ture) that can be developed in a contained deflagration of an optimum fuel–air mixture.

(2) Partially blocking the open end of the tube to simulate a heat exchanger, then filling the tube with a well-mixed stoichiometric fuel–air mixture (10 volumes of air to 1 volume of fuel for natural gas). The mixture is ignited at the closed end of the tube, and the pressure that develops is measured and compared to the maximum pressure (from literature) that can be developed in a contained deflagration of an optimum fuel–air mixture.

A.6.2.12.1 A burner is suitably ignited when combustion of the air–fuel mixture is established and stable at the discharge port(s) of the nozzle(s) or in the contiguous combustion tunnel.

N **A.6.2.12.3** Igniters not constructed with suitable electrical insulation and/or safety guards pose a severe electrocution hazard.

A.6.3 In the design and use of oil-fired units, the following factors should be considered.

(1) Unlike data on fuel gases, data on many important physical/chemical characteristics are not available for fuel oil, which, being a complex mixture of hydrocarbons, is relatively unpredictable.
(2) Fuel oil has to be vaporized prior to combustion. Heat generated by the combustion commonly is utilized for this purpose, and oil remains in the vapor phase as long as sufficient temperature is present. Under these conditions, oil vapor can be treated as fuel gas.
(3) Unlike fuel gas, oil vapor condenses into liquid when the temperature falls too low and revaporizes whenever the temperature rises to an indeterminate point. Therefore, oil in a cold furnace can lead to a hazardous condition, because, unlike fuel gas, it cannot be purged. Oil can vaporize (to become a gas) when, or because, the furnace operating temperature is reached.
(4) Unlike water, for example, there is no known relationship between temperature and vapor pressure for fuel oil. For purposes of comparison, a gallon of fuel oil is equivalent to 140 ft^3 (4.0 m^3) of natural gas; therefore, 1 oz (0.03 kg) of fuel oil equals approximately 1 ft^3 (0.03 m^3) of natural gas.

There are additional considerations beyond the scope of this standard that should be given to other combustible liquids not specified in Section 6.3.

Δ **A.6.3.2** For additional information, refer to NFPA 31.

A.6.3.3.4 A long circulating loop, consisting of a supply leg, a back-pressure regulating valve, and a return line back to the storage tank, is a means of reducing air entrainment.

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

A.6.3.3.6 The weight of fuel oil is always a consideration in vertical runs. When the oil is going up, pressure is lost. A gauge pressure of 100 psi (689 kPa) with a 100 ft (30.5 m) lift nets only a gauge pressure of 63 psi (434 kPa). When the oil is going down, pressure increases. A gauge pressure of 100 psi (689 kPa) with a 100 ft (30.5 m) drop nets a gauge pressure of 137 psi (945 kPa). This also occurs with fuel gas but usually is of no importance; however, it should never be overlooked with fuel oil.

A.6.3.4.1.6 Lubricated plug valves require lubrication with the proper lubricant to shut off tightly. The application and type of gas used can require frequent lubrication to maintain the ability of the valve to shut off tightly when needed.

A.6.3.4.3 Customarily, a filter or strainer is installed in the supply piping to protect the pump. However, that filter or strainer mesh usually is not sufficiently fine for burner and valve protection.

A.6.3.4.5 Under some conditions, pressure sensing on fuel oil lines downstream from feed pumps can lead to gauge failure when rapid pulsation exists. A failure of the gauge can result in fuel oil leakage. The gauge should be removed from service after initial burner startup or after periodic burner checks. An alternative approach would be to protect the gauge during service with a pressure snubber.

A.6.3.6.1 The atomizing medium can be steam, compressed air, low pressure air, air–gas mixture, fuel gas, or other gases. Atomization also can be mechanical (mechanical-atomizing tip or rotary cup).

A.6.3.8.1 A burner is suitably ignited when combustion of the air–fuel mixture is established and stable at the discharge port(s) of the nozzle(s) or in the contiguous combustion tunnel.

A.6.4 Oxy-fuel burners often are utilized in conjunction with arc melting furnaces to augment electric heating. Some of these burners utilize air as well. Stationary burners are attached to the furnace shell, cover, or both. Movable burners that normally are not attached to the furnace are suspended from structural members outside a furnace door. These burners are manipulated from the operating floor, and the oxygen and fuel are introduced into the furnace through long, concentric pipes.

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

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

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

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

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

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

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

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

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

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

Δ **A.6.4.3.2** CGA G-4.4, *Oxygen Pipeline and Piping Systems*, specifies maximum gas velocity criteria, materials of construction, installation methods, joining methods, metering methods, use of filters, and specifications for oxygen-compatible sealing materials, gasket materials, and thread sealants.

A.6.4.3.3 See CGA G-4.1, *Cleaning Equipment for Oxygen Service.*

A.6.4.3.4 This requirement is intended to prevent the contamination of surfaces that must be clean for oxygen service from the oil normally present in plant compressed air.

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A.6.4.3.10 See CGA G-4.4, *Industrial Practices for Gaseous Oxygen Transmission and Distribution Piping Systems.*

A.6.4.3.12 Commercial grade carbon steel pipe exhibits a marked reduction in impact strength when cooled to subzero temperatures. Consequently, it is vulnerable to impact fracture if located downstream from a liquid oxygen vaporizer running beyond its rated vaporization capacity or at very low ambient temperatures.

A.6.4.5.2 Diffusers commonly are used to disperse oxygen into an airstream, effecting rapid and complete mixing of the oxygen into the air. High-velocity impingement of oxygen is a potential fire hazard.

A.6.5.2(2) The following sample calculation is provided to demonstrate a method of determining the required exhaust flow moving through the collecting and venting system for unsupervised radiant tube burners such that the atmosphere in the collecting and venting system is less than 100 percent LFL equals noncombustible state requirement. The sample calculation is based on the following assumptions:

(1) The fuel is methane gas.
(2) All burners are not firing.
(3) All burner fuel valves are open.
(4) The main safety shutoff valve is open.

Overall, the sample calculation is based on the following conservative conditions:

(1) Use of the maximum fuel input rate for each burner
(2) Assumption that all burner fuel valves are open
(3) The design limit of <100% of LFL = noncombustible state
(4) Inclusion of the effects of elevated furnace temperature on the LFL
(5) The use of ambient air to dilute the products of combustions exiting the radiant tubes and being conveyed in the collecting and venting system

The effects of temperature on fuel gas LFL were obtained from Bureau of Mines Bulletin 680, "Investigation of Fire and Explosion Accidents in the Chemical, Mining, and Fuel-Related Industries — A Manual." Figure 34 in that bulletin, "Temperature effect on lower limits of flammability of 10 normal paraffins in air at atmospheric pressure," shows temperature (°C) versus combustibles (volume percent) and includes curves for methane, butane, and propane. It also includes a formula for computing LFL at elevated temperature. The formula, from Bureau of Mines Bulletin 627, "Flammability Characteristics of Combustible Gases and Vapors," is as follows:

[A.6.5.2(2)a]

$$L_T = L_{25}\left[1 - 0.000721\left(T - 25^\circ\text{C}\right)\right]$$

where:
L_T = LFL at the desired elevated temperature T (°C)
L_{25} = LFL at 25°C
T = Desired elevated temperature (°C)

Sample Problem — U.S. Customary Units

Objective. Calculate the exhaust flow moving through the collecting and venting system for unsupervised radiant tube burners so as to maintain the collecting and venting system atmosphere below 100 percent LFL (i.e., noncombustible state).

Given the following information:

(1) Furnace type: Continuous
(2) Fuel: Methane
(3) Number of burners: 10
(4) Maximum fuel input per burner: 600 scfh
(5) Furnace temperature: 1200°F

(6) Radiant tube exhaust temperature: 2000°F
(7) Collecting and venting system temperature: 500°F, or 260°C

Step 1. Determine LFL at 500°F (which will be the same as the LFL at 260°C) using the formula from above.

[A.6.5.2(2)b]

$$\begin{aligned} L_{500^\circ\mathrm{F}} &= L_{260^\circ\mathrm{C}} = L_{25^\circ\mathrm{C}}\left[1-0.000721\left(T-25^\circ\mathrm{C}\right)\right] \\ &= 5.3\left[1-0.000721\left(260^\circ\mathrm{C}-25^\circ\mathrm{C}\right)\right] \\ &= 4.4\% \text{ by volume} \end{aligned}$$

Step 2. Determine exhaust flow at 70°F to control fuel input to <100% LFL.

[A.6.5.2(2)c]

$$\begin{aligned} & Q_{\mathrm{EXH\ 70^\circ F\ \&\ 100\%\ LFL}} > \left(Q_{\mathrm{FUEL\ INPUT}}\right) \bullet \left[(1.0)\% \text{ exhaust volume}\right] \\ & / \begin{bmatrix} \left(LFL_{\mathrm{T\ FCE\ TEMP}}\right) \\ (1.0)\% \text{ fuel volume at } 100\% \text{ LFL} \end{bmatrix} \\ & > \left[(600 \text{ scfh/burner})(10 \text{ burners})(1 \text{ hr}/60 \text{ min})\right] \\ & \bullet\ (1.0)\ /\ (0.044)(1.0) > 2.272 \text{ scfm @ } 70^\circ\mathrm{F} \end{aligned}$$

Step 3. Determine the temperature correction factor for volume. This formula is similar to the temperature correction factor formula used in 11.6.5.1.

[A.6.5.2(2)d]

$$\begin{aligned} T_{\mathrm{CF\ VOL}} &= \left(T_{\mathrm{EXH\ TEMP}} + 460^\circ\mathrm{F}\right)/\left(70^\circ\mathrm{F}+460^\circ\mathrm{F}\right) \\ &= \left(500^\circ\mathrm{F}+460^\circ\mathrm{F}\right)/\left(70^\circ\mathrm{F}+460^\circ\mathrm{F}\right) \\ &= 1.81 \end{aligned}$$

Step 4. Determine exhaust flow at collection and venting system operating temperature to limit fuel input rate to 100% LFL at $T_{\mathrm{FCE\ TEMP}}$.

[A.6.5.2(2)e]

$$\begin{aligned} Q_{\mathrm{EXH\ 500^\circ F\ \&\ 100\%\ LFL}} &> Q_{\mathrm{EXH\ 70^\circ F\ \&\ 100\%\ LFL}}\left(T_{\mathrm{CF\ VOL}}\right) \\ &> \left(2272 \text{ cfm @ } 70^\circ\mathrm{F}\right)(1.81) \\ &> 4112 \text{ cfm @ } 500^\circ\mathrm{F} \end{aligned}$$

Conclusion. The calculated exhaust rate of >4112 scfm @ 500°F is required to keep the collecting and venting system <100% LFL at its operating temperature with all burners off and fuel gas flowing at the maximum input rate.

Sample Problem — SI Units

Objective. Calculate the exhaust flow moving through the collecting and venting system for unsupervised radiant tube burners so as to maintain the collecting and venting system atmosphere below 100% LFL (i.e., noncombustible state).

Given the following information:

(1) Oven type: Continuous
(2) Fuel: Methane
(3) Number of burners: 10
(4) Maximum fuel input per burner: 16.99 m^3/hr @ 21°C
(5) Furnace temperature: 649°C
(6) Radiant tube exhaust temperature: 1093°C
(7) Collecting and venting system temperature: 500°F (260°C)

Step 1. Determine LFL at 260°C using the formula from above:

[A.6.5.2(2)f]

$$\begin{aligned} L_{500^\circ\mathrm{F}} &= L_{260^\circ\mathrm{C}} = L_{25^\circ\mathrm{C}}\left[1-0.000721\left(T-25^\circ\mathrm{C}\right)\right] \\ &= 5.3\left[1-0.000721\left(260^\circ\mathrm{C}-25^\circ\mathrm{C}\right)\right] \\ &= 4.4\% \text{ by volume} \end{aligned}$$

Step 2. Determine exhaust airflow at 21°C to control fuel input to <100% LFL. This formula follows an approach similar to that given in Chapter 11.

[A.6.5.2(2)g]

$$\begin{aligned} & Q_{\mathrm{EXH\ 21^\circ C\ \&\ 25\%\ LFL}} > \left(Q_{\mathrm{FUEL\ INPUT}}\right) \bullet \left[(1.0)\% \text{ exhaust vol.}\right] \\ & /\ \left[\left(LFL_{\mathrm{T\ FCE\ TEMP}}\right)(1.0)\% \text{ fuel vol. at } 25\% \text{ LFL}\right] \\ & > \left[\left(16.99 \text{ m}^3\text{/hr @ } 21^\circ\mathrm{C}/\text{burner}\right)(10 \text{ burners})(1 \text{ hr}/60 \text{ min})\right] \\ & \bullet\ (1.0)/(0.044)(1.0) \\ & > 64.33 \text{ m}^3\text{/min @ } 21^\circ\mathrm{C} \end{aligned}$$

Step 3. Determine the temperature correction factor for volume. This formula is similar to the temperature correction factor formula used in Chapter 11.

[A.6.5.2(2)h]

$$\begin{aligned} T_{\mathrm{CF\ VOL}} &= \left(T_{\mathrm{EXH\ TEMP}} + 273^\circ\mathrm{C}\right)/\left(21^\circ\mathrm{C}+273^\circ\mathrm{C}\right) \\ &= \left(260^\circ\mathrm{C}+273^\circ\mathrm{C}\right)/\left(21^\circ\mathrm{C}+273^\circ\mathrm{C}\right) \\ &= 1.81 \end{aligned}$$

Step 4. Determine exhaust flow at oven operating temperature to limit fuel input rate to 100% LFL at $T_{\mathrm{FCE\ TEMP}}$. This formula follows an approach similar to that given in Chapter 11:

[A.6.5.2(2)i]

$$\begin{aligned} Q_{\mathrm{EXH\ 260^\circ C\ \&\ 100\%\ LFL}} &> Q_{\mathrm{EXH\ 21^\circ C\ 100\%\ LFL}}\left(T_{\mathrm{CF\ VOL}}\right) \\ &> \left(64.33 \text{ m}^3\text{/min @ } 21^\circ\mathrm{C}\right)(1.81) \\ &> 116.63 \text{ m}^3\text{/min @ } 260^\circ\mathrm{C} \end{aligned}$$

Conclusion. The calculated exhaust rate of >116.63 m^3 @ 260°C is required to keep the collecting and venting system <100% LFL at its operating temperature with all burners off and fuel gas flowing at the maximum input rate.

A.6.5.2(3) The designer and user are cautioned that hazard conditions can result in common exhaust systems even when the radiant tube burners connected to the common exhaust system are equipped with flame supervision.

A.6.6.2 Vacuum furnaces using induction, resistance, electron beam, plasma arc, or electric arc heating systems include an electric power supply with a high demand current. High voltage supply used for electron beam, plasma arc, or ion discharge furnace units can have unique safety considerations.

A.6.6.4.2.1 Transformers should be of the dry, high fire point type or the less flammable liquid type. Dry transformers should have a 270°F (150°C) rise insulation in compliance with Section 4.03 of NEMA TR 27, *Commercial, Institutional and Industrial Dry-Type Transformers.*

A.6.7 Fluid heating systems are used to heat lumber dry kilns, plywood veneer dryers, carpet ranges, textile ovens, and chemical reaction vessels. A fluid heating system typically consists of a central heat exchanger to heat the thermal fluid. Firing can be by conventional gas or oil burners. The hot gases pass through a heat exchanger to heat the thermal fluid indirectly. The heat exchanger can be a separate, stand-alone unit or an integral part of the heater. Conventional water-tube boilers have been used as heaters, with thermal fluid replacing the water.

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

A.6.7.1.1 Suitable relief valves should be provided where needed. Where relief valves are provided, they should be piped to a safe location. See design criteria in API STD 520 P1, *Sizing, Selection, and Installation of Pressure-Relieving Devices in Refineries, Part 1: Sizing and Selection,* and API RP 520 P2, *Sizing, Selection, and Installation of Pressure-Relieving Devices in Refineries, Part 2: Installation.*

A.6.7.1.3 If a combustible heat transfer fluid is used, consideration should be given to the use of automatic actuating fire-safe isolation valves. The actuating mechanism should operate even when it is exposed to high temperatures. Fireproofing of the mechanism to maintain operational integrity might be necessary.

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

A.7.1.1 Commissioning might be required again following modification, reactivation, or relocation of the furnace.

A.7.1.3 Typically, inspection and leak tests of furnace piping that conveys flammable liquids or flammable gases are performed at a pressure not less than their normal operating pressure using the test method detailed in NFPA 54.

A.7.1.4.1 The testing and verification of the burner management system logic should be completed by a competent person other than the system designer.

A.7.1.6 It is recommended that all system settings and parameters are documented for future maintenance and operational needs.

Δ **A.7.1.7** The evacuation/purging, charging, and confirmation of the fuel or flammable gas supply in the piping upstream of the equipment isolation valve is governed by other codes, standards, and recommended practices. One example is Section 8.3 of NFPA 54, which establishes requirements based upon the fuel gas pressure, pipe size, and pipe length. Careful consideration should be given to the potential hazards that can be created in the surrounding area for any fuel or flammable gas discharge.

In NFPA 54, the term *appliance shutoff valve* is analogous to the term *equipment isolation valve* in NFPA 86.

NFPA 54 does not address the use of nitrogen for an inert purge and its property as an asphyxiant, nor does it address how to monitor that nitrogen has displaced sufficient oxygen in the piping system prior to the introduction of flammable gas. In this regard, 7.3.5 of NFPA 56 is helpful in identifying the requirements for an oxygen detector and 7.2.2.3 is helpful for determining an adequate inert (oxygen depleted) condition.

Paragraphs 7.1.2.1 and 7.1.2.2 of NFPA 56 might also be helpful in engaging the involvement of the fuel gas supplier with the evacuation and charging procedure and implementation.

A.7.2.1 The training program might include one or more of the following components:

(1) Review of operating and maintenance information
(2) Periodic formal instruction
(3) Use of simulators
(4) Field training
(5) Other procedures
(6) Comprehension testing

The following training topics should be considered for inclusion when the training program is being developed:

(1) Process and equipment inspection testing
(2) Combustion of fuel–air mixtures
(3) Explosion hazards, including improper purge timing and purge flow and safety ventilation
(4) Sources of ignition, including auto-ignition (e.g., by incandescent surfaces)
(5) Functions of controls, safety devices, and maintenance of proper set points
(6) Handling of special atmospheres
(7) Handling of low-oxygen atmospheres
(8) Handling and processing of hazardous materials
(9) Confined space entry procedures
(10) Operating instructions (see 7.4.2)
(11) Lockout/tagout procedures
(12) Hazardous conditions resulting from interaction with surrounding processes
(13) Fire protection systems
(14) Molten material
(15) Quench systems

A.7.3.4 See Annex B, Annex C, Annex G, or Annex H, as appropriate.

A.7.3.8 Examples of different modes of operations are oil vs. gas vs. other fuel; dry-out/pre-heat; auto/manual; and normal/standby.

N **A.7.4.1** A safety device should be tested for proper function, or replaced, if exposed to conditions (e.g., pressure, temperature, corrosive gases) outside of manufacturer's specifications.

N **A.7.4.4.1** The following inspections should be performed:

(1) Ensure that the pressure connection is correct.
(2) Check for entrapped gas in liquid lines or entrapped liquid in gas lines.
(3) Check for leaks.

A.7.4.5 In cases where minimal operating states, such as safety ventilation, must be established to prevent a hazardous condition, it is recommended that the precision of the set point be confirmed. When precision is inadequate, the component should be either recalibrated or replaced. Frequency of this testing and calibration should be established based on the components' mean time between failures (MTBF) data and the component manufacturer's recommendations.

Δ **A.7.4.9** The following is an example of a leak test procedure for safety shutoff valves on direct gas-fired ovens with a self-piloted burner and intermittent pilot. With the oven burner(s) shut off, the main shutoff valve open, and the manual shutoff valve closed, the procedures are as follows:

(1) Place the tube in test connection 1, immersed just below the surface of a container of water.
(2) Open the test connection valve. If bubbles appear, the valve is leaking, and the manufacturer's instructions should be referenced for corrective action. Energize the auxiliary power supply to safety shutoff valve No. 1 and open that valve.
(3) Place the tube in test connection 2, immersed just below the surface of a container of water.
(4) Open the test connection valve. If bubbles appear, the valve is leaking. Reference the manufacturer's instructions for corrective action.

This procedure is predicated on the piping diagram shown in Figure A.7.4.9(a) and the wiring diagram shown in Figure A.7.4.9(b).

It is recognized that safety shutoff valves are not entirely leak free. Because valve seats can deteriorate over time, they require periodic leak testing. Many variables are associated with the valve seat leak testing process, including gas piping and valve size, gas pressure and specific gravity, size of the burner chamber, length of downtime, and the many leakage rates published by recognized laboratories and other organizations.

Leakage rates are published for new valves and vary by manufacturer and the individual listings to which the manufacturer subscribes. It is not expected that valves in service can be held to these published leakage rates, but rather that the leakage rates are comparable over a series of tests over time. Any significant deviation from the comparable leakage rates over time will indicate to the user that successive leakage tests can indicate unsafe conditions. These conditions should then be addressed by the user in a timely manner.

The location of the manual shutoff valve downstream of the safety shutoff valve affects the volume downstream of the safety shutoff valve and is an important factor in determining when to start counting bubbles during a safety shutoff valve seat leakage test. The greater the volume downstream of the safety shutoff valve, the longer it will take to fully charge the trapped volume in the pipe between the safety shutoff valve and the manual shutoff valve. This trapped volume needs to be fully charged before starting the leak test.

Care should be exercised when performing the safety shutoff valve seat leakage test, because flammable gases will be released into the local environment at some indeterminate pressure. Particular attention should be paid to lubricated plug valves used as manual shutoff valves to ensure that they have been properly serviced prior to the valve seat leakage test.

The publications listed in Annex M include examples, although not all inclusive, of acceptable leakage rate methodologies that the user can employ.

Figure A.7.4.9(a) through Figure A.7.4.9(c) show examples of gas piping and wiring diagrams for leak testing.

Example. The following example is predicated on the piping diagram shown in Figure A.7.4.9(a) and the wiring diagram shown in Figure A.7.4.9(b).

With the oven burner(s) shut off, the equipment isolation valve open, and the manual shutoff valve located downstream of the second safety shutoff valve closed, the procedures are as follows:

(1) Connect the tube to leak test valve No. 1.
(2) Bleed trapped gas by opening leak test valve No. 1.
(3) Immerse the tube in water as shown in Figure A.7.4.9(c). If bubbles appear, the valve is leaking. Reference the manufacturer's instructions for corrective action. Examples of acceptable leakage rates are given in Table A.7.4.9(a).
(4) Apply auxiliary power to safety shutoff valve No. 1. Close leak test valve No. 1. Connect the tube to leak test valve No. 2 and immerse it in water as shown in Figure A.7.4.9(c).
(5) Open leak test valve No. 2. If bubbles appear, the valve is leaking. Reference the manufacturer's instructions for corrective action. Examples of acceptable leakage rates are given in Table A.7.4.9(a).

$$L = \frac{|\Delta p| \times V_{test} \times 3600}{P_{atm} \times T_{test}} \qquad \textbf{[A.7.4.9]}$$

where:

L = leakage rate (cm^3/hr)
$|\Delta p|$ = absolute value of initial test pressure (mbar) — final test pressure (mbar)
V_{test} = total volume of the test (cm^3)
P_{atm} = atmospheric pressure (atmospheres)
T_{test} = test time (seconds)

Conversion factors

1 in. water col. = 2.44 mbar

1 psi = 27.7 in. water col.

1 atmosphere = 14.7 psi

This test method can be done by tapping into the following ports and performing the test method in Table A.7.4.9(b).

Other Methods for Leak Testing Safety Shutoff Valves.

Other methods for leak testing safety shutoff valves follow:

(1) Another method to leak test safety shutoff valves — and without energizing any of the valves — is bubble tightness testing. With leak test valve No. 1 upstream of V_1, leak test

valve No. 2 between V_1 and V_2, and leak test valve No. 3 downstream of V_2, proceed as follows:

(a) The procedure for leak testing of V_1 is as follows:

i. Ready a tube that connects to leak test valve No. 2 *[see Figure A.7.4.9(c) for tube dimensions]*.
ii. Ready a glass of water as shown in Figure A.7.4.9(c).
iii. Open leak test valve No. 2, and bleed any trapped gas.
iv. Immerse the tube on leak test valve No. 2 in water as shown in Figure A.7.4.9(c).
v. If bubbles appear, the valve is leaking. Reference the manufacturer's instructions for corrective action. Examples of acceptable leakage rates are given in Table A.7.4.9(a).
vi. Remove all tubes, and close the test valves.

(b) The procedure for leak testing of V_2 is as follows:

i. Ready a tube of sufficient length that will connect leak test valve No. 1 to leak test valve No. 2.
ii. Ready another tube that connects to leak test valve No. 3 *[see Figure A.7.4.9(c) for tube dimensions]*.
iii. Ready a glass of water as shown in Figure A.7.4.9(c).
iv. Install a tube of sufficient length that will connect leak test valve No. 1 to leak test valve No. 2 without crimping or kinking the tubing.
v. Install another tube that connects to leak test valve No. 3 *[see Figure A.7.4.9(c) for tube dimensions]*.
vi. Open leak test valve No. 2, and bleed any trapped gas.
vii. Close the manual shutoff valve downstream of V_2.
viii. Connect the tube to leak test valve No. 2.
ix. Open leak test valve No. 1, and immediately connect the tube on leak test valve No. 2 to leak test valve No. 1. This will change the volume between V_1 and V_2 with gas pressure.
x. Immerse the tube on leak test valve No. 3 in water as shown in Figure A.7.4.9(c).
xi. If bubbles appear, the valve is leaking. Reference the manufacturer's instructions for corrective action. Examples of acceptable leakage rates are given in Table A.7.4.9(a).

After any test method is complete, close the test valves, remove all tubing, and restore the system to its original pretest condition.

(2) A combination of pressure decay testing and bubble tightness testing can be done to leak test safety shutoff valves. Depending on the fuel gas train arrangement, the leak test valves and pressure port available, and the availability of manual valves on the fuel gas train, a pressure decay test on valve No. 2, followed by bubble tightness testing on valve No. 1, might be desirable.

N **A.7.4.10** Recommended checks in the field should include the following:

(1) Inspection of the physical condition
(2) Inspection for dirt, liquids, or other conditions that might prevent proper operation
(3) Inspection to determine that the point of termination is still vented to an approved location and that the vent line is protected from the entry of water and insects without restricting the flow capacity of the vent

A.7.4.11.2 Where a means is not provided to count the actual number of safety shutoff valve cycles, it becomes a maintenance responsibility to maintain an estimate of safety shutoff valve cycles so that the safety shutoff valve is replaced before it exceeds 90 percent of the life cycles established by the safety shutoff valve manufacturer.

A.7.4.13 Lubricated plug valves require lubrication with the proper lubricant in order to shut off tightly. The application and type of gas used can require frequent lubrication to maintain the ability of the valve to shut off tightly when needed.

A.7.4.14 Exercising the valve means that the valve is operated but not necessarily through the full range.

A.7.4.15 See CGA G-4.1, *Cleaning Equipment for Oxygen Service,* and CGA G-4.4, *Industrial Practices for Gaseous Oxygen Transmission and Distribution Piping Systems.*

A.7.4.16 The intent is to verify that the temperature indicator of the excess temperature controller is reading correctly.

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Δ Table A.7.4.9(a) Maximum Acceptable Leakage Rates for New Production Valves

NPT Nominal Size (in.)	DN Nominal Size (mm)	UL 429, ANSI Z21.21/CSA 6.5				FM Approval 7400				BS EN 161			
		ft^3/hr	mL/hr cc/hr	mL/min cc/min	Bubbles/ min	ft^3/hr	mL/hr cc/hr	mL/min cc/min	Bubbles/ min	ft^3/hr	mL/hr cc/hr	mL/min cc/min	Bubbles/ min
0.38	10	0.0083	235	3.92	26	0.014	400	6.7	44	0.0014	40	0.67	4
0.50	15	0.0083	235	3.92	26	0.014	400	6.7	44	0.0014	40	0.67	4
0.75	20	0.0083	235	3.92	26	0.014	400	6.7	44	0.0014	40	0.67	4
1.00	25	0.0083	235	3.92	26	0.014	400	6.7	44	0.0014	40	0.67	4
1.25	32	0.0083	235	3.92	26	0.014	400	6.7	44	0.0021	60	1.00	7
1.50	40	0.0124	353	5.88	39	0.014	400	6.7	44	0.0021	60	1.00	7
2.00	50	0.0166	470	7.83	52	0.014	400	6.7	44	0.0021	60	1.00	7
2.50	65	0.0207	588	9.79	65	0.014	400	6.7	44	0.0021	60	1.00	7
3.00	80	0.0249	705	11.75	78	0.014	400	6.7	44	0.0035	100	1.67	11
4.00	100	0.0332	940	15.67	104	0.014	400	6.7	44	0.0035	100	1.67	11
6.00	150	0.0498	1,410	23.50	157	0.014	400	6.7	44	0.0053	150	2.50	17
8.00	200	0.0664	1,880	31.33	209	0.014	400	6.7	44	0.0053	150	2.50	17

Δ Table A.7.4.9(b) Test Methods

Test Port Location	Test Method
A test port between both safety shutoff valves	Pressure decay on V_2 Pressure rise on V_1
A test port downstream of both safety shutoff valves	Pressure rise on V_1 and V_2 (requires manual shutoff valve downstream both safety shutoff valves and that it be leak tightness tested).
A test port upstream of both valves	Pressure decay on V_1 and V_2 (requires a leak tightness test on the upstream, manual isolation valve)

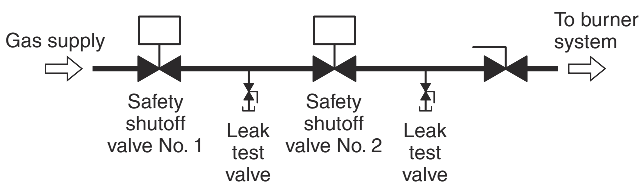

FIGURE A.7.4.9(a) Example of a Gas Piping Diagram for Leak Test.

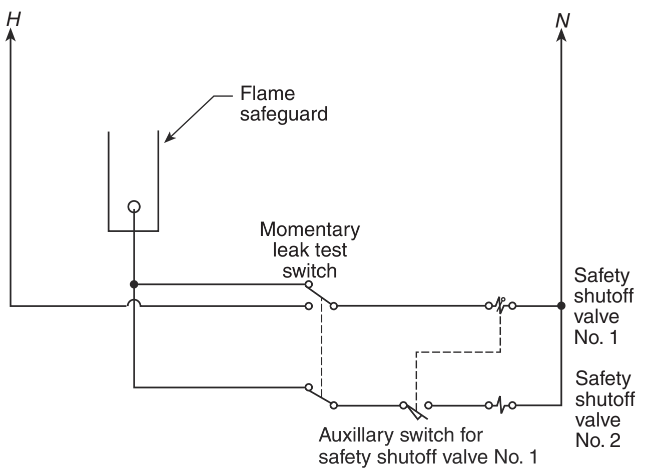

FIGURE A.7.4.9(b) Example of a Wiring Diagram for Leak Test.

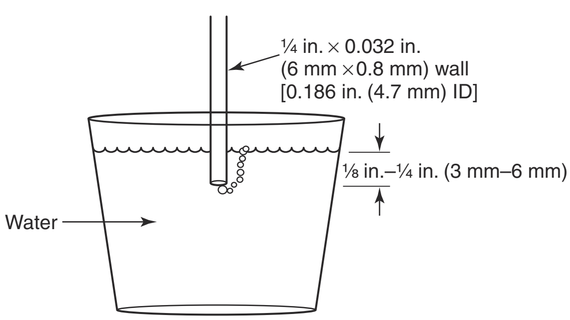

FIGURE A.7.4.9(c) Leak Test for a Safety Shutoff Valve.

A.7.6 Procedures for confined space entry can be found in 29 CFR 1910.146, "Permit-Required Confined Spaces," and ANSI Z117.1, *Safety Requirements for Confined Spaces.* Information on hazards of chemicals can be found in *NIOSH Pocket Guide to Chemical Hazards.*

A.8.1 For the protection of personnel and property, consideration should be given to the supervision and monitoring of conditions that could cause or that could lead to a potential hazard on any installation.

A.8.2.1 A flame rod is not required to be listed.

A.8.2.2 The AHJ should consider reliability and durability during the selection process when approving a device.

A.8.2.3 Consideration should be given to the effects of radiant heat on the safety devices. Radiant heat can cause safety devices to be exposed to temperatures greater than their ratings. Adequate insulation, heat shields, ventilation, or other measures should be used in cases where radiant heat causes safety devices to reach temperatures above their ratings.

A.8.2.8 The actions resulting from a manual emergency switch action take into account the individual system design and the hazards (e.g., mechanical, combustion system, special atmosphere, etc.) associated with changing the existing state to another state and initiates actions to cause the system to revert to a safe condition.

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

A.8.2.9 The manual intervention applies only to shutdowns of a safety function. Safety devices such as burner safeguard controllers can contain non-safety-related control sequences that can shut down the heating system due to a process control function, such as temperature control. Even though the action is within a safety device, the shutdown is not by a safety function.

N **A.8.2.9.1** This requirement permits the mushroom-style switch to act as a hardwired fuel stop by directly de-energizing the safety shutoff valves, or it can be used as an input to a safety programmable logic controller (PLC) when more complicated stop sequences are required. If the safety PLC is used to sequence the stop, dual contacts are required to dual safety inputs per the manufacturer's safety manual to ensure control reliability. If the single mushroom-style fuel stop eliminates all hazards associated with the furnace or machine, the mushroom-style button can display the yellow ring at its base and it can be labeled an emergency stop per NFPA 79.

N **A.8.2.9.2** Some furnaces include complex control of motion, hydraulics, and special atmospheres that cannot be immediately depowered without creating additional hazards when the fuel stop button is depressed. For that reason, the fuel stop button can be wired to a safety PLC so that a shutdown sequence is initiated to bring the furnace and ancillary equipment to a safe state. This controlled stop is consistent with a Category 1 or 2 stop function defined in NFPA 79.

It is the designer's responsibility to analyze each of the ancillary function's hazards against the appropriate standards to ensure the entire furnace or machine is brought to a safe state when commanded to do so.

A.8.2.10 A single pressure transmitter with associated logic can be used to provide both of the required low and high pressure interlock functions. A single flow transmitter with associated logic can be used to provide both of the required low and high flow interlock functions.

A.8.3 Furnace controls that meet the performance-based requirements of standards such as ANSI/ISA 84.00.01, *Application of Safety Instrumented Systems for the Process Industries*, and IEC 61511, *Functional Safety: Safety Instruments Systems for the Process Industry Sector*, can be considered equivalent. The determination of equivalency will involve complete conformance to the safety life cycle including risk analysis, safety integrity level selection, and safety integrity level verification, which should be submitted to the authority having jurisdiction.

A.8.3.1.4 This standard requires that the signal from the safety device be directly transmitted to the safety PLC input. Once the safety PLC processes the signal the resulting data can be used for any purpose.

A.8.3.1.5 The control circuit and its non-furnace-mounted or furnace-mounted control and safety components should be housed in a dusttight panel or cabinet, protected by partitions or secondary barriers, or separated by sufficient spacing from electrical controls employed in the higher voltage furnace power system. Related instruments might or might not be installed in the same control cabinet. The door providing access to this control enclosure might include means for mechanical interlock with the main disconnect device required in the furnace power supply circuit.

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

A.8.4 The PLC approach to a burner management system (BMS) is as follows:

(1) Interlocks relating to purge are done via PLC.
(2) The purge timer is implemented in the PLC.
(3) Interlocks relating to combustion air and gas pressure are done via PLC.
(4) Gas valves for pilots and burners directly connected to the PLC should conform to the requirements of 8.8.2.
(5) Operation of pilot and burner gas valves should be confirmed by the PLC.
(6) The PLC should perform the safe start check.
(7) The PLC should perform the trial of ignition per 8.5.2.
(8) The PLC should monitor all limits and all permissives and close the safety shutoff valves when appropriate.

Δ **A.8.4.2** Compliance with the manufacturer's safety manual would achieve actions such as, but not limited to, the PLC detecting the following:

(1) Failure to execute any program or task containing safety logic
(2) Failure to communicate with any safety I/O
(3) Changes in software set points of safety functions
(4) Failure of outputs related to safety functions
(5) Failure of timing related to safety functions

The burner management system logic, memory, and I/O should be characterized by the following:

(1) Independent from nonsafety logic and memory
(2) Protected from alteration by non-BMS logic or memory access
(3) Protected from alteration by unauthorized users

The requirements for SIL capability in 8.4.2 pertain only to the PLC and its I/O and not to the implementation of the burner management system (BMS). The purpose of the SIL capability requirement is to provide control reliability.

A SIL 3–capable PLC includes third-party certification, the actions in A.8.4.2(1) through A.8.4.2(5), and partitioning to separate safety logic from process logic. SIL 3–capable PLCs automate many of the complexities of designing a safety system, namely, the PLCs have separate safe and nonsafe program and memory areas and the safe areas can be locked with a signature. The inputs and outputs are monitored for stuck bits and loss of control. The firmware, application code, and timing are continually checked for faults. The outputs are internally redundant to ensure they will open even with a hardware failure. By contrast, SIL 2–capable PLCs require that many of these functions be implemented by the application code developer.

Codes have traditionally relied on independent third-party companies to test and approve safety devices suitable for use in the specific application. In the United States, companies such as FM and UL develop design standards and test safety equipment to those standards to ensure the devices will operate properly when used correctly. Safety shutoff valves, scanners, combustion safeguards, and pressure switches are some of the items that need to be approved for their intended service. Combustion systems have become far more complex, requiring greater computing power and greater flexibility, so the industry has turned to PLCs to address the increased complexity. Using a PLC as the BMS makes the PLC a safety device. Just like every other safety component, the PLC must be held to a minimum standard to ensure that it performs predictably and reliably and that its failure modes are well understood.

When assessing a PLC's ability to perform safety functions, the internationally recognized standard is IEC 61508, *Functional Safety of Electrical/Electronic/Programmable Electronic Safety-Related Systems*. IEC 61508 is a detailed quantitative guideline for designing and testing electronic safety systems. By following the directives in this standard, a piece of equipment can be certified by an independent body as capable of meeting a SIL.

The goal of IEC 61508 is to quantify the probability that the safety device will fail in an unsafe fashion when commanded to act. The term used is *probability of failure on demand* (PFD). The data required and the circuit and software expertise needed to get to the PFD can be quite overwhelming, but once calculated they are categorized as shown in Table A.8.4.2.

One can quickly see that the SIL number is a power of 10 change in PFD. The PFD for SIL 1 states that the probability of an unsafe failure in any year is 1 percent to 10 percent, and SIL 3 has the probability of an unsafe failure in any year of 0.01 percent to 0.1 percent. Stated otherwise, a SIL 1 system has the probability of an unsafe failure every 10 to 100 years, and a SIL 3 system has the probability of an unsafe failure, when demanded, once every 1,000 to 10,000 years.

When the PLC, sensor, or final element is certified to SIL 2, it carries the language "SIL 2–capable." This is done because the device in question is capable of performing at that level only when the manufacturer's safety manual has been followed, and the installation is correct per the manufacturer's safety manual.

Stipulating that the PLC and its associated I/O should be SIL 2–capable is only setting the floor for performance and helping to ensure that the hardware selected is suitable for use as a safety device — nothing else is implied.

Confusion might occur when users assume that because the hardware has been certified to IEC 61508 and is SIL-capable, the system must be designed according to IEC 61511 or ANSI/ISA-84.00.01, *Functional Safety: Safety Instrumented Systems for the Process Industry Sector*. That is not the intent. IEC 61511 is a performance-based standard that offers advice and guidance to quantify, analyze, and subsequently mitigate risks associated with hazards in safety instrumented systems (SIS). When following IEC 61511, each safety function (e.g., flame failure, emergency stop, high gas pressure) is analyzed. A systematic approach is taken to determine the severity of the failure of that safety function and then the appropriate SIL is assigned to that safety function. Once assigned, the appropriate sensors, logic solvers, and final elements are chosen so that three or more of them working together can achieve the required SIL. Placing a sensor in series with a logic solver in series with a final element lowers the SIL and increases the PFD, because their individual unsafe failures are cumulative. Therefore, it is possible to start with all SIL 2–capable components and end up with a SIL 1 safety function due to the cumulative failures of the individual devices.

Offered here is an extremely brief and simple overview of SIS; however, its proper application is extremely complicated and requires expertise. NFPA 87 requirements do not specify or imply that SIS must be implemented, nor that a safety function meet a specified SIL target.

An extremely effective risk-reducing technique is the use of layers of protection. Analyzing the layers is called *layer-of-protection-analysis* (LOPA). This technique applies safeties that are independent of other safeties and therefore cannot fall victim to common mode errors or failures. As an example, picture a storage tank being filled by a pump that is controlled by a level sensor. It is important to contain the liquid but also not overpressurize the tank. A layer of protection could be a pressure relief valve because that is independent of the pump control and the level sensor. Another layer could be a dike around the tank in case the pressure relief valve relieves or the tank fails. Again, the dike is completely independent of the other safeties and should not suffer failures that might attack the other safeties.

Common mode failures can be insidious. Think about this example of independent safeties and then think about a massive earthquake and tsunami hitting the dike, tanks, and controls — all destroyed by a common mode disturbance (e.g., Fukushima). This technique can be effective in providing independent layers of protection that can reduce the risk by a factor of 10 — or an entire SIL. Modern combustion systems take advantage of layers of protection, thus reducing the SIL of each individual safety function. Following are some examples: burner flows set up with mechanical locking devices to stay within the burner's stable operating range, gas pressures monitored for variances, combustion air pressure monitored, and the flame scanned.

ISA prepared IEC 61511 calculations and scenarios on boiler systems and did not identify any functions above SIL 2, with the majority being SIL 1 or less.

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N **A.8.4.2(5)(a)** This standard does require a physical manual emergency switch. In other words, the manual emergency switch cannot be an image on a user interface screen. The logic initiated by operating the physical manual emergency switch can be processed within the safety PLC.

A.8.5.1.1 Procedures for admitting and withdrawing flammable special processing atmospheres are covered in Chapter 13.

In some applications, purging with the furnace doors open could force combustible or indeterminate gases into the work area and the area surrounding the furnace, thereby creating a potential hazard to those areas. Purging with the doors closed ensures that furnace gases exit out of the furnace through the intended flue or exhaust system.

Igniting the furnace burners with the furnace doors open is an effective way to avoid containment during the ignition cycle.

Chambers that are indirect-fired or that use flammable special atmospheres should include in the operating instructions procedures that will provide a nonflammable chamber atmosphere prior to the heating of the chamber.

A chamber's atmosphere could become flammable if either of the following occur:

(1) The chamber's radiant tubes and their safety shutoff valves leak.
(2) The chamber's flammable special atmosphere gas safety shutoff valves leak.

In such cases where a chamber's atmosphere could become flammable, there is a possibility of an unsafe condition when the chamber is heated to autoignition temperatures.

The operating instructions should include procedures to ensure a nonflammable chamber atmosphere prior to the heating of the chamber. Procedures should include the following:

(1) Closure of all flammable gas isolation valves whenever the chamber is not in use
(2) Inert purging of the chamber prior to heating

Table A.8.4.2 SIL Level Calculated Values

Safety Integrity Level (SIL)	Probability of Failure on Demand (PFD)	Risk Reduction Factor (1/PFD)	Safety Availability (1 – PFD)
4	> 0.00001 to < 0.0001	> 10,000 to < 100,000	> 99.99 to < 99.999
3	> 0.0001 to < 0.001	> 1,000 to < 10,000	> 99.9 to < 99.99
2	> 0.001 to < 0.01	> 100 to < 1,000	> 99 to < 99.9
1	> 0.01 to < 0.1	< 10 to < 100	> 90 to < 99

(3) Testing for a nonflammable chamber atmosphere prior to heating

Δ **A.8.5.1.2** Equipment that is not explosion resistant, has no combustion air blower or exhaust blower, and relies on a natural draft to meet the purge requirements of this 8.5.1.2, should address the following conditions to ensure conformance:

(1) The natural draft flow rate can be affected by furnace doors, covers, and dampers. If the purge rate and timing depend on the setting of these devices, they should be interlocked to meet the requirements in 8.5.1.2.3(1), 8.5.1.2.4, and 8.5.1.2.5.
(2) The proof of minimum required purge flow should handle cases in which the natural draft flow rate can be affected by differences in pressure between the heating chamber and the inside or outside of the building.
(3) The specific gravity of the fuel must be considered in the design of the furnace purge path. For example, there should be no collection areas at the bottom of the heating chamber with a heavier-than-air fuel gas.
(4) If the purge flow rate is not known or is not directly proved, then the purge time to be set in the timer should be determined by measurement. The party commissioning the burner system is responsible for this measurement and the documentation. The measurement should be conducted at the time when the furnace is at normal ambient temperature and is at its lowest purge flow rate. Confirming calculations and measurement data should be available for review in accordance with Chapter 7. Combustible gas analyzers and oxygen analyzers should be used to measure the time from the end of unburned gas release for the trial-for-ignition period until the combustible concentration of the system volume is below 25 percent LFL. The test should be repeated immediately for a second release of gas and time delay to ensure that the measurement is still below 25 percent LFL. If it is not, then the purge time must be increased, with repeated purge and trial-for-ignition sequences, until there is no successive buildup of the combustible concentration.

N **A.8.5.1.2.1** Any system that is equipped with flue gas recirculation should be analyzed to evaluate the consequences if the flue gas recirculation system fails to be purged with fresh air or inert gas. The flue gas recirculation passageway should be prepurged with any associated damper(s) in the appropriate and proven position(s).

A.8.5.1.2.3(1) Equipment such as thermal oxidizers commonly process sources of contaminated air. Contaminated air is an indeterminate purge medium. Design of the preignition airflow interlocks should incorporate a means to prove a source of fresh air and also prove the isolation of contaminated air sources during preignition purge. In complex systems involving multiple sources where it is not always possible to shut down all indeterminate sources, providing a fresh air source and positive isolation from all contaminated sources is necessary to ensure proper preignition purging.

A.8.5.1.2.3(2) See Figure A.8.5.1.2.3(2).

N **A.8.5.1.2.4** A preignition airflow interlock can be provided by a variety of devices. Most commonly, a fixed orifice plate is used to generate a differential pressure at the desired (calculated) preignition airflow rate. A differential pressure switch, used in conjunction with the fixed orifice, provides the electrical permissive to verify the presence of air movement at the required flow rate.

Similarly, a differential pressure switch can be used as an airflow interlock by monitoring the differential pressure across a burner, either in single or multiburner systems. Single burner applications would include package burner assemblies. Burners provide a fixed airflow rate at a known pressure; therefore, a burner can be utilized as the flow element. Burner manufacturer's literature will typically provide the pressure-flow data for each specific burner size available. Valves that can restrict airflow below the minimum required preignition airflow rate should not be installed downstream of the pressure switch location. *(See Figure A.8.7.4.)* If the furnace internal pressure is operated above atmospheric pressure, the reference connection on the pressure switch should be connected to the furnace heating chamber in lieu of an atmospheric pressure reference.

A vane- or paddle-type flow switch is another example of a device that can be used to provide the required preignition airflow interlock. When utilizing a vane flow switch, the purge time should be calculated based on the minimum airflow for the particular vane size being used. Manufacturer's literature will typically specify the airflow range for each size vane available.

N **A.8.5.1.2.6** A system that has no valve(s) in the flow path(s) downstream of the air pressure proving interlock and a constant airflow is considered to have proven airflow.

If the furnace internal pressure is operated above atmospheric pressure, the reference connection on the pressure switch should be connected to the furnace heating chamber in lieu of an atmospheric pressure reference.

N **A.8.5.1.5.2** See A.8.5.1.9(3)(c) for an example method to calculate LFL.

A.8.5.1.9 The following sections of this standard continue to apply where the provisions of 8.5.1.9 are applied:

(1) The combustion air safety device requirements of Section 8.7.
(2) Each burner and pilot is supervised by a combustion safeguard in accordance with Section 8.10.
(3) Each burner system is equipped with safety shutoff valves in accordance with Section 8.8.

See Figure A.8.5.1.9.

A.8.5.1.9(2) Consideration should be given to the proximity of operating burners when the common combustion chamber exception to repeating purges is utilized. Accumulation of localized vapors or atmospheres is possible even with an operating burner in a chamber, depending on the size of the chamber, the number of burners, and the proximity of operating burners to the accumulation. In addition to proximity, burner design and exposure of the flame may also impact the ability of the operating burner to mitigate vapor or gaseous accumulations.

Δ **A.8.5.1.9(3)(c)** In accordance with 8.5.1.9(3)(c), fuels other than natural gas, butane, or propane might require additional consideration. These additional considerations would be addressed using Section 1.5. The concern with other fuel gases is the variability of fuel gas content being delivered over time. Specific examples include landfill gas and bio gas.