PROCESS FURNACES

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1.0 SCOPE

This data sheet discusses the fire and explosion hazards inherent in gas- or oil-fired furnaces, flammable special atmosphere furnaces and special atmosphere gas generators. Recommendations are made for the installation, maintenance and operation of these furnaces and gas generators, as related to fuel and special atmosphere fire and explosion hazards. Furnaces typically operate at temperatures greater than 800°F (427°C) as opposed to lower temperature ovens and dryers covered in Data Sheet 6-9, *Industrial Ovens and Dryers.*

Individual furnaces of less than 100 ft^3 (2.8 m^3) volume, based on external dimensions, will generally not need special attention.

Arrangement of the recommendations is in three sections:

1. Furnaces and burner systems
2. Special atmosphere furnace systems
3. Special atmosphere generator safeguards

References have been inserted, where appropriate, to data sheets concerning ancillary equipment and processes.

1.1 Changes

April 2012. Terminology related to ignitable liquids has been revised to provide increased clarity and consistency with regard to FM Global's loss prevention recommendations for ignitable liquid hazards.

2.0 LOSS PREVENTION RECOMMENDATIONS

2.1 General

2.1.1 Construction and Location

2.1.1.1 Location

2.1.1.1.1 Furnaces and special atmosphere generators preferably should be located in one-story, noncombustible buildings or on the ground floor of multi-story buildings. Basement locations should be avoided because of restricted ventilation and accessibility.

2.1.1.1.2 If it is necessary to locate furnaces and generators in upper stories with non-watertight floors, the floor should be waterproofed, curbed and drained under and around the units for at least 20 ft (6 m) in all directions.

2.1.1.1.3 Where hazardous equipment (such as quench tanks) is located near the furnace entrance, provide partitions of at least one-hour fire resistance rating to separate the equipment from combustible occupancies. If this is not practical, at least partial enclosures of noncombustible material should be installed around the heat treat or curing process. Sheet metal or noncombustible draft curtains, for example, will prevent the rapid spread of heat during a fire.

Provide curbs or ramps at doorways and watertight floors if located above the first story or over a basement. Drainage of the area around the quench tanks should be in accordance with Data Sheet 7-83, *Drainage Systems for Ignitable Liquids.* Heat vents in the roof are desirable. See Data Sheet 1-10, *Smoke and Heat Venting in Sprinklered Buildings*.

2.1.1.1.4 Keep any necessary storage of combustibles in process at least 10 ft (3 m) from the furnace or generator.

2.1.1.1.5 If sprinklers are needed above a furnace or generator, provide adequate clearance to permit proper installation. Provide clearance around heaters, fans and ducts to facilitate the use of hose streams and extinguishers.

2.1.1.2 Construction and Insulation

2.1.1.2.1 Use noncombustible construction throughout. Interiors should have smooth surfaces to permit easy and complete cleaning, with no inaccessible spaces. All racks, trays, spacers or containers placed inside furnaces should be entirely noncombustible and easily cleanable.

2.1.1.2.2 The furnaces or special atmosphere generators should be insulated, and the space above and below ventilated to keep temperatures at combustible building ceilings and floors below 160°F (70°C). The units located at floor level should be placed on noncombustible floors or supports. If the existing floor is combustible, remove the section under and around the furnace for at least 1 ft (300 mm) in all directions and replace it with a concrete floor slab.

An acceptable alternative is to provide sufficient insulation and air circulation to keep the surface temperature of the combustible floor below 160°F (70°C). Hollow tile, 8 in. (200 mm) thick, of the 4- or 6-cell type, is usually appropriate for this purpose. It is laid to form continuous air channels parallel with the short axis of the furnace. Free or forced air movement through these channels, depending on such factors as the operating temperature of the oven and the size of the floor area that it occupies, provides the required circulation.

2.1.1.2.3 In addition to the above safeguards, floors of furnaces that operate above 300°F (150°C) should be insulated to the same degree as the furnace walls and roof, and protected against physical damage. Insulation may consist, for example, of a smoothly troweled layer of insulating concrete, applied after the side walls are erected. Aggregates in the insulating concrete should be perlite, vermiculite, diatomaceous earth or the equivalent. The layer should be two in. thick for 300°F over heat, three in. for 400°F, etc., adding one in. for each 100°F increase (50 mm for 150°C, 80 mm for 205°C, etc., adding 25 mm for each 38°C increase).

2.1.1.2.4 Combustible floors immediately surrounding oil burners should be covered with noncombustible material. The same insulation provided under the furnace, or insulating concrete, may be used.

2.1.1.2.5 Outdoor furnaces require special construction to withstand windstorms. See Data Sheet 1-28, *Design Wind Loads*.

2.1.1.2.6 Outdoor furnaces may be susceptible to freezing damage. See Data Sheet 9-18/17-18, *Prevention of Freeze-ups*, for further guidance.

2.1.1.3 Ducts

2.1.1.3.1 Ducts should be insulated and the space around them ventilated to keep temperatures at combustible building members below 160°F (70°C). See Data Sheet 7-78, *Industrial Exhaust Systems*.

2.1.1.3.2 Avoid passing metal ducts or stacks through fire walls. If metal ducts must be passed through major fire walls, protect the duct opening in the wall with an automatic fire door with a fire rating equivalent to the wall. See Data Sheet 2-0, *Installation Guidelines for Automatic Sprinklers*. At locations other than major fire walls, automatic fire dampers may be used. See Data Sheet 1-45, *Air Conditioning and Ventilating Systems*, for possible designs. Ducts should not be passed through MFL fire walls.

2.1.1.3.3 Exposed ducts, susceptible to damage, should be protected by guards.

2.1.1.3.4 The clearance between metal ducts and stored combustible materials should be at least 18 in. (450 mm). Guards should be installed to assure this clearance.

2.1.1.4 Electrical

2.1.1.4.1 Install wiring in accordance with the National Electrical Code NFPA No. 70. Wiring insulation should be suitable for the maximum temperatures employed. For areas exposed to open flames and hot surfaces, refer to NFPA 497A, *Classification of Class I Hazardous (Classified Locations for Electrical Installations in Chemical Process Areas* [1986]).

2.1.1.4.2 Both ac and dc safety control circuits should be two-wire, one-side grounded and preferably not over 120 volts nominal. All safety control switching should be in the ungrounded conductor. Overcurrent protection should be provided as usual. In addition to circuit grounds, noncurrent carrying metal parts such as equipment enclosures and conduits should also be grounded.

Exception: In unusual cases where an ungrounded dc power supply cannot be avoided practically, all switching should be located in one conductor and ground fault detection provided.

2.1.2 Equipment and Processes

2.1.2.1 FM Approved Equipment

2.1.2.1.1 FM Approved equipment and devices, such as fuel safety shutoff valves, supervisory switches, combustion safeguards, etc., should be used when available and suitable for the application. *FM Approved* means equipment tested by FM Approvals and listed in the *Approval Guide*, a publication of FM Approvals.

2.1.2.1.2 Because of the size and arrangement of many installations, FM Approved equipment may not be available to meet specific installation arrangement or particular field operating conditions. In these cases, the equipment chosen should be from a reliable manufacturer and have a proven satisfactory field experience.

2.1.2.2 Manually Operated Shutoff Valves

2.1.2.2.1 Provide each furnace and special atmosphere generator with manually-operated, emergency shutoff valves for flammable gases and ignitable liquids. These valves should be prominently and accessibly located, preferably outside the furnace area.

2.1.2.3 Explosion Vents

2.1.2.3.1 Explosion vents are impractical on most industrial furnaces, kilns, atmosphere generators, and similar equipment due to their structure and heavy insulating and/or refractory materials. The explosion hazard from the passage of fuel into the furnace can be lessened by the use of FM Approved automatic closing safety shutoff valves and periodic testing of all valves and safety control devices.

2.1.2.4 Integral Quench Tanks and Furnaces

2.1.2.4.1 For protection of the furnace associated with or attached to the quench tank (shown in Fig. 1), consult the appropriate sections of this data sheet. For protection of the quench tank, see Data Sheet 7-41, *Heat Treating of Materials Using Oil Quenching and Molten Salt Baths*.

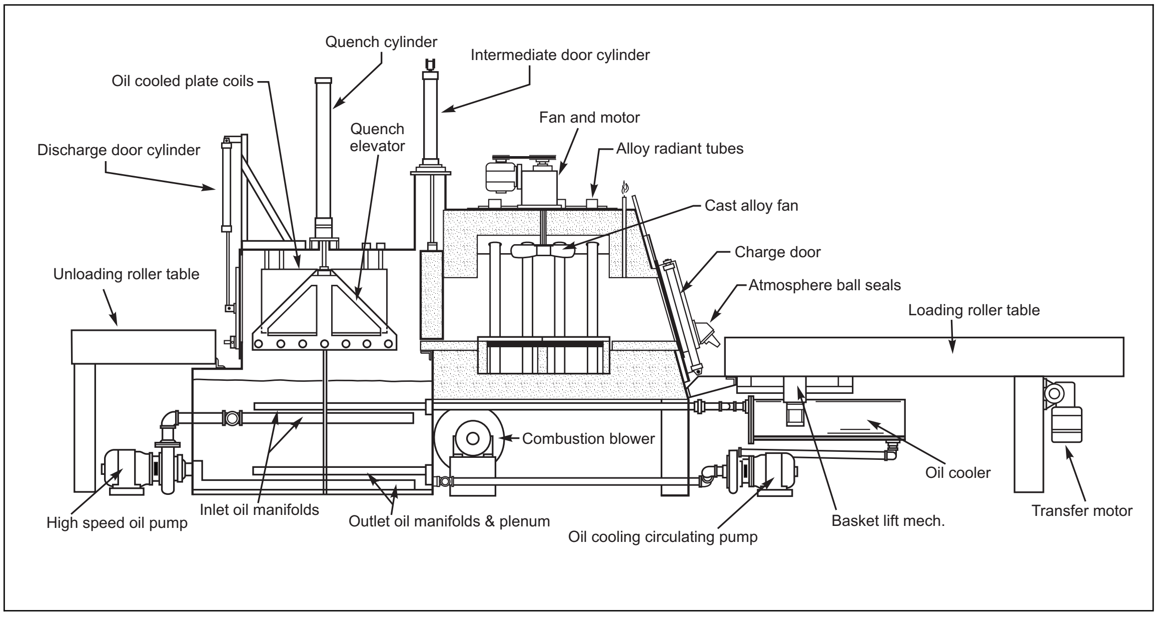


Fig. 1. Special atmosphere radiant-tube furnace with integral quench system.

2.1.2.5 Computer Controlled or Assisted Operations

2.1.2.5.1 Newer furnaces may be controlled or assisted by computers or programmable logic controllers. Size of computer facilities or process rooms may vary considerably. Information on protection of process control rooms can be found in Data Sheet 7-45, *Instrumentation and Control in Safety Applications*; on computer rooms in Data Sheet 5-32, *Electronic Data Processing Systems*.

2.1.2.6 Emergency Cooling

Provide a means of emergency cooling for furnaces that require a cooling medium for safe operation. The emergency cooling system can be powered by batteries or an internal combustion engine-driven generator, or a gravity-fed system can be used. The emergency cooling system should be automatically activated upon a loss of power or detection of abnormally high temperature.

2.1.2.7 Combustion Safeguards and Interlocks

2.1.2.7.1 Purge-Ventilation

2.1.2.7.1.1 A furnace purge should be done prior to burner light-off in order to remove possible accumulations of unburned fuel vapor and flammable gases.

2.1.2.7.1.2 When mechanical ventilation is provided, exhaust and recirculation fan operation should be proved by interlocks. The furnace should be purged for a specified period and regulated by a time delay to achieve at least four furnace volume air changes.

2.1.2.7.1.3 For natural draft furnaces, provide at least a five-minute purge period, regulated by time delay relays.

2.1.2.7.1.4 For both mechanical and natural draft ventilation systems, it may be necessary to remove furnace covers, open doors and have the fresh air inlet and exhaust dampers in the open position to allow sufficient purge air movement. When necessary, interlocks should be provided to prove the dampers and doors are in the correct position. Mechanical stops and cut-away dampers may also be used.

2.1.2.7.2 Purge-Relighting

2.1.2.7.2.1 In the event of an unscheduled shutdown from flame failure or the operation of various limit switches, a relight may be attempted without a timed repurge for the furnace or individual furnace zone, provided that either:

- Mechanical ventilation is specifically designed to prevent the accumulation of a hazardous atmosphere. Continued operation of the fans exhaust, combustion air and recirculation may maintain the purged condition.
- The furnace temperature is at least 1,400°F (760°C).

2.1.2.7.2.2 Where sufficient mechanical ventilation or furnace temperature is not available, provide a purge as outlined in Section 2.1.2.7.1, Purge Ventilation.

2.1.2.7.2.3 Operators should be carefully trained in relighting procedures after accidental flame failure. The procedure will vary with the individual furnace.

2.1.2.7.2.4 Burners having pilots should be re-ignited individually with the pilots in accordance with the normal lighting sequence. Do not attempt to ignite burners from the hot refractory.

2.1.2.7.3 Combustion Air Blower and Products of Combustion Ventilation Fan Interlocks

2.1.2.7.3.1 Adequate combustion air, which may be from the operation of combustion air blowers, exhaust or recirculation fans, should be provided for proper operation of the burners and mixers, and for subsequent combustion. Where natural draft and inspirating-type burners are used, interlocks may not be applicable.

2.1.2.7.3.2 Interlock each fan and blower to ensure that they are placed in operation before:

1. the fuel safety shutoff valves can be energized and opened, and

2. the electric ignition can be activated.

This also ensures that failure of any fan will automatically close the safety shutoff valves and deactivate the ignition system.

2.1.2.7.3.3 Fans and blowers should be multibelt-driven unless a direct coupling drive is used. Acceptable interlocking methods include:

- mounting a rotational switch on the fan's drive shaft and wiring it into the safety control circuit. The switch closes when the fan reaches the predetermined speed for adequate ventilation.

- wiring an extra contact of an overcurrent-protected starter for the fan motor into the safety control circuit.
- wiring a contact of a relay, whose coil is energized from the load side of an overcurrent-protected starter for the fan motor, into the safety control circuit.
- energizing the safety control circuit directly (or through a transformer) from the load side of an overcurrent-protected starter for the fan motor. *Caution*: The overcurrent protection of the starter should not exceed the conventional rating required for the fan motor alone.
- wiring an airflow switch into the safety control circuit.

Caution: This interlocking method alone is not acceptable for furnaces processing materials that give off condensable fumes or dust that can cause improper operation or the switch sticking in the unsafe position.

For combustion air blowers, there are other acceptable interlocks:

1. wiring a pressure-supervising switch into the safety control circuit.
2. on certain oil-fired burners, connecting a direct shaft from the combustion air fan to the fuel oil pump.

2.1.2.7.4 Fuel Pressure Interlocks

2.1.2.7.4.1 Provide interlocks for the fuel pressure; low and high gas pressure switches for gas burners; low oil pressure switches for oil burners; and, where applicable, the atomizing air or steam for oil burners. The acceptable interlocking methods include:

1. wiring a pressure supervising switch into the safety control circuit.
2. utilizing a combination electric and pressure-holding fuel safety shutoff valve.

2.1.2.7.5 Oil Preheating Equipment and Low Oil Temperature Interlocks

2.1.2.7.5.1 For oil burners using heavy (No. 5 and 6) oils, provide fuel-oil preheating equipment and piping to ensure that the oil temperature is high enough to bring the oil viscosity to the burner manufacturer's recommended value. Proper viscosity is necessary for good atomization to permit prompt ignition and stable firing. Some unusual climactic conditions may require that light oils (No. 1, 2, and 4) also be preheated.

2.1.2.7.5.2 Preheating may be omitted in certain oil burners that are designed to burn No. 5 fuel oil of specified viscosity. If there is any doubt about the No. 5 fuel oil meeting the specified viscosity, provide preheating facilities.

2.1.2.7.5.3 Provide oil temperature interlocks for heavy oil burners that require preheated oil. The interlocks should prevent lighting-off if the oil temperature is below that recommended by the burner manufacturer. Shut off all fuel (close oil safety shutoff valves) if oil is not at recommended temperature during firing.

2.1.2.7.6 Proved Low-Fire Start Interlock

2.1.2.7.6.1 Provide a low-fire start interlock for oil-fired furnaces that have pilots supervised by combustion safeguards and trial-for-ignition periods of more than 15 seconds. (Low firing rate does not exceed 33% of maximum rate.)

Other gas or oil burner systems may require driving to a low fire condition or using a slow opening safety shutoff valve (motorized or manual) to accomplish the smooth light-off condition.

2.1.2.7.7 Excess Temperature Interlock

2.1.2.7.7.1 When the burners have the capability of causing destructive furnace temperatures, provide an excess temperature limit switch. This device should be independent of the normal operating temperature control and arranged to shut off and lock out all fuel to the burners.

2.1.2.7.8 Indirect-Fired (Radiant-Tube) Furnaces

2.1.2.7.8.1 Certain types of radiant-tube burners (Fig. 2) are explosion resistant. Therefore, unless they are in poor condition and leaky, there is no fuel explosion hazard in the furnace. However, to protect against a discharge of unburned fuel into the furnace room or into the products-of-combustion exhaust duct system, the fuel supply and the combustion air should be interlocked. This interlock should be such that failure or dangerous reduction of either the fuel or combustion air pressure and dangerous excessive fuel gas pressure will immediately shut off and lock out all fuel supply to the burners. Direct-spark electric ignition in place of pilots is also acceptable for use on radiant-tube burners.

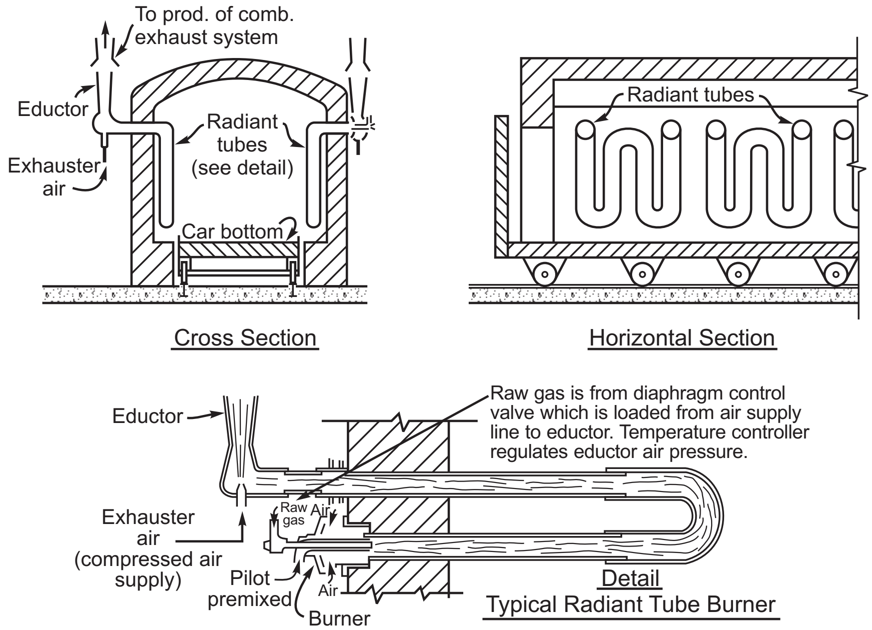


Fig. 2. Indirect internal-fired radiant-tube furnace (car-bottom type).

2.1.2.7.9 Individual Burner Valves and Observation Ports

2.1.2.7.9.1 At manually operated furnaces, provide a separate manually operated, quarter-turn valve for each burner whenever practical. Valve handles should be constructed of metal and display the ON and OFF positions at a glance.

2.1.2.7.9.2 Provide observation ports for each of the burners so that pilots, electric ignitors and flame-sensing elements of combustion safeguards can be easily observed.

Burners fueled through individual valves should have observation ports located so that the ignition sources can be positively observed *before* and *while* the operator opens the valve to light the burner.

2.1.2.7.10 FM Cock Safety Control System

2.1.2.7.10.1 Provide an FM Cock Safety Control System for multi-burner, gas-fired furnaces that are direct internal-fired and manually or semi-automatically lighted (Figs. 3 and 4).

On many systems, a separate cock for each burner is needed. However, permissible one valve can be used to control fuel to a few burners of a closely spaced group if the operator can observe the ignition sources and all burner flames while opening the valve.

For detailed information regarding FM Cock Systems, see Data Sheet 6-18, *FM Cock Safety-Control System*.

Exceptions:

1. At multi-burner, gas-fired furnaces that are direct internal-fired and manually or semi-automatically lighted, and where combustion safeguards are installed, an FM Cock System may be omitted.

2. An FM Cock System may be omitted for indirect-fired furnaces, provided their heating systems are explosion resistant, as with certain types of radiant tubes.

2.1.2.7.11 Safety Shutoff Valves

2.1.2.7.11.1 If an explosion resistant (including heat recovery system) radiant tube-type of heating system is used, a single safety shutoff valve is adequate. See Section 2.1.2.7.18 Exception (2).

For gas-fired burners, provide two safety shutoff valves for each pilot and burner system, a system being one or more burners operated as a unit. If the pilot or burner system exceeds 400,000 Btuh, provide proof-of-closure on one of the safety shutoff valves.

For a multi-burner system, if it is desired to shut off an individual burner for process reasons or upon loss of flame, provide a common main safety shutoff valve and individual safety shutoff valve with proof-of-closure at each burner. The burner safety shutoff valve should be proved closed after shutdown. If it is not proved closed, all safety shutoff valves in the system should close.

For oil-fired burners, provide a single safety shutoff valve; or provide two safety shutoff valves, one having proof-of-closure if the oil pressure is greater than 125 psi (862 kPA), the oil pump is independent of the burner, or the oil pump operates during gas-firing for combination oil/gas burners.

Exceptions:

1. If an oil burner using No. 4, or lighter, oil is provided with an individual control unit (i.e., pump, pressure regulators and shutoff valve) in the burner assembly, a safety shutoff valve, external to the burner assembly, may be omitted. The control unit should shut off fuel within five seconds following de-energization of the oil burner motor.

2. If an oil burner using No. 4, or lighter, fuel oil is provided with an individual motor-driven blower in the burner assembly and air supplied by this blower is used to aspirate and supply the fuel oil to the burner, a safety shutoff valve external to the burner assembly is not required. The system should shut off fuel within five seconds following de-energization of the combustion air blower motor.

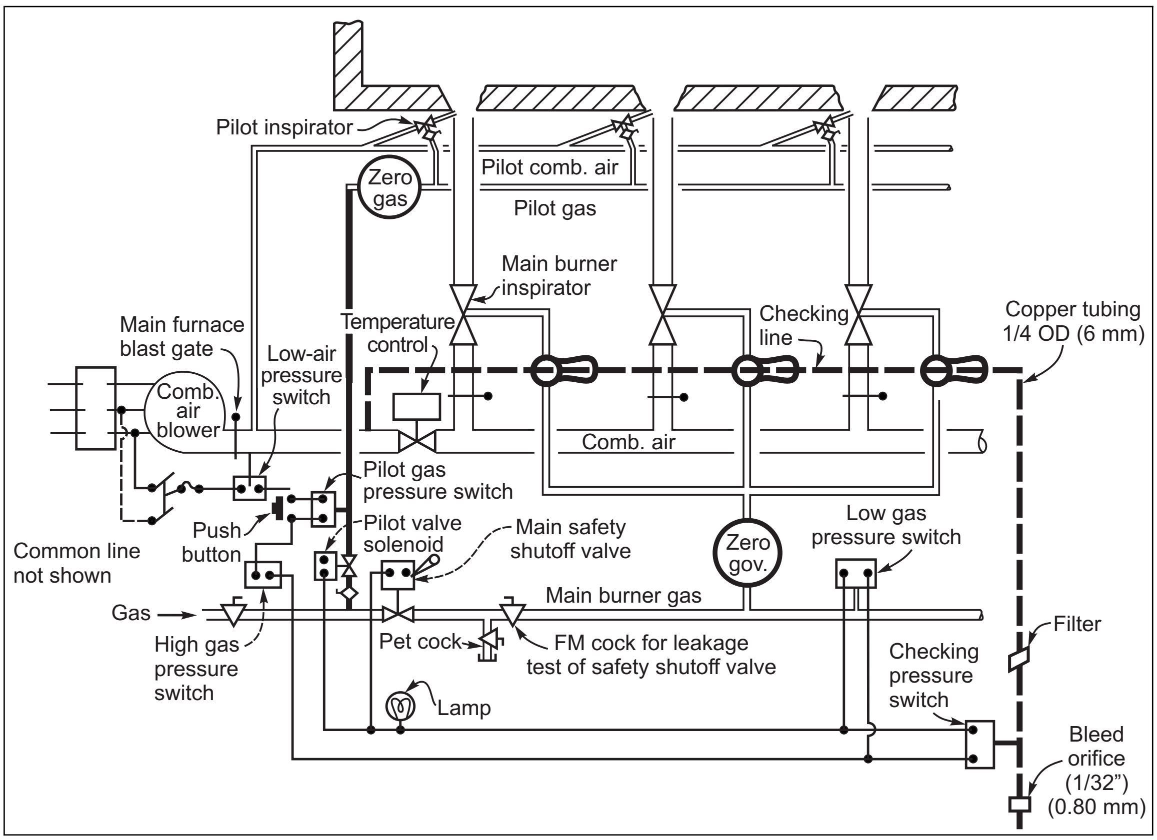


Fig. 3. Direct internal-fired multi-burner furnace.

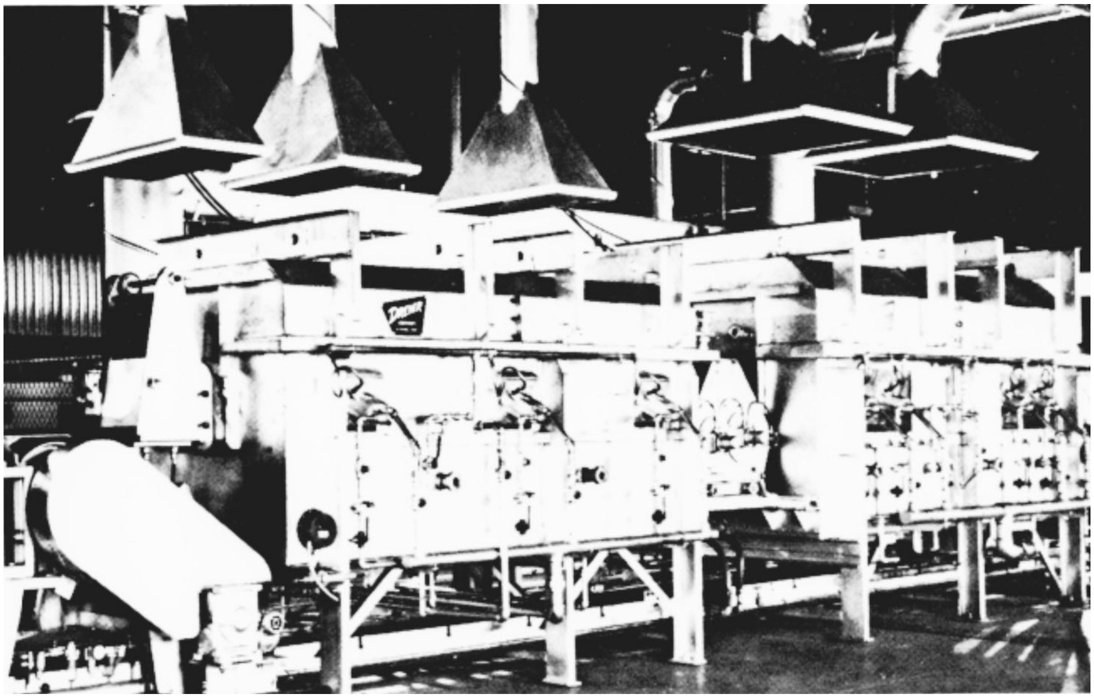


Fig. 4. Gas-fired continuous conveyor sintering furnace with FM Cock Safety Control System.

3. If an oil burner using No. 4, or lighter, fuel oil is of the aspirating type, using compressed air to suck oil from a reservoir, a fuel-oil safety shutoff valve cannot usually be practically applied. A gas safety shutoff valve should be installed in the aspirating air line to the burner to shut off fuel within five seconds following de-energization of the safety shutoff valve.

2.1.2.7.11.2 Provide permanent and ready means to periodically check the tightness of the main gas burner's safety shutoff valves. See Data Sheet 6-0/12-1, *Elements of Industrial Heating Equipment*.

2.1.2.7.12 Fuel-Air Mixers

2.1.2.7.12.1 Well-designed, fuel-air mixers are recommended to safeguard against the accumulation of flammable products of incomplete combustion. These products may form when burners are operated with too little air, and may become explosive when diluted with air in the furnace. Mixers should maintain a reasonably constant air-fuel ratio at sufficient pressure throughout turndown to ensure that safe combustion occurs independently of pressure conditions and secondary air within the furnace. In no case should the proportion of air supplied from the mixer fall below 85% of that needed for complete combustion.

2.1.2.7.12.2 A gas-air mixer with a blower or compressor is preferable to high pressure, atmospheric inspirators. Low pressure (below 1 psi [6.9 kPa, 0.069 bar]) atmospheric inspirators should not be used.

Exception for Gas-Fired External Heaters: For gas-fired, external heaters that have low pressure, atmospheric inspirator mixers may be accepted provided the chambers in the heaters into which the burners fire are continuously maintained sufficiently negative (at least -0.20 in. water column [-50 Pa, -0.5 mbar]) with respect to room air pressure by motor-driven fans to ensure proper amounts of fresh air for complete combustion (Figs. 5 and 6). Insufficient heater suction can result in a deficiency of secondary and flammable products of incomplete combustion.

2.1.2.7.12.3 The secondary air openings around such burners should not be restricted. When it is necessary to limit the amount of air drawn in through the burner box, the heater suction should be adjusted by positioning the system dampers.

2.1.2.7.12.4 A stop for the primary air shutter should be provided to prevent further closure. This is set after adjusting the amount of primary air to 50% of rated burner input at maximum heater suction without the occurrence of flashback.

2.1.2.7.12.5 A temperature-limit switch should be installed at the heater outlet, set to open at 300°F (150°C) above normal outlet temperature. With insufficient secondary air at the burner, the flame (possibly carrying flammable products of incomplete combustion) could lengthen beyond the burner block toward the heater outlet where free air in the recirculated atmosphere would support the combustion. The temperature-limit switch can detect this condition because temperatures on the outlet side of the heater would increase. The switch contact should be wired into the oven's safety control circuit so that when it opens, all fuel will be shut off. This limit switch is installed in addition to excess temperature-limit switches required for fire prevention.

2.1.2.7.13 Limiting Burner Turndown

2.1.2.7.13.1 Limit burner turndown at gas- and oil-burner systems so that stable flames and complete combustion are obtained at the low firing rate. Gas-fired furnaces, for example, may have burners utilizing zero governor inspirator mixers (Fig. 7) where the heater pressure is highly negative with respect to room pressure. Turndown should be limited so that the proportion of air at the mixer does not fall below 85% of the amount needed for complete combustion. Where the desired turndown would reduce the air below 85%, the diaphragm of the zero governor may be specially loaded by connecting the space in the housing above the diaphragm (which is normally vented outdoors or some other safe location) to the combustion heater chamber.

2.1.2.7.13.2 At gas-fired heaters that have burners using low pressure atmospheric-inspirator mixers, the burner should generally be installed only for constant firing at a fixed rate or on-off firing. It may be used for high-low or modulated firing, provided the low firing is 50% or more of rated burner input.

2.1.2.7.14 Combustion Air Piping Systems

A serious type of explosion sometimes occurs in the combustion air piping supplying the gas burners, rather than within the furnace or oven enclosure. While damage is usually not heavy, the destruction of the blower can seriously interrupt production, especially if it supplies several furnaces.

2.1.2.7.14.1 Interlock the combustion air and fuel supplies so that failure of either will shut off and lock out the fuel. Fuel gas usually leaks through zero governors if gas cocks have not been closed after blower shutdown. The mixture in the combustion air piping may be ignited by a flashback through the burner started by hot furnace refractory. Even with furnaces under 100 ft^3 (2.8 m^3) in volume, interlocking should be provided where two or more furnaces are supplied by one blower.

2.1.2.7.14.2 If the combustion air blower can aspirate fuel, interlocks should be provided to prevent blower operation during the purge period to minimize possible leakage from the aspirating effect. Provide one of the following:

1. a second safety shutoff valve.

2. an FM Cock System installed so that the cocks must be closed before and during pre-ventilation period.

3. a safety shutoff valve with proof-of-closure switch and valve seal over-travel proved to be closed before and during the pre-ventilation period.

2.1.2.7.15 Automatic Fire Checks and Safety Blowouts

2.1.2.7.15.1 Provide automatic fire checks and safety blowouts (sometimes called backfire preventers) in piping systems distributing flammable, air-gas mixtures from gas mixing machines to protect the piping and the machines in the event of explosion. Install in accordance with the following recommendations:

2.1.2.7.15.2 Automatic fire checks

2.1.2.7.15.2.1 Install the automatic fire checks upstream, as close as practical to the burner inlets. Be certain to follow the fire check manufacturer's instructions. Two basic methods are generally used: one, a separate fire check at each burner (Fig. 8); two, a separate fire check at each group of burners. The second method is generally more practical if a system consists of many closely-spaced burners.

2.1.2.7.15.3 Separate gas cock at each automatic fire check

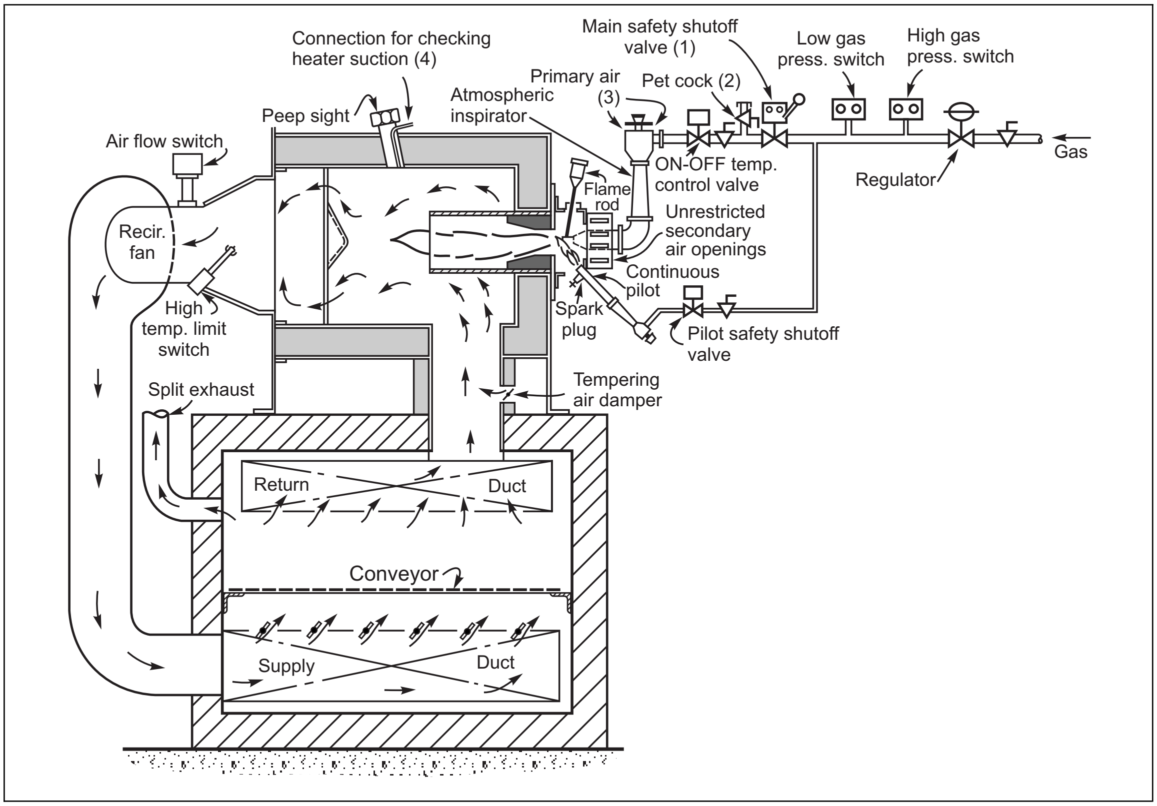


Fig. 5. Direct external-fired recirculating furnace. (Numbers in the diagram refer to the list under Fig. 6).

2.1.2.7.15.3.1 Provide a separate, manually operated gas cock at each automatic fire check to shut off the flow of the air-gas mixture after a flashback has occurred. Locate the cocks upstream, as close as practical to the inlets of the automatic fire checks.

Caution: Never reopen any of these cocks after a flashback has occurred until the fire check has cooled sufficiently to prevent re-ignition of the flammable mixture and it has been properly reset.

2.1.2.7.15.4 Safety blowout devices

2.1.2.7.15.4.1 Provide a safety blowout device or backfire preventer near the outlet of each gas-mixing machine where the piping is larger than 2-½-in. (65 mm) ips (or the equivalent) to protect the machine in the event an explosion passes through an automatic fire check. Follow the manufacturer's instructions in installing these devices. Acceptable safety blowouts are available from some manufacturers of gas-mixing machines.

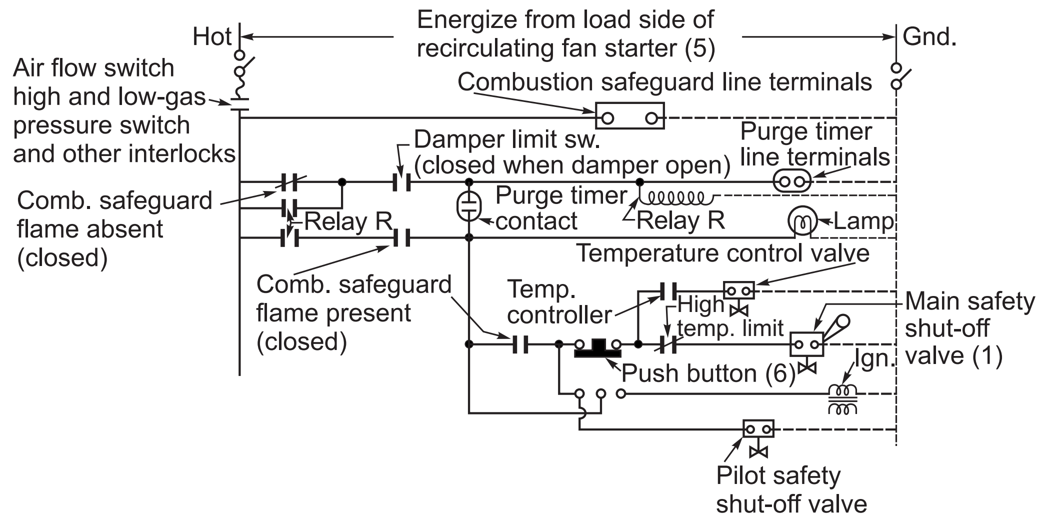
They incorporate the following components and design features:

1. flame arrestor

2. a blowout disk

3. provision for automatically shutting off the supply of air-gas mixture to the burners in the event of a flashback passing through an automatic fire check

Note: Automatic fire checks and safety blowouts cannot be installed in burner systems using blower mixers that do not permit valves to be located in piping downstream from their outlets.



1. Main safety shutoff valve. Manual-opening, automatic-closing Approved safety shutoff valve.
2. For leakage test of safety shutoff valve, located just downstream of safety shutoff.
3. Primary air shutter. This shutter on main burner should be “stopped” against further closure after adjustment at maximum heater suction so that flashback does not occur at 50 percent rated burner input.
4. Connection for checking heater suction, 1/8-in. (3 mm) IP connection. Minimum heater suction should not be less than -0.20 in. WC (-50 Pa) (-0.5 mbar).
5. Repeat of purge on flame failure. On furnaces having more than one combustion safeguard, repeat of purge on flame failure is not practical.
6. Start push button, located within sight of burner flame.

Fig. 6. Typical safety-control wiring, direct external-fired recirculating furnace.

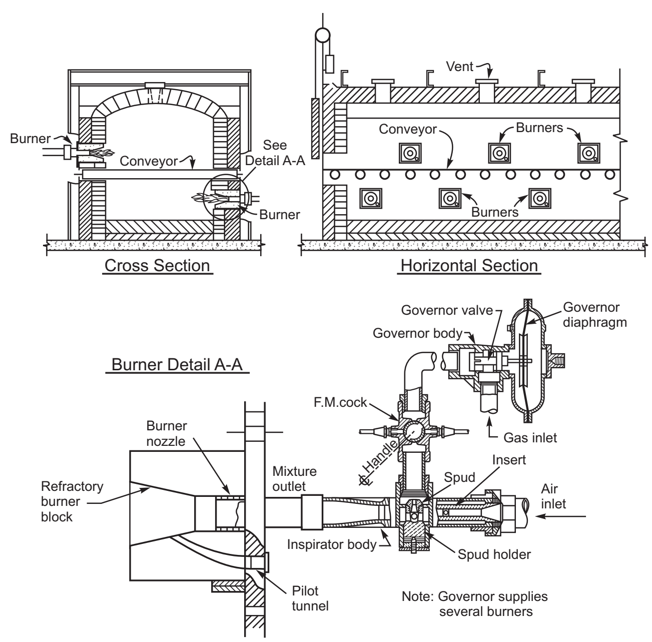


Fig. 7. Typical piping with zero governor, direct internal-fired multi-burner furnace.

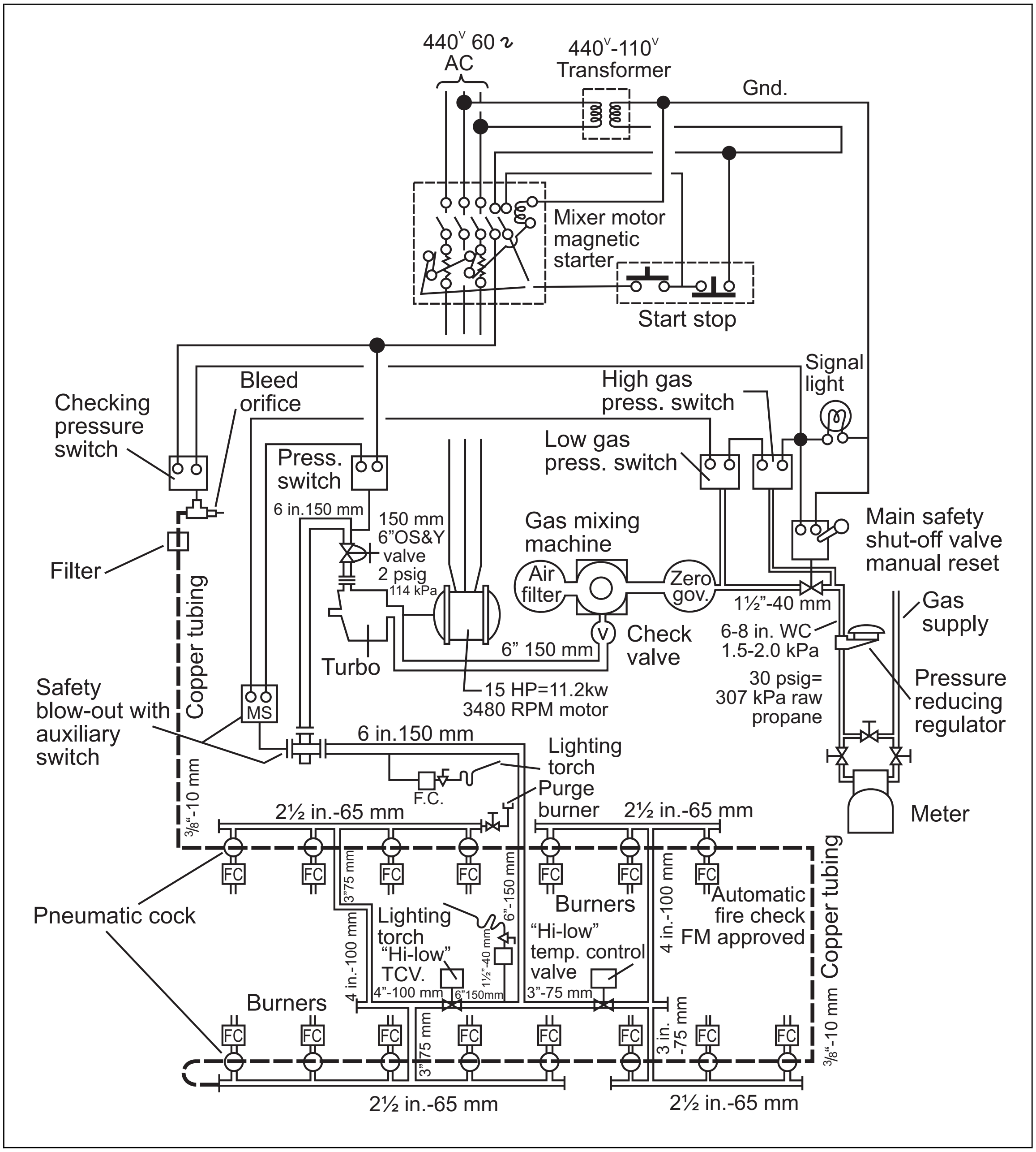


Fig. 8. Direct internal-fired multi-burner furnace supplied by a gas-mixing machine through automatic fire checks.

2.1.2.7.16 Pilots and Ignitors

2.1.2.7.16.1 The main burners of gas- and oil-fired furnaces should have premixed pilots with sufficiently large capacities to ensure ignition of the main burners. The pilot flame should be stable, even during substantial fluctuations in draft or back pressure. Each pilot-mounting assembly should be ruggedly designed and securely installed so that the pilot cannot be moved out of the position where it will furnish reliable ignition for the burner.

Exceptions:

1. External heaters may have pilots with low pressure (gas pressure below 1.0 psi [6.9 kPa, 0.069 bar]) atmospheric-inspirator mixers supplied with undiluted gas, provided that the heater chambers into which the pilots fire are continuously maintained sufficiently negative (at least -0.20 in. water column [-50 Pa, -0.5 mbar]) with respect to room-air pressure. To ensure this negative pressure, motor-driven fans should induce the proper amount of fresh air needed for complete combustion.

2. The main burners of gas- and oil-fired automatic and semi-automatic lighted furnaces do not require premixed pilots, but may be ignited by gas or oil-fired power burner pilots, or oil-soaked swabs, placed in proximity to the burner nozzles by the operators. Provide combustion safeguards wired into the safety control circuit as described under 2.1.2.7.19, Combustion Safeguards — Operation Sequencing, unless the furnaces are indirect-fired and have explosion-resistant heating systems.

3. Gas and light (No. 4 or lighter) oil-fired furnaces may have direct electric ignition if the burner’s design makes gas pilots impractical.

2.1.2.7.17 Direct Electric Ignition

2.1.2.7.17.1 At gas or light-oil burners, including multi-nozzle power burners and continuous-line burners having direct electric ignition, the trial-for-ignition periods should be automatically limited to 15 seconds and a low-fire start should be provided by use of a slow-opening valve or a modulating motor with interlock.

2.1.2.7.17.2 There should be no automatic recycling during firing, upon flame failure detection or operation of a burner system or exhaust interlock.

2.1.2.7.18 Combustion Safeguards

The term ‘‘combustion safeguard’’ means a safety control that responds directly to flame properties. This control senses the presence of flame and causes fuel to be shut off in the event of flame failure.

2.1.2.7.18.1 Install combustion safeguards at gas- and oil-fired furnaces to supervise burner flames. They will help prevent dangerous accumulations of unburned fuel and air mixtures in the furnace and/or heating systems upon accidental flame failure. Combustion safeguards should be FM Approved for use with the burners and ignition system installed.

2.1.2.7.18.2 Direct supervision of main burner flames alone is preferable to supervising the pilot and main burner flames simultaneously. With the former system, the main burner’s trial-for-ignition periods can be automatically limited.

2.1.2.7.18.3 It is acceptable to supervise the flames of two adjacent main burners with a single combustion safeguard if the burners will ignite one from the other at all firing rates.

2.1.2.7.18.4 Flame-sensing elements of combustion safeguards should be installed in accordance with the manufacturer’s instructions, and securely mounted so that their position, in respect to the pilot and main burner flames, will not change. They should be accessible for inspection and maintenance.

2.1.2.7.18.5 Combustion safeguards should be wired into safety control circuits as described under 2.1.2.7.19, Operation Sequencing.

Exceptions:

1. Unapproved combustion safeguards, such as safety pilots for gas burners and radiant heat-actuated flame failure protective devices for oil burners, may be installed in place of Approved combustion safeguards. This is provided that the maximum fuel input per burner does not exceed 150,000 Btu/hr (158 J/hr) for gas burners or 300,000 Btu/hr (317 J/hr) for oil burners and provided there is no possibility of a serious interruption to production because of a fuel explosion in the furnace.

2. Combustion safeguards may be omitted at indirect fired ovens if the heating systems are explosion resistant, as with certain types of radiant tubes (Fig. 2).

3. Combustion safeguards may be omitted at multi-gas burner, direct internal-fired gas furnaces if the number and type of burners make their application impractical (see 2.1.2.7.10, FM Cock System). Provide pilots or direct electric ignition for the burners that must be activated throughout firing periods to reduce the magnitude of fuel explosions in event of accidental flame failure.

4. For furnaces that operate at 1,400°F (760°C) and above, combustion safeguards can provide valuable protection during light-off and warm-up, when the temperature is below 1,400°F (760°C). While the temperature is 1,400°F (760°C) and above, because of the supervisory equipment design and maintenance aspects, it may be desirable to omit or discontinue the flame supervision of operating burners until the temperature returns to 1,400°F (760°C). When furnaces are operating above 1,400°F (760°C), the furnace surfaces generally provide reliable ignition sources for any flammable vapors and bases. Therefore, the formation of explosive mixtures is unlikely.

2.1.2.7.19 Operation Sequencing

Combustion safeguards should be wired into furnace safety control circuits, which should provide an acceptable sequence of operations during lighting-off, firing and relighting as follows:

2.1.2.7.19.1 At main gas and oil burners (including multi-nozzle power, continuous-line or radiant-cup burners, or line-burner sections attached consecutively to a common burner manifold and having reliable flame propagation characteristics from one to the other) having fixed gas or oil pilots, or portable torches, prove the existence of the pilot flames at locations where they will reliably ignite the main burners before permitting the main safety shutoff valves to be energized and opened.

2.1.2.7.19.2 The main burners should be immediately ignited by the pilots even when the pilots are reduced to the minimum flame that will hold the flame-sensing relay of the combustion safeguard in the energized (flame) position.

2.1.2.7.19.3 There should be no automatic recycling after accidental flame failure; all fuel should be shut off (safety shutoff valves tripped closed) and electric ignition deactivated.

2.1.2.7.19.4 It is acceptable at automatic-lighted ovens to provide automatic recycling. (Automatic recycling refers to one attempt to relight automatically after accidental flame failure during firing.)

2.1.2.7.19.5 For gas and light (No. 4 and less) oil pilots and main burners, automatically limit the trial-for-ignition (interrupted pilots) and flame-establishing periods to 15 seconds.

2.1.2.7.19.6 For heavy oil (No. 5 and 6), automatically limit the trial-for-ignition periods to 30 seconds and provide a low oil temperature interlock and a low fire start interlock.

2.1.2.7.19.7 A less desirable but acceptable alternative for gas or oil burners is to provide an intermittent pilot. This omits the main burner trial for ignition period. The main flame and pilot flame are supervised simultaneously by a single flame sensor. When the intermittent pilot is used; a) the trial-for-ignition periods are automatically limited to 15 seconds, b) the fuel pressure on the inlet side of the pilot burner(s) is supervised by a pressure switch, c) here is no automatic recycling after accidental flame failure, and d) a low oil temperature interlock and a low fire start interlock are provided for heavy oil.

2.1.2.7.19.8 For manually lighted gas burners, acceptable alternatives are to manually limit the trial-for-ignition periods to not more than five seconds, or omit this limitation, and supervise the main and pilot flames simultaneously during firing (except at multi-nozzle power and continuous-line burners).

2.1.2.7.19.9 For manually lighted oil burners, an acceptable alternative is to manually limit the trial-for-ignition periods to five seconds at light oil burners and 15 seconds at heavy oil burners.

2.1.2.7.20 Furnace Safety Control Circuits

2.1.2.7.20.1 Furnace safety control circuits may incorporate programmable logic controllers provided the intent of the safety logic and reliability expressed in this data sheet is fulfilled. The design should ensure that any malfunction of the programmable logic controller system or operating of an emergency stop function brings the controlled process and equipment to a failsafe condition or shutdown. See Data Sheet 7-45, *Instrumentation and Control in Safety Applications*.

2.1.3 Operation and Maintenance

2.1.3.1 Maintenance

2.1.3.1.1 Maintain all equipment in good condition. Safety controls require regular maintenance in accordance with the manufacturer's instructions, and should be inspected and tested periodically. Failure to do this may result not only in fire or explosion damage, but may also contribute to accidental shutdowns and loss of production.

2.1.3.1.2 Shutoff valves, interlocks and other safety controls may malfunction without the operator's knowledge, unless the faulty controls cause nuisance shutdowns. Operators concerned with production may even bypass a faulty safety control without reporting the trouble.

2.1.3.2 Inspection

2.1.3.2.1 Inspect and test safety controls periodically. The tests should be made by personnel who are familiar with the equipment and specific functions of the various controls. It is usually preferable to have maintenance personnel from the mechanical or electrical departments, rather than the regular furnace and generator operators, make inspections and tests. In larger plants, several people should be trained so that a competent inspector will always be available. The inspectors' reports should go to the management executive whose responsibilities include both safety and production. All arrangements should be made to ensure cooperation between operating and inspection personnel. In many cases, tests can be made during nonoperating periods. Upon completion of the tests, covers on all safety controls should be sealed to minimize tampering.

2.1.3.3 Inspection and Testing Report Forms

2.1.3.3.1 An inspection and test procedure should be drawn up for each furnace or generator. Tests should be recorded on a Safety Control Inspection and Testing Report which should list the controls to be tested, their condition and the proper sequence and methods of performing the tests. The report should be filled out by the inspector and turned over to a supervising official. The completed reports should be kept on file for review by the visiting fire protection consultants.

2.1.4 Training

2.1.4.1 Train operators in the proper operation of the furnace or generator, and in the specific functions of the various safety controls. Operating instructions should be posted near the furnace or kept available for ready reference at the supervisor's office.

2.1.4.2 Automatic safety controls furnish only partial protection against fire and explosion. The operators must carry out the vital precautions.

2.2 Oxygen-Enriched and Oxygen-Fuel Systems

2.2.1 Equipment and Processes

2.2.1.1 Bulk Storage, Cylinders and Piping

2.2.1.1.1 Bulk storage, cylinders and piping for oxygen supply should be arranged as described in Data Sheet 7-50, *Compressed Gases in Portable Cylinders and Bulk Storage*.

2.2.1.2 Shutoff Valves

2.2.1.2.1 Provide a readily accessible shutoff valve on the oxygen main supply in the event of equipment fires or other emergencies.

2.2.1.3 Back Flow of Oxygen

2.2.1.3.1 Prevent the back flow of oxygen into fuel and air lines, fuel into oxygen and air lines, and air into oxygen and fuel lines by providing check valves or appropriate valving and piping arrangements. Where it is impractical to provide such protection for large combustion air systems, eliminate oils, grease and combustibles.

2.2.1.4 Oxygen Pressure Regulator

2.2.1.4.1 Oxygen pressure regulator and/or flow control valves should be provided with operational limits to maintain the pressures and flows within the safe operating range of the system.

2.2.1.5 Vents and Piping

2.2.1.5.1 Vents from pressure relief valves and piping for oxygen and fuels should be arranged to prevent mixing of the oxygen and fuels.

2.2.1.6 Fuel-combustion Air System

2.2.1.6.1 Provide combustion safeguards, interlocks and valving for the fuel-combustion air system as recommended in Section 2.1.2.7 of this data sheet.

2.2.1.7 Safety Shutoff Valves

2.2.1.7.1 Provide safety shutoff valves for the oxygen and fuel supplies to the burners. These valves should close upon excessive high and low oxygen and fuel flows, flame failure, excessive high temperature, burner liquid coolant low flow and other safety interlock operations.

2.2.1.8 Oxygen-Enriched Systems

2.2.1.8.1 For oxygen-enriched systems, interlock the oxygen safety shutoff valve to prevent operation until the combustion air flow has been established.

2.2.1.9 Oxygen Flow Failure

2.2.1.9.1 For oxygen-enriched systems, upon oxygen flow failure, the fuel and burner operation may continue provided the combustion air is not interrupted and the system can maintain a safe fuel-air ratio.

2.3 Special Atmosphere Furnaces

2.3.1 Equipment and Processes

2.3.1.1 Furnaces with one or more zones operating at 1,400°F (760°C) and above during start-up and shutdown

As shown in Figures 9, 10, 11, 12 and 13. See Section 2.3.2.2 for operational sequences and procedures.

2.3.1.1.1 Provide safety shutoff valves for flammable gas and ignitable liquid atmosphere supplies, opened by operator action, with leak test facility for gas service.

Some furnaces operating below 1,400°F (760°C) after start-up, and supplied by nonflammable exothermic generated gas atmosphere for both purge and process, may not need safety shutoff valves.

2.3.1.1.2 Provide an interlock to prevent flammable atmosphere supply valves from opening until at least one furnace zone or all hot zones are 1,400°F (760°C) or above. Temperature monitoring devices should be provided for all heating chambers.

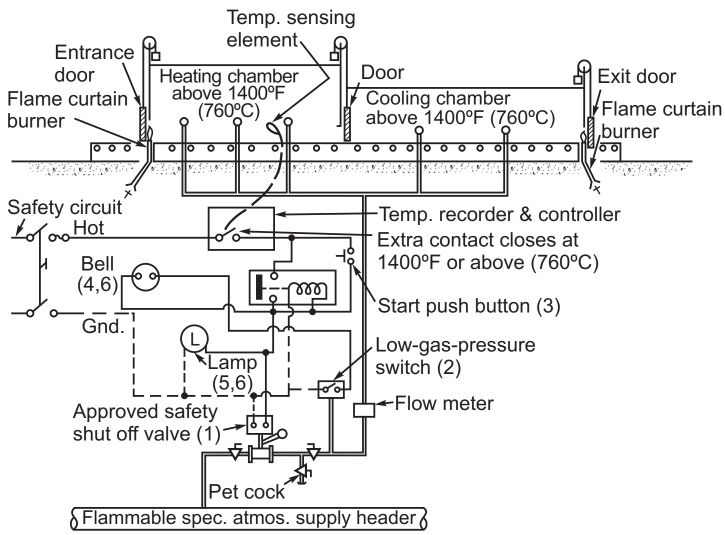
For furnaces with outer doors or covers, if the furnace temperature drops below 1,400°F (760°C) because of a cold charge, an interlock bypass may be provided and actuated after the atmosphere flow has been initiated. A low flow alarm should be provided. When furnaces are operated below 1,400°F (760°C) after start-up, the bypass will be necessary.

2.3.1.1.3 Provide low flow detection alarms for all atmosphere supplies. The minimum furnace temperature and atmosphere flow rate needed to maintain a positive furnace pressure should be determined.

2.3.1.1.4 Provide pilots at outer doors with flame supervision to prevent opening of the vestibule doors upon flame failure, shut off the curtain burner (if provided) fuel-gas safety shutoff valve, and actuate an alarm. Unsupervised pilots should be provided at effluent ports.

Flame supervision of the pilots may be omitted for furnaces without inner doors or covers operating above 1,400°F (760°C).

2.3.1.1.5 Provide for manually opening the outer doors upon power failure or loss of atmosphere gas flow.



Safety Shutoff Valve
1. Manual-opening, automatic-closing Approved gas safety shutoff valve. If special atmosphere is above 125ºF (52ºC), use valve suitable for elevated temperature.

Low-gas Pressure Switch
2. Low special-atmosphere flow to furnace will cause an alarm to sound.

Start Push Button
3. Locate near safety shutoff valve.

Alarm and Signal Lights (Need and arrangement depend on local conditions.)
4. Electric alarm bell.
5. Electric signal lamp.
6. An alarm is sounded by the bell, on failure of gas pressure in pipeline supplying flammable special-atmosphere gas to the furnace. In the event the main fuse in the safety circuit blows out or power to the safety circuit fails, no alarm is sounded but the signal light would be extinguished. For greater reliability, an arrangement like that outlined in Fig. 11 could be used.

Fig. 9. Method of interlocking flammable special atmosphere with furnace temperature. Several furnaces supplied by single atmosphere generator. All furnace chambers above 1400°F (760°C).

2.3.1.1.6 Provide relief vents, usually capped 5 in. to 8 in. (127mm to 203 mm) pipe openings, for vestibules and quench chambers, when applicable on furnaces with inner doors.

2.3.1.1.7 Provide accessible manual shutoff valves for the flammable gas and ignitable liquid atmosphere supplies.

2.3.1.1.8 Conduct an inert gas purge as follows:

1. Provide an inert purge system to automatically actuate upon loss of power and atmosphere gas flow.

2. Provide an alarm for abnormal inert purge gas flow rates and visual indication of adequate flow rate.

3. Provide a portable gas analyzer to verify purge.

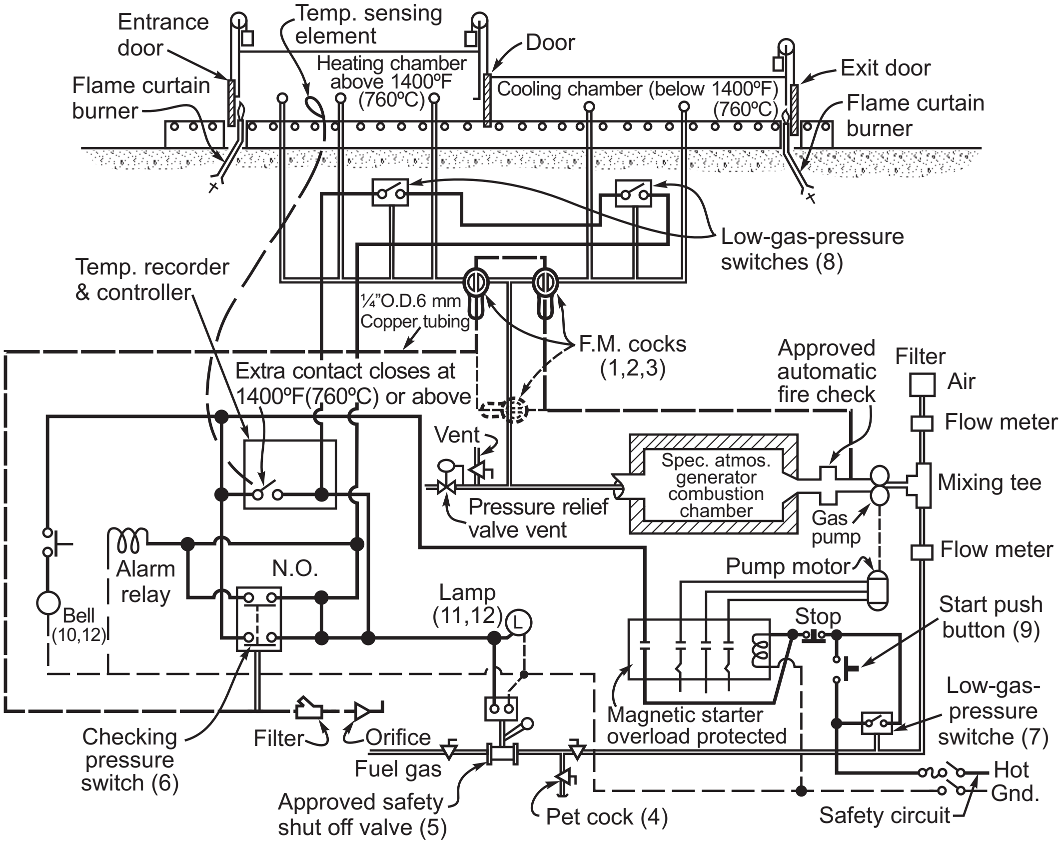
Inert gas purge is not required when a burn-in and burn-out procedure is permitted. The burn-in and burn-out procedure is not permitted for furnaces under 1,400°F (760°C) with outer doors or covers.

2.3.1.1.9 In addition to the other recommendations, where liquid atmosphere components (alcohol) are admitted in a liquid state:

1. the liquid atmosphere component should not be introduced until the chamber has been purged of air.

2. provide a second interlock to prevent the continued introduction of the liquid atmosphere component if the furnace falls below 800°F (427°C).

3. provide an falls gas purge, automatically actuated, if the temperature falls below 800°F (427°C).



Pneumatic FM Cocks

1. Do not open to cooling chamber until both chambers are completely purged.
2. Use special lubricant for high temperatures.
3. If all chambers of furnace operate above 1400ºF (760ºC), omit individual cocks in supply lines to heating and cooling chambers and provide single cock in main supply line.

Leak Test Connection

4. For leakage test of safety shutoff valve located downstream of safety shutoff.

Safety Shutoff Valve

5. Manual-opening, automatic-closing Approved gas safety shutoff valve.

Checking-pressure Switch

6. Pressure switch. When the normally open contact closes on FM cock closure, the normal closed contact opens, silencing alarm while generator is brought up to operating temperature.

Low-gas-pressure Switches

7. For protection against loss of raw gas flow to generator, followed by resumption of gas flow.
8. Low special atmosphere flow or low furnace temperature less than 1400ºF (760ºC) will cause an alarm to sound.

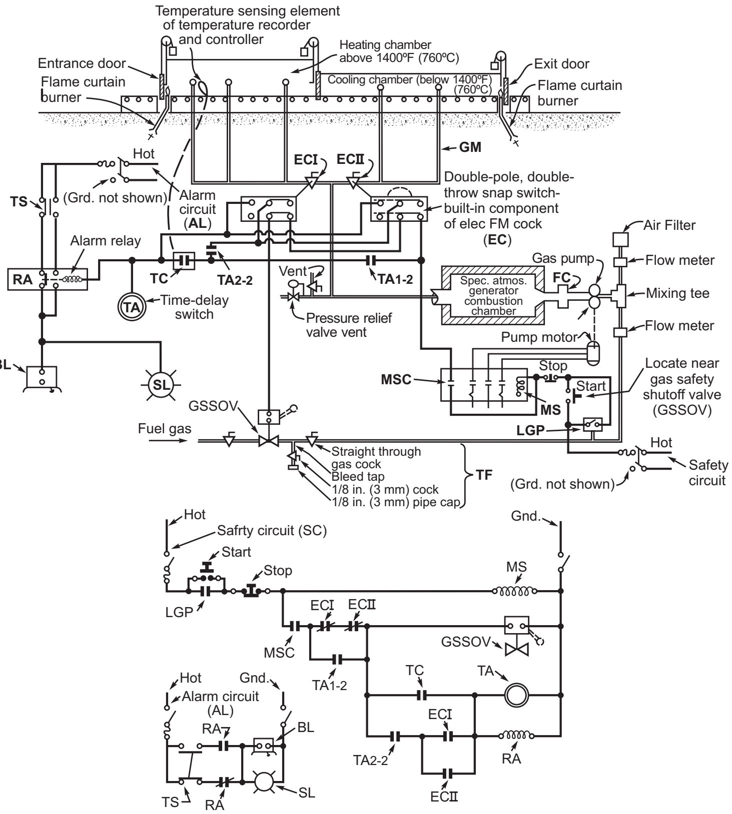
Start Push Button

9. Locate near safety shutoff valve.

Alarms and Signal Lights (Need and arrangement depend on local conditions.)

10. Electric alarm bell.
11. Electric signal lamp.
12. An alarm is sounded by the bell on failure of gas pressure in pipeline supplying fuel gas to the generator. In the event the main fuse in the safety circuit blows out or power to the safety circuit fails, no alarm is sounded but the signal light would be extinguished. For greater reliability, an arrangement like that outlined in Fig. 11 could be used.

Fig. 10. Method of interlocking flammable special atmosphere with furnace temperature, using pneumatic FM cocks. Furnace supplied by its own atmosphere generator.



Electric FM Cocks (EC)

Two Approved cocks (EC-1 and EC-11) are used at furnaces having a heating chamber and cooling chamber. When both chambers operate above 1400°F (760°C), omit these two cocks and install one ahead of the special atmosphere gas manifold (GM).

Each cock is a straight-through type with built-in switch having contacts that are closed when the cock is closed. The gas safety shutoff valves (GSSOV) can be opened only when both FM cocks are closed. Some cocks have extra switches with reversed operation.

Cocks require careful lubrication as directed by the manufacturer. Types having adjustable valve plugs need periodic adjustment, also as directed by the manufacturer.

Gas Safety Shutoff Valve (GSSOV)

The Approved safety shutoff valve may be either a manual-opening, automatic-closing or an automatic-opening, automatic-closing type.

A permanent means is provided for making periodic tightness tests (TF) of the safety shutoff valve.

Low-gas-pressure Limit Switch (LGP)

Approved low-pressure supervisory switch for fuel gas.

Auxiliary Switch (TC)

The auxiliary switch of the furnace temperature recorder and controller has contacts that are closed only when furnace temperature exceeds 1400°F (760°C).

Time-delay Switch (TA)

Approved delay-after-deenergizing type time-delay switch having a timing period between 2 and 30 sec. Contacts (TA 1-2 and TA 2-2) remain closed after the timer is deenergized until the end of the timing period. Used where atmosphere generators are kept in operation during furnace shutdowns. Where generators are shut down with the furnace, the time-delay switch is not needed and may be replaced by an auxiliary relay (RA).

Gas Pump Motor

The motor is equipped with a magnetic starter (MS) overload protected with an extra normally open built-in switch (MSC). Switch contacts are closed when the starter is energized.

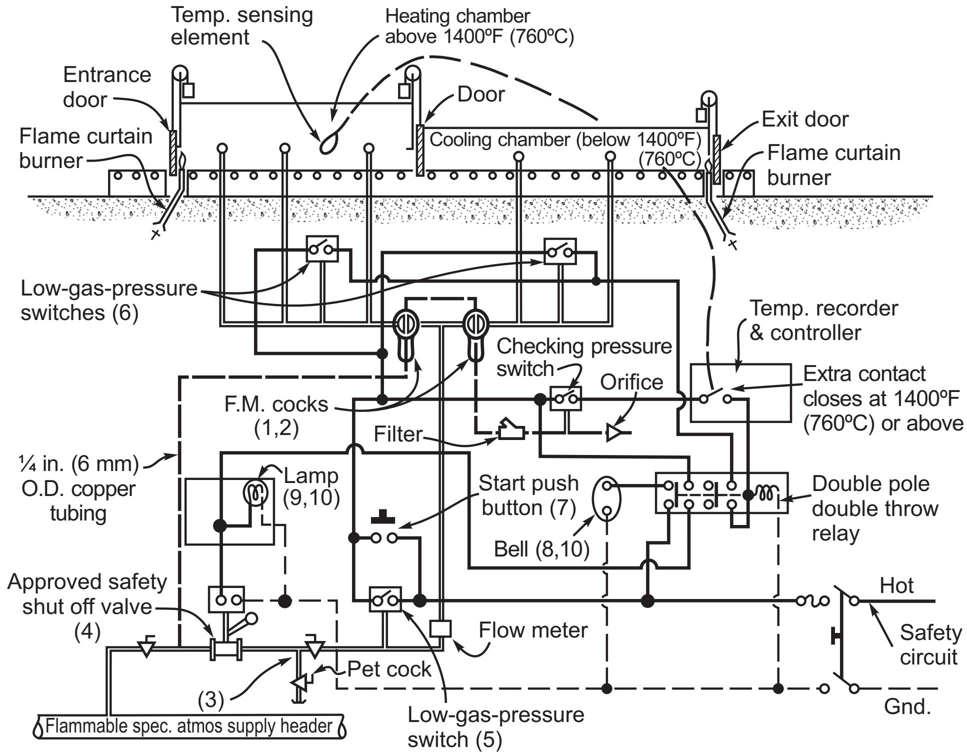
Automatic Fire Check (FC)

Approved automatic fire check located in fuel line ahead of special atmosphere generator.

Loss-of-atmosphere Alarm Circuit (Need and arrangement depend on local conditions.)

Components include alarm bell (BL), signal light (SL), alarm relay (RA), and alarm-silencing toggle switch (TS). An alarm is sounded by the bell, and the signal light is lighted on failure of gas pressure in pipeline supplying fuel gas to the generator or in the event the main fuse in the safety circuit blows out. If, for example, storage batteries were used to power this alarm circuit, an alarm would be sounded and the signal light lighted when power to the safety circuit failed.

Fig. 11. Method of interlocking flammable special atmosphere with furnace temperature, using electric FM cocks. Furnace supplied by its own generator.



Pneumatic FM Cocks

1. Do not open to cooling chamber until furnace is completely purged.
2. Use special lubricant for high temperature.
3. For leakage test of safety shutoff valve. Located just downstream of safety shutoff. Connected with ¼ in. (6 mm) OD copper tubing or pipe.

Safety Shutoff Valve

4. Manual-opening, automatic-closing approved gas safety shutoff valve. If special atmosphere is above 125ºF (52ºC), use valve suitable for elevated temperature.

Low-gas-pressure Switches

5. For protection against low gas pressure (special atmosphere).
6. For protection against loss of special atmosphere flow to furnace.

Start Push Button

7. Locate near safety shutoff valve.

Alarms and Signal Lights (Need and arrangement depend on local conditions.)

8. Electric alarm bell.
9. Electric signal lamp.
10. An alarm is sounded by the bell, and the signal light is extinguished on failure of gas pressure in pipeline supplying flammable special-atmosphere gas to furnace. In the event the main fuse in the safety circuit blows out or power to the safety circuit fails, no alarm is sounded but the signal light is extinguished. For greater reliability, an arrangement like that outlined in Fig. 11 could be used.

Fig. 12. Method of interlocking flammable special atmosphere with furnace temperature. Several furnaces supplied by single atmosphere generator. Cooling chamber below 1400°F (760°C).

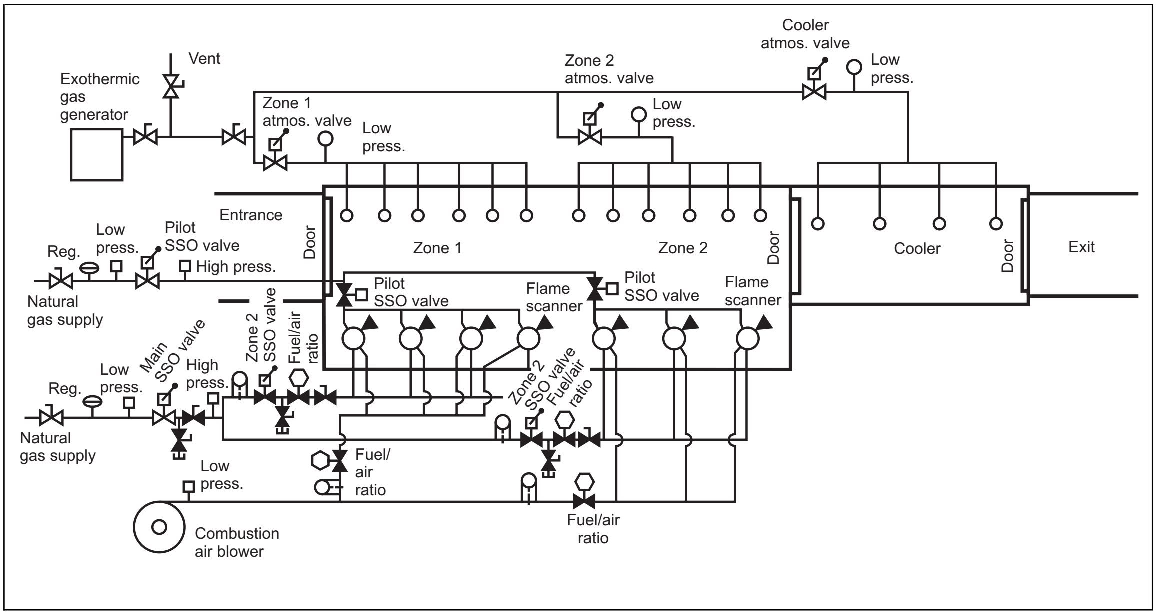


Fig. 13. Method of providing burner safeguards with flame supervision and interlocking flammable special atmosphere with furnace temperature-piping.

2.3.1.2 Furnaces with all zones below 1,400°F (760°C). (See 2.3.2.2 for operational sequences and procedures.)

2.3.1.2.1 Provide pilots at outer doors with flame supervision. Flame failure will prevent automatic opening of the outer doors, shut off the curtain-burner, fuel-gas safety shutoff valve and actuate an alarm.

2.3.1.2.2 Interlock the curtain-burner, fuel-gas safety shutoff valve to prevent opening until the special atmosphere supply has been established.

2.3.1.2.3 Provide safety shutoff valves for flammable gas and ignitable liquid atmosphere supplies. The valves should be operator-actuated to open, automatically shut on low primary special atmosphere flow, with an alarm and automatically shut on actuation of the inert gas purge. Exothermic-generated gas systems used for both purging and process may have the safety shutoff valve and low special atmosphere flow interlock omitted.

2.3.1.2.4 Provide an inert gas purge actuated upon low flow of the special atmosphere components when the temperature falls below 800°F (427°C).

2.3.1.2.5 The falls purge system should include operator alarm for abnormal purge flow rate, visual indication of purge flow rate and gas analyzing equipment to verify furnace purge.

2.3.1.2.6 Provide relief vents, usually capped five to eight in. pipe openings, for vestibules and quench chambers, when applicable, on furnaces with inner doors.

2.3.1.2.7 Provide accessible manual shutoff valves for the flammable gas and ignitable liquid atmosphere supplies.

2.3.1.2.8 When liquid is used as a primary special atmosphere, provide a low temperature interlock. The minimum temperature and related flow should be determined to maintain positive furnace pressures within the furnace.

2.3.1.3 Bell and Heating Cover Furnaces With and Without Retorts.

See Section 2.3.2.2 for operational sequences and procedures.

2.3.1.3.1 Provide safety shutoff valves for flammable atmosphere supplies interlocked to prevent opening until all zones are at 1,400°F (760°C) unless an inert gas or vacuum purge of the work chamber is provided. Temperature monitoring devices should be provided for all furnace zones (Figs. 14 and 15).

2.3.1.3.2 Provide atmosphere gas flow indication for visual determination of flow adequacy. Automatic work chamber pressure make-up may be required if operators are not available for monitoring pressure, flow rates and temperatures.

2.3.1.3.3 Provide visual and audible alarms for abnormal furnace temperature or atmosphere flows.

2.3.1.3.4 Provide pilots at effluent vents, supervised with combustion safeguards to set off an alarm on flame failure.

2.3.1.3.5 Provide accessible manual shutoff valves for the flammable atmosphere supplies.

2.3.1.3.6 Inert Purge System

1. Provide an alarm for abnormal purge flow rates, visual indication for inert purge flow adequacy, a portable gas analyzer to verify purge, and manual operation of the inert gas purge.

2. The inert gas control valve should open when the flammable special atmosphere line is closed (three-way valve).

2.3.1.3.7 Emergency Purge

1. Provide an emergency purge for operation in the event of power failure, loss of flammable special atmosphere or loss of normal inert purge gas.

2. The emergency purge gas should contain less than 1% oxygen.

3. The quantity of inert purge gas supplies should be sufficient for both normal and emergency inert gas demands.

2.3.1.3.8 Where bell cover furnace retorts are sealed by oil, do the following:

- Use Approved less hazardous fluids (Group 2 pure polyol ester). Otherwise, install automatic sprinklers outside the furnace, particularly over furnace pits where oil can accumulate.
- Perform fluid analysis 3 to 4 times per year.
- Install oil pump low flow alarm and return oil high temperature alarm. Oil temperature should never exceed 160°F (73°C). Set temperature alarm about 20% over normal. Normal temperature is typically about 110°F (43°C).
- Install an emergency automatic oil shutoff valve in the gravity feed line near the tank discharge. The means of actuation should be related to sensing a fire. There should also be a means for an operator to remotely operate this valve or there should be a separate remote-operated valve. Actuation of these valves or detection of fire should cause both a shutdown of the seal oil pump and the furnace.
- Refer to Data Sheet 7-32, *Ignitable Liquid Operations*, for recommendations on emergency shutoff and control valves (type, materials, means of actuation and location), piping systems and fire protection.

2.3.2 Operation and Maintenance

2.3.2.1 Inert Gas Purging

2.3.2.1.1 Where practical, thorough purging of the furnace with inert gas before starting, and after stopping, the flow of flammable special atmosphere is the preferred method of avoiding explosive flammable atmosphere air mixtures.

2.3.2.1.2 Inert gas purging should be provided for furnaces or sections of furnaces below the generally reliable gas-ignition temperature of 1,400°F (760°C).

2.3.2.1.3 The oxygen content of the inert gas-purged furnace atmosphere should be less than 1% (as proven by test) before introducing the flammable atmosphere.

2.3.2.1.4 The flammable content of the furnace atmosphere should be 50% or less of the lower explosive limit on removal of the flammable atmosphere.

2.3.2.1.5 Purge In Procedure (admitting special atmosphere)

The furnace may be heated before, after, or during the purge. Do not automatically cycle the furnace while purging.

1. Provide adequate inert purge gas.

2. Close all inner and outer doors (if provided).

3. Verify that all flammable gas and ignitable liquid atmosphere valves are closed, including fuel gas for flame curtains and pilots.

4. Purge with inert gas maintaining a positive pressure in all chambers.

5. The purge is complete when the oxygen content in all chambers is below 1%. Verify twice with an oxygen gas analyzer.

6. With the furnace at operating temperature, ignite the pilots at outer doors (if provided) and effluent lines and/or ports (if provided). The pilots should be able to remain ignited when exposed to the inert atmosphere.

7. With adequate special atmosphere supply, introduce the special atmosphere and immediately turn off the inert purge gas.

8. When flame appears at the outer doors (if provided) and ports, the special atmosphere introduction is complete.

9. Ignite flame curtains (if provided) at the outer doors (if provided).

10. Follow furnace manufacturer's instructions.

2.3.2.1.6 Purge Out Procedure (removing special atmosphere)

Do not automatically cycle the furnace while purging.

1. Provide adequate inert purge gas.

2. Close all inner and outer doors (if provided).

3. Purge with inert gas maintaining a positive pressure in all chambers.

4. Immediately shut off all special atmosphere gas and flame curtains.

5. The purge is complete when the ignitable content of the atmosphere in all chambers is below 50% of the lower explosive limit. Verify twice with a combustible gas analyzer.

6. Turn off door and effluent port pilots.

7. Turn off the inert gas supply to the furnace.

8. Follow furnace manufacturer's instructions.

2.3.2.2 Operational Sequences and Procedures

2.3.2.2.1 All Furnace Zones Above 1,400°F (760°C)

The following precautions apply to batch or continuous furnaces in which the flammable atmosphere is present only while the temperature of all zones is above 1,400°F (760°C). See Safeguards and Interlocks, Section 2.3.1.1 and Figure 9. Follow specific operating instructions from the furnace manufacturers.

2.3.2.2.1.1 Starting

1. When burning air out of the furnace, keep all sections above 1,400°F (760°C). Open the inner and outer doors, where provided. The operator should initiate the flow of special atmosphere and observe its ignition.

2. Any inner doors may be closed. Curtain burner pilots and atmosphere vent pilots should be ignited, where provided.

3. With all furnace sections above 1,400°F (760°C), mixtures of flammable atmosphere and air continue to be burned until flame appears at the slightly open entrance and exit doors when starting up. The furnace may be operated below 1,400°F (760°C) after flammable atmosphere introduction.

2.3.2.2.1.2 Shutting Down

1. When burning the flammable atmosphere out of the furnace, keep all sections above 1,400°F (760°C). Open the outer doors, shut off the flame curtain and open the inner door, where provided.

2. After shutting off the flow of flammable atmosphere, all flame should disappear from inside the furnace. The flammable atmosphere should be burned out.

2.3.2.2.2 Furnaces 1,400°F (760°C) and Above With Cooling Chamber Below 1,400°F (760°C)

The following precautions apply to those continuous process furnaces consisting of a heating chamber 1,400°F (760°C) or over and cooling chamber 1,400°F (760°C) and under (see Figures 10, 11, 12 and 13). See Safeguards and Interlocks, Section 2.3.1.1. Specific operating instructions from the furnace manufacturer should be followed.

2.3.2.2.2.1 Starting

1. When the heating chamber has reached at least 1,400°F (760°C), ignite the flame curtain pilots at the outer doors, open all doors, introduce special atmosphere only into the heating chamber, and observe ignition.

2. The heating chamber entrance door should be closed; the cooling chamber exit door and the doors between the chambers should be left wide open. Provide a reliable ignition source in the cooling chamber.

When a flame appears at the furnace door, it indicates that all air is burned out. The special atmosphere may now be admitted to the cooling chamber.

3. Flame curtains, if provided, should be ignited. Close outer doors. When flame appears at the outer doors, it indicates that all air is burned out. The furnace is now ready for production. The furnace may be operated below 1,400°F (760°C) after flammable atmosphere introduction.

2.3.2.2.2.2 Shutting Down

1. Keep the heating chamber above 1,400°F (760°C). Open the door wide between the heating and cooling chambers.

2. Make certain that a continuous and reliable ignition source is present at both heating chamber entrance and cooling chamber exit doors. Example: a flame curtain, flame curtain pilot or portable torch with flame extending slightly above the hearth threshold (i.e., too high flame tends to exclude fresh air).

3. Open the exit door of the cooling chamber and the entrance door of the heating chamber.

4. Shut off the flow of special atmosphere to all inlets to heating and cooling chambers. Watch the flame, formed by the mixture of air with the flammable atmosphere, burn backward throughout the cooling and heating chambers, a procedure which takes only a few minutes. Both chambers are now being air filled. Pilots and/or flame curtains may be extinguished, and the heaters may be shut off.

2.3.2.2.3 All Furnace Zones Below 1,400°F (760°C)

The following precautions apply to batch-type oven furnaces below 1,400°F (760°C) and to continuous furnaces with heating and cooling chambers below 1,400°F (760°C) while the flammable atmosphere is present. See Safeguards and Interlocks, Section 2.3.1.2. Specific operating instructions from the furnace manufacturer should be followed.

2.3.2.2.3.1 Starting

1. Purge the furnace chambers with an inert gas after closing the furnace chamber doors; cooling chamber doors should be open. Continue to regulate the inert gas flow in order to maintain a positive furnace pressure, and analyze the atmosphere in the furnace chamber. The chamber should be purged to less than 1% oxygen (O_2) by volume.

2. Provide continuous, reliable ignition sources, such as flame curtains and pilots, at all furnace and vestibule doors and effluent ports.

3. Start the flow of flammable atmosphere and then shut off the inert gas supply. When the flammable atmosphere burns at the furnace doors and outlets, the vestibule doors may be closed.

4. The flammable atmosphere flow should be regulated to maintain a positive furnace pressure at all operating temperatures.

2.3.2.2.3.2 Shutting Down

1. Make certain reliable ignition sources are at the furnace chamber doors and that the flammable atmosphere from the furnace is ignited.

2. With all doors closed, start the inert gas purge of all chambers, maintaining a positive furnace pressure. Shut off all flammable atmosphere supply valves.

3. Analyze the atmosphere in all chambers. When the total flammable content is below 50% of the lower explosive limit, shut off the inert gas supply and open the furnace doors.

4. The pilots may be turned off. Suitable personnel safety precautions should be observed regarding the inert atmosphere.

2.3.2.2.4 Bell Cover and Similar Furnaces

The following precautions apply to batch-type furnaces, such as bell cover (Fig. 14 & 15), box cover, car and elevator furnaces. Flammable atmosphere gas should not be introduced into a furnace unless an inert gas or vacuum purge has been completed of the work chamber, or the work chamber is at least 1,400°F (760°C). See Safeguards and Interlocks, Section 2.3.1.3.

2.3.2.2.4.1 Inert Gas or Vacuum Purge-Preferred Method

2.3.2.2.4.1.1 Starting

Inert gas purge for sealed inner bell. Use a similar procedure where only a cover is used without an inner bell.

1. After the work load has been positioned, inspect the fan blade clearance. Make sure that the fan diffuser fixture and work supports are properly positioned. The inner bell (retort) should be positioned over the work and sealed to the base. Ignite the effluent pilots and start any circulation fans. Follow manufacturer's instructions.

2. Start and regulate the inert gas flow into the inner bell. After five volume changes have been passed through the bubble or seal pot, check the atmosphere leaving the inner bell. When the atmosphere tests twice below 1% oxygen (O_2) by volume of the inert gas, the purge is considered complete. The inert gas system should be interlocked so that when the control valve in the inert gas line is open, the flammable atmosphere line is closed and vice versa.

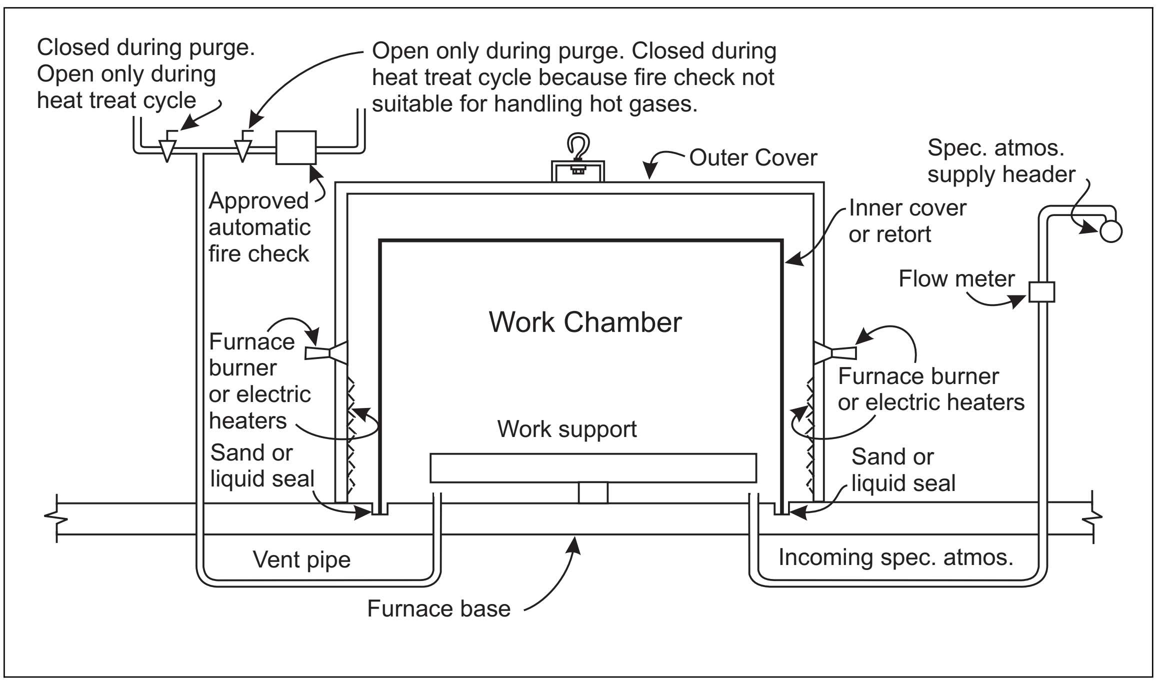


Fig. 14. Typical bell furnace showing special atmosphere piping and venting arrangements.

Vacuum purge (alternate). Following manufacturer's instructions, the air within the inner bell is pumped out with a mechanical pump to a vacuum, generally in the range of 100 microns Hg (abs), 13 Pa (abs), 0.13 mbar (abs).

3. Start and regulate the flow of flammable atmosphere into the inner bell. Place the outer heater cover over the inner bell (retort) and start the heating cycle. The inner bell seal should prevent the flammable atmosphere gas from entering the space between the inner bell and the outer heater cover.

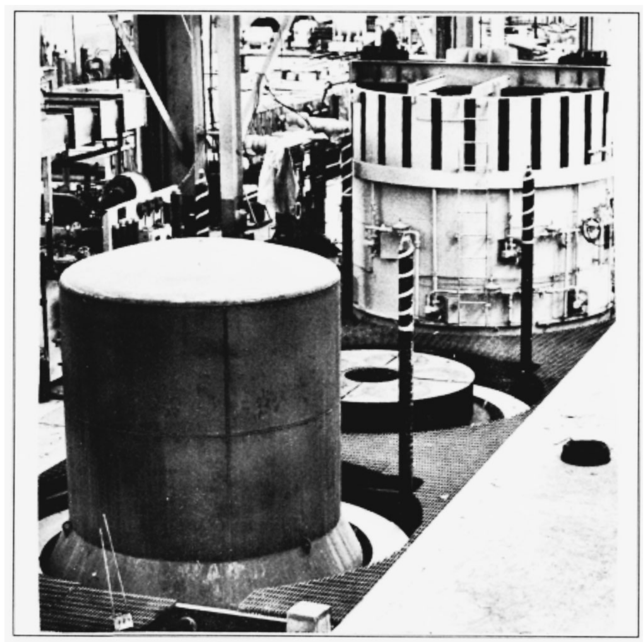


Fig. 15. Direct gas fired, bell type furnace, alloy retort and bases for annealing copper in exothermic gas atmosphere.

2.3.2.2.4.1.2 Shutting Down

1. After the heating cycle is stopped, remove the outer heater cover from over the inner bell (retort). When the work is ready for exposure to room atmosphere, shut off the flammable atmosphere gas supply.

2. Start and continue the inert gas purge of the inner bell for five volume changes, until the total flammable content is less than 50% of lower explosive limit.

Vacuum purge (alternate). Following manufacturer's instructions, the atmosphere within the inner bell is pumped out with a mechanical pump to a vacuum, generally in the range of 100 microns Hg (abs), 13 Pa (abs), 0.13 mbar (abs).

3. Shut off the vent pilots when used and stop any circulation fan. Remove the inner bell after shutting off the inert purge gas or relieving the vacuum.

2.3.2.2.4.2 At or above 1,400°F (760°C)-(Without Retort or With a Nonseal Retort and When Inert Gas or Vacuum Purge is Impractical)

The supply of a flammable special atmosphere to the furnace should be provided with a safety shutoff valve and should be interlocked so that the atmosphere cannot be admitted into the furnace until the temperature is above 1,400°F (760°C). See Safeguards and Interlocks, Section 2.3.1.3.

2.3.2.2.4.2.1 Starting

1. After the work load has been positioned, inspect the fan blade clearance. Make sure that the fan diffuser fixture and work supports are properly positioned. The outer heater cover should be positioned over the work and sealed to the base. Follow manufacturer's instructions.

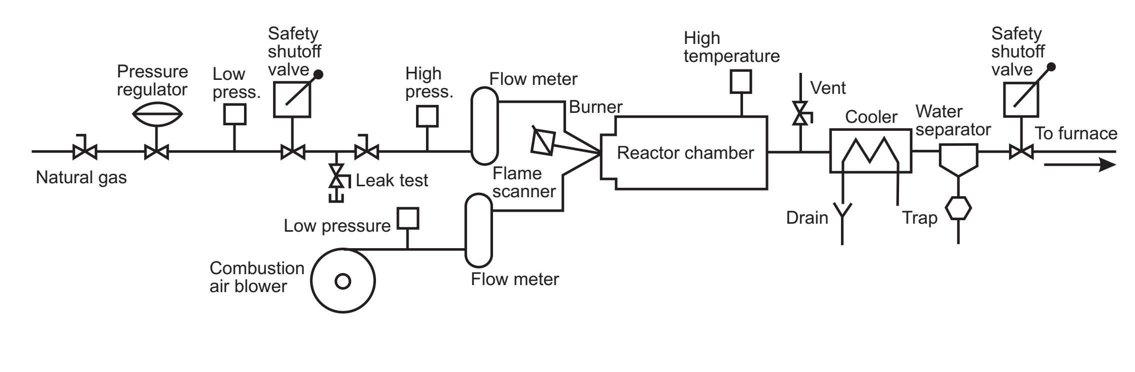


Fig. 16. Schematic piping diagram of a typical exothermic gas generator.

2. When the entire heat chamber has reached a temperature of at least 1,400°F (760°C), light the vent pilots.

3. Start and then regulate the flammable atmosphere flow into the chamber to maintain a positive pressure. When the flammable atmosphere is burning at all vents, the furnace is ready for production. The furnace may be operated below 1,400°F (760°C) after flammable atmosphere introduction.

2.3.2.2.4.2.2 Shutting Down

1. While the heater chamber is at least 1,400°F (760°C) and sealed to the base, provide a reliable ignition source at the base of the heater chamber to ignite the flammable atmosphere as soon as the seal is broken.

2. Turn off the heat and stop the circulation fan.

3. Gradually lift the heater chamber off the base and check that the flammable atmosphere is ignited.

4. Shut off the flammable atmosphere and continue to lift the heater chamber. This will allow air to enter and complete the burnout.

2.3.2.2.5 Procedures if Special Atmosphere or Electric Power is Interrupted

2.3.2.2.5.1 If the flow of special atmosphere to the furnace stops while the furnace is in normal operation (filled with flammable atmosphere) or the electric power fails, the seriousness of the hazard created will depend upon the speed with which the operator takes corrective action. Generally, an inert gas purge should be started by introducing the gas into the chamber at a rate sufficient to provide positive pressure. The purge will be complete when the atmosphere in all chambers contains less than 50% of its lower explosive limit.

2.3.2.2.5.2 When the heating chamber is above 1,400°F (760°C), an operator may burn out the heating and cooling chambers. Room air should immediately be admitted to the heating chamber to replace flammable atmosphere before the temperature drops below 1,400°F (760°C). Gas pilot burners or, in an emergency, twisted newspapers should be lighted across the length of outside openings of chamber doors below 1,400°F (760°C). The chamber doors should then be partly opened. The pilots should be kept burning until the chambers are burned out.

2.3.2.2.5.3 Furnaces with a heating chamber operating below 1,400°F (760°C) and batch-type, bell cover furnaces should be provided with an emergency purge gas system. This system should be actuated immediately in the event of electric power failure or failure of both the flammable atmosphere and normal inert purge gas supply.

2.3.2.2.5.4 The emergency inert gas system should be completely independent of the normal inert gas purge system. It should contain enough inert gas to provide at least five furnace volumes. The inert gas should contain less than 1% oxygen (O_2) and contain flammables at less than 50% of its lower explosive limit.

2.3.2.2.5.5 Provide separate inlets to the furnace chamber, storage tank monitoring and alarms for high and low pressures. Also, provide necessary hand valves, regulators, relief valves, and flow and pressure monitoring devices. Vaporizer systems should be rated for at least 150% of the system’s highest demand.

2.4 Special Atmosphere Generator Safeguards

2.4.1 Equipment and Processes

2.4.1.1 Exothermic Generators

See Figure 16 for a schematic diagram of a typical exothermic gas generator.

2.4.1.1.1 Limit devices should be provided to sound an alarm and to shut off and lock out the fuel-gas supply and air supply or mechanical mixers. These limit devices should supervise low gas pressure, high gas pressure, low combustion air pressure, power failure and flame failure.

2.4.1.1.2 Combustion safeguards should be provided, preferably only for main flame supervision. Direct electric spark ignition is permitted. Some designs may require the supervision of a constant pilot, interrupted pilot or dual supervision — one for the pilot and one for the main burner. The trial for ignition period for the main flame should not exceed 15 seconds.

Flame supervision for this type of gas generator not only protects the generator, but also provides a vital quality control measure for the atmosphere gas going to the process furnace.

2.4.1.1.3 Flow indicators should be installed in each of the fuel gas and combustion air supply lines to permit visual checking of correct aeration of the gas being supplied to the generator burner, and the output volume to the furnace.

2.4.1.1.4 When the generator is supplied with a flammable gas-air mixture from a mixing machine or diluter, an Approved automatic fire check should be provided to protect the mixing equipment against flashback.

2.4.1.1.5 Arrange piping for the safe disposal of unwanted atmosphere and to prevent unwanted atmosphere from entering the process furnace.

2.4.1.1.6 A leakage test facility should be provided for the fuel gas safety shutoff valve.

2.4.1.1.7 A readily accessible manual shutoff valve should be provided upstream of the safety shutoff valve.

2.4.1.2 Endothermic Generators

See Figure 17 for a schematic piping diagram of a typical gas generator.

2.4.1.2.1 Limit devices should be provided to shut off and lock out the reaction gas supply and reaction air supply or mechanical mixer in case of low reaction gas pressure, high reaction gas pressure, low reaction air pressure and power failure.

2.4.1.2.2 For fuel-gas heated generators, limit devices should be provided to shut off and lock out the fuel-air supply (where provided) or the mechanical mixer and the fuel-gas supply in case of low fuel gas pressure, high fuel gas pressure, low fuel air pressure, flame failure (where supervised), excess temperature and power failure.

2.4.1.2.3 For fuel-oil heated generators, limit devices should be provided to shut off and lock out the fuel oil supply and combustion air supply in case of low oil pressure, low atomizing medium pressure, low combustion air supply, low oil temperature (for preheated oils), excess temperature, flame failure (when supervised) and power failure. When an atomizing medium is used, limit devices should be provided to shut off the supply in case of low oil pressure, low combustion air supply and low oil temperature (for preheated oils).

2.4.1.2.4 When the generator is supplied with a combustion reaction- or fuel-gas-air mixture from a mixing machine or diluter, an Approved automatic fire check should be provided to protect the mixing equipment against flashback.

2.4.1.2.5 The reaction gas and reaction air supplies should be interlocked to prevent flow until the generator is at proper temperature.

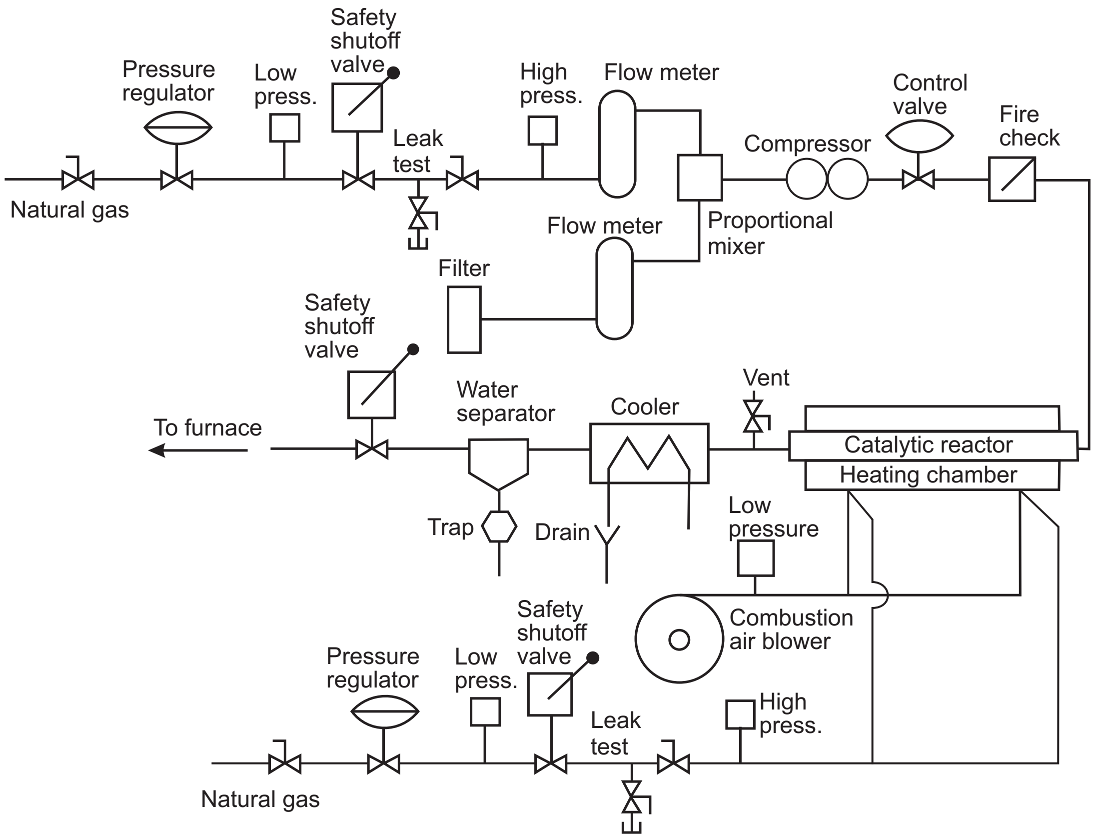


Fig. 17. Schematic piping diagram of a typical endothermic gas generator.

2.4.1.2.6 Arrange piping for safe disposal of unwanted atmosphere and to prevent unwanted atmosphere from entering the process furnace.

2.4.1.2.7 Leakage test facilities should be provided for the reaction gas and fuel-gas safety shutoff valve.

2.4.1.2.8 A readily accessible manual shutoff valve should be provided upstream of the reaction gas, fuel-gas and fuel-oil safety shutoff valves.

2.4.1.2.9 Electrically heated generators should be provided with a main disconnect device capable of de-energizing the entire heating system under full load. This device should de-energize the heating system in case of complete or partial loss of power, or excess generator temperature.

The interrupting capacity of the main disconnect device should be adequate to clear the maximum fault current capability of the immediate power supply system. Fault current should be determined from the voltage and impedance of the furnace power supply circuit, not from the summation of the operating load currents. Other disconnect methods in this power supply circuit may be used as the heating equipment main disconnect, provided that furnace operation can be terminated without affecting the operation of other essential equipment. Automatic versus supervised operation of the main disconnect should be governed by the furnace size, design characteristics and the potential hazards involved.

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

2.4.1.3 Ammonia Dissociators

See Figure 18 for a schematic piping diagram of a typical ammonia dissociator.

2.4.1.3.1 The vessel, valves, piping, and all other components should be designed and constructed suitable for ammonia service and for maximum pressures and temperatures.

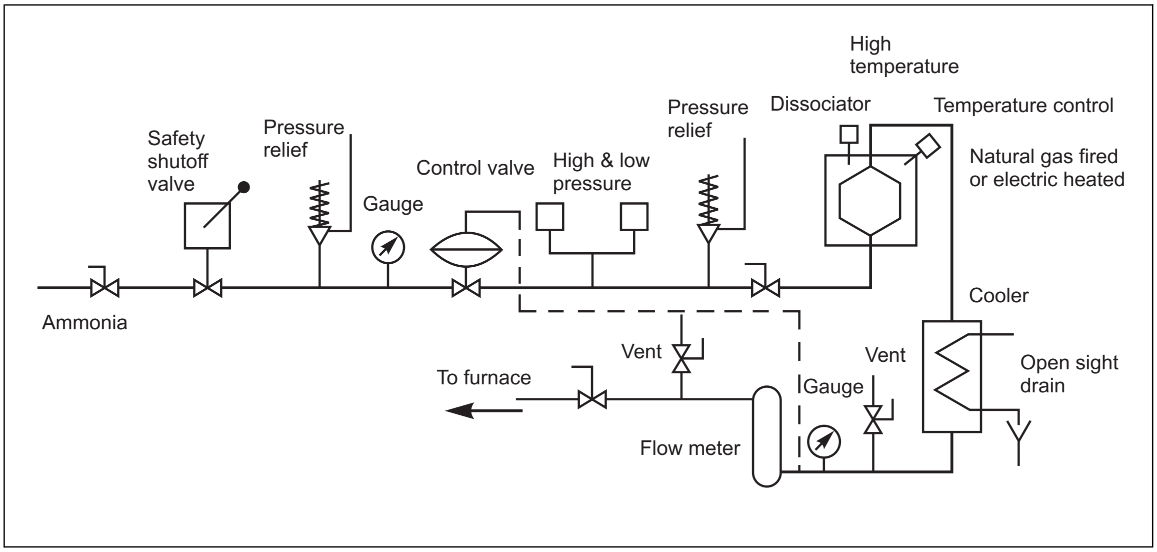


Fig. 18. Schematic piping diagram of a typical ammonia dissociator.

2.4.1.3.2 Relief valves should be provided in the high-pressure and low-pressure ammonia lines on each side of the pressure regulator, and set at the design pressure of the manifold and dissociator vessel.

2.4.1.3.3 Temperature and pressure limit devices should be provided to shut off the ammonia supply in the event of abnormal high or low conditions.

2.4.1.3.4 Ammonia flow should be shut off if the dissociator is not at operating temperature.

2.4.1.3.5 A high-temperature limit device should be provided to shut off and lock out the heat source in the event that designated temperatures are exceeded.

2.4.1.3.6 A readily accessible manual shutoff valve should be provided downstream of the pressure regulator.

2.4.1.3.7 Arrange piping for safe disposal of the unwanted atmosphere and to prevent the unwanted atmosphere from entering the process furnace.

2.4.1.3.8 For protection of the reactor vessel heating system, see Section C.1.6.2, on Endothermic Gas Generators.

2.4.1.3.9 Interlock hydraulic lifting mechanisms for retorts (or furnace covers when there is no retort or inner bell) with furnace temperature when using a flammable special atmosphere. This is to prevent accidental operation when the temperature is above the autoignition temperature of the special atmosphere gas and before the special atmosphere has been purged out.

2.4.1.4 Generated Atmosphere Gas Storage

See Figure 19 for a schematic piping diagram of a typical atmosphere gas-storage system.

2.4.1.4.1 To reduce the exposure hazard, the storage tank should be located outdoors, preferably at least 50 ft (15 m) from important buildings, with the tank heads pointed away from buildings. If no outdoor yard space is available, the tank should be located on a building roof.

2.4.1.4.2 The atmosphere generator, surge tank, compressor, and aftercooler should preferably be located in a noncombustible building nearby. If it is necessary to house the equipment in a main building, it should be located in a large well-ventilated area.

2.4.1.4.3 The compressor motor should be interlocked with the atmosphere gas generator temperature so that the compressor will be stopped if the generator temperature falls below normal. (See Data Sheets 7-50, *Compressed Gases in Portable Cylinders and Bulk Storage*, and 7-95, *Compressors*.)

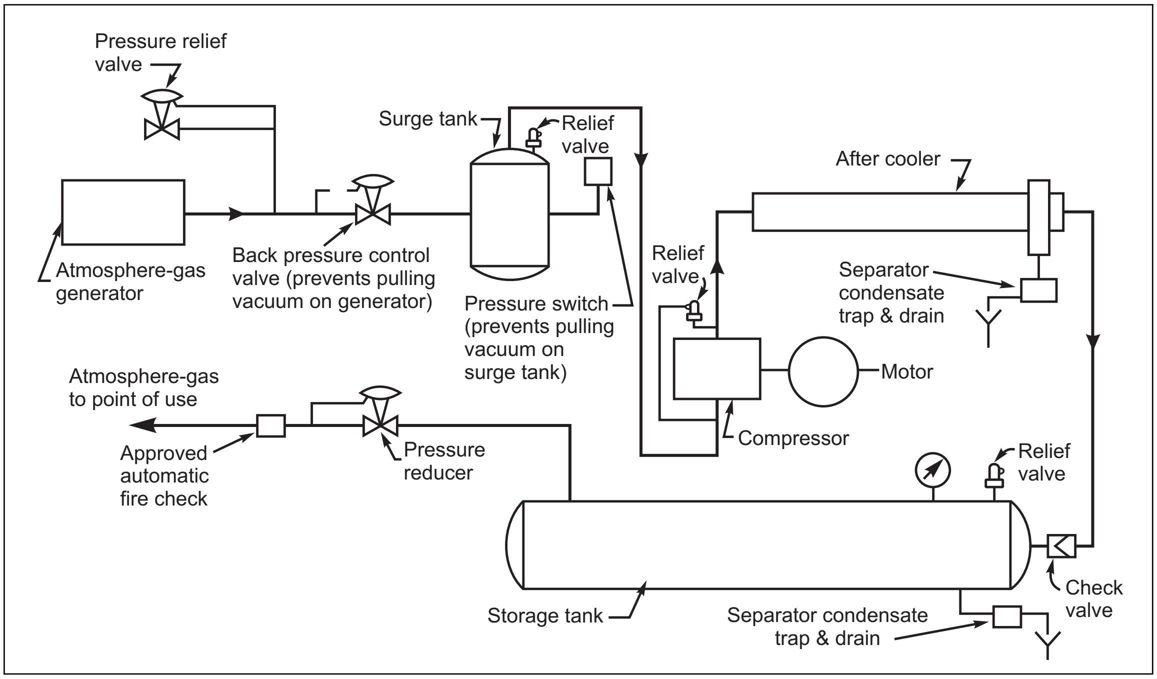


Fig. 19. Schematic piping diagram of a typical atmosphere gas-storage system.

3.0 SUPPORT FOR RECOMMENDATIONS

3.1 Loss History

A study of 45 explosions in process furnaces, which occurred between 1980 and 1989, showed that 39 involved gas fired furnaces including 5 with special atmosphere, one oil-fired furnace, and 6 electric heated furnaces with special atmosphere. The smaller proportion of explosions in oil fired furnaces is due to the smaller number in service and not necessarily to a lower degree of hazard.

Of the explosions in gas-fired furnaces, 62% occurred during the lighting off period, 33% during operation (firing), and 5% during the relighting. No explosions occurred while the work space temperature was above 1,400°F (760°C). However, a number of explosions occurred while warming up furnaces, whose normal operating temperature exceeded 1,400°F (760°C).

Lighting off explosions were mostly in multi-burner furnaces where the operator failed to follow procedures: not closing all individual main burner gas cocks or not establishing reliable pilot flames at all burners before opening the main furnace gas valve or the individual burner valve. Inadequate maintenance, cracked leaking radiant tubes and maladjusted fuel-air ratios were other factors.

Firing explosions were caused by poor equipment maintenance, maladjusted fuel-air ratios, loss of inert gas purges and combustible wood or oils improperly placed in the furnace. The maladjusted fuel-air ratios would cause operation of the burners with scant air for combustion, resulting in the formation of an explosive carbon monoxide and hydrogen-air mixture.

Relighting explosions following accidental extinguishment were due to (1) manual lightoff attempts with gas pressure regulator failure, (2) zero governor malfunction for fuel rich combustion and (3) flammable atmosphere introduction into a furnace below 1,400°F (760°C).

The explosions involving furnaces using flammable special atmosphere were mostly caused by (1) malfunctioning of sequencing controls, (2) leaking atmosphere gas valves and (3) inadequate interlocks.

4.0 REFERENCES

For more information, please refer to the following data sheets as cited in the text.

4.1 FM

Data Sheet 1-10, *Smoke/Heat Venting in Sprinklered Buildings*
Data Sheet 1-28, *Design Wind Loads*
Data Sheet 1-45, *Air Conditioning and Ventilating Systems*
Data Sheet 5-32, *Electronic Data Processing Systems*
Data Sheet 6-0, *Elements of Industrial Heating Equipment*
Data Sheet 6-18, *FM Cock Safety-Control System*
Data Sheet 7-41, *Heat Treating of Materials Using Oil Quenching and Molten Salt Baths*
Data Sheet 7-45, *Instrumentation and Control in Safety Applications*
Data Sheet 7-50, *Compressed Gases in Portable Cylinders and Bulk Storage*
Data Sheet 7-78, *Industrial Exhaust Systems*
Data Sheet 7-83, *Drainage Systems for Ignitable Liquids*
Data Sheet 7-95, *Compressors*
Data Sheet 9-18/17-18, *Prevention of Freeze-ups*
Approval Guide, a publication of FM Approvals

4.2 NFPA Standards

NFPA 86, *Ovens and Furnaces*

NFPA 86-C, *Industrial Furnaces Using a Special Processing Atmosphere*

NFPA 497A, *Classification of Class 1 Hazardous (Classified Locations for Electrical Installations in Chemical Process Areas* [1986])

APPENDIX A GLOSSARY OF TERMS

Approved: references to ''Approved'' in this data sheet means the product and services have satisfied the criteria for FM Approval. Refer to the *Approval Guide*, a publication of FM Approvals, for a complete listing of products and services that are FM Approved.

Combustion safeguard: a safety control that responds directly to flame properties. This control senses the presence of flame by means of a flame detector and causes fuel to be shut off in the event of flame failure. Other safety controls can also be interlocked with this device. And startup and shutdown sequencing can be controlled by a combustion safeguard.

APPENDIX B DOCUMENT REVISION HISTORY

April 2012. Terminology related to ignitable liquids has been revised to provide increased clarity and consistency with regard to FM Global's loss prevention recommendations for ignitable liquid hazards.

January 2007. Minor editorial changes were made for this revision.

September 2003. The Section 1.1 ''Changes'' has been revised to identify changes made in the September 2000 revision. The summary of January 2000 changes has been moved to Appendix B, ''Document Revision History.''

September 2000. Recommendation 2.1.2.7.11.1 has been modified as follows:

1. For gas fired pilots and burners provide two safety shutoff valves in series regardless of burner or pilot heat input.

2. For multi-burner systems, provisions have been made to permit individual burners to (be) shutdown while allowing the other burners in that multi-burner system to remain in operation.

January 2000. The document was reorganized to provide a consistent format.

A recommendation was added to Section 2.3.1.3 to address bell furnace oil sealing systems. Some of these recommendations are covered in Data Sheet 7-32, *Ignitable Liquid Operations*. There was a large loss which illustrated the need for these recommendations to be added to this data sheet. A Loss Abstract was added also.

A recommendation was added to Section 2.4.1.3 to interlock furnace cover hydraulic lifting mechanisms with temperature to prevent accidental opening when the furnace is filled with flammable special atmosphere gas and furnace temperature is above the autoignition point of the gas.

In Section 2.3.2.2.4, the words ‘‘both the furnace and’’ and in Section 2.3.2.2.4.1 the words ‘‘cover and’’ have been deleted because it is not necessary to inert the furnace (combustion or heating chamber) and because it is not practical to do this according to the starting procedure outlined in Section 2.3.2.2.4.1.

The safety shutoff valve recommendation in section 2.1.2.7.11 for gas burners has been changed to be in agreement with NFPA 86 1999. All burners and pilots, regardless of size, must have two safety shutoff valves. Losses have occurred due to small pilot safety shutoff valve leaks. This can happen with natural draft equipment because there is no purge. Even with fan-assisted equipment, purging may be inadequate because it is sometimes done at a slow rate. There is no minimum rate required as is the case with boilers.

A recommendation for an emergency cooling system was added to Section 2.1.2. This will protect furnaces which have cooling systems when there is a loss of power.

APPENDIX C SUPPLEMENTAL INFORMATION

C.1 Background Information

C.1.1 General

Process furnaces are used for heat-treating, annealing, vitreous enameling, carbon baking, thermal and catalytic reforming, cracking, and similar industrial and chemical processes, usually carried on at temperatures above 700°F (370°C).

Special atmospheres are maintained in some heat-treating furnaces for metallurgical purposes, such as bright annealing, carburizing, nitriding, and copper brazing. In addition to the hazard created by the fuel used for heating, furnaces of this type often have a hazard posed by the flammable gases in the work chamber, used for the special treatment of the work. Special attention must be given to minimize the explosion hazard in the equipment used to produce the flammable special atmosphere. Inert (nonflammable), special atmospheres, such as those used in the copper and brass industry, normally present no special hazard.

C.1.2 Pulse Firing Sequence-Furnace Zones

Multiple burner furnaces may be fired by short-term operation (pulses) of burner sets at fixed optimum burner input rates. The burners are pulsed on and off using frequencies up to ten cycles per minute, one cycle every six seconds. The quantity of fuel fired per burner each cycle is constant. The heat Btu input to the furnace is varied by slowing or increasing the pulse frequency.

For an eight-burner furnace firing at a 25% input rate, a set of two burners would fire for about six seconds during every 24 seconds or ¼ of the time. The other three sets of burners would fire in sequence. At 50% firing rate the set of two burners would fire for two six-second intervals during every 24 seconds, and at 75% firing rate the set of two burners would fire for three six-second intervals during every 24 seconds.

The furnace operation and burner sequencing is monitored and controlled by microprocessor based systems. The fuel and air control solenoid valves are designed to sustain the severe operation high cycling sequences. When not firing or being pulsed, the burner may be set at a very low fire rate, supplied through valve bypass orifices, or turned completely off. Ignition may be by direct spark or with intermediate or interrupted pilots. Flame supervision is provided for each burner by either a flame rod or ultraviolet scanner. Flame establishing time may be ten seconds with two seconds for flame failure reaction. Flame failure at any one burner need not affect shutdown of the other burners.

The fuel-air control system can use a biasing regulator, operating at different ratios: excess air, stoichiometric or reducing atmosphere.

C.1.3 Regenerative Burner Systems

Regenerative burner systems are used to preheat the combustion air to 80% or more of the furnace exhaust temperature. These systems have proven efficient particularly for furnaces operating in the 1,500°F (815°C) to 2,200°F (1,200°C) range. In a double burner system, exhaust gases are passed through one of the beds of metal or ceramic material. Combustion air is drawn in through the other similar bed that has been previously heated by exhaust gases. The firing of the burner and cycling of the combustion air and exhaust from one burner assembly to the other may occur in less than a minute. A microprocessor based sequencer provides the control for the fuel gas, combustion air and exhaust based upon the furnace temperature. Conventional fuel gas and combustion air interlocks are provided along with combustion safeguards normally using intermittent pilots.

C.1.4 Oxygen-Enriched and Oxygen-fuel Systems

Oxygen-enriched and oxygen-fuel burner systems are principally used in high temperature applications such as electric arc furnace scrap melting, lime and cement rotary kilns, glass melting, aluminum and copper remelting and steel label heating. High-flame temperatures, increased heat input from small burners, increased melt rates and high energy efficiency are the major advantages. The fuel gases or fuel oils and oxygen are supplied to the burner through interconnected but separate regulating systems. Oxygen-enriched systems may have an oxygen content from 21% to 45% giving flame temperatures up to 3600°F (1,980°C) to 4,500°F (2,480°C). Some burners may be water cooled while others are gas-air cooled using concentric air, oxygen and fuel nozzles.

Combustion safeguards and interlocks for the fuel and oxygen systems are similar. Conventional flame supervision is normally applicable, although it may be impractical on some furnaces such as electric arc units. High furnace temperatures, over 1,400°F (760°C), and electric arcs provide reasonable ignition sources.

C.1.5 Special-Atmosphere Furnaces and Generators

C.1.5.1 General

In some heat-treating furnaces, special atmospheres are maintained for metallurgical purposes such as prevention of oxidation, bright annealing, carburizing, nitriding, and copper brazing. These furnaces often have flammable gases in the work chamber, in addition to the fuel used for heating. Special attention should be given to eliminating the explosion hazard in equipment used to produce the flammable special atmosphere. Inert (nonflammable) special atmospheres, commonly used in the copper and brass industry, present no special hazard.

Most important for the safe operation of special atmosphere furnaces and generators are well-trained operators, who will carry out all phases of furnace and generator operating procedures, test controls periodically and provide written records of maintenance inspections, tests and repairs.

C.1.5.2 Formation of Explosive Furnace Atmosphere

Whether a special furnace atmosphere is inert under all conditions, or can become flammable when air is added, is determined by the amount of flammable products of incomplete combustion (carbon monoxide, hydrogen, and sometimes small amounts of methane) in the flue gas from the atmosphere generator. This, in turn, is dependent on the amount of aeration provided for the natural gas, manufactured gas, propane, or butane burned in the generator. Aeration is the ratio of air furnished to the burner to that required for chemically complete combustion of the fuel, expressed as a percentage.

If aeration at the generator burner exceeds 82.5%, the flue gas will contain less than 8.8% total flammable products of combustion and when mixed with air, will be nonflammable (Fig. 20). If aeration of the burner gas is 82.5% or less, the resultant products of combustion will contain more than 8.8% CO and H_2 and will enter the explosive range, when mixed with air, for the furnace atmosphere. With 60% aeration, for example, the products of combustion will contain approximately 5.5% CO_2, 9% CO, and 11.5% H_2, with nitrogen making up the remainder. With total flammable products of 20.5%, Figure 20 indicates that 60% aeration makes this flue gas flammable with an explosive range in air of about 32 to 75% by volume.

With less than 50% aeration at the burner, heat of combustion is insufficient to continue the combustion reaction in the generator and external heat must be provided. Generators designed for less than 50% aeration are endothermic types. These require reaction heat supplied indirectly from electric or fuel-burner sources. This promotes the cracking of rich raw fuel-air mixtures used for producing the endothermic atmospheric gas. Atmospheres from endothermic generators are always flammable, while atmospheres from exothermic generators may be either inert or flammable, depending on the generator design and range of operation.

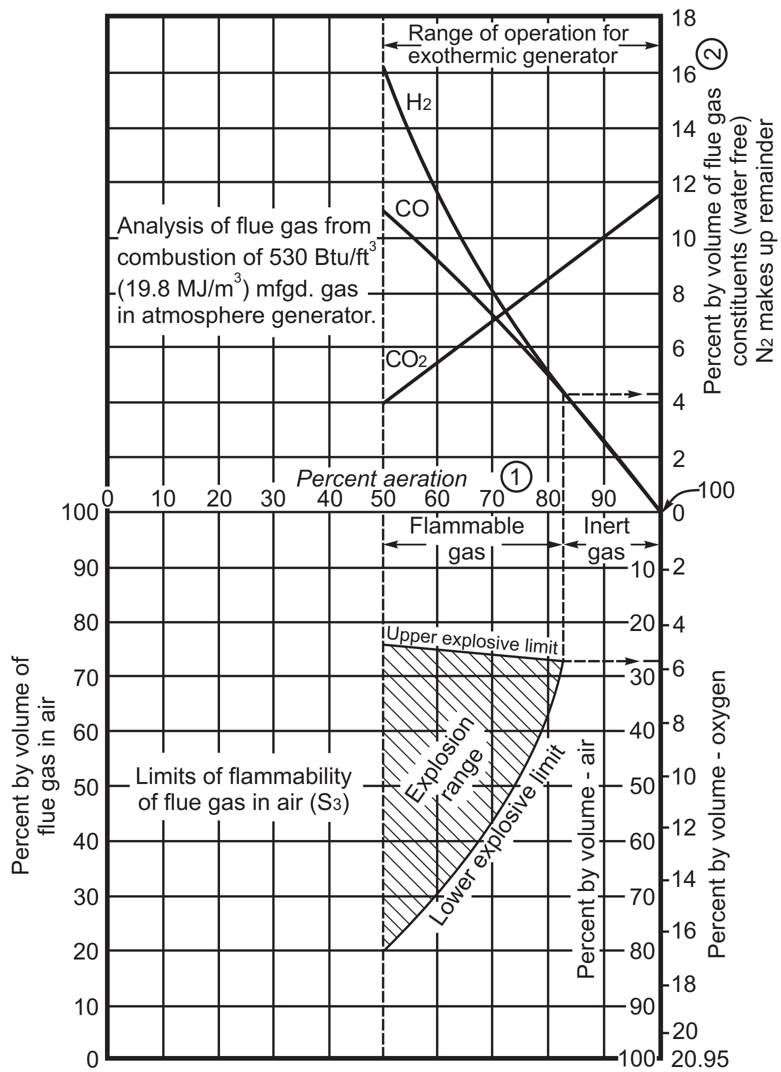


Fig. 20. Upper: Analysis of flue gas in exothermic atmosphere generator. Lower: Limits of flammability of flue gas in air. Numbers in circles refer to sampling points shown in Fig. 21.

Although not shown in Figure 20, decreasing aeration below 50%, which is common for endothermic generators, will cause flammable constituents in the generator flue gas to continue increasing, resulting in a widening of the explosive range.

Sampling points for gas analysis on a special-atmosphere generator are shown in Figure 21. The approximate air-gas ratio (as indicated by flowmeters) at 82.5% aeration for common fuel gases is shown in Table 1.

Explosive mixtures are most likely to occur while the air in the equipment is being replaced with flammable atmosphere, and during shutdown while the flammable atmosphere is being replaced with air. Accidental interruption of the continuous supply of the flammable atmosphere is also dangerous since air may immediately start to enter the furnace.

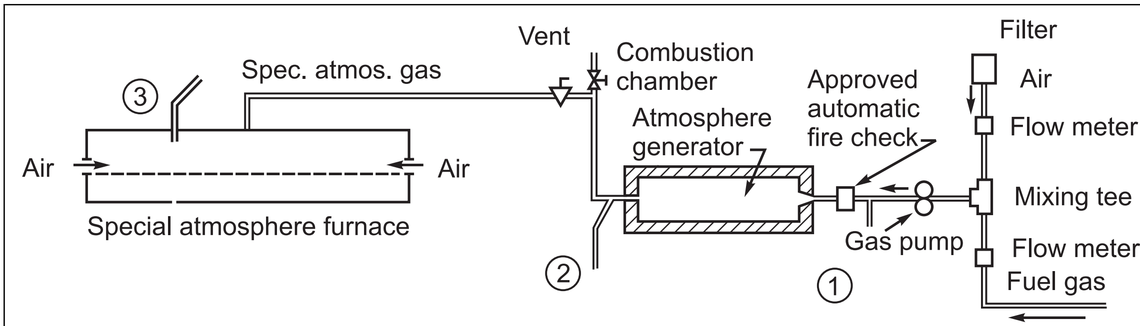
Table 1. Air-Gas Ratios for Common Fuel Gases

Type of Gas	Btu/ft^3	MJ/m^3	Approx. Combining Proportions (100% Aeration)	Approx. Air-Gas Ratio at 82.5% Aeration
Manufactured	535	20.0	4.6 -1	3.8 -1
Natural	1000	37.4	10 -1	8.25-1
Propane	2500	93.4	24 -1	19.8 -1
Butane	3200	119.6	30.5 -1	25.2 -1

C.1.5.3 Inert-Gas Purge

Thorough purging with inert gas, before starting and after stopping the flow of flammable special atmosphere, is the preferred method of avoiding explosive flammable atmosphere-air mixtures. Purging is especially desirable in furnaces or sections of furnaces below the generally reliable gas-ignition temperature of 1,400°F (760°C).

On average, an amount of atmosphere gas equal to five times the volume of the chamber is required. It is often possible, during start-up and shutdown, to adjust the air-gas ratio of a generator so that an inert atmosphere, practically free of flammable content (above 82.5% aeration) or oxygen is obtained. In many instances, it may be practical to obtain an inert gas from a bank of nitrogen or carbon dioxide cylinders. Stored inert purge gas should be essentially free of oxygen (below 1%) and contain less than 50% of the lower explosive limit of flammables.



1. Sampling point for determining percent aeration.
2. Sampling point for determining percent by volume of flue-gas constituents.
3. Sampling point for determining limits of flammability of flue gas in air or percent of oxygen concentration to render flue-gas constituents flammable.

Fig. 21. Sampling points for gas analysis on exothermic-atmosphere generator.

Given sufficient time, gases of different densities diffuse and form a uniform mixture throughout a container. A minimum of mixing during purging makes diffusion more rapid, and the least amount of gas is used. In furnaces with vertical chambers, such as the tower type, lighter-than-air atmosphere gas should be admitted at the top of the furnace and heavier-than-air atmosphere gas at the bottom, so that the air will be discharged at the opposite end.

C.1.5.4 Burnout Procedure

Where it is impractical to obtain an inert atmosphere, it is necessary during start-up to burn out the air, and during shutdown to burn out the flammable atmosphere. During start-up, when the air in the furnace is replaced with flammable atmosphere, and during shutdown, when the flammable atmosphere is replaced with air, the possibility of explosion is avoided if the temperature of the entire furnace is above 1,400°F (760°C). If, at the point where flammable atmosphere or air enters a furnace, the temperature is below 1,400°F (760°C), a reliable ignition source should be provided. In special furnaces, such as the tower type, which has an almost totally closed work chamber, an inert gas should be used to purge the work chamber, whether the furnace is above or below 1,400°F (760°C). In such cases, the burnout method should not be used.

C.1.5.5 Synthetic Atmospheres, Heat Treat Furnaces

Synthetic atmospheres are derived from chemical liquids or liquefied gases such as anhydrous ammonia, alcohols or hydrocarbon liquids usually introduced into the furnace where they react or decompose. For example: injection of nitrogen along with a metallurgical grade of methanol will yield a CO, H_2, N_2 atmosphere similar to an endothermic gas. The use of synthetic atmospheres has been promoted by several companies and has become economically feasible because of natural gas shortages, gas supply interruption and variations in gas quality.

Synthetic atmosphere systems are composed of four parts: 1) gas and liquid storage cylinders and bulk tanks; 2) the distribution piping; 3) the control panel; and 4) the related furnace controls and interlocks (see Fig. 22). The typical storage arrangement and distribution piping are described in other data sheets.

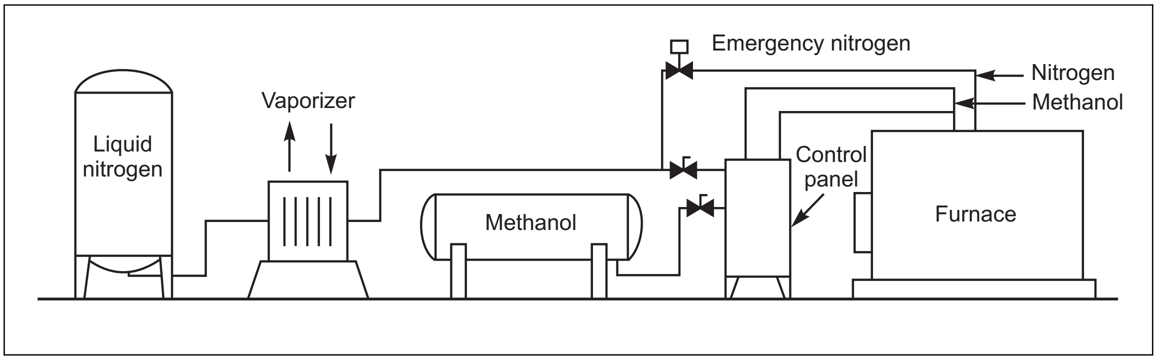


Fig. 22. Synthetic atmospheres, heat treat furnace.

The control panels are equipped with valves, flow meters and suitable related temperature and pressure actuated switches. The quantity of atmosphere being supplied to the furnace may vary depending upon the requirements of the work being processed and the operational cycle of the furnace. For example, when the furnace doors are opened to charge and discharge the furnace, the atmosphere flow is increased to prevent air infiltration.

C.1.6 Special Atmosphere Gas Generators

C.1.6.1 Exothermic Generators

Exothermic generators produce special atmospheric gas by completely or partially burning fuel gas with air at a controlled ratio, usually at 60% to 100% aeration. Atmospheres from exothermic generators may be either inert or flammable, depending on the generator design and range of operation (Fig. 23).

C.1.6.2 Endothermic Generators

Endothermic generators produce special atmospheric gas by partially burning fuel gas with air at a controlled ratio of less than 50% aeration. External heat must be provided because the reaction heat of combustion is insufficient to continue the combustion reaction in the generator. The added heat, provided indirectly from electric or fuel burner sources, promotes the cracking of rich, raw fuel-air mixtures. Atmospheres from endothermic generators are always flammable.

C.1.6.3 Ammonia Dissociators

Dissociated ammonia, 25% nitrogen and 75% hydrogen, is produced from ammonia (NH_3) by temperature reaction with a catalyst in an externally heated vessel (Fig. 24). Mechanical damage, pipe corrosion and reaction retort corrosion are the usual failures which result in fire.

C.1.7 Generated Atmosphere Gas Storage

For installations where the rate of flow of the flammable special atmosphere fluctuates widely, the flammable atmosphere may be compressed and stored in pressure tanks to ensure an adequate supply during high flows (Fig. 19).

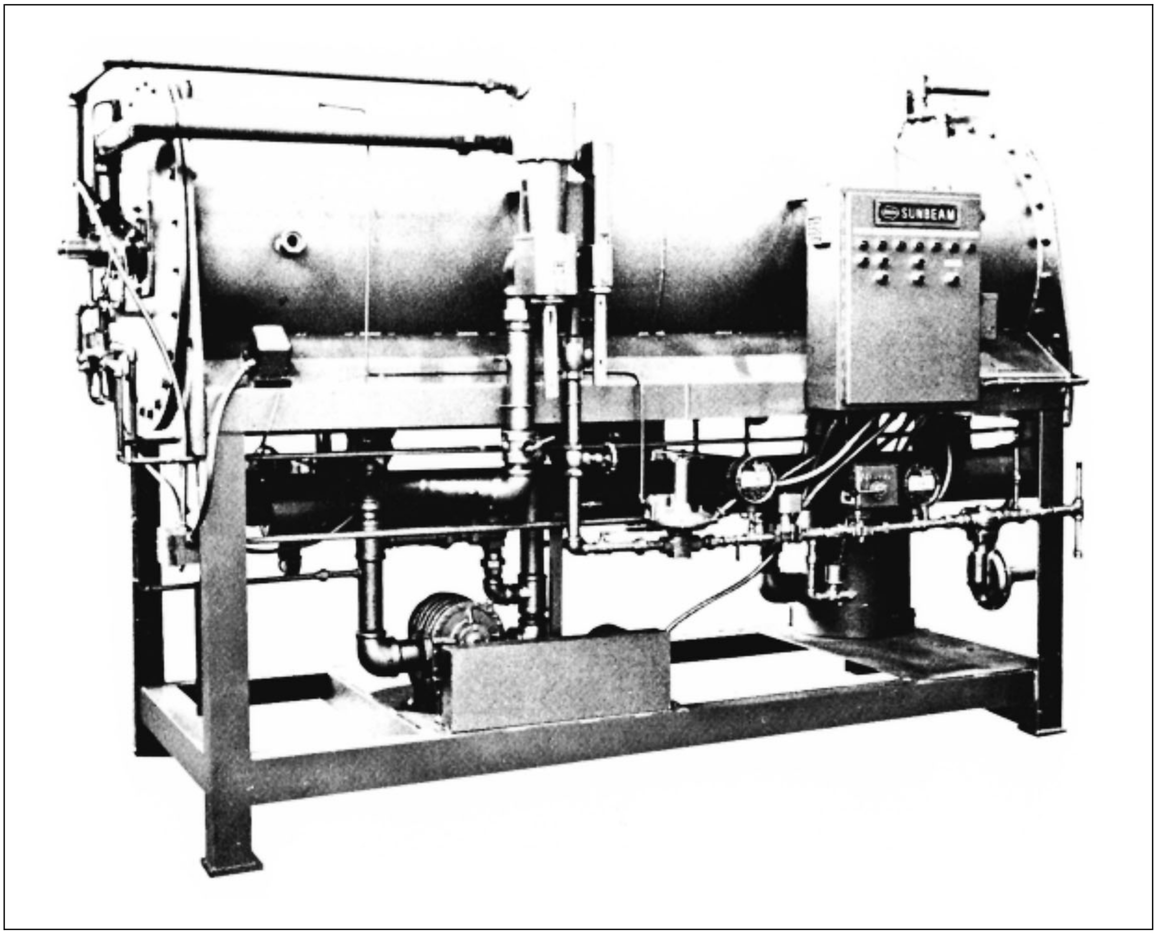


Fig. 23. Exothermic rich or lean ratio, special atmosphere generator.

C.2 Comparison with NFPA Standards

As noted in Section 4.2, the corresponding NFPA standard is NFPA 86 *Ovens and Furnaces*. There are no known major conflicts with this standard. One deviation is that NFPA 86 permits 60 seconds trial for ignition under certain conditions.

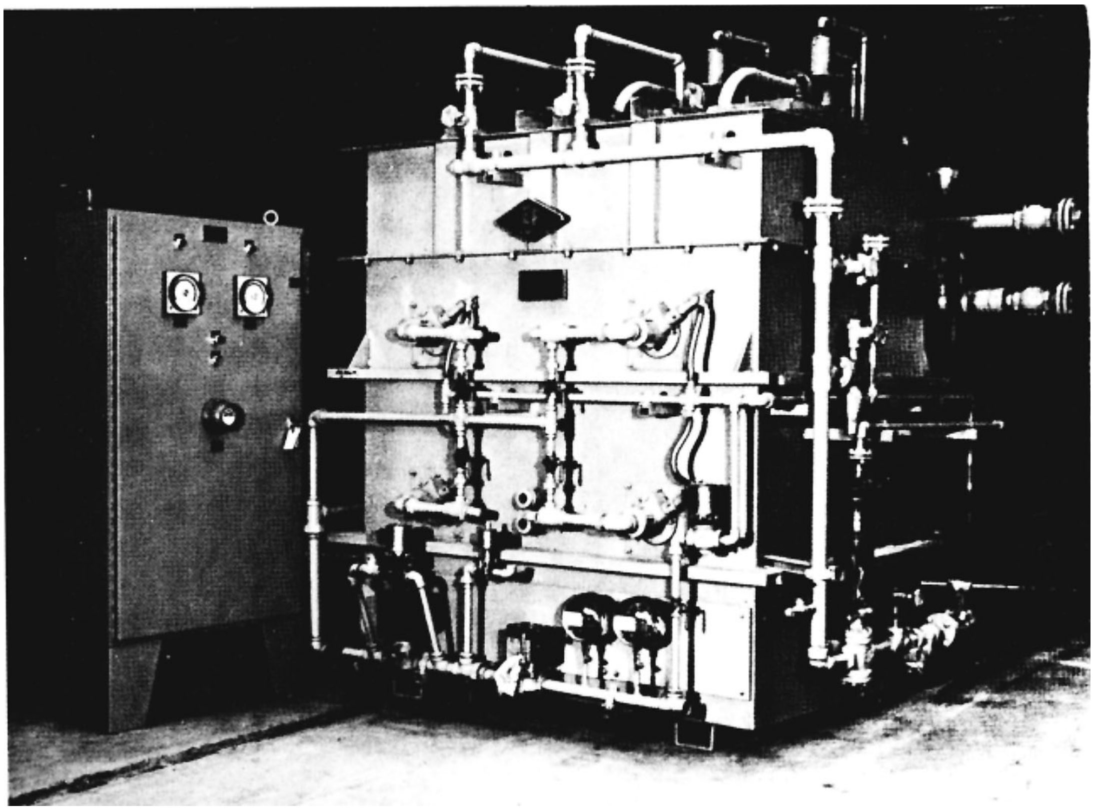


Fig. 24. Ammonia dissociator unit.