustion and the safety of chains, carrier belts, hoods, racks and carts.

4-1.3 The consideration of all these factors and their evaluation, the selection of the equipment and its design including arrangement to meet safely all requirements of safe operation, and adequate ventilation, shall be done by a qualified person familiar with oven design and basic rules of safety.
4-1.4 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.

Exception No. 1: Ovens with 64 cu. ft. volume or less need not be equipped with mechanical ventilation except when it is known that the products or materials processed in the oven give off flammable vapors or toxic fumes.

Exception No. 2: Ovens using steam or electrical energy for heat, or gas or oil fired indirect heating equipment, and which do not at any time liberate combustible or injurious (toxic) fumes, do not require fresh air ventilation for safety. Also, such ovens may be arranged to recirculate any portion of the air supplied.

4-1.5 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 outdoor atmosphere as directly as practical in accordance with applicable local, state, and federal regulations, such as 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: 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.

(f) On small installations subject to the approval of the authority having jurisdiction, it may be permissible to connect the draft flue to the oven exhaust system, provided that: The temperature of the products of combustion shall be reduced (if necessary) by the addition of fresh air to a point where it will prevent ignition of any combustible fumes in the oven exhaust system.

(g) 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 typical unacceptable safety ventilation systems, see Figure 4-1.5.

4-1.6 When ventilation is required for ovens and furnaces, the following shall be complied with:

(a) **Interlocks.** (See 5-2 and 5-5.)

1. Mechanical interlocks actuated by devices such as air flow or pressure switches, or centrifugal switches actuated by the fan shaft.

2. Electrical interlocks obtained through interconnection with a motor starter.

(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 4-2 and 4-3).

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 4-2 and 4-3).

2. Ovens heated by electric or infrared lamps or by combustion of any fuel shall have the exhaust fans electrically and me-
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.

(d) Purging Interval. Purging cycle or preventilation shall be in accordance with 5-2.

NOTE: The following ventilation requirements are 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.

4-1.7 Forced Ventilation.

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

4-1.8 Natural ventilation shall not be used on Class A ovens when flammable volatiles or toxic fumes are given off from the work in process.

NOTE: Subject to the approval of the authority having jurisdiction, natural ventilation may be used in ovens having only the fuel hazard provided the burner-mixer design is such that all air necessary for complete combustion of the fuel is reliably obtained by means independent from and not adversely affected by the natural draft.

4-1.9 Temperature Corrections. Temperature conversion factors shall be taken into consideration of the application of the following requirements since the volume of gas varies in direct proportion to its absolute temperature (°F equivalent to 460°F absolute) (see Table 4-1.9).

NOTE: For example, in order to draw 9,200 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 x 9,200 or 13,150 cfm of 300°F air.

Table 4-1.9 Temperature-Volume Conversion Table

<table>
<thead>
<tr>
<th>Temp.</th>
<th>Factor</th>
<th>Temp.</th>
<th>Factor</th>
<th>Temp.</th>
<th>Factor</th>
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<tbody>
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<td>950°</td>
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<td>275</td>
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<tr>
<td>300</td>
<td>1.43</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
4-1.10 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 all volatile solvents and thinners commonly used in finishing materials are heavier than air; consequently, bottom ventilation is of prime importance (see Table 4-2). Liquefied petroleum gases are heavier than air and other fuel gases are lighter than air (see Table I-4.1).

4-1.11 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, such as EPA.

4-1.12 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 discharged from an oven by the supply system to the exhaust duct must 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 amounts 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 examples:

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 velocimeter, anemometer, pitot tube, or other suitable means, and calculate the cubic feet of air per minute by multiplying the velocity in lineal feet per minute by the cross sectional area of the exhaust duct in square feet. The temperature of the exhaust air should also be read and the volume referred to 70°F.

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 are often 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.

NOTE 3: Theoretical Determination of Required Ventilation.

The temperature of the air discharged from the exhaust will be the average of the temperatures 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.
Temperature of air in oven within exhaust area: 300°F.
Temperature of air outside of oven exhaust system, short circuited into oven: 70°F.

Problem:

How many parts of air at 300°F. and at 70°F. when mixed will produce a resultant temperature of 242.5°F.?

\[ x = \text{parts @ 300°F.} \]
\[ y = \text{parts @ 70°F.} \]
\[ 242.5 \times (x + y) = 300x + 70y \]
\[ 242.5x + 242.5y = 300x + 70y \]
\[ 172.5y = 57.5x \]
\[ y = \frac{x}{3} \]

Therefore,

3 parts @ 300°F. + 1 part @ 70°F. = 4 parts total.

Therefore, 75% of the air being discharged by the exhaust fan in this example is from inside the oven, and 25% from the space outside the oven. Correcting this volume for 70°F., 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 preceding exhaust calculations.

NOTE 3: Theoretical Determination of Required Ventilation.

1. Determine the number of gallons of paint or coating which will be baked in oven per hour (for example, 10 gallons).
2. Determine the total percentage of solvent in coating (for example, 60% = 6 gallons).
3. Determine air volume rendered barely explosive by vapor from one gallon of solvent.

For example, use toluol as the solvent.

a. The lower explosive limit (L.E.L.) = 1.4% by volume in air. (See Table 4-2.)

As given, this value for the lower explosive limit is at the ordinary ambient temperature (approximately 70°F.). (See 4-3.3.)

b. The specific gravity of this liquid (Sp.Gr) = 0.9 (water = 1.0).

c. The vapor density (V.D.) = 0.9 (air = 1.0).

d. The weight per cubic foot of dry air at 70°F. and 29.9 inches Hg = 0.075lbs.

e. One gallon of water weighs 8.33 lbs. at 70°F.
To determine the cubic feet of vapor per gallon of solvent, use the following formula:

\[ 8.33 \times \text{Sp.Gr.} \times 0.075 \times \text{V.D.} = \text{cu. ft. per gallon @ 70°F} \]

For this example,

\[ 8.33 \times 0.9 \times 0.075 \times 3.1 = 32.2 \text{ cu. ft.} \]

The L.E.L. being 1.4%, the cubic feet of air rendered explosive by one gallon of toluol is

\[ \frac{(100 - 1.4) \times 32.2}{1.4} = 2,268 \text{ cu. ft. @ 70°F} \]

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,

\[ \frac{t°F. + 460}{70°F. + 460} = \expansion\ factor = \frac{300 + 460}{70 + 460} = 1.43 = \text{ratio of absolute temperatures at 70°F and 300°F} \]

At oven exhaust temperature, the volume of air rendered barely explosive by vapor from one gallon of toluol is

\[ 2,268 \times 1.43 = 3,243 \text{ cu. ft. per gallon of solvent at 300°F} \]

**NOTE 4: Another Method of Computation.**

For this example, use xylol (or xylene) as the solvent.

Sp.Gr. = 0.9

Then:

Weight of 1 gallon liquid = 8.33 x 0.9 = 7.5 lbs.

Molecular weight of \( \text{C}_6\text{H}_5\text{(CH}_3\text{)}_2 \) = 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 cubic feet at 70°F and 29.9 inches of mercury.

The volume of one gallon of xylol, when vaporized, is, therefore:

\[ \frac{7.5 \times 388}{106} = 27.5 \text{ cu. ft. @ standard conditions} \]

L.E.L. for xylol = 1.0% by volume.

\[ \frac{(100 - 1.0) \times 27.5}{1.0} = 2,723 \text{ cu. ft. per gallon @ 70°F} \]

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

\[ \frac{300 + 460}{70 + 460} = 1.43 = \text{ratio of absolute temperature at 70°F and 300°F} \]

Then:

\[ 2,723 \times 1.43 = 3,894 \text{ cu. ft. of air rendered barely explosive per gallon of solvent at 300°F} \]

### 4-2 Continuous Process Oven

#### 4-2.1 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 4-4). For such installations the continuous vapor concentration indicator and controller shall be arranged to alarm and shutdown 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.

#### 4-2.2 Estimated Rate of Ventilation Method

In continuous process ovens the rate of safety ventilation shall not be less than 10,000 cu. ft. of fresh air referred to 70°F per gallon of solvent evaporated in the oven except as permitted in 4-2.3.

**NOTE:** The basis for the above general rule is that one gallon of common solvent produces a quantity of flammable vapor which will diffuse in air to form roughly 2,500 cu. ft. of leanest explosive mixture. (See calculation 4-2.3.)

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. (referred to -70°F), 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. (Column J, Table 4-2), the factor of safety in this estimation method decreases in proportion.

The total volume of air, in cubic feet per minute, required for ventilation of the oven is obtained by multiplying the cubic feet of air required per gallon of solvent by the gallons of solvent per minute.
### Table 4-2

**TABLE OF PROPERTIES OF COMMONLY USED FLAMMABLE LIQUIDS IN UNITED STATES CUSTOMARY AND ENGLISH UNITS**

The data in this table have been obtained, with few exceptions as noted, from NFPA Pamphlet No. 325 (1980 Edition) "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 state of evaporation by actual use on particular mains formulations in use needs to be emphasized. Some of these multi component preparations may contain several solvents with widely differing values of "lower explosive limit," "specific gravity," and "vapor density." Until such determinations are made, the operation should be on the side of safety. The largest single result, wide range of the most required volume of air per gallon, should be used as the "data for safe ventilation. Corrections and factors of safety for final ventilation values are to be applied as indicated in the footnotes.

#### Footnotes:
- For final required safety ventilation values in each particular case, operation these figures are multiplied by the following factors as they apply (see 410 and 420 of text and calculation examples Appendix C, pages 906-906):
  - (1) Temperature — Volume Conversion (see table — 400-10).
  - (2) Standard factor of safety of 4 for continuous process ovens.
  - (3) L.E.L. Correction factor for batch ovens between 260°F and 500°F, multiply by 1.4 (see 430-2).
  - (4) The maximum number of gallons of solvent evaporated per unit of time on the basis of maximum possible loadings.
    - (a) "Handbook of Chemistry" Ninth Edition — Lange.
    - (b) Clarified as a potentially explosive chemical (see NBFU Research Report No. 12 Nonflammability and their Hazards).

#### Table 4-2 Content:

<table>
<thead>
<tr>
<th>A</th>
<th>Molecular Weight (g)</th>
<th>B</th>
<th>Flash Point (°F)</th>
<th>C</th>
<th>ignite.</th>
<th>D</th>
<th>Explos. Limits</th>
<th>E</th>
<th>Specific Gravity (Air = 1)</th>
<th>F</th>
<th>Boiling Point (°F)</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
<th>% Approximate Ca. Pt. of Air rendered barely explosive per gal. of solvent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethyl Methyl Ether</td>
<td>48</td>
<td>130</td>
<td>574</td>
<td>1.3</td>
<td>54</td>
<td>3.1</td>
<td>7.6</td>
<td>0.7</td>
<td>1.2</td>
<td>3.8</td>
<td>2.5</td>
<td>174</td>
<td>3.0</td>
<td>3.0</td>
<td>211</td>
<td>8.33</td>
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<tr>
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<td>3.0</td>
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<td>211</td>
<td>8.33</td>
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</tbody>
</table>

**Note:** Column J gives the ratio of 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.
### Table 4-2: TABLE OF PROPERTIES OF COMMONLY USED FLAMMABLE LIQUIDS

The data in this table have been obtained with few exceptions as noted, from NFPA Pamphlet No. 325 (1960 Edition), "Fire Hazards of Flammable Liquids, Gases, and Vapors." Available figures from numerous sources will be found to vary over a wide range in many instances, depending on the purity or grade of sample and on the test conditions prevailing during the test. Therefore, values here given should be regarded as approximate standards.

The importance of obtaining precise data on the rate of evaporation by actual tests on particular formulation in use is in keeping with the belief that values of such data for any given component may vary with the solvent mixture and even with the sample tested. However, the values shown are based on tests made on material that is reasonably well defined. In general, values shown for any given solvent mixture are based on tests made on material that is reasonably well defined.

Evaporators should be kept tightly closed when not in use to prevent evaporation of these highly volatile liquids, and when such liquids are used, the operation should be on the side of safety. Therefore, the individual solvent, whose data result in the largest required volume of air per liter, should be used as the basis for safe ventilation. Corrections and factors of safety for final ventilation volumes are to be applied as indicated in the footnotes.

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</table>

Note: Column J gives the cubic meters of air required hourly to exhaust 1 liter of solvent. However, for most practical calculations, this value is close enough to the actual volume of the vapor-air mixture.

(a) For final required safety ventilation values in each particular solvent class these figures are multiplied by the following factors as they apply (see 410 and 420 of text and calculations examples Appendix C). (1) Temperature Volume Conversion (see table — 400-100). (2) L.E.L. Correction factor for batch oven between 121 C. and 260 C., multiply by 1.4 (see 142-3). (3) Classified as a potentially explosive chemical.
4-2.3 Calculated Rate of Ventilation Method. In continuous process ovens when the rate of ventilation is calculated the following method shall be used.

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.

Required ventilation = \( \frac{444 \times \text{Sp. Gr.} \times (100 - \text{L.E.L.})}{\text{V.D.} \times \text{L.E.L.}} \) cu. ft. of air referred to 70°F per gallon solvent evaporated, where:

- Sp. Gr. = Specific gravity of solvent (water = 1).
- V.D. = Vapor density of solvent vapor (air = 1).
- L.E.L. = Lower explosive limit expressed in per cent by volume. (For example, L.E.L. of gasoline written 1.3, not .013.)

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

One gallon of solvent produces \( 8.33 \times \text{Sp. Gr.} \times (100 - \text{L.E.L.}) \) cu. ft. of flammable vapor per gallon of solvent evaporated.

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

\( 4 \times \frac{8.33 \times \text{Sp. Gr.} \times (100 - \text{L.E.L.})}{0.075 \times \text{V.D.} \times \text{L.E.L.}} \) cu. ft. of the barely explosive mixture.

The total volume of air required to render this amount of vapor barely explosive is \( \left( \frac{100 - \text{L.E.L.}}{\text{L.E.L.}} \right) \times \) this figure, or 1 gallon of solvent will form

\( \frac{8.33 \times \text{Sp. Gr.} \times (100 - \text{L.E.L.})}{0.075 \times \text{V.D.} \times \text{L.E.L.}} \) cu. ft. for 70°F condition.

NOTE 1: Example For a Continuous Liquid Solvent Paint Oven.

This direct gas-fired oven has a 224 million Btu/hour burner system and the heating process is intended to evaporate 14 gallons per hour of toluol from a dipped liquid finish on sheet steel products being baked at 400°F.

When this calculation for 70°F equivalent volume is shown to be more than one-third of the volume determined for the removal of chemical by-products (from 4-2.1, 2 or 3), the minimum exhaust volume for the oven will be the sum of the two computations adjusted for thermal expansion as per 4-1.9. When the combustion products are shown to be less than one-third of the volume determined for removal of chemical by-products, the minimum exhaust volume shall be based on the volume determined for removal of chemical by-products only, with adjustment for thermal expansion as per 4-1.9.

4-2.4 In continuous process ovens when a direct-fired combustion system (within the oven chamber or remote) is used to heat a paint or powder curing oven, the volume of combustion products from burners shall be determined for stoichiometric operation by the formula:

\[ \text{Btu/hr (Total Burner Rating)} = \frac{\text{Cubic feet of air per minute (SCFM) referred to 70°F}}{95 \times 60} \] (Standard density)

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

When this calculation for 70°F equivalent volume is greater than one-third (\( \frac{1}{3} \)) of the volume determined for removal of chemical by-products (from 4-2.1, 2 or 3), the minimum exhaust volume for the oven will be the sum of the two computations, adjusted for thermal expansion as per 4-1.9. When the combustion products are shown to be less than one-third of the volume determined for removal of chemical by-products, the minimum exhaust volume shall be based on the volume determined for removal of chemical by-products only, with adjustment for thermal expansion as per 4-1.9.

NOTE 2: Example 1. For a Continuous Powder Coating Oven.

This direct gas fired oven has a 2 million Btu/hour burner system being used to fuse an organic powder finish on steel products at 450°F. Seven thousand square feet (7,000 sq. ft.) of surface is to be covered hourly to a depth of 3 mils with a powder intended to provide 135 square feet of 1 mil coating per pound.

(a) The exhaust indicated for combustion products is (see 4-2.4):

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

(b) Ventilation for solvent vapors is (see 4-2.2):

\[ \frac{14 \times 10,000}{60} = 2,331 \text{ SCFM} \]

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

\[ \frac{2,331 \times 1.62}{95 \times 60} = 3,776 \text{ CFM (at 450°F)} \]

NOTE 2: Example 1. For a Continuous Liquid Solvent Paint Oven.

This direct gas-fired oven has a 224 million Btu/hour burner system and the heating process is intended to evaporate 14 gallons per hour of toluol from a dipped liquid finish on sheet steel products being baked at 400°F.

When this calculation for 70°F equivalent volume is shown to be more than one-third of the volume determined for the removal of chemical by-products (from 4-2.1, 2 or 3), the minimum exhaust volume for the oven will be the sum of the two computations adjusted for thermal expansion as per 4-1.9. When the combustion products are shown to be less than one-third of the volume determined for removal of chemical by-products, the minimum exhaust volume shall be based on the volume determined for removal of chemical by-products only, with adjustment for thermal expansion as per 4-1.9.

(a) The exhaust indicated for combustion products is (see 4-2.4):

\[ \frac{2,000,000}{95 \times 60} = 351 \text{ SCFM (at 45°F)} \]

(b) The amount of powder to enter the oven is:

\[ \frac{7000 \times 3}{135} = 156 \text{ lb. per hour} \]

(c) Ventilation for constituents released from powders will be (see 4-2.5):

\[ \frac{156 \times 0.09 \times 360 \times 4}{60} = 337 \text{ SCFM} \]

(d) The adjustment for thermal expansion is based on the sum of a and b:

\[ \frac{351 + 337 \times 1.72}{60} = 1183 \text{ CFM (at 450°F)} \]
NOTE 3: Example 2. For a Continuous Powder Coating Oven.
(a) This 450°F, electrically-heated oven is required to cure 156 pounds of powder per hour as in Example 1. However, there are no combustion products to be considered. Accordingly, the ventilation rate for constituents released from powders will be:

\[
\frac{156 \times 0.09 \times 360 \times 4}{60} = 336 \text{ SCFM (standard density)}
\]

(b) The adjustment for thermal expansion will be:

\[
337 \times 1.72 = 580 \text{ CFM (at 450°F)}
\]

If this is adequate to avoid undesirable fume spill at oven work openings, no additional ventilation will be required.

4-2.5 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:

\[
W \times R \times 360 = \text{cubic feet per hour referred to 70°F (standard density)}
\]

Provide a factor of safety of 4 and convert to cubic feet 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:

\[
W = \frac{S \times T}{C} = \text{Weight of powder in pounds entering oven per hour}
\]

Where:

- \(W\) = Maximum intended hourly rate of powder delivery into the oven.
- \(R\) = Percent of powder constituents released during oven cure cycle.
- \(S\) = Surface area of parts to be coated in square feet per hour.
- \(T\) = Maximum powder coating thickness in mils.
- \(C\) = Manufacturers' recommended coverage in square feet per pound for one mil thickness (135 typical).

4-3 Batch Process Oven.

4-3.1 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 gallon of flammable volatiles except as permitted in 4-3.2.

4-3.2 Calculated Rate of Ventilation Method. In batch ovens processing other than coated sheet metal type work, the figure of 380 cfm referred to 70°F 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, shutdown 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 gallons evaporated during any one hour 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 cubic feet per minute referred to 70°F shall be at least equal to the gallons of solvent evaporated during the maximum hour multiplied by the volume of air (referred to 70°F) computed as rendered flammable at the lower explosive limit (per formula in 4-2.3) then multiply by an empirical factor of 10 and divide 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. There are 3 gallons of volatiles, mostly xyloil, contained in the paint used to coat the load. The ventilation, required in sections 420-1(a) and 420-2, is figured as follows:

Required Ventilation cfm. referred to 70°F = 300 \times 3 \text{ (gallons of xyloil)} \times 1.4 \text{ (L.E.L. correction factor -- see 420-2)} = 1,596 \text{ cfm. referred to 70°F}.

or Required Ventilation at the oven temperature of 300°F would be:

\[
\frac{300 + 460}{70 + 460} = \frac{1,506}{2,290} \text{ cfm. of air at 300°F}. \]

(b) Types of Work other than Coated Metal where Evaporation Rate Tests Have Been Made.

A batch oven operates at 255°F with load of small transformer coils impregnated with material containing 4.8 gallons of volatiles, mostly toluol. Tests under plant operating conditions indicate that over five hours were required to evaporate all volatiles and that the peak evaporation rate, occurring in the first 5 minutes after loading, was .06 gallons per minute. The ventilation, required in 420-1(b) would be figured as follows:

Required Ventilation cfm. referred to 70°F =

Peak evaporation rate gpm. (determined by test) \times \text{ cu. ft. of air to form a barely explosive mixture per gallon of toluol (see Example A)} \times \text{ Factor of 4 (to prevent vapor concentration exceeding 25 percent L.E.L.)} \times \text{ L.E.L. Correction Factor (see 420-2)}

or \( = .06 \times 2,268 \) (From Example A) \times 4 \times 1.4

\( = 762 \text{ cfm. referred to 70°F}. \)

or Required Ventilation at the oven temperature would be:

\[
\frac{255 + 460}{70 + 460} = 1,029 \text{ cfm. air at 255°F}. \]

(c) Alternate Estimation of Ventilation — All Types of Work.

A batch oven cures at 480°F 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 one hour is 2.3 gallons, and the total loss of weight throughout the cure is equivalent to 6.6 gallons. The estimated ventilation, required in 4-3.2, Exception 2, is figured as follows:

Estimated Ventilation cfm. referred to 70°F = gallons of solvent evaporated during maximum hour \times \text{ cu. ft. of air rendered barely explosive per gallon of Mineral Spirits No. 10 (see Table 4-2) x empirical factor of 10 x L.E.L. Correction Factor (see 4-3.3, Note 2)}

or \( = 2.3 \times 2,802 \times 10 \times 1.4 \)

\( = 2,667 \text{ cfm. at 480°F}. \)

4-3.3 Volumes of air specified or calculated as per 4-3.1 or 4-3.2 corrected for operating temperature, shall apply for oven temperatures up to 250°F. For batch ovens operating at temperatures over 250°F, the volume shall be increased by a multiplier of 1.4 and correct the temperature as outlined in 4-1.9.

NOTE 1: The 1.4 multiplier is not required on continuous process ovens.

NOTE 2: Extensive tests have been conducted by the Underwriters Laboratories Inc. to obtain data as to the effect of elevated temperatures on the L. E. L. of many of the solvents commonly used in connection with ovens. These tests show that the L. E. L. of all solvents tested decreases as the temperature increases. The actual figures vary considerably with different solvents, but for the sake of simplicity the preceding requirement applies.

4-4 Vapor Concentration Indicators and Controllers.

4-4.1 Continuous vapor concentration indicators and controllers means devices which measure and indicate, directly or indirectly in percentage of the lower explosion 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 automatically to
sound an alarm, open or close dampers, 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 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.

4-4.2 Flammable vapor concentration indicators shall be used to test flammable vapors having a flash point below 70°F unless it is possible to maintain the sampling line and measuring assembly at the temperature of the vapors, so that condensation will not occur.

4-4.3 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 5 Safety Equipment and Application

5-1 General.

5-1.1 For safety of personnel and protection of property, careful 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.

5-1.1.1 Fuel-fired units, and units where combustible or flammable vapors or gases are involved, shall be provided with all safety devices in accordance with established good and safe practices.

5-1.1.2 Safety considerations shall extend to allied equipment, and to other proximate equipment, to avoid additional contributory hazards.

5-1.1.3 A safety shutdown of the heating system by any of the prescribed safety features or devices shall require either:

(a) Manual intervention of an operator for re-establishment of normal operation of the system, or

(b) Automatic recycling of the system by an approved automatic programming system.

5-1.2 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.

5-1.3 It shall be continually borne in mind that:

(a) The mere 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) Automatic steam valves, electric relays and fuel safety shutoff valves are not substitutes for main shutoff cocks (valves) and disconnects.
5-1.4 Regularly scheduled inspection and maintenance of all safety devices shall be performed as required to insure that the intended protection against the anticipated hazards, real or potential, is available at all appropriate times.

5-1.4.1 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 field conditions of operation are.

5-1.4.2 It shall be the responsibility of the equipment manufacturer to provide suitable recommendations and/or suggestions on maintenance and inspection procedures.

5-1.5 Safety devices shall be properly installed, and maintained in accordance with the manufacturer's instructions.

5-1.6 Safety devices shall be guarded against physical damage and inadvertent tampering.

5-1.7 Safety devices shall not be shorted-out nor shall they be bypassed.

*Exception: Deadman switch usage on vent valve, to leak test the safety shut-off valve.*

5-2 Preventilation (Pre-purge, Purging Cycle).

5-2.1 Prior to each operational cycle, positive provision shall be made for the removal of, or for dilution to a point below the LEL of, all combustible/flammable vapors and/or gases which may have entered during the shutdown period.

5-2.1.1 At least four (4) standard cubic feet (SCF) of fresh air per cubic foot of oven volume shall be introduced during the purging cycle.

5-2.1.2 Timed preventilation shall be provided for all ovens and heaters in which flammable vapors or fuels can accumulate during a shutdown period.

*Exception: Timed preventilation can be omitted on ovens of less than 350 cu. ft. volume provided:*

(a) Fans are proven operating, and
(b) Doors are proven open before admitting heat, and
(c) Door area is at least one (1) sq. ft. per fifteen (15) cu. ft. of oven volume.

5-2.1.3 Timed preventilation cycle shall be repeated after each and every shutdown of the recirculating and/or exhaust fans.

5-3 Ventilation Safety Devices.

5-3.1 Whenever any fan is essential to safe operation of the oven or allied equipment, fan operation shall be proven.

5-3.1.1 Electrical interlocks and/or flow switches shall be arranged in the safety control circuit so that loss of ventilation or air flow will immediately shut down the heating system of the particular oven section affected; or if necessary loss of ventilation should shut down the entire oven heating system as well as the conveyor.

5-3.1.2 Air pressure switches and air suction switches shall not be used to prove air flow if dampers can be closed to the point of reducing flow to an unsafe operating level.

5-3.2 Air flow 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.

5-3.3 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, and/or limit switches interlocked into the safety circuitry to assure that dampers are in a safe operating position.

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

5-4.1 If all, or a portion of, the air required for combustion of the fuel is contingent upon air movement, caused by the exhaust and/or recirculating fans, air flow shall be proven prior to ignition attempt and reduction of air flow to an unsafe level shall result in de-energization of the safety shut-off valve (see 5-3).

5-4.2 When a combustion air blower is used, presence of the minimum combustion air pressure required for safe burner operation shall be established prior to each attempt at ignition.

5-4.2.1 Motor starter shall be interlocked (5-3.1.1).

5-4.2.2 An approved low pressure combustion air switch (N.O. Contact) shall be used to sense and monitor pressure, interlocked into the safety circuitry.
5-4.3 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 and approved high pressure switch (N.C. Contact) and an approved low pressure switch (N.O. Contact) shall be used.

5-4.4 Combustion air shall be established during the pre-ventilation (pre-purge) cycle whenever necessary to provide cooling air for the burner or to otherwise establish air flow through the burner for reasons of safety.

5-4.5 Use of combustion air for a post-purge period (following shut-down) shall be considered whenever exhaust/recirculating fans continue in operation and/or whenever exposure to residual heat can lead to excessive rate of burner deterioration.

5-5 Fuel Safety Devices.

5-5.1 General.

5-5.1.1 As with all safety devices, full consideration shall continually be given to the fact that improper-application and/or adjustment can result in repeated and unscheduled shutdowns. Improper corrective action (by-passing, jumpering-out, etc.) can lead to a hazardous condition, and shall not be taken to sustain production.

5-5.1.2 One or more safety devices shall be provided to prevent unintentional recycling of the safety system, or any portion of it.

5-5.2 Safety Shut-off Valves (Gas or Oil).

5-5.2.1 General.

NOTE 1: The safety shut-off valve is the "Key Unit" of all the 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.

NOTE 2: Safety shut-off valves are designed to automatically shut off the fuel to the burner system within 5 seconds after interruption of the holding medium by any one of the interlocking safety devices. They are self-closing (usually by means of an internal spring) and cannot be readily bypassed or blocked open. Most approved valves have an open/shut indicator actuated by the closure element. They are available with end switches, actuated at both the closed and the open end of the stroke for signal and alarm purposes.

5-5.2.1.1 Valve components shall be of a material suitable for the fuel handled.

5-5.2.1.1 It shall be the user's responsibility to inform the equipment manufacturer of any deviation from the standard, clean fuel.

5-5.2.1.2 Valves shall not be subjected to pressures in excess of manufacturer's rating.

5-5.2.1.2.1 If normal inlet pressure to the fuel pressure regulator immediately upstream from the valve exceeds valve's pressure rating, a relief valve shall be provided and shall be vented to a safe location.

5-5.2.1.3 Position indication shall be provided for safety shut-off valves to main burners in excess of 150,000 Btu/hour. The use of signal lights shall be permitted for valves not equipped with position indication.

5-5.2.1.4 Safety shut-off valves shall not be used in lieu of manual cocks/valves when shutting down.

5-5.2.2 Gas Safety Shut-off Valves.

5-5.2.2 If main or pilot gas burner capacity exceeds 400,000 Btu/hr., two safety shut-off valves (piped in series) shall be used. In addition, a vent with an approved normally open vent valve shall be located between them, and sized in accordance with Table 5-5.2.2 (or larger).

5-5.2.2.1.1 Vent pipe shall terminate in a safe location where vented gas cannot re-enter the building without extreme dilution, and outlet shall be suitably protected against foreign matter, rain, etc.

<table>
<thead>
<tr>
<th>Table 5-5.2.2 Vent Pipe Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel Line Diameter</td>
</tr>
<tr>
<td>---------------------</td>
</tr>
<tr>
<td>Up to 1½&quot;</td>
</tr>
<tr>
<td>2&quot;</td>
</tr>
<tr>
<td>2½&quot;</td>
</tr>
<tr>
<td>3&quot;</td>
</tr>
<tr>
<td>3½&quot;</td>
</tr>
<tr>
<td>4&quot;</td>
</tr>
<tr>
<td>5&quot;</td>
</tr>
<tr>
<td>6&quot;</td>
</tr>
<tr>
<td>8&quot;</td>
</tr>
</tbody>
</table>
5-5.2.2.2 If main or pilot gas burner capacity is 400,000 Btu/hr. or less, a single approved safety shut-off valve may be used in place of the double safety shut-off valves as required in 5-5.2.2.1.

Exception No. 1: If spring loaded solenoid valves may be used as the primary safety shut-off valve with fuel flow up to 400,000 Btu's per hour, or as the secondary safety shut-off valve with the double safety shut-off valve and vent system provided:

(a) The sealing force of the spring is a minimum of five pounds, exclusive of "dead weight" of the assembly and fuel pressure exerted.

(b) Their use does not necessitate any abnormal settings of either the high or low gas pressure switches to counter any transient pressure fluctuations created by sudden operations of the valve.

Exception No. 2: Other solenoid valves, not meeting the above specifications may be used when all three of the following conditions prevail:

(a) The flow is less than 150,000 Btu's per hour.

(b) The valve size and pipe size is ¾ in. or less.

(c) The gas pressure is five (5) psig, or less.

5-5.2.2.3 A permanent and ready means for making tightness checks of all main burner gas safety shut-off valves shall be provided (see Chapter 7, Inspection and Maintenance).

5-5.2.3 Oil Safety Shut-off Valves.

5-5.2.3.1 An approved safety shut-off valve or valves shall be provided for shutting off fuel to the burner or burners being protected.

5-5.3 Fuel Pressure Switches (Gas or Oil).

5-5.3.1 At least one low pressure switch (N.O.) shall be provided for, and interlocked with, each burner system's safety shut-off valve.

5-5.3.2 Whenever the normal fuel pressure to the pressure regulator immediately upstream from the safety shut-off valve exceeds the design limits of the burner system, at least one high pressure (N.C.) switch shall be provided, and interlocked with burner system's safety shut-off valve, as in 5-5.3.1.

5-5.3.3 Pressure switch settings shall be made in accordance with design limits of the burner system and/or the heating unit, whichever is the more stringent.

5-5.4 Combustion Safeguards (Flame Supervision).

5-5.4.1 Each burner flame shall be supervised by an approved Combustion Safeguard, having a nominal flame response timing of 4 seconds or less, interlocked with the safety circuitry.

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

Exception No. 2: Multiple burners where combustion safeguards for each burner are too numerous to be practical, but continuous line-burner type pilots for groups of burners (see 3-3.5.2) can be used: An approved practically instantaneous 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 shut-off valve must be initially opened by a manual momentary push button.

Exception No. 3: Where two burners, which will reliably ignite one from the other, are used, it shall be permissible to use a single approved instantaneous 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. 4: Burners for direct fired heating system which supply a furnace at a fuel rate not exceeding 150,000 Btu/hour 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. 5: In general, for greatest security, all burners should be protected with combustion safeguards as outlined in the foregoing sections. When this is not technically feasible the maximum practical protection shall be furnished by providing a reliable continuous pilot at each burner, and/or operating burners on high-low flame, and by installing devices (pressure switches and safety shut-off valves) to assure, where practical, closure of all individual burner cocks before the main burner safety shut-off 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. 6: Radiant tube heating systems utilizing explosion resistant tube construction do not require combustion safeguards.

5-5.4.1.1 Consideration shall be given to the supervision of the main flame, which can be done by:
(a) Use of a second sensor applied only to the main flame, or
(b) Interrupting the pilot.

Figure 5-5.4.1.1(a) Supervising Cock and Gas Safety Control System.

NOTE: A method of assuring closure of all individual gas burner cocks before the main burner gas safety shut-off valve can be opened is the supervising cock and gas safety control system. A typical piping and wiring arrangement using the pneumatic type supervising cock is illustrated in Fig. 5-5.4.1.1(a). (See 1-4, Supervising Cock.) The number and location of pressure switches, arrangement of tubing and other details will vary with the individual installation. In the illustration, the main burner safety shut-off valve cannot be opened until all supervising cocks are closed, combustion air pressure is normal, and normal 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 shut-off valves. Once the initial check has been completed and the main burner safety shut-off valve is opened, the low pressure switch downstream from the safety shut-off 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 Fig. 5-5.4.1.1(b). The main burner safety shut-off valve cannot be opened until all supervising cocks are closed (cock switch contacts in series are all closed), ventilation fans operating, ventilation purge completed and other interlocks satisfied.

5-5.4.2 Line burners and pipe burners shall have at least one Combustion Safeguard per 50 ft. of continuous single path length [see Fig. 5-5.4.1.1(a)]. Radiant cup burners may utilize only one Combustion Safeguard when equipped with flame propagation tubes/devices provided that cup spacing does not exceed 30", and flame propagation path does not exceed 50 ft. and that there are not more than 50 radiant cup burners [see Fig. 5-5.4.1.2(b)].

5-5.4.3 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% of the L.E.L. will not be exceeded in the extended time.

5-5.5 Oil Atomization, other than Mechanical Atomization.

5-5.5.1 Adequate pressure/flow of the atomizing medium shall be proven to exist before the oil enters the burning zone.

5-5.5.2 If a low pressure switch is used to sense/supervise this pressure, 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.

2. Permanent and ready means for making periodic checks of main gas safety shut-off valve.
3. Approved pilot gas safety shut-off valve.
4. Main flame-sensing element. (Flame rod shown, but a photoconductive cell may be used.)

Figure 5-5.4.1.2(a) Example of application of an approved combustion safeguard supervising a pilot for a continuous line burner during lighting-off and the main flame alone during firing.

5-5.6 Low Oil Temperature Limit Devices (N.C.).

5-5.6.1 Approved limit devices shall be provided whenever the temperature of the fuel oil can drop below a safe level for proper atomization.

5-5.6.1.1 Devices shall be provided when oil preheaters are used.
5-5.6.1.2 Devices shall be required for No. 2 fuel and No. 4 fuel oil when its temperature may reach congealing point, whether or not preheaters are used.

5-5.6.2 The limit device shall be interlocked to de-energize the oil safety shut-off valve whenever oil temperature falls below a safe predetermined level.

5-5.7 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.

5-5.7.1 When dual fuel burners are used, positive provision shall be made to prevent simultaneous introduction of both fuels.

NOTE: Not applicable to combination burners.
5-6 Gas Mixing Machines.

5-6.1 Safety equipment and installation shall comply with NFPA. 54-1974, National Fuel Gas Code.

5-7 Ignition of Main Burners.

5-7.1 Burners shall be ignited by a fuel-fired pilot burner or by direct electrical means.

5-7.1.1 Sufficient energy shall be presented for safe and proper light-off at the burners' input at light-off.

5-7.1.2 If any specific input, or a limited range of inputs is required for safe light-off, the fuel control valve shall be properly positioned prior to each and every attempt at ignition.

5-7.2 Electrical ignition energy for direct spark ignition systems shall be terminated after main burner trial for ignition period. Exception: Repetitive sparking of multiple burners is allowed where the input per burner does not exceed 150,000 Btu/hour.

5-7.3 UV scanners, if used as the combustion safeguard's flame sensor, shall be shielded mechanically or electrically from spark excitation when a spark-ignited pilot burner is used.

5-7.4 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.

5-7.5 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.

5-8 Excess Temperature Limit (ETL).

5-8.1 One or more approved excess temperature limits shall be used on any heating unit where it is possible for the controlled temperature to exceed a safe limit.

5-8.1.1 The thermal element of the ETL shall be suitable for the atmosphere to which it will be exposed.

5-8.1.2 The ETL shall be fail safe.

5-8.2 The ETL shall be interlocked with the safety circuitry to cut off the source of heat when safe temperature is exceeded.

5-9 Conveyor interlocks shall be provided in conveyor ovens having a flammable volatile hazard so that the conveyor cannot move unless ventilating fans are operating and discharging the proper amount of air, as required in Chapter 4, and purge cycle completed.

5-9.1 An audible and/or visible alarm shall be provided in the safety circuit to give warning of unsafe conditions and interruption of the safety circuit.

Exception No. 1: It is permissible to install provision for operating the conveyor manually or by means of a constant pressure push button for the purpose of removing material from the oven in event of conveyor stoppage from ventilation failure.

Exception No. 2: When an automatic material feeding system supplies a conveyor at a point adjoining the oven entrance, such as a lithograph oven coater, the material feeding system may be interlocked with the ventilation system and the conveyor interlocks omitted.

Exception No. 3: Certain one line conveyor systems supplying several processes may prevent a practical ventilation interlocking arrangement. Omitting the interlocks in such cases is subject to the approval of the authority having jurisdiction.

5-10 Power. 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: This control circuit and its "nonfurnace or oven mounted control and safety components" should be housed in a dust-tight panel or cabinet, protected by partitions or secondary barriers 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.

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 (see 5-112.2).

Temperatures within this control enclosure shall be limited to 125°F for suitable operation of plastic components, thermal elements, fuses, and various mechanisms as may be employed in the control circuit.
5-11 Safety Devices for Systems Lacking Fuel Hazards.

5-11.1 General.

5-11.1.1 Safety control application for furnaces lacking fuel hazards shall provide protection from excess temperatures, loss of secondary systems (cooling, material handling, etc.) essential to normal operation of the furnace. Controls and arrangement shall be as outlined in the safety control application for electric furnaces. Instruments shall be of the fail-safe type.


5-11.2.1 Each furnace, or heat processing system (including resistance, induction, electric arc or plasma device) shall be provided with the following control devices and safety control circuits for proper operation.

5-11.2.2 Heating Equipment Controls.

5-11.2.2.1 Electric heating equipment of other than the portable type shall be equipped with a main disconnect device, capable of de-energizing the entire heating system under load to provide safety for secondary measures necessitated by one or more of the following conditions:

(a) A system short circuit not cleared by supplemental branch circuit protection.
(b) Excess furnace temperature.
(c) Failure of normal operating controls.
(d) Complete or partial loss of power, such as single phasing of a multiple phase power system.

5-11.2.2.2 The interrupting capacity of the main disconnect device (see Table 5-11.2.2.2) shall be adequate to clear the maximum fault current capability of the immediate power supply system (fault current shall be determined from the voltage and impedance of the furnace power supply circuit, not from the summation of the operating load currents).

NOTE: Other disconnect means in this power supply circuit may be used as the heating equipment "main disconnect" provided furnace operation can be terminated without affecting operation of other essential equipment.

5-11.2.2.3 Automatic versus supervised operation of the "main heating system disconnect" shall be governed by the furnace size, design characteristics and the potential hazards involved.

### Table 5-11.2.2.2 Main Disconnect to Power Supply System

<table>
<thead>
<tr>
<th>Identification or Trade Name</th>
<th>Current Carrying Capacity-Amperes</th>
<th>Symmetrical Interrupting Capacity-RMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plastic Case Breakers*</td>
<td>A. Std. Industrial Duty</td>
<td>70-2,500</td>
</tr>
<tr>
<td></td>
<td>B. High Interrupting Capacity with Current Limiting Fuses</td>
<td>100-1,600</td>
</tr>
<tr>
<td>Steel Case Air Circuit Breakers</td>
<td></td>
<td>100-4,000</td>
</tr>
</tbody>
</table>

**Typical Current Limiting — Time Delay — Fuses**

- Fuselron: 1-600
- Low Peak: 1,600
- Limitron: 600-6,000
- Hi-Cap: 600-6,000

**High Interrupting Capacity — Pressure Switches**

- Manually and Electrically Operated Types: 800-4,000

- *Available with numerous optional features for furnace and/or oven protection from ground faults, short-circuit faults, over-temperature, single/or multiple phase power failure.

For proper selection of "main disconnect" equipment it is necessary to know:

(a) The full load operating current and voltage of the equipment to be served.
(b) The impedance of the furnace and/or oven power supply system including its transformer.
5-11.2.2.4 Portable furnaces may be equipped with main disconnect devices to meet the above requirements, but if not, the power supply circuit to the furnace shall be so equipped. Supplemental electrical controls (contactors, circuit breakers, relays, signaling devices, etc.) shall be provided in accord with safety, temperature control, branch circuit and auxiliary system requirements.

5-11.2.2.5 The capacity of all electrical devices used to control energy for the heating load shall be selected on the basis of continuous duty load ratings when fully equipped for the location and type of service proposed.

NOTE: This may require de-rating some components as listed by manufacturers for other types of industrial service, motor control, etc., and shown in Table 5-11.2.2.5.

5-11.2.2.6 All controls, using thermal protection or trip mechanisms, shall be so located or protected as to preclude faulty operation due to abnormal temperatures or other furnace hazards.

5-11.2.3 Ventilation Controls. When removal of by-product vapors is essential to the safe operation of the furnace, controls and interlocks shall be provided as outlined in 5-2.

<table>
<thead>
<tr>
<th>Control Device</th>
<th>Resistance Type Heating Devices</th>
<th>Infrared Lamp and Quartz Tube Heaters</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rating in % of Load</td>
<td>Permissible Current in % of Rating</td>
</tr>
<tr>
<td>Fusible Safety Switch (rating of fuse employed)</td>
<td>125</td>
<td>80</td>
</tr>
<tr>
<td>Individually Enclosed Circuit Breaker</td>
<td>125</td>
<td>80</td>
</tr>
<tr>
<td>Circuit Breakers in Enclosed Panelboards</td>
<td>133</td>
<td>75</td>
</tr>
<tr>
<td>Magnetic Contactors</td>
<td>111</td>
<td>90</td>
</tr>
<tr>
<td>0-30 Amperes</td>
<td>111</td>
<td>90</td>
</tr>
<tr>
<td>150-600 Amperes</td>
<td>111</td>
<td>90</td>
</tr>
</tbody>
</table>

NOTE: The above applies to “maximum load” or open ratings for safety switches, circuit breakers, and industrial controls approved under current NEMA standards.

5-11.2.4 Material handling or positioning controls shall be arranged for proper sequence of operation with other furnace (special atmosphere and safety controls), and also to assure emergency action as may be needed in the event of malfunction of the material handling system.

Exception: It is permissible to install provision for operating conveyors manually or by means of a constant pressure pushbutton for the purpose of removing material from the furnace in event of malfunction in the automatic system.

5-11.2.5 Where a furnace is subject to damage, an excess furnace temperature limit control shall be provided for annunciation and interruption of power supply to the furnace heating system.

5-11.2.5.1 Manual reset shall be provided to prevent automatic restoration of power.

5-11.2.5.2 These controls shall be in addition to any normal operating temperature control devices.

5-11.2.6 Branch circuits and branch circuit protection for all electrical circuits in the furnace heating system shall be provided in accordance with NFPA 70-1978, National Electrical Code.
Chapter 6 After-burner and Catalytic Combustion Systems

6-1 After-burner System.

6-1.1 Fuel systems and controls for after-burners shall comply with the requirements for direct-fired oven heaters. Additionally, concurrent operation with the fume generating process shall also be guaranteed by proper interlocking means, usually requiring intended operating temperatures within the after-burner for proving periods both before and after fumes may be entrained for thermal destruction.

NOTE: After-burner systems may or may not employ catalysts and various heat exchange principles to aid the combustion process.

6-1.2 Where the relative location of equipment and/or the type of fumes generated is such that they may condense between the originating process and the after-burner, to form combustible liquids or solids, further safeguards shall be taken to avoid fire hazard or to guarantee delivery to the after-burner in true vapor form or combustible particulate form.

6-1.3 Excess-temperature protection shall be provided in the form of increased air dilution or interruption of the feed to the originating process, as thermal expansion of gases may otherwise cause the system to spiral out of control. (Energy release exceeding the designed volume dilution rate of the treated exhaust gases.)

NOTE: Proper design of the stacking or heat recovery system from the after-burner exhaust is also important as the latent energy in some hydro-carbon fumes (although diluted to 25 percent L.E.L.) may add as much as 650°F to the effluent temperature during after-burner treatment.

6-1.4 When portions of the potential energy are returned to earlier stages of the heating system (oven, fume delivery manifold or after-burner), safeguards shall be provided to avoid recycling untreated gases in the event of system malfunction.

6-2 Catalytic Combustion System.

6-2.1 Catalytic-type systems, whether employed for oven heat supply, exhaust energy recovery or for air pollution control shall be subject to the same safety precautions as other direct-fired oven heaters or after-burner systems.

NOTE 1: Heaters of this type may be employed to burn a fuel gas with substantial portions of the energy being released as radiation to the processing zone (or oven, if enclosed) similar to direct fired internal heaters.

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 1-4, Direct Fired External Heater). [See Figures 6-2.1(a), (b), (c), and (d).]

Figure 6-2.1(a) Catalyst System Independent of Oven Heater for Air Pollution Control.

Figure 6-2.1(b) Direct Type Catalytic Oven Heater for Partial 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 gas fuel 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.

NOTE 3: Heating systems employing catalysts are finding wide applications for the conservation of oven fuel and for correction of organic and combustible type air pollution emissions. Some limitations must be recognized because of their inability to oxidize or consume silicones, chlorine compounds, and metallic vapors as from tin, mercury, and zinc. These elements and various inorganic particulates (dust) may retard or paralyze catalyst activity, thus suggesting specific maintenance requirements. Consultation with qualified equipment manufacturers is recommended prior to installation and at periodic intervals during use to assure appropriate maintenance and reliable operation.

6-2.2 The usual oven safety standards shall be applied with respect to location, plan approval, construction, piping, safety controls, interlocks and dampers, and re-use of oxidized exhaust products.

6-2.3 Exhaust from several ovens, kettles, or dryers shall only be manifolded to a single catalytic unit when a double-jacketed, heated manifold is provided and without provision for heat recovery to the original process.

6-2.4 An excess temperature limit device, downstream from the catalyst bed, shall be arranged to shut down the process burners, material handling equipment, and operate exhaust relief dampers to provide maximum discharge to the outside atmosphere. In special instances where an exothermic reaction may occur within a process being served, further protection shall be provided by arranging for complete diversion of fumes from the catalyst system when the high limit temperature control is actuated.

6-2.5 Consideration shall be given to measure the temperature increase (ΔT) and the pressure drop (ΔP) across the catalyst bed.

NOTE: Separate temperature indicator controls may be used to arithmetically determine the ΔT. For example, an instrument measuring temperature on the upstream or entry side of the catalyst may be used to control fuel or electrical energy for preheating the fume stream, while a second controller measuring the downstream or catalyst exit temperature is employed as a limit device to actuate the fuel safety shut-off valve and fume diversion or exhaust relief dampers. The temperature difference (ΔT) indicated by these instruments will serve as a guide to the combustible energy release within the catalyst bed. A ΔT of 500°F is usually a practical maximum for most fume destruction processes.

6-2.6 Sufficient exhaust ventilation shall be provided to maintain vapor-air mixtures below 50 percent (automatic shutdown point) of the L.E.L. (understanding that a fixed, continuous vapor concentration indicator is installed and properly interlocked with fuel input and stock conveyor).
NOTE: Where the size of the installation may not require a continuous vapor concentration indicator, maximum vapor concentration in the exhaust shall not exceed 25 percent of the L.E.L.

6-2.7 Explosion relief of one square foot for each fifteen cubic feet of volume shall be provided for large catalytic units (above 64 cubic foot size) subject to excess energy release or fuel hazards.

NOTE: The access door can usually be used to provide all, or a portion, of this relief if equipped with explosion relief latches.

6-2.8 The plant management and the authority having jurisdiction shall recommend suitable time interval at which catalytic elements and related safety controls shall be tested for service reliability based on recommendations of the equipment manufacturer.

NOTE: Numerous arrangements for circulation of oxidized combustion products from the catalyst bed may be provided [see Figures 6-2.1(a) and (c)]. Repeated cycling of such products through the oven heating zone and the catalyst bed [Figure 6-2.1(b)] is not recommended unless continuous supervision of the catalyst is provided by a combustible vapor concentration indicator or catalyst temperatures are maintained at sufficient levels to assure effective oxidation of major combustible constituents by natural combustion means. This does not apply when heat recovery is provided by a single pass through the oven or through sealed heat exchanger surfaces as in a double manifold fume collection system or an appropriately designed heat exchanger [see Figure 6-2.1(c)].

Chapter 7 Inspection and Maintenance. (See Appendix F.)

7-1 Responsibility of the Manufacturer and User. The equipment manufacturer shall impress upon the user the need for adequate operational checks and maintenance and shall issue complete and clear maintenance instructions. The final responsibility of establishing a maintenance program which ensures that the equipment is in proper working order shall rest with the user.

NOTE: An essential safety aid is an established maintenance program which ensures that the equipment is in proper working order.

7-2 Check List. (See Appendix F.) The user's operational and maintenance program shall include all listed procedures that are applicable to the oven. An operational maintenance check list 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.

7-3 Cleaning. Foreign material, parts, and residue shall be removed from recirculation blowers, and exhaust blowers, burner and pilot ports, combustion blower, ductwork and oven interior. Ductwork shall be checked for obstructions (i.e., improperly adjusted dampers).

7-4 Tension and Wear. Recirculation and exhaust system blowers that are V-belt driven shall be checked for proper belt tension and excessive belt wear.

7-5 Solvent Loading. It shall be the user's responsibility to periodically check the type and amount of solvent entering the oven, to assure that the solvent loading does not exceed the capacity of the oven exhaust system.
Chapter 8 Fire Protection

8-1 Basic Fire Protection.

8-1.1 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 arrangement 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, also if an appreciable amount of flammable drippings of finishing materials accumulates within the oven.

8-1.2 Dip tanks and drainboards included in the oven enclosure shall be protected in accordance with NFPA 34-1974, Dip Tanks Containing Flammable or Combustible Liquids.

8-1.3 Automatic Sprinkler Systems.

8-1.3.1 Automatic sprinkler installations shall conform to NFPA 13-1976, Installation of Sprinkler Systems.

NOTE 1: When oven temperatures are over 465°F 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.

8-1.4 Water Spray Systems.

8-1.4.1 Water spray systems shall be fixed systems, automatic in operation and conforming to NFPA 15-1973, Water Spray Fixed Systems.

NOTE: Protection systems utilizing the application of water in finely divided form may be provided to protect oven enclosures.

8-1.4.2 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.

8-1.4.3 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.

8-2 Supplementary Fire Protection.

8-2.1 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.

8-2.2 Carbon Dioxide Extinguishing Systems.

8-2.2.1 Carbon dioxide equipment shall be automatic and shall be installed in accordance with NFPA 12-1973, Carbon Dioxide Extinguishing Systems. Manual control shall also be provided.

NOTE: These systems will provide good protection for ovens and dryers containing materials or deposits that would provide surface burning fires principally those involving flammable liquids.

8-2.3 Foam Extinguishing Systems.

8-2.3.1 Foam equipment shall be installed in accordance with NFPA 11-1976, Foam Extinguishing 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.

8-2.4 Dry Chemical Systems.

8-2.4.1 Dry chemical extinguishing equipment as a supplement to the required automatic sprinkler protection shall be automatic and shall be installed in accordance with NFPA 17-1975, 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.

8-2.5 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 B for details.
8-3 Portable Protection Equipment.

8-3.1 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 10-1975, Portable Fire Extinguishers.

NOTE: Small hose with combination nozzles should be provided so that all parts of the oven structure can be reached by small hose streams.

8-3.2 Means of Access. Doors or other effective means of access shall be provided in ovens and duct work 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.

8-4 Maintenance of Fire Protection Equipment.

8-4.1 Inspection. All fire protection equipment shall be inspected and maintained at regular intervals, in accordance with NFPA standards.

8-4.2 Records of inspection and tests shall be kept on forms prepared for this purpose and brought to the attention of management.

8-4.3 Testing shall be done by responsible men familiar with the operation and maintenance of this type of fire protection equipment.

8-4.4 Outlets. Sprinkler heads and outlets of other extinguishing equipment shall be kept clean and free of deposit under a regular inspection program.
Steam extinguishes fires by the exclusion of air or the reduction of the oxygen content of the atmosphere in a manner similar to carbon dioxide or other inert gas. The use of steam antedates other modern smothering systems. It is not a practical extinguishing agent except where a large steam supply is continuously available. The possible personal injury hazard of burns should be considered in any steam extinguishing installation. A visible cloud of condensed vapor, popularly described as steam, does not furnish any material protection.

While many fires have been extinguished by steam, its use has often been unsuccessful due to lack of understanding of its limitations. Except for specialized applications, other types of smothering systems are preferred in modern practice. No complete standard covering steam smothering systems has been developed.

One pound of saturated steam at 212°F and normal atmospheric pressure has a volume of 26.75 cu. ft. A larger percentage of steam is required to prevent combustion than in the case of other inert gases used for fire extinguishment. Fires in substances which form glowing coals are difficult to extinguish with steam, owing to the lack of cooling effect. There are some types of fires for which steam is completely ineffective, such as fires involving ammonium nitrate and similar oxidizing materials.

Steam smothering systems are permissible only when oven temperatures exceed 225°F and large supplies of steam are available at all times when the oven may be in operation. Complete standards paralleling those for other extinguishing agents have not been developed for the use of steam as an extinguishing agent, and until this has been done, the use of this form of protection is not as dependable or the results as certain as those qualities of water, carbon dioxide, dry chemical or foam.

Release Devices for steam smothering systems should be manual and controls should be arranged to close down oven outlets as far as practicable.

Life Hazard.
(a) Equipment should be so arranged as to prevent operation of steam valves while doors of box type ovens or access doors or panels of conveyor ovens are open.
(b) A separate outside steam manual shut-off valve should be provided for closing off the steam supply during oven cleaning and shall be locked closed whenever employees are in the oven.
(c) The main valve should be designed to open slowly as the release should first open a small bypass in order to allow time for employees in the vicinity to escape and also to protect the piping from severe water hammer. A steam trap should be connected to the steam supply near the main valve to keep this line free of condensate.

Steam Outlets. If steam is used, then steam outlets should be sufficiently large to supply 8 pounds of steam per minute for each 100 cubic feet of oven volume. They should preferably be located near the bottom of the oven, but may be located at the top, pointing downward if the oven is not over 20 feet high. Steam jets should be directed at dip tanks (in a manner to avoid disturbing the liquid surface) or other areas of special hazard.
### Appendix C
Adapted from Form No. 69, Factory Mutual Engineering Division

**TYPICAL OVEN DESIGN CHECK LIST FOR ACCEPTANCE**

<table>
<thead>
<tr>
<th>PART A: PLANS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>NAME &amp; ADDRESS OF CUSTOMER (OWNER)</td>
<td>NAME &amp; ADDRESS OF MANUFACTURER</td>
</tr>
<tr>
<td>DRAWINGS SUBMITTED, NO.</td>
<td>NO. OF SETS</td>
</tr>
<tr>
<td>INSTALLATION</td>
<td></td>
</tr>
<tr>
<td>SHEET &amp; ADJUSTMENTS (SEE PART B) BY:</td>
<td>OTHER (DESCRIBE)</td>
</tr>
<tr>
<td>SAFETY VENTILATION AIR FLOW TESTS (SEE PART B) TO BE MADE AFTER</td>
<td>OTHER (DESCRIBE)</td>
</tr>
<tr>
<td>ERECTION BY:</td>
<td>MANUFACTURER</td>
</tr>
<tr>
<td>TYPE</td>
<td>BATCH</td>
</tr>
<tr>
<td>CONSTRUCTION</td>
<td></td>
</tr>
<tr>
<td>SHEET-STEEL ON STEEL FRAME</td>
<td></td>
</tr>
<tr>
<td>NON-COMBUSTIBLE INSULATION</td>
<td></td>
</tr>
<tr>
<td>RATED HEAT INPUT</td>
<td></td>
</tr>
<tr>
<td>BTU/hr</td>
<td>FUEL OIL NO.</td>
</tr>
<tr>
<td>SIZE</td>
<td></td>
</tr>
<tr>
<td>LENGTH (external)</td>
<td>nock</td>
</tr>
<tr>
<td>LOCATION OF EQUIPMENT</td>
<td></td>
</tr>
<tr>
<td>BUILDING FLOOR CONSTRUCTION AND NO. OF FLOOR OR STORY</td>
<td></td>
</tr>
<tr>
<td>LOCATION &amp; NO. NAME</td>
<td>BUILDING FLOOR CONSTRUCTION AND NO. OF FLOOR OR STORY</td>
</tr>
<tr>
<td>EXPLOSION VENTING AREA</td>
<td></td>
</tr>
<tr>
<td>ACCESSIBLE IN EVENT OF FIRE</td>
<td>YES</td>
</tr>
<tr>
<td>FIRE PROTECTION IN OVEN</td>
<td></td>
</tr>
<tr>
<td>MANUFACTURER AND TYPE LATCH</td>
<td></td>
</tr>
<tr>
<td>TOTAL AREA</td>
<td></td>
</tr>
<tr>
<td>VENT</td>
<td>VENT AREA</td>
</tr>
<tr>
<td>FUEL SHUT-OFF</td>
<td></td>
</tr>
<tr>
<td>OPEN END</td>
<td>LOOSE ROOF PANELS</td>
</tr>
<tr>
<td>MANUFACTURER AND TYPE LATCH</td>
<td>TOTAL AREA</td>
</tr>
<tr>
<td>OTHER, DESCRIBE</td>
<td></td>
</tr>
<tr>
<td>FIRE PROTECTION FOR DIP TANK &amp; DRAINBOARD</td>
<td></td>
</tr>
<tr>
<td>MATERIAL</td>
<td>IMPREGNATED-COATED AMORTENT</td>
</tr>
<tr>
<td>PAPER</td>
<td>LATEX</td>
</tr>
<tr>
<td>CLOTH</td>
<td>DECO</td>
</tr>
<tr>
<td>METAL</td>
<td>DIPPED</td>
</tr>
<tr>
<td>SOLVENTS ENTERING OVEN</td>
<td></td>
</tr>
<tr>
<td>NAME OF SOLVENT USED</td>
<td>LENGTH OF BAKE</td>
</tr>
<tr>
<td>DESIGNATED SAFETY VENTILATION</td>
<td></td>
</tr>
<tr>
<td>ARRANGEMENT</td>
<td></td>
</tr>
<tr>
<td>SEPARATE CONTINUOUS FANS</td>
<td>NO</td>
</tr>
<tr>
<td>NATURAL EXHAUST</td>
<td></td>
</tr>
<tr>
<td>FAN</td>
<td></td>
</tr>
<tr>
<td>EXHAUST OUTLET</td>
<td></td>
</tr>
<tr>
<td>FAN MFR. SIZE, TYPE</td>
<td></td>
</tr>
<tr>
<td>RADIAL</td>
<td>BACKWARD</td>
</tr>
<tr>
<td>HEATING ARRANGEMENT</td>
<td>METHOD OF LIGHTING OFF</td>
</tr>
<tr>
<td>---------------------</td>
<td>------------------------</td>
</tr>
<tr>
<td>INTERNAL DIRECT FIRED</td>
<td>PORTABLE</td>
</tr>
<tr>
<td>NON-RECYCLING</td>
<td>FIXED</td>
</tr>
<tr>
<td>INTERNAL DIRECT FIRED</td>
<td>PILOT</td>
</tr>
<tr>
<td>RECYCLING</td>
<td>OIL</td>
</tr>
<tr>
<td>EXTERNAL DIRECT FIRED</td>
<td>(SPARK</td>
</tr>
<tr>
<td>RECYCLING</td>
<td>IGNITOR</td>
</tr>
<tr>
<td>INDIRECT FIRED</td>
<td>RECIRCULATING</td>
</tr>
<tr>
<td>RECIRCULATING</td>
<td></td>
</tr>
</tbody>
</table>

**EXTRACTION**:
- Internal direct fired
- Non-recirculating
- Recirculating
- External direct fired
- Recirculating
- External indirect fired
- Internal direct fired
- Recirculating
- Internal direct fired
- Recirculating
- Direct fired
- Recirculating
- Non-recirculating

**METHOD OF LIGHTING OFF**:
- Portable
- Fixed
- Pilot
- Oil
- Gas
- Spark ignitor

**METHOD OF FIRING**:
- On-off
- Modulating
- Automatic-lighted
- Manual-lighted
- Semi-automatic-lighted

**MIXER TYPE**:
- Gas
- Oil
- Air (18-20 oz.) atomizing
- Other

**PROTECTION AGAINST FUEL**:
- No fuel and duration until
- Time-ventilation by
- Exclusion and recirc. fans
- Pilot-fan, establishing
- Hot or slow system air atomizing
- No. of main burners
- No. of pilot burners
- Can dripping off work fall on heating elements
- Yes
- No

**EXPLOSION**:
- Heat cut-off automatically
- Requiring manual operation to restore or failure of
- Combustion air
- Recirculating
- Fan
- Fuel pressure
- Flame
- (combustion safeguard)
- Rod or scanner location devices
- Pilot-lights main flame
- Mfr. and type no. of f.m. cocks & timer

**MANUFACTURER & TYPE NO.**:
- Mfr.
- Pressure switches
- Air-flow switches

**PART A**
- Accepted as submitted
- Subject to any changes indicated
- Date

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

**PART C - FIELD EXAMINATION OF COMPLETED-INSTALLATION**
- Rod or scanner location devices
- Pilot-lights main flame
- Installation acceptable

**INSTRUCTIONS**
- Customer's operator
- Tested for proper response
- Application for acceptance
- Printed operating instructions left
- Filed with control panel

**SAFETY VENTILATION**
- Cpm. ref. to 31°F
- Measured by (specify)
- Measured with fresh air inlet & exhaust outlet dampers in maximum closed position
- Yes
- No

**BURNERS**
- Lighted
- Mfr.
- Adjusted
- Mixers
- Other
- Temp. control
- Yes
- No

**SAFETY CONTROLS**
- Adjusted
- Tested for proper response

**SIGNATURES**
- Mfr.
- Field ref.
- Test witnessed by
- Date

**PART B ACCEPTED**
- Subject to any changes indicated
- Date

**PART C - FIELD EXAMINATION OF COMPLETED-INSTALLATION**
- Rod or scanner location
- Pilot-lights main flame
- Installation acceptable
- Date
# Appendix D

Adapted from Form No. 23, Factory Mutual Engineering Division

## TYPICAL FURNACE DESIGN CHECK LIST FOR ACCEPTANCE

<table>
<thead>
<tr>
<th>PART A - PLANS</th>
<th>SHEET 1 OF 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>NAME OF CUSTOMER (name of owner)</td>
<td></td>
</tr>
<tr>
<td>ADDRESS (ST. &amp; NO.)</td>
<td>CITY</td>
</tr>
<tr>
<td>NAME OF MANUFACTURER</td>
<td></td>
</tr>
<tr>
<td>ADDRESS (ST. &amp; NO.)</td>
<td>CITY</td>
</tr>
<tr>
<td>DRAWINGS SUBMITTED, NO.</td>
<td>NO. OF SETS</td>
</tr>
<tr>
<td>INSTALLATION TYPE</td>
<td>BATCH</td>
</tr>
<tr>
<td>CONSISTS OF</td>
<td></td>
</tr>
<tr>
<td>RATED HEAT INPUT</td>
<td></td>
</tr>
<tr>
<td>STU./HR.</td>
<td>GAS</td>
</tr>
<tr>
<td>SIZE (EXTERNAL IN FT.)</td>
<td>LENGTH</td>
</tr>
<tr>
<td>LOCATION OF EQUIPMENT</td>
<td>BLDG. NO. OR NAME</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## FUEL SHUT-OFF

<table>
<thead>
<tr>
<th>ACCESSIBLE IN EVENT OF FIRE</th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEPARATE EXCESS TEMPERATURE</td>
<td>LIMIT SWITCH SHUT-OFF</td>
<td>HEAT</td>
</tr>
<tr>
<td>YES</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>GET FOR</td>
<td>°F</td>
<td></td>
</tr>
</tbody>
</table>

## FIRE PROTECTION OF OIL QUENCH TANK

<table>
<thead>
<tr>
<th>TYPE OF OIL PROTECTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>NONE</td>
</tr>
<tr>
<td>IF OTHER, DESCRIBE</td>
</tr>
</tbody>
</table>

## TYPE OF WORK

<table>
<thead>
<tr>
<th>BEAT TREATING METALS</th>
<th>WITH SPECIAL FLAMMABLE ATMOSPHERE</th>
<th>WITH SPECIAL INERT ATMOSPHERE</th>
</tr>
</thead>
<tbody>
<tr>
<td>IF OTHER, DESCRIBE</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## HEATING ARRANGEMENT

<table>
<thead>
<tr>
<th>DIRECT FIIRED</th>
<th>INDIRECT FIIRED</th>
</tr>
</thead>
<tbody>
<tr>
<td>IF OTHER, DESCRIBE</td>
<td></td>
</tr>
</tbody>
</table>

## METHOD OF ELECTRIC HEATING ELEMENTS AND LOCATION

<table>
<thead>
<tr>
<th>MUFFLE</th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>RADIANT TUBES</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## NO. OF OIL QUENCHERS

<table>
<thead>
<tr>
<th>NO. OF OIL QUENCHERS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<tr>
<td></td>
</tr>
</tbody>
</table>

## METHOD OF LIGHTING OFF

<table>
<thead>
<tr>
<th>PORTABLE</th>
<th>PILOT</th>
<th>GAS</th>
<th>SPARK IGNITOR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## METHOD OF FIRING

<table>
<thead>
<tr>
<th>IN-LOW</th>
<th>MODULATING</th>
<th>ON-OFF</th>
<th>CONTINUOUS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

## MIXER TYPE

<table>
<thead>
<tr>
<th>GAS</th>
<th>EXHAUST COVENIENCE TYPE</th>
<th>ATMOSPHERIC INSPIRATOR</th>
<th>BLOW DOWN 1.0 CO</th>
<th>LOW PRESSURE</th>
<th>OTHER</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO. OF OIL QUENCHERS</td>
<td>EXHAUST COVENIENCE TYPE</td>
<td>ATMOSPHERIC INSPIRATOR</td>
<td>NO. OF OIL QUENCHERS</td>
<td>LOW PRESSURE</td>
<td>OTHER</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## IF OTHER DESCRIBE (FINISH & TYPE)

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## APPENDIX D

86A-112

OVENS AND FURNACES

466
### Typical Furnace Design Check List for Acceptance

#### Part A - Protection Against Fuel Explosion

<table>
<thead>
<tr>
<th>Protection</th>
<th>Against Fuel Explosion</th>
</tr>
</thead>
<tbody>
<tr>
<td>HEAT CUT-OFF AUTOMATICALLY</td>
<td>REQUIRED</td>
</tr>
<tr>
<td>AIR FLOW TO OVEN</td>
<td>RESTRICTED</td>
</tr>
<tr>
<td>BURNER LIMITS</td>
<td>FOR SAFETY</td>
</tr>
</tbody>
</table>

#### Part B - Manufacturer's Inspection & Test

- MANUFACTURER AND TYPE
- ALARM AND AUTOMATIC LOCKOUT OF FUEL AND CONSUMPTION AIR IF FAILURE OR
- CLEAN UP ENCLOSURE |
- OVEN | AT MILL |
- SAFETY SHUT-OFF VALVE | AT GENERATOR |
- PRESSURE SWITCH |

#### Part C - Field Examination of Completed Installation

- BURNERS | CHECKED |
- SAFETY CONTROLS | TESTED |
- INSTALLATION ACCEPTABLE | FOR |
Appendix E  Availability of Publications Other than NFPA Standards Referenced in 86A

American National Standards Institute
1430 Broadway
New York, New York 10018

B31.1-1973, Power Piping, with Addenda
B93 Series
Y14.17-1966, Fluid Power Diagrams (Section 17)
Y32.10-1967, Graphic Symbols for Fluid Power Diagrams
Z50.1-1971, Safety Requirements for Bakery Equipment
Z50.1a-1973, Supplement to Z50.1-1971

American Society for Testing and Materials
1916 Race Street
Philadelphia, Pennsylvania 19103

D396 — 1973, Specifications for Fuel Oils

Underwriters Laboratories Inc.
207 East Ohio Street
Chicago, Illinois 60611

Bulletin of Research No. 43

National Electrical Manufacturers Association
155 East 44th Street
New York, NY 10017

TR 27-1971

Appendix F  Suggested Operational and Maintenance Check List

Operational Check List.
(a) Check burners for proper ignition and combustion characteristics.
(b) Check pilots or spark plugs, or both, for proper main burner ignition.
(c) Check for proper inlet air-gas ratios.
(d) Check for proper operating temperatures.
(e) Check sight drains or gauges, or both, for proper water flow and water temperature.
(f) Make sure atmospheric burners or pilots, or both, are protected from improper drafts, and adequate combustion air.
(g) Check for proper operation of ventilating equipment.

Regular Shift Check List.
(a) Take necessary gas analyses; if automatic gas analyzers are used make sure the manual and automatic readings coincide. Recalibrate automatic gas analyzers.
(b) Standardize or balance instruments.
(c) Check hand valves, manual dampers, secondary air openings or adjustable bypasses, or both, for proper positions.
(d) Check blowers, compressors and pumps, for unusual bearing noise and shaft vibration; if V-Belt driven, check belt tension and belt fatigue.
(e) Lubricate as per manufacturer's requirements.

Weekly Check List.
(a) Make sure flame and sensing devices are in good condition, properly located and free of foreign deposits.
(b) Test thermocouples and lead wire for shorts and loose connections.
(c) Check setting and operation of lower temperature limit device.
(d) Test visible or audible alarm systems, or both, for proper signals.
(e) Check ignition spark electrodes and check proper gap.
(f) Check all pressure switches for proper pressure settings.
(g) Check valve motors and control valves or dampers for free, smooth action and adjustment.

Monthly Check List.
(a) Test interlock sequence of all safety equipment. Manually make each interlock fail, noting that related equipment closes or stops as specified by the manufacturer.
(b) Test (Leak test) safety shutoff valves for tightness of closure.
(c) Test main fuel hand valves for operation.
(d) Test pressure switch settings by checking switch movements against pressure settings and comparing with actual impulse pressure.
(e) Inspect all electrical switches and contacts; clean if necessary.
(f) Test all amplifier and thermocouple fail-safe devices, making certain that the instrument drives in the proper direction.
(g) Clean the air blower filters.
(h) Clean water, gas compressor and pump strainers.
(i) Clean fire check screens and valve seats, and test for freedom of valve movement.
(j) Inspect burners and pilots; clean if necessary.
(k) Check all orifice plates, air-gas mixers, flow indicators, meters, gages, and pressure indicators; and clean or repair, if necessary.
(l) Check ignition cable and transformers.
(m) Test automatic or manual turn-down equipment.
(n) Check oven and furnace, interior, and ventilation, and duct work systems for cleanliness and restrictions.
(o) Test pressure relief valves, clean if necessary.
(p) Inspect air, water, fuel, and impulse piping for leaks.

Periodic Check List.
The frequency of maintenance of the following will depend on the recommendations of the equipment manufacturer.

(a) Inspect radiant tubes, and heat exchanger tubes for leakage, and repair if necessary.
(b) Lubricate the instrumentation, valve motors, valves, blowers, compressors, pumps, and other components.
(c) Test instrumentation, clean slidewires, check amplifier tubes and battery.
(d) Test flame safeguards units.

Maintenance of Gas Equipment

(1) General. These recommendations are prepared for maintenance of gas equipment. Special types of equipment command special attention. A preventive maintenance program should be established and followed. This program should include adherence to the manufacturer’s recommendations. In this program a minimum maintenance schedule should include inspection and action on the recommendations given in the following paragraphs. An adequate supply of repair parts should be maintained.

(2) Burners and Pilots. Burners and pilots should be kept clean and in proper operating conditions. Burner refractory parts should be examined at frequent regular intervals to assure good condition.

(3) Flame Safeguard Equipment. When automatic flame safeguards are used, a complete shut-down and restart should be made at frequent intervals to check the components for proper operation.

(4) Other Safeguard Equipment. Accessory safeguard equipment, such as manual reset valves, with pressure or vacuum switches, high temperature limit switches, draft control, shut-off valves, air flow switches, door switches, and gas valves, should be operated at frequent regular intervals to insure proper functioning. If inoperative, they should be repaired or replaced promptly. When fire checks are installed in air-gas mixture piping, the pressure loss across the fire checks should be measured at regular intervals. When excessive pressure loss is found, screens should be removed and cleaned. Water type backfire checks should be inspected at frequent intervals and liquid level maintained.

(5) Safety Shut-off Valves. All safety shut-off valves should be checked for leakage and proper operation at frequent regular intervals. A procedure for making tests of gas safety shut-off valves is outlined as follows:

Recommended Leak Test Procedure for Safety Shut-off and Blocking Valves on Direct Gas Fired Oven.

(1) Safety Shut-off Valve Check.
(a) With oven in the resting position and main shut-off cock open.
(b) Place a tube on the downstream side of the safety shut-off valve.
(c) Open V3 test cock.
(d) After immersing the tube into a glass of water, if more than 30 bubbles per minute appear, the valve is faulty.

(2) Blocking Valve.
(a) Start oven as normal to operating conditions (main burner on).

NOTE: For convenience purposes, the temperature controller may be set at a low temperature.
(b) Place a tube on the downstream side of the blocking valve.
(c) Open V5 test cock.
(d) Press and hold leak test button.
(e) Immerse the tube into a glass of water. If more than 30 bubbles appear, the valve is faulty.

This procedure is predicated on a piping diagram shown in Figure F-7-1 and a wiring diagram, F-7-2, entitled “Typical Safety Controls for a Direct Gas-fired Continuous Process Oven.”
Figure F-7-1 Piping Diagram.

Figure F-7-2 Typical Safety Controls for a Direct Gas-fired Continuous Process Oven.
Part II

Amendments to Standard for
Industrial Furnaces Using
Special Processing Atmosphere

NFPA No. 86C — 1974

1. Revise 700-7, Scope, to add a new paragraph (c) to read:
   (c) Within the scope of this standard, a molten salt bath furnace shall be any heated container that holds a melt or fusion composed of one or more relatively stable chemical salts which form a liquid-like medium into which metal work is immersed for various processes which include, but are not limited to, heat treating, brazing, stripping, and descaling.

2. Revise 100-2, Definitions, to add a new paragraph (d) to read:
   (d) **MOLTEN SALT BATH FURNACES** are furnaces that employ salts heated to the molten state. These do not include aqueous alkaline baths, hot brine, or other systems utilizing salts in solution.

3. Renumber existing paragraph (d) to (e) in 100-2.

4. Renumber Chapters 5-11 as Chapters 4-10.

5. Add a new Chapter 11, Molten Salt Bath Furnaces, as follows:

**CHAPTER 11. MOLTEN SALT BATH FURNACES**

**ARTICLE 1100. GENERAL**

**1100-1. Scope.** This chapter covers molten salt bath furnaces, internal quench molten salt bath furnaces, and associated equipment. Molten salt bath furnaces will include any heated container that holds a melt or fusion of one or more relatively stable salts as a fluid medium into which metal work is immersed.

**1100-2. Responsibility.** Molten salt bath furnaces shall be properly selected and operated for a specific process.

(a) Responsibility for selection shall rest with the person or agency authorizing the equipment, and with the manufacturer supplying the equipment.

(b) Responsibility for observing the operating instructions shall rest with the person or agency operating the equipment.

**ARTICLE 1110. LOCATION AND CONSTRUCTION**

**1110-1 Location.**

(a) A liberal area shall be allocated for the installation of each salt bath furnace and the zone of operation shall be spaced-off immediately around the bath to prevent congestion and to prevent interference with normal operations.

(b) Every salt bath furnace shall be located either inside of a shallow cement lined pit or within a curbed area. In either case, the pit or curbed area shall be designed to contain the contents of the molten salt in the furnace.

(c) All salt bath furnaces shall be located so that the bath will not be exposed to leakage from overhead liquid conveying piping (service piping, steam piping, sprinkler piping, oil piping, etc.), liquid entry through wall openings (windows, air intakes, etc.), or anticipated leakage or seepage through roofs or floors above. When it is not possible to protect against possible liquid leakage entering the salt bath because of location, then the salt bath shall be provided with a noncombustible hood that is designed and installed so that leakage into the molten salt is impossible.

(d) Where adjacent equipment (oil or water quench tanks, etc.) are located so that potential “splash over” could expose a molten salt bath, then the adjacent equipment shall be provided with deflecting baffles or guards to prevent the “splash over” from entering the salt bath.

**1110-2. Construction.**

(a) All molten salt bath furnaces shall be constructed of noncombustible materials.

(b) All molten salt bath furnaces shall be constructed of materials that are resistant to the corrosive action of the chemical salts at the maximum design operating temperature.

(c) The design of molten salt baths, and the materials selected for construction, shall minimize the possible effects of explosions, fires, spattering and leakage, both as regards protection of property as well as safety to operating personnel.

(d) All requirements outlined in Chapter 2 (Location and Construction) shall also apply for the construction of salt bath furnaces.
ARTICLE 1120. SALTS

1120-1. General. For the purpose of this section, a salt shall be considered to be any chemical compound, or mixtures of compounds, that may be utilized to form a melt or fluid medium into which metal parts are immersed for processing. A list of commonly used salts and mixtures are contained in Appendix G.

1120-2. Storage and Handling.
   (a) All salts shall be stored in tightly covered containers that are designed to prevent the possible entrance of liquids or moisture (most salts are hygroscopic).
   (b) All storage and shipping containers shall be prominently marked with the identification of the salt (or salt mixture) it contains, so that the possibility of accidentally mixing noncompatible salts will be minimized.
   (c) The supply of nitrate salts shall be stored in a separated, fireproof and damp-free room or area that is away from heat, liquids and reactive chemicals. This room or area shall be secured against entry by unauthorized personnel at all times. Only the required amount of nitrate salt shall be removed from the storage room or area that is required for make-up or full bath charges. When nitrate salts have been transported to the furnace area, they shall be immediately added to the salt bath. Excess salt for later addition shall not be permitted in the furnace area.
   (d) All furnace chargings (full charge or make-up) shall be from drums or metal containers. The use of fabric or paper sacks or bags shall be avoided.

ARTICLE 1130. HEATING SYSTEMS

1130-1. General.
   (a) For the purpose of this section, the term “salt bath furnace heating system” shall include the heating source and all associated piping, electrodes, radiant tubes, and all other equipment or devices necessary to safely convey the heat to the bath that is required to create the salt melt or fusion.
   (b) The heat source may be externally applied or may be by direct immersion of radiant tubes or electrical heating elements.
   (c) All of the requirements outlined in Chapter 3 (Heating Systems) and Chapter 4 (Safety Control Equipment) will apply.

1130-2. Gas and Oil Heating Systems.
   (a) The design of a salt bath furnace shall never permit direct flame impingement upon the wall of the salt container.
   (b) Whenever burner immersion tubes or radiant tubes are used, the design shall prevent any products of combustion from entering the salt bath.
   (c) All immersion or radiant tubes shall be fabricated of materials that are resistant to the corrosive action of the salt, or salt mixture, being used.
   (d) All immersion tubes shall be designed so that the tube outlet is above the salt level and the inlet shall be below the salt bath level. The burner shall be sealed at tube entry to prevent salt leakage outside of the bath upon tube failure.
   (e) The design of a molten salt bath furnace shall eliminate (or minimize) the potential build up of sludge and foreign materials that can result in “hot spots” on immersion tubes.
   (f) For control equipment requirements, see Article 1150.

   (a) Whenever immersed or submerged electrodes are used, the design shall prevent the possibility of stray current leakage (which could result in electrolytic corrosion and subsequent perforation of the wall of the salt container) and the electrodes shall be fixed or restrained to prevent possible arcing to the salt bath container or metal work in process.
   (b) When internal resistance heating elements are used, they shall be fabricated of materials that are resistant to the corrosive action of the salt and the salt bath shall be designed to prevent sludge build-up on the element that can result in damage from “hot-spots.”
   (c) Whenever immersed or submerged electrodes or internal resistance heating elements are used, they shall be positioned in the bath so that all heat transfer surfaces will be below the salt level at all times.
   (d) For control equipment requirements, see Article 1150.
ARTICLE 1140. VENTILATION

1140-1. Hoods. In order to remove, and appropriately control, the emission of heat and toxic (or otherwise deleterious) fumes, molten salt bath furnaces shall be provided with vented hoods that are constructed of noncombustible materials which are resistant to the maximum design temperature of the salt bath and the corrosive action of the salt being used.

1140-2. Exhaust.
(a) Salt bath furnace hoods shall be provided with exhaust ductwork and a blower (mounted external to the hood) for the continuous evacuation of fumes and heat.
(b) When required for the reduction of pollution by exhaust emissions, an air washer, chemical scrubber or fume destructor shall be installed that will perform the required altering of the exhaust without reducing the exhaust system effectiveness.

ARTICLE 1150. SAFETY CONTROL EQUIPMENT

1150-1. General.
(a) A molten salt bath furnace shall be equipped with control instrumentation and interlock systems that provide protection against the various and known types of potential equipment malfunction.
(b) Gas and oil fired salt bath furnaces shall be provided with controls as specified in Chapter 4 of this standard. In addition, an approved flame supervisory device shall be provided for each burner which shall be interlocked to shut off the fuel supply to the affected burner and activate the alarms.
(c) All salt bath furnaces shall be provided with a temperature control instrument that will maintain the set temperature of the furnace. The temperature control instrument shall be of the “fail safe” type. Any failure of the instrument or failure of the circuit to the temperature sensing device shall immediately drive the instrument upscale and automatically open the safety contacts or shunt trip. This shall shut down the furnace and activate the alarms.
(d) An excess temperature control instrument shall be provided, which shall have its own temperature sensing element, and shall be interlocked to shut off the heating system and activate the alarms when an excess temperature condition is detected.
(e) All immersion-type temperature sensing elements or devices shall be resistant to damage from the maximum design temperature and the corrosive action of the salt being used.
(f) When a salt bath is operating in a temperature range close to the melting point of the metal work in process, or when nitrate salts are being used, it is recommended that a second over-temperature control instrument be provided. As possible alternates, a preset timer which limits the “on” time of the heating system may be used or the original instrument may be of a “fail safe” design.
(g) When nitrate salts are being used (regardless of the type of heating system) a “heat rate” controller should be installed to prevent a too rapid heat-up, thus preventing localized overheating and ignition of the salt.
(h) All electrical wiring and control cabinets and cubicles shall conform to the requirements of NFPA 70–1978, National Electrical Code.
(i) Each salt bath furnace shall be provided with audible and visual alarms. These alarms shall be interlocked with the operating and safety control instrumentation so that the alarms will be activated upon instrument failures or instrument detected malfunctions.

1150-2. Electrically Heated Salt Bath Furnaces.
(a) A step-switch power transformer shall be used to provide a simple and positive control of the heating load. When the salt bath furnace is idled over long periods, left unattended or when not operating, the lower voltage taps should be used.
(b) A transformer switch interlock shall be provided and shall be interlocked to disengage the operating contactor. This will protect against the hazard of changing secondary voltage taps under load.
(c) Whenever transformers are forced-air cooled, a transformer air flow switch shall be provided. This air flow switch shall be interlocked to open the safety control contactor or actuate the shunt trip in the event of loss of air flow.
(d) Whenever water cooled furnace electrodes are used, safety control instrumentation shall be provided to detect failure of the cooling-water system and shall be interlocked to open the safety control system contactor or actuate the shunt trip. This instrumentation may be a water flow switch or a thermal detector on the drain side, or both.
(e) The current input shall be constantly measured by ammeters and voltmeters, with constant visual read out. These instruments shall read out amperes and voltage for each phase.
ARTICLE 1160. INTERNAL QUENCHING SALT BATHS

1160-1. General. Whenever a salt bath is utilized as an internal quenching tank in an internal quench furnace, then all requirements in Chapter 10 shall apply, in addition to the requirements outlined in this chapter.

1160-2. Low Temperature Salt Bath Quench Tanks. Salt bath quench tanks (350°F to 750°F), that utilize sodium and/or potassium nitrates and nitrites and operate with a combustible furnace atmosphere above all, or part, of the salt bath surface, shall be designed to:

(a) Control the interface between the atmosphere and the salt surface to prevent carbon precipitation onto the salt surface, and

(b) Provide adequate circulation of the salt to prevent localized overheating of the salt where it is exposed to furnace temperatures.

Note 1: Carbon concentration on the salt surface can cause localized overheating when hot material in process enters the salt quench from the furnace.

Note 2. A typical arrangement is shown in Appendix H.

1160-3. High Temperature Salt Bath Quench Tanks. Salt bath quench tanks that operate between 700°F and 1300°F shall utilize salts, or salt mixtures, that are chemically and physically stable at operating temperatures and are nonreactive to furnace atmospheres.

ARTICLE 1170. HAZARDS OF SALT BATHS

1170-1. General. The hazards that are inherent in the operation of molten salt bath furnaces can result in explosions or fires, or both. These explosions and fires can occur inside the salt bath furnace or may occur external to the furnace. Basic causes can be chemical or physical reactions and may occur in combination.

Since molten salts have high heating potential, low viscosities, and relatively little surface tension, even minor physical disturbances to the molten salt bath can result in spattering or ejection of the molten salt out of the furnace container. This ejection can become violent when liquids (water, oil, etc.) or reactive materials are allowed to penetrate the surface of the salt bath.

Nitrate salts can produce violent explosions because of chemical chain reactions when the nitrate salt is overheated. Overheating can occur because of a malfunction of the heating system controls, from a floating or "hung-up" work load, or from an operator processing error.

While this standard deals primarily with the protection and conservation of property, salt bath explosions (chemical or physical) can be expected to involve injury to personnel. As a result, it is recommended that all aspects of personnel safety be thoroughly investigated.


(a) Each molten salt bath operator shall be thoroughly trained, as specified in Chapter 1, Section 100-5. Only trained, qualified operators shall be permitted to operate or service molten salt bath furnaces.

(b) Each molten salt bath installation shall be furnished with a prominently displayed wall chart, which shall be supplied by the manufacturer. These charts shall contain all of the instructions and information specified in Chapter 1, Section 100-5, paragraphs (d) and (e). In addition, a clearly visible, and conspicuous, sign shall be posted at each salt bath furnace. This sign shall state which salt— or salt mixtures—are to be used, and what the maximum design operating temperature is.

(c) A complete operation and service manual shall be available at each salt bath furnace.

(d) Since emergency procedures are not utilized on a day-to-day basis, all emergency procedures shall be reviewed with the operators on a regularly scheduled basis.

(e) Because of the potential for spattering of the molten salts, it is recommended that consideration be given to the provision of heat resistant clothing, safety glasses or goggles, full face shields, heat resistant gloves, safety shoes, and all other personnel protection recommended by the equipment manufacturer, user standards, industrial safety standards, and local, state or federal requirements.


(a) All fixtures, tools, baskets, parts, etc., that are to be immersed in a molten salt bath must be thoroughly dry before immersion.
(b) If a crust forms on the surface of a molten salt bath because of salt freezing, no attempt shall be made to physically break the crust while the furnace is in operation. Instead, the temperature of the bath shall be gradually raised until the crust melts. Care must be taken so that the bath temperature does not exceed the maximum design operating temperature at any time.

(c) All salt bath furnace covers shall be in the closed position whenever the furnace is not in use or is being idled over prolonged periods.

(d) All public fire department and plant emergency organizations that will respond to fires and explosions within the plant shall be made familiar with the nature of the chemical salts being used, the location and operation of each molten salt bath furnace, and the extinguishing and control methods that can be safely employed.

6. Add a new Appendix G, as follows:

**APPENDIX G.**

MELTING POINTS OF COMMON CHEMICAL SALTS

<table>
<thead>
<tr>
<th>Salt</th>
<th>°F</th>
<th>°C</th>
</tr>
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<tbody>
<tr>
<td>Barium Chloride</td>
<td>1764</td>
<td>963</td>
</tr>
<tr>
<td>Barium Fluoride</td>
<td>2336</td>
<td>1280</td>
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<td>Boric Oxide (Anhydride)</td>
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<td>980</td>
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<td>Strontium Chloride</td>
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MELTING POINTS OF COMMON SALT MIXTURES
(Lowest Constant Melting Point Given)
(Proportions given are percentages by weight.)

<table>
<thead>
<tr>
<th>Mixture and Proportion</th>
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<th>°C</th>
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<tr>
<td>Lithium Nitrate 23.3, Sodium Nitrate 16.3, Potassium Nitrate 60.4</td>
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<tr>
<td>Potassium Hydroxide 80, Potassium Nitrate 15, Potassium Carbonate 5</td>
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<td>Potassium Nitrate 53, Sodium Nitrate 7, Sodium Nitrite 40</td>
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<td>Potassium Nitrate 56, Nitrite 44</td>
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<tr>
<td>Sodium Hydroxide 90, Sodium Nitrate 8, Sodium Carbonate 2</td>
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<td>294</td>
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<td>Calcium Fluoride 48, Magnesium Fluoride 52</td>
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</tr>
</tbody>
</table>

7. Add a new Appendix H (a figure showing Typical Arrangement to Prevent Salt Overheating and Carbon Precipitation) as follows:

**APPENDIX H.**

Typical arrangement to prevent salt overheating and carbon precipitation