OIL- AND GAS-FIRED SINGLE-BURNER BOILERS

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1.0 SCOPE

This FM loss prevention data sheet discusses the fuel hazards inherent in gas-fired or oil-fired single-burner boilers. Recommendations are made for the installation, maintenance, and operation of combustion safeguards and boilers as related to the fuel explosion and fire hazards.

Similar guidelines may also be applied to the firing of other liquid or gaseous fuels. For example, liquefied petroleum gas (LPG) such as propane is sometimes used as a backup fuel source. The recommendations in this data sheet for gaseous fuels also apply to LPG, with additional guidance related to venting located in Data Sheet 7-55, *Liquefied Petroleum Gas.* Each installation must be carefully evaluated, with consideration given to the characteristics of the fuel, the hazards involved, the suitability of the equipment, and the need for special protection.

This data sheet applies to oil-fired and gas-fired single-burner boilers rated greater than 400,000 Btuh (117 kW), with the following exceptions:

A. This data sheet does not apply to natural draft boilers; refer to ASME CSD-1, *Controls and Safety Devices for Automatically Fired Boilers.*

B. This data sheet does not apply to boilers 2,500,000 Btuh (732 kW) or less that are listed by a nationally recognized testing laboratory agency.

Oil and gas fired multiple-burner boilers are covered in Data Sheet 6-5, *Oil- or Gas-Fired Multiple Burner Boilers.*

1.1 Changes

January 2024. Interim revision. Minor editorial changes were made.

2.0 LOSS PREVENTION RECOMMENDATIONS

2.1 Introduction

2.1.1 FM Approved Equipment

Use FM Approved equipment and devices, such as fuel safety shutoff valves (SSOVs), fuel and air supervisory switches, timers, flame sensors, combustion safeguards, flexible hose assemblies, etc. when available for the intended service. See Table 1 for a summary of safety control recommendations.

2.1.2 Provide equipment and devices that are suitable for the environment in which they are installed. Equipment used in dusty or moist areas requires careful selection.

Table 1. Summary of Safety Control Recommendations.

Safety Device/Control	*Gas-Fired Boilers*	*Oil-Fired Boilers*
Fan motor interlocks and air flow/ pressure switches: forced draft, induced draft, and/or recirculation fans	Yes	Yes
Pre-purge at 50% maximum airflow, minimum 4-volume changes	Yes	Yes
Post-purge, 15 seconds minimum	Yes, if >12.5 MMBtuh (3662 kW)	Yes, if >2.8 MMBtuh (820 kW)
Igniter/pilot	See Section 2.4.3	See Section 2.4.3
Pilot SSOV	Yes	Yes
Main burner SSOV	Yes, see Table 2.	Yes, see Table 3
Tightness test connections for main SSOVs	Yes, see Data Sheet 6-0.	
Low gas pressure switch	Yes, if > 2.5 MMBtuh (732 kW)	
High gas pressure switch	Yes, if > 2.5 MMBtuh (732 kW)	
Interlock for low fire light-off	Yes, if >2.5 MMBtuh (732 kW)	Yes, if >2.8 MMBtuh (820 kW)
Nonrecycling combustion safeguard	Yes, if >2.5 MMBtuh (732 kW)	Yes, if >2.8 MMBtuh (820 kW)
10-second pilot flame establishing period	Yes	Yes
Limited main flame trial-for-ignition	10 seconds	10 seconds for No. 2 & No. 4 Oil; 15 seconds for No. 5 & No. 6 Oil
SSOV proved closed prior to and during purge	See Table 2	See Table 3
Low oil pressure switch		Yes, if >2.8 MMBtuh (820 kW), unless oil pump is integral with burner motor shaft
High/low oil temperature switch		Yes (for heated oils)
Atomizing steam/air switch		Yes (if applicable)
Electric igniter proved fully inserted	Yes (if applicable)	Yes (if applicable)
High steam pressure/temperature	Yes	Yes
Low water cutout*	Yes	Yes

* Refer to Data Sheet 6-12, *Low Water Protection for Boilers.*

2.2 Construction and Location

2.2.1 Locate boilers in rooms of noncombustible construction that are separated from the rest of the occupancy.

2.2.2 Do not locate boilers and fuel piping in below-grade locations. When below-grade installations are unavoidable, work with the local fire service to provide adequate access for manual firefighting.

2.2.3 Locate fuel system components outside the boiler room, and arrange and protect them in accordance with Data Sheet 7-32, *Ignitable Liquid Operations;* Data Sheet 7-54, *Natural Gas and Gas Piping;* Data Sheet 7-88, *Ignitable Liquid Storage Tanks;* or other applicable data sheets. Examples of such equipment include storage tanks and pumps. If these components are located within the boiler room, evaluate the room as an ignitable liquid and/or flammable gas occupancy, and provide construction features, containment, and emergency drainage in accordance with Data Sheet 7-32, *Ignitable Liquid Operations;* Data Sheet 7-54, *Natural Gas and Gas Piping;* Data Sheet 7-88, *Ignitable Liquid Storage Tanks;* or other applicable data sheets.

2.2.4 If oil piping within the boiler room is not designed in accordance with this data sheet (refer to Section 2.4.1), such that the potential exists for an ignitable liquid release to occur beyond the boiler face, provide construction features, containment, and emergency drainage within the room in accordance with Data Sheet 7-32, *Ignitable Liquid Operations.*

2.2.5 Avoid passing metal stacks through combustible walls, floors, and ceilings, including Class 2 steel deck roofs. Where this is unavoidable, provide metal collars, rain shields, and clearances or suitable insulation and/or clearances to keep the surface temperature of the combustible material below 160°F (71°C).

2.2.6 Provide clearance between metal stacks and stored combustible materials of at least 30 in. (0.76 m). Install guards that will ensure this clearance is provided.

2.3 Protection

2.3.1 Gas-Fired Boilers

2.3.1.1 Provide automatic sprinklers in boiler rooms of combustible construction (including Class 2 steel deck roofs) and in noncombustible boiler rooms that contain sufficient combustibles.

2.3.1.2 Design the sprinkler system in accordance with Data Sheet 3-26, *Fire Protection Water Demand for Nonstorage Sprinklered Properties.*

2.3.2 Oil-Fired Boilers

2.3.2.1 Provide automatic sprinklers in rooms containing oil-fired boilers.

2.3.2.2 Design the sprinkler system as follows:

A. Where the equipment and piping is designed in accordance with this data sheet (e.g., fuel oil system components located outside the boiler room, proper piping design and construction, automatic interlocks to shut down the flow of fuel in the event of a fire, etc.), design the system in accordance with Data Sheet 3-26, *Fire Protection Water Demand for Nonstorage Sprinklered Properties.*

B. If fuel oil system components (e.g., tanks, pumps) are located within the boiler room, or the oil piping system in the boiler room is not designed in accordance with this data sheet (refer to Section 2.4.1), provide automatic sprinkler protection in accordance with Data Sheet 7-32, *Ignitable Liquid Operations.*

2.3.2.3 Provide standard response, ordinary temperature rated, K5.6 (80) or larger sprinklers under any obstruction that exceeds 3 ft (0.9 m) in width or diameter, or 10 ft^2 (0.9 m^2) in area. This includes obstructions associated with the boiler face.

2.3.3 Provide FM Approved portable extinguishers in accordance with Data Sheet 4-5, *Portable Extinguishers.* Refer to Data Sheet 4-5 to determine effective sizes and locations for the extinguishers.

2.4 Equipment and Processes

2.4.1 Fuel Supply

Arrange fuel supply, transfer, and piping systems in accordance with Data Sheet 7-32, *Ignitable Liquid Operations;* Data Sheet 7-88, *Ignitable Liquid Storage Tanks;* Data Sheet 7-54, *Natural Gas and Gas Piping;* and other FM recommended practices for handling, piping, and storage of gas and oil. This includes, but is not limited to, the following:

A. Proper design and location of piping systems, including appropriate arrangement of piping within buildings; protection of piping against mechanical and corrosion damage; use of appropriate materials of construction for piping, hoses, and pipe joints; and adequate flexibility and support of piping systems

B. Proper heating and insulation of piping systems

C. Provision of valves to ensure proper system control and regulation

D. Use of emergency shutoff valves

E. Proper design of transfer systems (e.g., pumping systems)

2.4.2 Combustion Air and Preignition Purge

2.4.2.1 Interlock any fans for combustion air (forced draft fans) or for removal of combustion products (induced draft fans) so that fuel SSOVs are closed and electric ignition deactivated unless fans are in operation and proper flow is provided. Provide air flow or pressure switches. For three-phase blower motors, interlock the airflow switch with the motor starter. Design the system such that loss of airflow or fan motor not running causes a complete shutdown of the boiler. Air flow supervision is not needed with oil-firing if the fan is integral with the burner motor shaft. If a flue gas recirculation fan is provided and its operation is required whenever the boiler is in operation, provide interlocks as per forced draft and induced draft fans.

2.4.2.2 Design for a supervised preignition purge of the boiler furnace, passes, and horizontal breeching with air flow not less than 50% of the air flow at the maximum firing rate for a duration sufficient to achieve not less than four volume changes of the furnace/firebox and boiler passes. Flame failure or failure to ignite on startup requires a full repurge before attempting a relight.

2.4.2.3 Interlock induced- or forced-draft dampers that are automatically positioned by the combustion control system so that, on lighting off, the induced-draft dampers will be open and the forced-draft dampers will be in position for smooth light-off. Adjust the control for these dampers so that proper amounts of air for complete combustion at all firing rates will flow through the boiler furnace. Smooth light-off depends on proper draft setting and on proper throttling of the fuel input. Control the burner fuel and air supplies to give smooth light-off at low-fire conditions. Locate low fire position switches, when they are used, on the controlled device in case of linkage separation.

2.4.2.4 If there is no ducted air supply to the boiler, provide openings or the equivalent in the boiler room to permit entrance of sufficient fresh air for complete combustion of the fuel at all firing rates. Interlock any dampers installed in these openings so the boiler will operate only if the dampers are open.

Some plants utilize exhaust fans to rid the area of dust or vapors. If the boiler room is not separate from these areas, duct the combustion air supply directly from out-of-doors.

Air preheating may be necessary in colder climates as cold air can interfere with proper operation of a boiler, and can cause a freeze-up of pneumatic control lines. Keep control air clean and dry. Refer to Data Sheet 9-18, *Prevention of Freeze-ups.*

2.4.3 Igniters, Safety Shutoff Valves, and Combustion Safeguards

2.4.3.1 Provide igniters that have sufficiently large capacities to ensure prompt ignition of the main burners. It is preferred that igniters be used that are stable with the main burner extinguished and with maximum boiler draft. Do not use direct spark igniters on light oil burners greater than 2.8 MMBtuh (820 kW) input or gas-fired burners greater than 2,500,000 Btuh input unless the burner lights off at a fuel input less than or equal to these ratings. Igniters are described in Appendix C.

2.4.3.2 Install the pilot, electric-spark igniter, and flame-sensing element of the combustion safeguard securely so that the position of each in respect to the others and the main flame will not change. Provide observation ports so that the positions can easily be observed while the pilot and/or main burner are firing. Ensure these units are readily accessible for inspection and cleaning.

2.4.3.3 Install safety shutoff valves (SSOVs) in the fuel supply lines to both the pilots and main burners.

Refer to Tables 2 and 3 for SSOV recommendations. For small pilots or fuel burners having less than 400,000 Btuh (117 kW) input, one SSOV is adequate. Using an FM Approved automatic leak detection device fulfills the requirements for proof-of-closure (as recommended in Table 2). This device pumps gas above line pressure between the two safety shutoff valves and monitors for pressure drop for a predetermined period of time before purge can begin. Once the test has been completed, the pressurized gas is bled back into the supply line. See Appendix C for more information on SSOVs.

Table 2. Safety Shutoff Valve Recommendations for Gas-fired Boilers. See Section 2.2.2.3.

400,000 Btuh–≤5 MMBtuh (117–1465 kW)	*>5−12.5 MMBtuh (1465–3662 kW)*	*>12.5 MMBtuh (>3662 kW)*
Two SSOVs or one SSOV with proof-of-closure	Two SSOVs, one with proof-of-closure	Two SSOVs with proof-of-closure

Table 3. Safety Shutoff Valve Recommendations for Oil-fired Boilers

400,000 Btuh–12.5 MMBtuh (117–3662 kW)	*>12.5 MMBtuh (>3662 kW)*
Two SSOVs or one SSOV with proof-of-closure[1]	Two SSOVs with proof-of-closure[1]

[1]Install a relief device between valves if there is a possibility of pressure buildup due to location in a hot area.

2.4.3.4 Emergency Shutoff Valves

2.4.3.4.1 In addition to the SSOVs recommended in Section 2.4.3.3, provide fusible link actuated emergency shutoff valves in the oil supply line to oil-fired boilers. Locate the valve in the boiler room at the termination of the welded piping supply, prior to the fuel train components. Locate the emergency shutoff valve to minimize the liquid holdup in the piping downstream of the valve. Locate the fusible link for the valve above the burner at the boiler burner front. For multi-boiler locations with a common oil supply pump, either link the cable for each boiler to a separate valve or connect the links in series to a single valve so the fusing of any one link will allow the valve to close. Test the valve periodically to ensure it will close when released.

2.4.3.4.2 Alternatives to fusible link actuated emergency shutoff valves include, but are not limited to, the following methods:

A. Actuation by use of heat detectors (e.g., HADs) located above the burner. Actuation of this device would cause the fuel train's SSOV to become deenergized.

B. If applicable, operation of the automatic sprinkler system to cause the fuel train's SSOV to become deenergized. Arrange the system to permit protection system alarm testing without unwanted shutdown of the equipment.

2.4.3.4.3 Install emergency shutoff valves or equivalent interlocks elsewhere in the oil supply piping system to ensure the prompt shutdown of oil flow in the event of a fire. The number and location of emergency shutoff valves will vary depending on the piping system size, complexity, and the potential exposure created by a release. Refer to Data Sheet 7-32, *Ignitable Liquid Operations,* for additional information on these devices and their appropriate placement in the piping system.

2.4.3.4.4 Provide each oil- or gas-fired boiler with a manually operated fuel shutoff valve for emergency closing in case of fire. Ensure the valve is prominently marked and located, preferably outside the boiler room, so as to be accessible in the event of a boiler room fire and to limit fuel holdup downstream.

2.4.3.5 Provide an FM Approved non-recycling flame-supervisory combustion safeguard arranged to first prove the existence of a reliable pilot flame before permitting the main burner SSOV to open. Limit the pilot trial-for-ignition period to ten seconds. When an Approved high-voltage spark igniter is provided, the fuel burning pilot and pilot trial-for-ignition may be omitted. Where the igniter is of the retractable type, it must be proved in the correct position for proper lighting off of the main-burner fuel before the ignition cycle can proceed. After a shutdown occurs due to a flameout, the combustion safeguard is allowed to recycle once on a gas-fired boiler rated at less than 2.5 MMBtuh (732 kW) or on an oil-fired boiler rated at less than 2.8 MMBtuh (820 kW).

2.4.3.6 Except when Class 1 pilots are provided, arrange a non-recycling flame-supervisory combustion safeguard for direct supervision of the main burner flame only, following proof of pilot flame and opening of the main burner SSOV. Limit the main burner trial-for-ignition to the shortest practical time, but not more than ten seconds (15 seconds for No. 5 and No. 6 oil).

2.4.3.7 Install the combustion safeguard flame-sensing element(s) in accordance with the manufacturer's instructions. Locate the main-burner flame-sensing element so that it reliably senses the main flame at all firing rates. De-energize the fuel SSOVs within four seconds of loss of flame. When a pilot is proved by a combustion safeguard, ensure supervision is at a location where it will reliably sense the presence of a flame. Ensure the main burner is ignited immediately by its pilot even when the pilot is reduced to the minimum flame capable of holding the flame-sensing relay of the combustion safeguard in the energized (flame present) position.

2.4.3.8 Do not allow the safe-start check of the combustion safeguard to be nullified by the action of operating or limit controls. A safe-start check, which takes place each time a boiler is started, determines if the flame scanner will detect a flameout. For boilers that are in continuous operation or where an operating cycle exceeds 24 hours, provide an automatic self-checking UV flame scanner (when a UV flame scanner is used). Self-checking is not needed on electronic UV scanners that do not use UV cells.

2.4.3.9 A combustion safety control system may be linked to a programmable logic controller (PLC) approved for burner management or combustion safety. The PLC may be used for boiler control such as combustion control and feedwater control, but not for any other process control. Refer to Data Sheet 7-45, *Instrumentation and Control in Safety Applications.*

2.4.3.10 During installation, verify that setup of the system (such as damper linkage adjustments and cam settings) is in agreement with calculations by means of on-site testing performed under the direction of the manufacturer.

2.4.3.11 Establish the stable operating range of the burners and the maximum rate of increasing and decreasing load change by test in accordance with the manufacturer's instructions. Provide interlocks and operating controls to prevent operation outside the ranges required for stable operation.

2.4.4 Additional Safety Controls

2.4.4.1 Provide at least one high water temperature or steam pressure operating limit control on all boilers, with operation of the device(s) causing the boiler to shut down. Additionally, for automatically operated unattended boilers, provide at least one high water temperature or steam pressure safety limit control. Set the safety limit control above the operating limit control(s), with operation of the limit control causing a safety shutdown requiring manual reset (safety shutdown and lockout).

2.4.4.2 Provide interlocked low-fire lighting off on automatic boilers so that on a call for heat, and after the preignition purge has been satisfied, fuel and air controls are in the correct minimal low firing positions before the ignition cycle can proceed for gas burners greater than 2.5 MMBtuh (732 kW) and for oil burners greater than 2.8 MMBtuh (820 kW).

2.4.4.3 Provide low water protection interlocks. See Data Sheet 6-12, *Low Water Protection for Boilers.*

2.4.4.4 Provide combustibles/oxygen analyzers, as an aid to safe and efficient operation, on boilers of 100,000,000 Btuh (29,300 kW) capacity and over, and preferably on smaller units as well. This recommendation does not apply to automatically operated, unattended boilers.

2.4.4.5 Lock manual isolation or three-way valves in piping to pressure switches or transmitters, if provided, in their open/normal operating position to prevent unintended isolation of the instrument. Alternatively, these valves can be spring-returned to their open/normal position.

2.4.5 Additional Recommendations for Gas Firing

An example of a permissive start-up and firing sequence for a gas-fired automatically lighted boiler burner is shown in Figure 1 and a typical fuel train is shown in Figure 2.

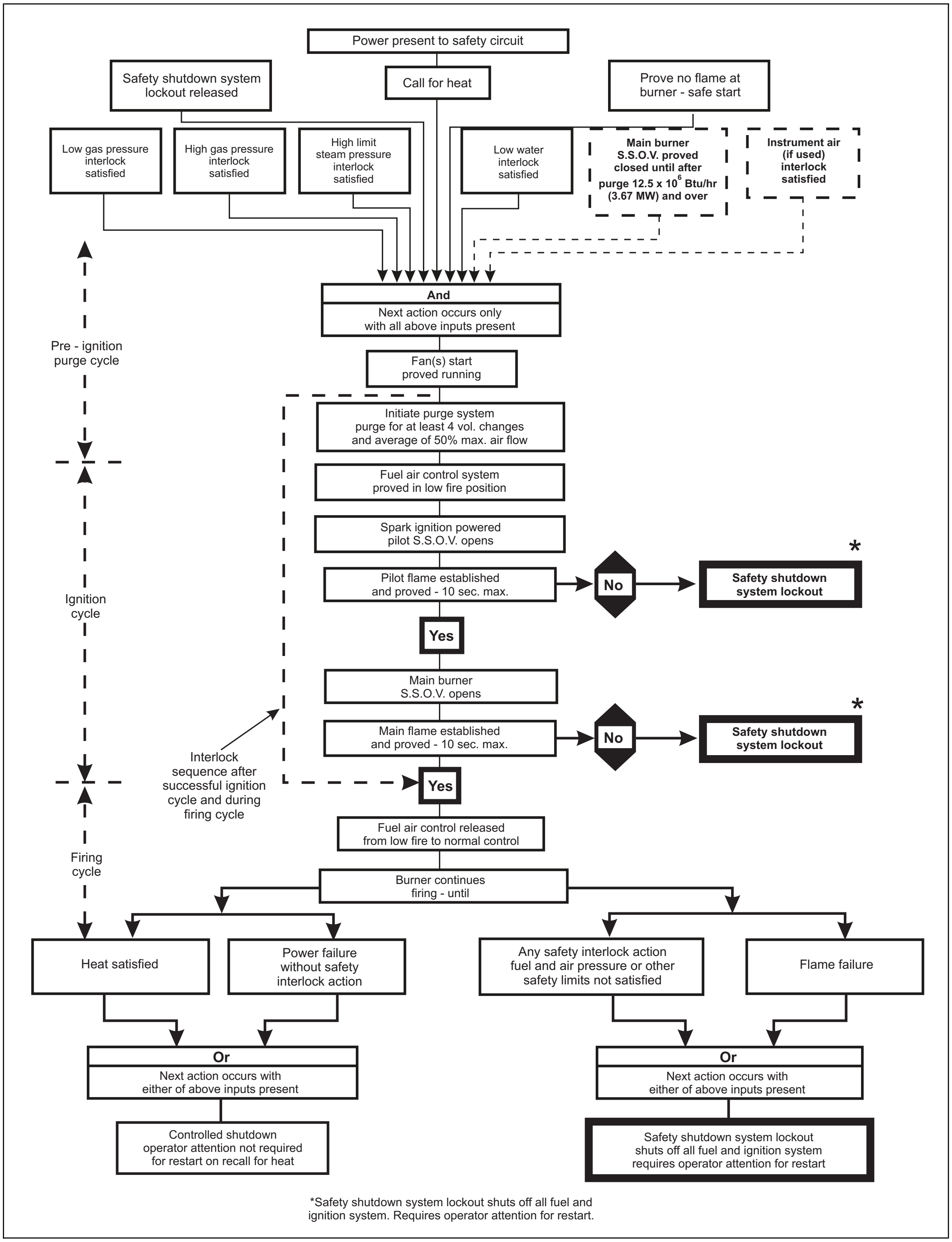

Fig. 1. Single-burner automatic-lighted gas-fired boiler. Example of a permissive start and firing sequence.

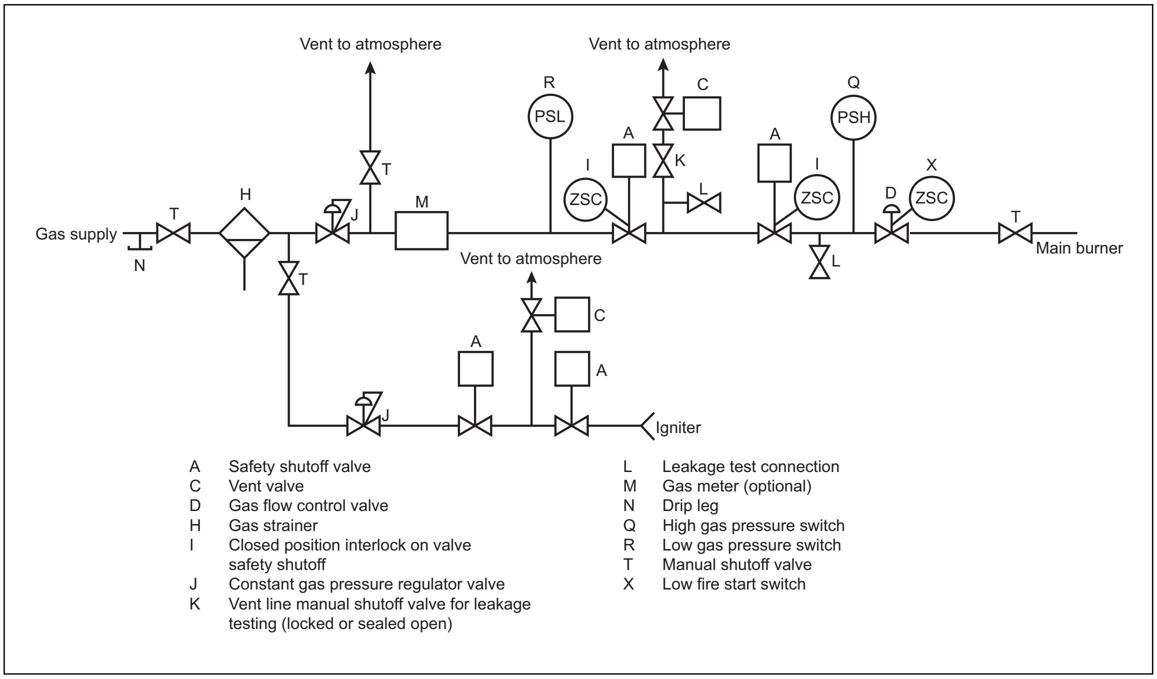

Fig. 2. Schematic of typical gas-fired piping arrangement over 12.5 × 10^6 Btuh (3660 kW)

For an operator supervised system, the permissive start and firing sequence is essentially as shown in Figure 1. The operator initiates the start of the sequence. Then, as the sequence steps are completed and the interlocks are satisfied, the subsequent steps may be initiated. When changes in firing rate are made manually, adjust the fuel and air supplies simultaneously at a pre-established optimum air-fuel ratio. Manipulate only one control device to achieve the change in firing rate.

2.4.5.1 Provide permanent and ready means for making periodic tightness checks of the main burner safety shutoff valves. See Data Sheet 6-0, *Elements of Industrial Heating Equipment.* Perform a manual leak test at least annually to determine that leakage does not exceed the limits in Data Sheet 6-0, *Elements of Industrial Heating Equipment.*

2.4.5.2 Provide low and high gas pressure interlocks for boilers greater than 2.5 MMBtuh (732 kW) by means of FM Approved pressure switches or transmitters arranged to shut off and lock out all fuel and electric ignition in the event of dangerously low or high pressures. Low and high gas pressure interlocks are required for boilers less than 2.5 MMBtuh (732 kW) if provided with a direct spark or hot surface ignition, but are optional with pilot ignition. Set the switches within the turndown or safe operating range of the burner. Locate the switches or transmitters between the pressure regulator and safety shutoff valves. Alternatively, the high pressure switch or transmitter can be located downstream of the safety shutoff valves, as shown in Figure 2. Account for pressure drops in the fuel train when setting the low and high pressure interlocks.

Design the fuel train to withstand the maximum pressure that can develop as the result of failure of the pressure regulator. If the fuel train cannot withstand this pressure or this pressure can exceed 60 psig (4.1 bar), install a relief valve vented to a safe location downstream of the regulator and upstream of the safety shutoff valve(s). Set the high pressure switch lower than the relief valve setting but no higher than 150% of normal pressure. Preferably, set the switch at about 125% of the normal operating pressure, provided nuisance tripping does not occur as a result.

2.4.5.3 Lock manual isolation valves, if present in vent piping, in a double block and vent arrangement for the safety shutoff valves, in the open position to prevent an unintended impairment of the vent.

2.4.6 Additional Recommendations for Oil Firing

2.4.6.1 Provide a low-fuel-oil supply pressure interlock by means of an FM Approved pressure switch or transmitter arranged to shut off and lock out all fuel and electric ignition in the event of inadequate supply pressure. Ensure operation of the devices causes a safety shutdown requiring a manual reset before the boiler can be restarted.

2.4.6.2 Provide a low-temperature interlock for oil that requires preheating to ensure the oil is at the viscosity recommended by the burner manufacturer before the burner can be fired. Additionally, provide a high temperature cutout switch if the oil can be overheated and cause vapor lock at the pump. To ensure prompt ignition during trial-for-ignition, arrange the piping and preheating system so the volume of unheated oil immediately upstream of the burner tip is minimized. Ensure operators understand specifications for all oils used as a fuel.

2.4.6.3 Interlock atomizing air or steam supply to the burner (generally used for Nos. 5 and 6 oil) so all fuel and electric ignition will be shut off and locked out in the event of inadequate atomizing pressure or lack of proper differential between the oil pressure and atomizing medium pressure.

2.4.6.4 An example of a permissive startup and firing sequence for an oil-fired automatically lighted boiler burner is shown in Figure 3 and a typical fuel train is shown in Figure 4.

For an operator supervised system, the permissive start and firing sequence is essentially as shown in Figure 3. The operator initiates the start of the sequence. Then, as the sequence steps are completed and the interlocks are satisfied, the subsequent steps may be initiated. When changes in firing rate are made manually, adjust the fuel and air supplies simultaneously at a pre-established optimum air-fuel ratio. Manipulate only one control device to achieve the change in firing rate.

2.4.7 Gas-Fired Multiport Burner Grid

2.4.7.1 Apply the recommendations previously given in this data sheet.

2.4.7.2 Provide either spark-ignited or manually ignited pilots.

2.4.7.3 Provide the light-off pilots with FM Approved non-recycling flame supervision combustion safeguards, arranged to prove the existence of reliable pilot flame before permitting the main burner safety shutoff valve to open and during main burner operation.

2.4.7.4 Supervise the stabilization pilots, with failure of the pilot flame causing shutoff of the fuel to the pilots and main burners.

2.4.8 Flue Gas Recirculation (FGR) Interlocks

Provide the following interlocks as applicable to prevent unstable combustion due to an FGR malfunction, with the interlocks causing a boiler shutdown and closure of the FGR damper:

A. An FGR fan motor electrical interlock, using motor starter auxiliary contacts (three-phase motors only)

B. An FGR fan flow switch to verify proper gas flow through the system

C. An FGR control damper position interlock to compare actual damper position with control position and prevent the boiler from operating if the damper is not within the limits

D. An FGR circuit trouble interlock, such that the boiler will not operate if there is circuit trouble or loss of power

E. A stack low temperature interlock

2.5 Operation and Maintenance

2.5.1 General

2.5.1.1 Maintain all equipment in proper operating condition. Maintenance details and schedules depend on the equipment and operating conditions. Follow a specific maintenance routine recommended by the manufacturer and include, at scheduled intervals, maintenance of burner equipment, gas SSOV leakage

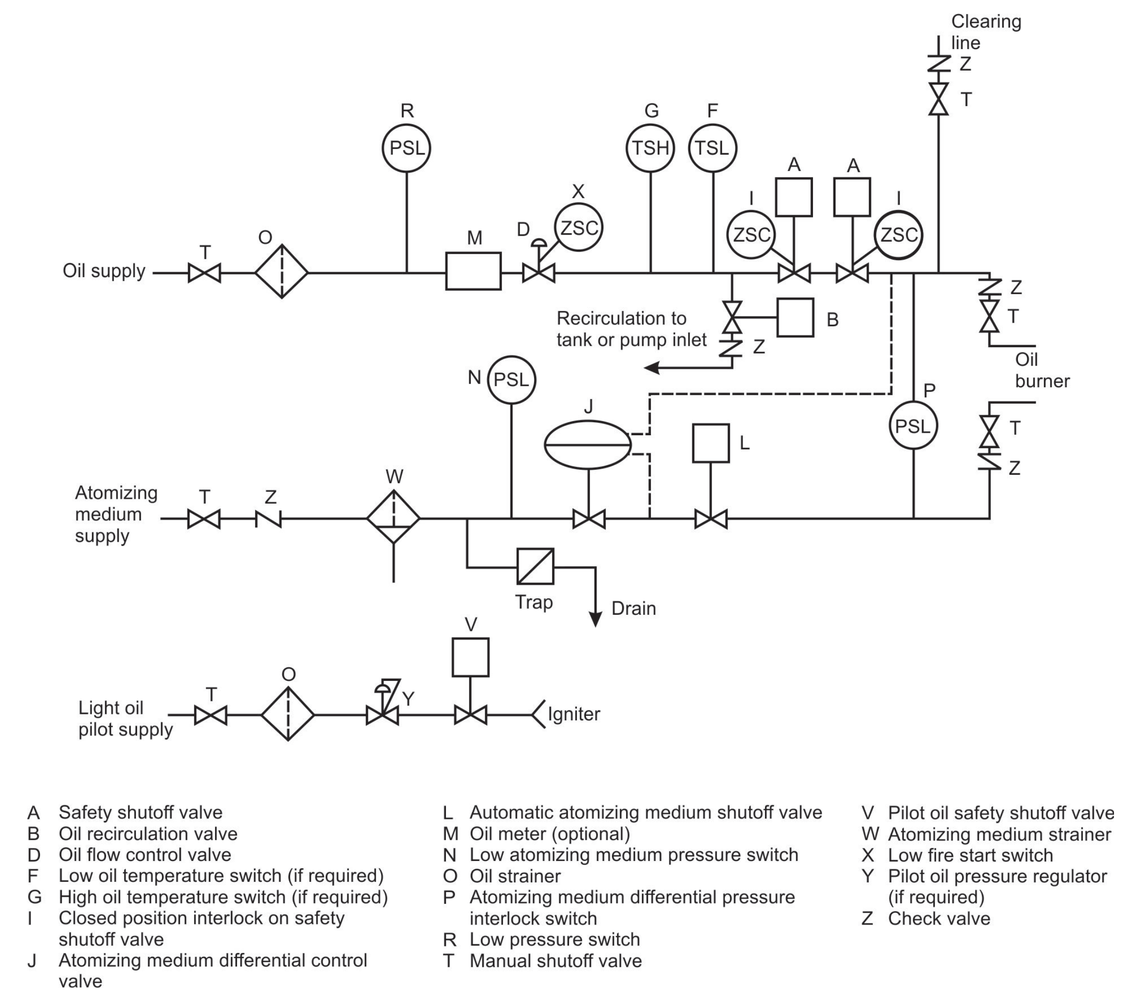

Fig. 3. Single-burner automatic-lighted oil-fired boiler. Example of a permissive start and firing sequence.

testing, inspection and cleaning of the electric-igniter and/or pilot-burner assembly, adjustment of linkages and controllers for fuel-air ratio control dampers and valves, and maintenance and testing of combustion safeguards and safety controls.

Inspect and maintain SSOVs in accordance with manufacturers' instructions. Keep valve stems and guides clean to prevent sticking. Replace soft parts such as packing, seals, and O-rings as necessary, as they may harden with time.

ASME CSD-1, *Controls and Safety Devices for Automatically Fired Boilers,* includes a guideline for documenting boiler controls and safety devices, as well as a recommended checklist for preventive testing and maintenance of these devices. These forms may be used as guides in developing suitable inspection reports for specific boilers.

2.5.1.2 Examine flexible hoses carefully, as they are a likely place for a fuel leak to develop. Replace braided oil hoses periodically, based on usage and consultation with the hose or boiler manufacturer. Older hoses may not flex properly and may leak at threaded connections in the fuel piping or result in hose breakage, especially if there are 90 degree bends. Hoses that are bulged, stiff, or corroded need immediate replacement. Hoses are subject to both tensile and compressive stresses, to internal pressure, and to the extremes of temperature, vibration, corrosive atmospheres, and physical impact and reactive forces.

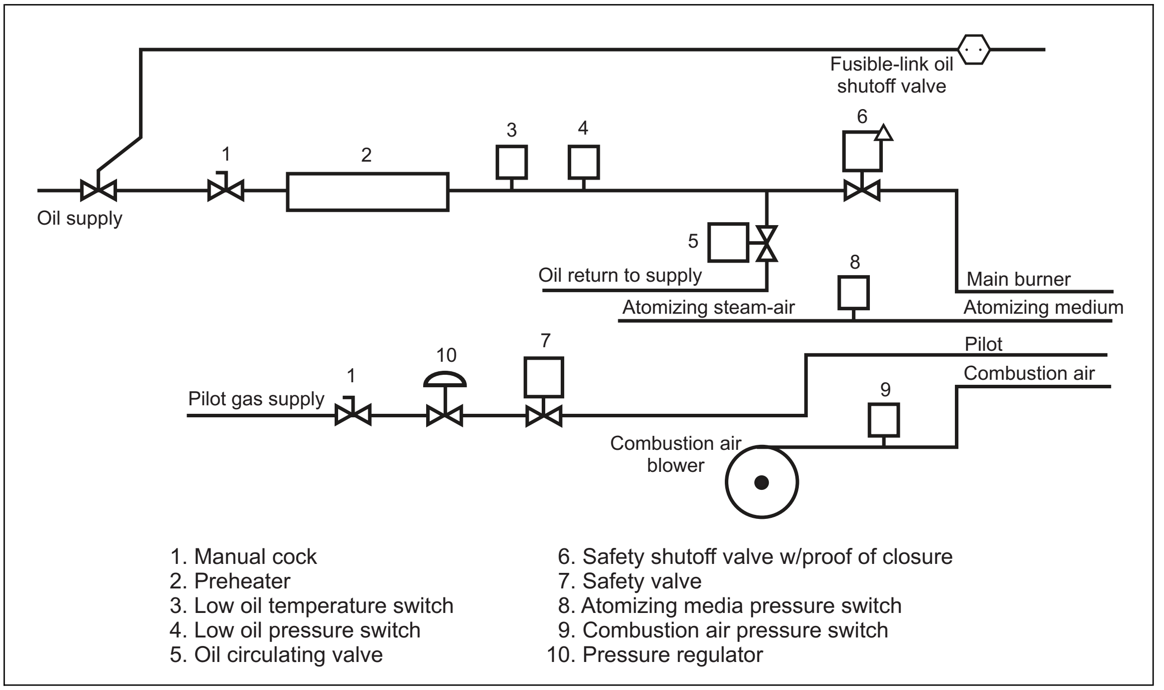

Fig. 4. Schematic of typical oil-fired piping arrangement over 12.5 x 10^6 Btuh (3660 kW)

2.5.1.3 Inspect and test safety controls at least annually, whenever maintenance involving the safety controls is done, and after any modification to the safety controls. Conduct inspection and testing in accordance with manufacturers' instructions. Use properly trained personnel or qualified contractors. The purpose is to ensure proper functioning when emergencies arise. Failure to make periodic checks may not only result in fire or explosion damage, but may also contribute to accidental shutdown with consequent loss of production.

Document the inspection and test procedures. Record tests listing the date of testing, what was tested, and the test results. Confirm proper operation of interlocks. Correct any defects prior to returning the boiler to service. Refer to Data Sheet 9-0, *Maintenance and Inspection,* for additional guidance.

Inspection and testing includes, but is not limited to, the following:

A. Flame failure detection system

B. Fan and airflow interlocks

C. Fuel safety shutoff valves for leakage. Refer to Data Sheet 6-0, *Elements of Industrial Heating Equipment*

D. Low fire start interlock, if provided

E. High steam pressure or temperature interlock

F. For oil: Fuel pressure and temperature interlocks

G. For gas:

1. Gas cleaner and drip leg

2. Low and High fuel pressure interlocks

H. *Igniter and burner components.* Verify a smooth, reliable light-off in the required period of time. Proper flame color and shape and exhaust color are indicative of good combustion.

I. *Combustion air supply system.* Check air flow or pressure switches, and damper high/low fire interlocks.

J. *Flame failure system components.* Check flame scanners and all safety controls that interlock with the SSOV through the combustion safeguard controller.

K. *Piping, hoses, wiring, and electrical connections* of all interlocks and shutoff valves. Check for leaks, corrosion, and loose connections.

L. *Combustion control system.* Check the fuel-air control system at various loads to see that proper air-fuel stoichiometry is maintained during turndown.

M. *Calibration* of indication and recording instruments.

N. Boiler low water protection: Follow guidance in Data Sheet 6-12, *Low Water Protection for Boilers.*

O. Operator manual emergency shutdown switch(es), when provided in control rooms

P. As required for oil-firing:

1. Disassemble and clean atomizers
2. Clean strainers

2.5.1.4 Upon completion, ensure covers of all safety controls are secured in place to minimize tampering and the introduction of dust and dirt.

2.5.2 Alternate and Simultaneous Fuel Systems

2.5.2.1 Alternate Fuel Firing and Transfer System

Some single-burner boilers may fire either gas or oil. The combustion control system is arranged to provide a proper fuel-air ratio for individual firing of either fuel, but only one fuel at a time. The transfer to the alternate fuel may be accomplished either manually or automatically through a suitable fuel transfer system. Ensure the various interlocks, flame supervision, and safety shutoff valves are in service for the fuel being fired. Design the transfer procedure such that it is compatible with the specific combustion control system, and include the following sequence: (1) shut the burner down; (2) place the alternate fuel system, with its respective interlocks and the combustion control system adjusted for the alternate fuel, in service; and (3) follow a light-off procedure compatible for the fuel. Follow these procedures when switching to other fuels such as propane. Never change over in a high firing position. If simultaneous transfer is necessary, reduce the boiler to low fire.

2.5.2.2 Alternative Fuel System-Simultaneous Fuel Firing Transfer

Some steam demands may require transfer from firing one fuel to another without shutting down the boiler even though the combustion control system is suitable for firing only one fuel at a time. Perform the transfer using a qualified operator following a procedure that will prevent a fuel-rich condition.

Ensure the burner is capable of burning two fuels simultaneously and the system is equipped with the various interlocks, flame supervision, and SSOVs necessary for the combustion safe guard system for each fuel. Provide a fuel selector switch with a gas position in which oil cannot be fired, an oil position on which gas cannot be fired, and a gas-oil position that permits simultaneous firing of both fuels provided all interlocks for both fuels are satisfied, including light-off position for both fuels. Provide manual valves at the burner, downstream of the SSOVs in each fuel line. Install pressure gauges downstream of the manual valves.

2.5.2.2.1 Use the following procedure, or a comparable procedure prepared by the manufacturer, for changing from gas to oil:

1. If an intermittent pilot is available, place it in service.
2. Check that the manual oil valve at the burner is closed.
3. Establish oil fuel system to satisfy interlocks.
4. Install oil atomizer.
5. Open atomizing medium shutoff valve.
6. Place combustion control system in manual position.
7. Reduce gas flow to the low firing rate.
8. Place oil control valve in the normal light-off position.

9. Place fuel transfer switching system into oil-gas position.

If the oil safety interlocks are satisfied, the oil safety shutoff valve will open. Fuel oil pressure now will be upstream of manual oil valve at the burner.

10. Observe the gas pressure downstream from the manual gas shutoff valve and slowly close valve until the gas pressure starts to drop. At this point, the gas flow rate is controlled by the manual valve instead of by the normal control valve.

11. Simultaneously and slowly close the manual gas valve while operating the manual oil valve to light the oil flame from the gas flame. Continue to increase the oil firing rate while cutting back on gas firing rate to keep a constant heat input of the combined fuels to the burner until the manual gas valve is closed and manual oil valve is fully open. Care must be taken to maintain an adequate amount of excess air at all times by continuously observing the burner flame, or by observing the fuel-air ratio or oxygen indicator, if provided. During this period, air flow is maintained at a constant rate, with only the manual fuel valves in operation.

12. Place the fuel transfer system in the oil position. The gas safety shutoff valves will now close.

13. Return the combustion control system and burner firing rate to normal operation.

2.5.2.2.2 Use the following procedure, or a comparable procedure prepared by the manufacturer, for changing from oil to gas:

1. If an intermittent igniter is available, place it in service.

2. Check that the manual gas valve at the burner is closed.

3. Establish gas fuel system to satisfy interlocks.

4. Place combustion control system in manual position.

5. Reduce oil flow to the low firing rate.

6. Place gas control valve in the normal light-off position.

7. Place fuel transfer switching system in the gas-oil position.

If the gas safety interlocks are satisfied, the gas safety shutoff valves will open. Gas pressure now will be upstream of gas manual valve at the burner.

8. Observe the oil pressure downstream from the manual oil shutoff valve and slowly close valve until the oil pressure starts to drop. At this point, the oil flow is controlled by the manual valve instead of by the normal control valve.

9. Simultaneously and slowly close the manual oil valve while operating the manual gas valve to light the gas flame from the oil flame. Continue to increase the gas firing rate while cutting back on oil firing rate to keep a constant heat input of the combined fuel to the burner until the oil valve is closed and manual gas valve is fully open. Care must be taken to maintain an adequate amount of excess air at all times by continuously observing the burner flame, or by observing the fuel air ratio or oxygen indicator, if provided. During this period, air flow is being maintained at a constant rate, with only the manual fuel valves in operation.

10. Place the fuel transfer system in the gas position. The oil safety shutoff valve will now close.

11. Return the combustion control system and burner firing rate to normal operation.

2.5.2.3 Simultaneous Firing of Oil and Gas

Some single-burner assemblies and combustion control systems that maintain a proper fuel-air ratio for each fuel and the combined fuel input are suitable for simultaneous firing of oil and gas. Ensure the combustion control system is of the type that meters and totals inputs from both fuels, alone or in any combination, and controls air flow proportionally. Ensure the maximum total heat input is not exceeded. In most instances, a fuel selector switch is provided to permit firing of either fuel or both fuels simultaneously. Maintain the various interlocks, flame supervision and SSOVs in service for the fuel or fuels being fired. During simultaneous firing of two fuels, do not permit the interlocks for one fuel to bypass the interlocks for the second fuel. Develop operating procedures that are compatible with the specific combustion control system and that follow the manufacturers’ instructions.

2.5.3 Flue Gas Recirculation (FGR)

2.5.3.1 Purging Boilers with Flue Gas Recirculation

2.5.3.1.1 Purge boilers with flue gas recirculation systems in accordance with the manufacturer's recommendations.

2.5.3.1.2 At the end of the purge, stop air flow through the flue gas recirculation system.

2.5.3.2 Operation of Boilers with Flue Gas Recirculation

2.5.3.2.1 Maintain low-fire operation and do not allow the FGR damper to open until the stack temperature reaches a predetermined value established by the manufacturer.

2.5.3.2.2 Allow a minimum time delay, established by the manufacturer, after proper stack gas temperature is established before the FGR damper is permitted to open.

2.5.3.2.3 Limit maximum flue recirculation rates to that established by the manufacturer and confirmed by test.

2.5.3.3 Design Considerations for Systems with a Flue Gas Recirculation Fan

2.5.3.3.1 Size the flue gas recirculation (FGR) fan, which delivers flue gas back to the burner for the purpose of NO_x reduction, to deliver the correct volume of gas at the required pressure.

2.5.3.3.2 Provide a gas/oil selector switch for combination-fired boilers to change recirculation rates. Rates are typically lower for oil than for gas.

2.5.3.3.3 Allow a cool-down period (allowing the fan to run) for the FGR fan after boiler or FGR shutdown.

2.5.3.3.4 Ensure the FGR fan is started before flue gas recirculation system dampers are opened to establish flue gas recirculation during boiler operation.

2.5.3.4 Design Considerations for Induced Flue Gas Recirculation

2.5.3.4.1 If rapid changes in boiler load are expected, design the flue gas recirculation damper to modulate according to the firing rate. Design and test the combustion controls to ensure that the rate of change of FGR flow matches the fuel and air flows, with the flue gas recirculation matching the fuel in the lead-lag control arrangement if possible. This can be accomplished by means of a direct mechanical linkage to the fuel-air controller or by coordinated control loops. Evaluate controls for reliability. Design the damper to fail in the closed position if there is an actuator failure, linkage failure or loss of actuating medium. A fixed damper (positioned at initial startup) is acceptable for steady state operation and gradual changes in boiler load.

2.6 Training

2.6.1.1 Train operators in the proper operation of the boiler and in the specific functions of the various safety controls.

2.6.1.2 Post operating instructions or keep them in the boiler room for ready reference, and ensure they are adhered to.

2.7 Human Factor

2.7.1 Develop an emergency response plan that includes shutdown of ignitable liquid and flammable gas systems. Refer to Data Sheet 10-1, *Pre-Incident Planning,* for general guidelines on establishing and maintaining an emergency response plan.

2.8 Electrical

2.8.1 Design electrical installations in accordance with the National Electrical Code® or other applicable local codes. The burner front is normally classified as non-hazardous. Although there is a possibility of flammable vapors being present, the close proximity of the igniter, pilot, and burner make the additional risk of an explosion from an electrical spark negligible.

2.8.2 Ensure both ac and dc safety-control circuits are two-wire, one side grounded, and not over nominal 120 volts. Limit all safety-control switching to the ungrounded conductor.

Provide overcurrent and ground fault protection. In addition to circuit grounds, provide grounding for non-current carrying metal parts, such as equipment enclosures and conduit.

2.8.3 Where an ungrounded dc power supply cannot be avoided, locate all switching in one conductor and provide ground fault detection.

2.8.4 Emergency Shutdown

2.8.4.1 For automatically operated unattended boilers located in a boiler room, provide a manually operated remote shutdown switch or circuit breaker located just inside or outside each boiler room door. Design the system so activation of the emergency shutdown switch or circuit breaker will immediately shut off the fuel.

2.8.4.2 For automatically operated unattended boilers in a location other than a boiler room, provide a manually operated remote shutdown switch or circuit breaker marked for easy identification at a location readily accessible in the event of boiler misoperation. Design the system so activation of the emergency shutdown switch or circuit breaker will immediately shut off the fuel.

2.8.4.3 For boilers monitored and/or operated from a continuously occupied control room, provide an emergency shutdown switch in the control room that is hard-wired to immediately shut off the fuel upon activation.

3.0 SUPPORT FOR RECOMMENDATIONS

3.1 Loss History

3.1.1 Explosion Loss History

Age, coupled with inadequate maintenance and testing, was the leading cause for losses on oil- and gas-fired single-burner boilers, followed by contractor and boiler operator error (human element). The most common times for an explosion loss were during startup and when switching between fuels on dual-fuel-fired boilers. Of those occurring at startup, the most common cause was fuel leaking into the boiler during the idle period and purge. This shows the importance of testing safety shutoff valves. Operator training and adherence to documented, safe operating procedures have also proven to be critical. The loss history supports the need for safety devices, operator training, proper operating procedures, regular testing, and maintenance.

Table 4. Causes of Explosion Losses (FM Loss History, 2002-2012)

Primary Loss Factors	*Percentage of Losses[1]*
Age, inadequate maintenance or testing	56%
Human element	32%
Combustion safety interlock missing or out of service	4%
Operating control failure	4%
Pressure part failure	4%

[1]The cause was not identified in 20% of the losses occurring between 2002 and 2012. Some losses had more than one factor. The percentages shown are based on the losses for which cause(s) were identified.

3.1.2 Fire Loss History

The majority of fire losses associated with single-burner oil-fired and gas-fired boilers resulted from a leak of fuel within or at the boiler face, with subsequent ignition. Releases occurring upstream of the boiler have also occurred, although less frequently due to proper arrangement of the piping and pumping systems.

Table 5. Causes of Fire Losses (FM Loss History, 2002-2012)

Primary Loss Factors	*Percentage of Losses*
Fire at boiler	54%
Pump	8%
Flue, exhaust	8%
Electrical	8%
Human Element	8%
Unknown	14%

3.2 Illustrative Losses

3.2.1 Explosion Loss Examples

3.2.1.1 Watertube Boiler with Ultra Low-NO_x Burner

A single-burner watertube boiler producing 75,000 lb/hr (34,000 kg/hr) saturated steam at 260 psi (18 bar) was retrofitted with an ultra low-NO_x burner approximately three years prior to the incident. During normal operation, the boiler operators responded to a low-water alarm as the result of a rapid increase in steam demand. While operators were at the boiler opening the feedwater flow control valve bypass to restore drum level, the boiler experienced two combustion explosions, about ten seconds apart, with the second explosion reported as being larger than the first. Following the explosion, the operators quickly exited the boiler room, hitting the emergency stop button as they left. Damage to the boiler included bowing of both side casings as well as the roof and floor. And, while no tubes or other pressure parts ruptured, eight tubes were severely bent and required replacement.

A similar, less-severe explosion occurred shortly after the burner was installed, after which minor adjustments had been made to the control system. While no cause was specifically identified for either incident, it is believed they occurred due to an accumulation of unburned fuel or products of combustion as a result of the limited operating margins of the burner. Following the second incident, an upgrade to the control system was made to add a lead-lag system to prevent a fuel-rich condition from developing during load changes, a second flame scanner was added to monitor the outer ring of the burner, and a carbon monoxide/oxygen monitor was installed.

A rental boiler located, delivered, and installed in less than five days limited the TE impact of the incident.

3.2.1.2 Firetube Boiler Explosion Following Operation with Safety System Bypass

A gas-fired firetube boiler rated at 8,800 lb/hr (4,000 kg/hr) steam had a combustion explosion while in operational condition. For each of the three days prior to the incident, the boiler was tripping and locking out during operation. The servicing contractor came to the site each day and left the boiler in operational condition. Examination of the control panel wiring block following the explosion revealed two wires had been removed from their contacts and wired straight through.

The boiler was severely damaged and was replaced. A rental boiler was obtained and installed in three weeks to limit the interruption to production.

3.2.2 Fire Loss Examples

3.2.2.1 Inadequate Segregation of Pump Room, Lack of Automatic Shutoff Valve for Pumping System, and Impaired Sprinkler System Result in Significant Fire Damage

An electric power generating plant contained four conventional boiler-steam turbine-generator units, two of which were not operational. The two boilers that were in service were both rated at 1,225,000 lbs steam/hr (555,650 kg/hr) of steam. They were multiple-burner boilers, but this loss still demonstrates the importance of proper design and location of fuel supply systems.

The units operated on natural gas and/or No. 6 oil, which was supplied to a one-story pump room that contained four positive displacement fuel pumps, oil heaters, and other related equipment. The pump area was located along two exterior walls of the building. However, the interior walls of the room were open to the rest of the boiler building, with no fire-rated cutoffs, containment, or emergency drainage. Automatic sprinklers were installed in the pump area, but the system was impaired while upgrades were being made to the fire protection system control panel.

One of the turbine-generator units tripped due to a loss of excitation, which initiated a boiler master fuel oil trip (MFT). Upon unit trip, power supply to the turbine generator was automatically transferred from an auxiliary transformer to a starting transformer, which caused a voltage disturbance to the facility's equipment. This caused control air compressors to trip. The compressors were not provided with alarms, and operators were not aware they had been shut down.

The MFT also caused all fuel supply to the boiler to shut via a control valve, while a recirculation valve was installed to handle full oil pump flow. Upon unit trip, the fuel oil pump discharge pressure rose to approximately 430 psi (29.6 bar), which exceeded the 365 psi (25.2 bar) fuel oil relief valve setting, before the recirculation valve fully opened to reduce the pressure. However, as a result of the tripping of the compressors, the recirculation valve suddenly failed closed due to loss of control air. The oil pump discharge pressure rose to 525 psi (36.2 bar), which cracked a threaded nipple and released oil into the pump room as an atomized spray. The oil sprayed onto a large 480 V radiant ceiling-hung heater and ignited. Analysis after the fire estimated that the leak from the failed nipple released between 65 and 75 gpm (246 and 285 L/min).

Operators noticed heavy black smoke coming from the area, and the public fire service was called. Operators attempted to extinguish the fire using portable extinguishers, but their efforts were unsuccessful. The fuel oil supply was not shut down until approximately 15 minutes after the initial pipe failure, and the fire was extinguished approximately 2 hours later.

The roof support steel in the pump room had sagged due to the fire, and all equipment within the area (pumps, valves, heating equipment, etc.) was heavily damaged. Since the room was open to the rest of the building, smoke and heat traveled through the entire 175 ft (53 m) height of the building, damaging an adjacent elevator, buckling stairs, and damaging instrumentation, controls, and other equipment on the floors above the fire origin. The building's brick walls for the first two floors above the fire origin were damaged and required replacement, while fuel oil and natural gas piping suffered heat damage and had to be replaced. The roof of the boiler building (175 ft [53 m] above the level of fire origin) sustained minor heat damage, and smoke damage was noted throughout the building.

3.2.2.2 Lack of Automatic Shutoffs Allows Spreading Oil Fire

A wood particle boiler was supplemented by an oil burner during periods when the wood chips and dust supply to the boiler was interrupted, or to restart the boiler after a shutdown. The burner was located on the third floor of an open steel frame building. Oil pumps supplied oil to a 150 gal (39.6 L) preheater attached to the side of the oil burner.

Operators attempted to start the oil burner, but it failed. A second startup of the burner was successful, and the oil burner operated for approximately 5 minutes before an operator noticed a fire via a monitoring camera installed in the area. Investigation after the loss revealed that fire shutters installed to prevent heat and flames from travelling backward from the burning chamber had failed open. The resulting fire and heat outside the burning chamber impacted oil piping, and oil leaked from the piping and ignited. A three-dimensional spill fire ensued, with burning oil spilling from the oil preheater and piping on the third floor to areas below. Oil pooled on floors below the burner. Wood dust residue on the lower floors and on nearby cable trays further supported fire spread.

No emergency shutoff valves, or similar interlocks to shut down the oil systems, were installed at the boiler. However, operators responded quickly to manually shut down the oil pumps. Additionally, the fire service responded within 5 minutes to limit further damage. The fire damaged the burner, electric motors, ductwork, and cables in the area.

4.0 REFERENCES

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

4.1 FM

Data Sheet 3-26, *Fire Protection Water Demand for Nonstorage Sprinklered Properties*
Data Sheet 4-5, *Portable Extinguishers*
Data Sheet 6-0, *Elements of Industrial Heating Equipment*
Data Sheet 6-5, *Oil- or Gas-Fired Multiple Burner Boilers*
Data Sheet 6-12, *Low Water Protection for Boilers*
Data Sheet 7-32, *Ignitable Liquid Operations*
Data Sheet 7-45, *Instrumentation and Control in Safety Applications*
Data Sheet 7-54, *Natural Gas and Gas Piping*
Data Sheet 7-55, *Liquefied Petroleum Gas*
Data Sheet 7-88, *Ignitable Liquid Storage Tanks*

Data Sheet 9-0, *Maintenance and Inspection*
Data Sheet 9-18, *Prevention of Freeze-ups*
Data Sheet 10-1, *Pre-Incident Planning*

4.2 Other

ASME CSD-1, *Controls and Safety Devices for Automatically Fired Boilers*
NFPA 54, *Installation of Gas Appliances-Gas Piping*
NFPA 85, Boiler and Combustion System Hazards Code

APPENDIX A GLOSSARY OF TERMS

Continuous igniter: An igniter that is in operation at the completion of the igniter trial-for-ignition and remains in operation through the main burner trial-for-ignition and during the entire operating cycle of the main burner until it is shut down. (Defined as “intermittent” in ASME CSD-1. A continuous igniter for boilers falling within the scope of CSD-1 remains on at all times whether or not the boiler is in operation.)

FM Approved: References to “FM Approved” in this data sheet mean a product or service has satisfied the criteria for FM Approval. Refer to the Approval Guide, an online resource of FM Approvals, for a complete listing of products and services that are FM Approved.

Ignitable liquid: Any liquid or liquid mixture that will burn. A liquid will burn if it has a measurable fire point. Ignitable liquids include flammable liquids, combustible liquids, inflammable liquids, or any other term for a liquid that will burn.

Intermittent igniter: An igniter that is in operation at the completion of the igniter trial-for-ignition and remains in operation through the main burner trial-for-ignition. It may, but does not have to, remain in operation for all or part of the normal operating cycle of the main burner. (No equivalent definition exists in ASME CSD-1.)

Interrupted igniter: An igniter that is in operation at the completion of the igniter trial-for-ignition and remains in operation through the main burner trial-for-ignition. It may not be placed in service during the normal operating cycle of the main burner.

APPENDIX B DOCUMENT REVISION HISTORY

The purpose of this appendix is to capture the changes that were made to this document each time it was published. Please note that section numbers refer specifically to those in the version published on the date shown (i.e., the section numbers are not always the same from version to version).

January 2024. Interim revision. Minor editorial changes were made.

January 2016. Interim revision. Relevant text from the reference (″R″) document was imported to the data sheet for the convenience of the user, including the following:

A. Background information on multiport burner grids added to Appendix C.

B. Background information on NO_X reduction technologies added to Appendix C.

C. Inspection guidance added to Appendix C.

July 2014. The following major changes were made:

A. Revised terminology and guidance related to ignitable liquids to provide increased clarity and consistency. This includes replacing references to “flammable” and “combustible” liquid with “ignitable” liquid throughout the document.

B. Reorganized the document to be consistent with other data sheets.

C. Provided additional information relative to the construction and proper location of boiler rooms.

D. Added guidance to differentiate between the fire hazard associated with oil- and gas-fired boilers and the hazard of properly and improperly designed fuel supply systems (piping, pumping, storage).

E. Expanded the guidance on boiler fuel supply systems to be consistent with FM Global’s loss prevention recommendations for ignitable liquid hazards, including fuel tanks, piping, and pumping systems.

F. Provided guidance on the installation of emergency shutoff valves in the oil supply piping for oil-fired boilers. Depending on the design and layout of the oil piping system, additional shutoff valves may be necessary beyond the boiler face to limit an oil release elsewhere in the system.

G. Expanded the fire protection recommendations to address hazards beyond the boiler (e.g., fire protection of storage tanks, pumping systems, etc.)

H. Changed to term “supervised manual boilers” to “operator supervised boilers.”

May 2006. Editorial change was made to the recommendation 2.2.4.1.

May 2005. Recommendation 2.2.1.2 uses revised editorial changes to section C.3, other standards were made.

January 2003. Loss information in section 3.0 was revised.

September 2002. Clarification was made to Recommendation 2.2.2.1.

September 2001. A change was made to Recommendation 2.2.1.1.

January 2001. The following changes were made:

1. Recommendation on igniters changed to limit size of gas and light oil burners using spark igniters (2.2.2.1).

2. Recommendations on safety shutoff valves changed to state that using an Approved automatic leak detection device fulfills requirements for proof-of-closure, but does not eliminate the need for manual leak testing (2.2.2.3, 2.2.4.1).

3. Recommendation for self-checking UV flame scanners changed to state electronic UV scanners do not need self-checking (2.2.2.7).

4. Recommendation on PLCs used for safety control changed to state that a combustion safety control system can be linked to a PLC approved for burner management or combustion safety (2.2.2.8).

5. Recommendations on gas pressure switch settings revised, and recommendation on the need for a gas pressure relief valve added (2.2.4.2).

6. A recommendation on induced flue gas recirculation was revised to add a warning on the use of fixed dampers (2.4.3.3.1).

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

APPENDIX C SUPPLEMENTAL INFORMATION

C.1 Gas-Fired Multiport Burner Grids

Gas-fired multiport burner grids are used in cast iron or tubular steel sectional boilers where the boiler-burner sections are bolted together at the site. The number of sections assembled is determined by the amount of hot water or steam needed to meet the demands for building heat and processes. A series of gas-fired atmospheric ribbon burners or a bed of closely spaced atmospheric burners are installed in each section. Combustion air is drawn into and mixed with the gas by the inspirating action of the fuel gas. Gas is supplied to each section or group of burners through a manifold. Usually, several sections of burners are supplied by a single manifold. Some designs have manifolds on each side of the boiler supplying burners that heat each half of the section.

These multiport main burner assemblies require a multi-pilot igniter arrangement that is different from those provided for normal gun-type or nozzle-type power burners. Stabilization pilots may be provided to permit a light-off without flashback (see Figure 5).

The ratings of the burner per section can range from 10,000 Btuh (2930 W) to 200,000 Btuh (59 kW) per boiler.

The combustion chamber, burners, and flue gas passes may be arranged so that all sections form essentially one combustion zone. Other boilers may have sections where each are separated by baffles (partitions) extending from below the burners up to the top of the unit, including the flue gas stack connections. Where the sections are so separated, each may be considered an independent combustion chamber.

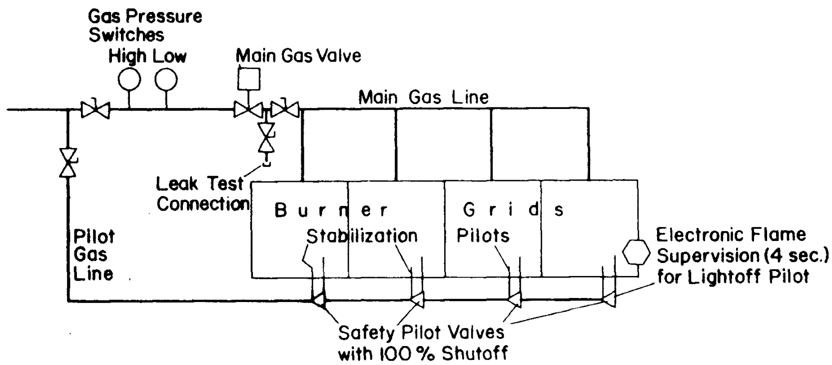

Fig. 5. Schematic of a burner grid arrangement

C.2 Igniters

An igniter is a fixed device that provides the energy required to ensure prompt ignition of the main burner fuel. A pilot is a fuel-fired type of igniter. NFPA 85, *Boiler and Combustion Systems Hazards Code,* and ASME CSD-1, *Controls and Safety Devices for Automatically Fired Boilers,* define continuous and intermittent igniters/pilots differently. ASME CSD-1 considers a continuous pilot to be a constant burning pilot which remains lit all of the time and an intermittent pilot to be one which remains lit only while the main burner is in operation. NFPA 85 and this data sheet use the definitions for igniters found in Appendix A.

There are four classes of igniters; Class 1, 2, 3, and 3 Special, defined as follows:

- **Class 1** provides energy generally in excess of 10% of burner fuel input, and should reliably ignite any combination of fuel and air under any light-off condition. Flame supervision of the igniter should be done in a manner that ensures that when flame is detected, it is of sufficient size and location to reliably ignite the main burner during all operating and transient conditions. Class 1 igniters can be operated as continuous, intermittent or interrupted igniters. Flame supervision of the main burner is not required when a Class 1 continuous igniter is used.
- **Class 2** igniters provide energy generally between four and ten percent of burner fuel input, and should reliably ignite fuel under normal light-off conditions. A Class 2 igniter can be operated as an intermittent or an interrupted igniter. When used as an intermittent igniter to support ignition under low load and other normal conditions, independent supervision of the main burner flame is required (at least two flame scanners).
- **Class 3** igniters generally provide energy less than four percent of burner fuel input, and should reliably ignite fuel under normal light-off conditions. This type of igniter can only be operated as an interrupted pilot and must shut off when the main burner trial-for-ignition is ended.
- **Class 3 Special** (electric igniters) are high-voltage igniters that will directly light off the main burner fuel. Power should be interrupted when the main burner trial-for-ignition is ended. If the igniter is a retractable type, it should be interlocked to be proven fully inserted prior to energization.

C.3 Safety Shutoff Valves

Various types of SSOVs are FM Approved. Pneumatically operated valves can be used, although these are slower closing valves and must have vents sized properly in order to close as quickly as possible without damaging valve seats. There are quick-acting solenoid-operated valves that are normally used as pilot SSOVs or as second main SSOVs. Hydraulically-operated SSOVs are quite commonly used as main SSOVs: these valves employ a solenoid and a hydraulic actuator and are slow opening and quick closing. Some SSOVs are electrically operated, but also must be latched in manually to open the valve. There are also valves available with a proof-of-closure interlock using valve seal overtravel: the valve must be proven closed before the purge and ignition cycles can begin. This type of SSOV is required on boilers above a certain size (see

Tables 2 and 3). SSOVs should be fully closed within one second after deenergization. A five-second closing time is allowed if the boiler is rated at less than 2.5 MMBtuh (732 kW); however, one second is preferred.

A method for checking gas leaks with this type of arrangement is to install the vent line to a tank partially filled with glycerine (see Figure 6). The vent line should enter the top of the tank and terminate inside below the fluid surface. The area above the surface should be vented to a safe location out-of-doors. Operators or maintenance personnel should inspect the tank during their rounds to determine if there is a gas leak by checking for bubbles in the tank. This method would provide a continuous leak test of the upstream SSOV during boiler shutdown. This would also provide a means to check for a vent valve leak during firing. Checking this inspection tank should be a part of the posted start-up procedures for the boiler.

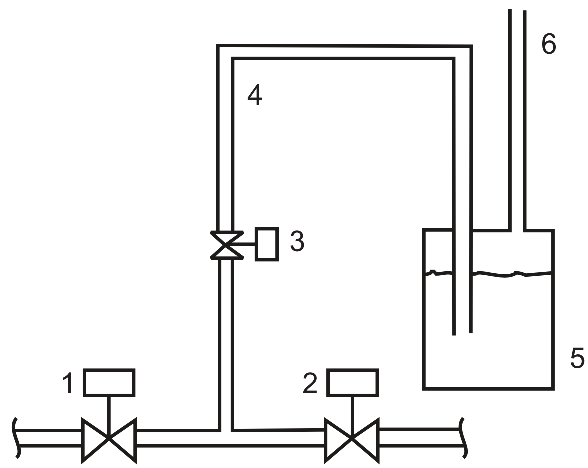

Fig. 6. Inspection tank for SSOV and automatic vent valve leak checking

C.4 Flue Gas Recirculation and Low NO_X Burners

A good combustion pollution control strategy will reduce NO_x without increasing CO or unburned hydrocarbons. It should also maintain combustion stability and boiler efficiency as close as possible to that which was achievable before implementing NO_x control. Oxides of nitrogen can be formed during combustion in different ways. The three types of NO_x are thermal, fuel-bound, and prompt. The formation of nitric oxide (NO) is the primary principal reaction that contributes most to boiler NO_x emissions. NO will start converting to NO_2 in the presence of excess air as the temperature of the exhaust drops, and will be the primary form of NO_x exiting the stack.

Thermally generated nitric oxide is formed by the oxidation of nitrogen in the combustion air at high temperatures (above 3200°F [1760°C]). This is the largest contributor to nitrogen oxide emissions resulting from combustion. Flue gas recirculation is aimed at reducing thermally produced NO_x.

Fuel-bound nitrogen can also be a significant contributor to NO_x emissions, depending on the concentration of nitrogen compounds in the fuel. NO_x formed from fuel-bound nitrogen increases slightly with an increase in temperature. Thus, flue gas recirculation (FGR) will assist only slightly with control of this type of NO_x.

The third type of nitrogen emission is called prompt NO_x. This reaction occurs at lower temperatures and is not a significant contributor. The predominant way to reduce NO_x emissions during the combustion process is to reduce the flame temperature, or to reduce the time the fuel-air mixture spends in the adiabatic primary combustion zone (residence time). This can be accomplished in a number of different ways.

C.4.1 Flue Gas Recirculation

Flue gas recirculation (FGR) is a method of reducing nitrogen oxide (NO_x) emissions from boilers.

Flue gas can be delivered back to the burners by means of a separate fan, or by induction using the forced draft fan or the dynamics of the burner itself. Flue gas recirculation introduces inert flue gas to the combustion flame and is a method for reducing the O_2 concentration of the combustion air (combustion air vitiation). Not only is the O_2 concentration of the fuel-air-flue gas mixture reduced, which lowers flame temperature (lower concentration reduces the rate of combustion reactions), but the mass of the flue gas absorbs heat energy from the flame and carries it away from the primary zone without contributing to the combustion reactions.

The amount of the reduction of NO_x emissions will depend on the recirculation rate as well as the type of fuel used and burner design. Emissions of NO_x can be reduced by 35% to 60% with gas-firing, and by 15% to 40% with oil-firing. The recirculation rate will vary according to the firing rate of the boiler. Higher FGR will usually increase NO_x reduction and may also reduce smoke and CO emissions.

Excessive flue gas recirculation can compromise the stability of a flame due to excessive lowering of the concentration of O_2 in the combustion air supply, and result in off-ratio firing and ultimately in a complete loss of flame. FGR can be accomplished in a safe manner by controlling or limiting the percentage of flue gas that is allowed to mix with the combustion air.

C.4.2 Low NO_x Burners

Low NO_x burners are specially designed burners that lower the combustion temperature and may lengthen the flame. Some low NO_x burners may have an integral primary and secondary burner with a rich mixture directed toward the center and a lean mixture on the outside. The flame is less stable than with conventional burners, and thus the controls for these burners are more critical. Excess air is kept as low as possible, and some of the air could be diverted to a separate zone above the burner in a process called “air staging.” FGR may be used in conjunction with a low NO_x burner.

C.5 Other Standards

Small gas-fired boilers are covered by NFPA 54, *National Fuel Gas Code* and small oil-fired boilers are covered by NFPA 31, *Standard for the Installation of Oil-Burning Equipment.* There are no known conflicts with FM standards.

Medium (>400,000 Btuh [117 kW]) oil- or gas-fired boilers are covered by ASME CSD-1, *Controls and Safety Devices For Automatically Fired Boilers.* There are no known conflicts with FM standards.

Large (>12,500,000 Btuh [3662 kW]) oil- or gas-fired single-burner boilers are covered by Chapters 1-5 of NFPA 85, *Boiler and Combustion System Hazards Code.* NFPA 85 applies to firetube and watertube boilers having a capacity equal to or greater than 12,500,000 Btuh (3662 kW). FM exceptions and comments are as follows:

A. Purge

The purge air flow rate and air change quantity should be sufficient to scavenge all gas vapor accumulations. Flow ratios and quantities which are greater than the FM’s recommended minimum may be used. NFPA recommends eight volume air changes at 70% air flow for watertube boilers and four volume air changes at 70% air flow for firetube boilers.

B. Power Failure

Safety shutdown and nonrecycle lockout on power failure are not considered necessary when the programming control automatically recycles to the prepurge sequence after power is restored. NFPA calls for a manual reset on any interlock shutdown.

C. Double Block and Vent

“Typical Schematic Arrangement of Safety Equipment” shows the gas pilot piping with two safety shutoff valves (A), with a vent valve (C) between. Some users, manufacturers, and authorities having jurisdiction prefer this arrangement for the gas pilot piping.

APPENDIX D INSPECTION GUIDANCE

The following is a typical inspection testing guide. If testing instructions were not provided by the manufacturer, this guide can be used to assist in developing a testing program for a particular boiler.

D.1. General Comments

D.1.1. Only allow qualified personnel to perform tests. A qualified person should either be certified by the manufacturer, or be a licensed heating contractor familiar with the equipment. An in-house instrumentation technician might also be qualified if familiar with the heating equipment. Experienced operators might also be qualified if properly trained. If facility personnel are not familiar with testing, then a testing program should be developed and a trained contractor should be hired to perform the tests.

Tests may be performed during purge or firing. The guidelines presented here indicate testing mostly performed during purge. If testing is done during firing, care must be taken not to create a hazardous condition. Never shut off the combustion air supply or reduce the fuel flow during firing. It is preferable to test during purge with the downstream manual fuel supply valve secured.

D.1.2. In testing an interlock, the best test is to actually simulate failure by interrupting the medium (i.e., turn off the combustion air blower, prevent dampers from going to high fire, etc.). When this is not possible, the second most desirable method is to change the setting on the sensor. A third method is to manually activate the switch (tip mercury bulb, for instance) and a fourth method, the least desirable, is to isolate the switch by disconnecting the leads. If the safety controls are wired to a programmable logic controller (PLC), conditions can possibly be simulated using programming methods to check the PLC, but not the source devices.

Whenever settings are changed, note the original so they may be restored to normal upon completion of testing. If switches are preset at the factory, it may not be advisable to tamper with the settings; consult the manufacturer's manual before testing. Some switches are factory calibrated and sealed, and cannot be adjusted in the field. With some systems, switch contacts must be in the correct position at startup; this can easily be done with a PLC. In essence, a test is performed at each startup; if the switches are the factory-set, tamper-proof type, there should be good assurance that the switches are performing as intended. In some cases, a sensor/transmitter could be used rather than a mechanical device.

D.2. Testing Safety Controls

A. Fuel Supply Interlocks

Fuel supply interlocks are needed to ensure correct pressure and temperature of fuel for proper mixing with air.

1. Low gas/oil pressure: Raise the setting of the switch above normal during purging. The purge cycle should be interrupted. An alternative method is to close the upstream manual valve when the equipment is shut down and vent the line between the manual valve and the safety shutoff valve to a safe location. Use a manometer to verify the pressure when the switch contacts open.

2. High gas pressure: Lower the setting of the switch below normal during purging. The purge cycle should be interrupted. If the switch is located downstream of the SSOV, this test should be done during firing or during the trial-for-ignition with the manual fuel valve downstream of the safety shutoff valves shut. Another method is to perform a bench test with compressed air or nitrogen during planned shutdowns. This can also be done in place, if the switch is connected to a tee, by connecting a portable inert gas bottle to the other end of the tee connection. This method will indicate the actual trip pressure; a calibrated pressure gauge should be used.

3. Low oil temperature: Raise switch setting during purging. The purge cycle should be interrupted.

4. Atomizing medium interlock: Shut off atomizing steam or air upstream of switch/sensor before purging. (The line may need to be vented or raise the switch setting during purge.) The purge cycle should not be begin or should be interrupted.

B. Start Permissives

1. Main burner SSOV proved closed: This prevents initiation of the pilot if the main burner valve is not closed. In order to prove that the SSOV is closed before purge, disconnect wire from the proof-of-closure switch on the SSOV before purging. The purge cycle should not begin.

2. Instrument air: Needed for proper operation of pneumatic control instruments. To test, shut off instrument air supply. The purge cycle should be interrupted. This can serve as an interlock also.

3. Safe start: Proves scanner will detect absence of flame. A safe start check test is done automatically each time a boiler is started. If the scanner responds as if a flame is detected at startup, a lockout will occur. To test, remove the scanner. Hold a flame up to the scanner. The purge should be interrupted.

C. Purge Interlocks

1. High/low fire interlocks: Proves air dampers in proper open position for purge, then proves modulator in minimum throttle position for light-off. To test, mechanically or electrically isolate switch from operating mechanism. The purge should not be completed with high fire disconnected, and the boiler should not proceed to ignition with low fire disconnected.

2. Air flow switch: Proves combustion air available for purge. To test, it is desirable to remove switch/sensor from source or disconnect the sensing line. If this is not practical, adjust sensor so that it will not operate and if this is not practical, electrically isolate switch. The purge should not be completed. Depending on the controller, the purge cycle may be interrupted. This test should be repeated during firing or during the trial-for-ignition to make certain the switch is working as a shutdown interlock as well as a start permissive if the purge switch and combustion air switch are the same. Also, if there are switches for combustion airflow or windbox pressure, forced draft fans, induced draft fans or flue gas recirculating fans, these switches should be tested during firing or during the trial-for-ignition.

3. Purge timer: Provides minimum amount of air changes during purge to insure that no residual fuel vapors remain in firebox. FM requires a minimum of 4 volume changes based on an average of 50% of the maximum airflow. To test, measure the time from purge start to purge complete or to when pilot valve opens on automatic boilers.

D. Ignition Safeguards

1. Prove pilot: Ensures pilot is lit before opening main valve. To test, remove pilot flame scanner or flame rod. Cycle burner and pilot should come on. After the pilot trial-for-ignition period (10 sec.), it should go into flame failure shutdown.

2. Main Burner

a. Trial for ignition: This gives the main burner a chance to light off. To test, listen to, feel or watch pilot and main burner SSOVs to determine if open. From the time the main SSOV is energized, an interrupted pilot should stay on for a specified time and then shut off. The time between the main SSOV opening and the pilot closing is the trial-for-ignition (usually 10 seconds for gas and light oils, and 15 seconds for heavy oils [Nos. 5 and 6]). If the main flame is not lit during this time, the main SSOV should be closed within 5 seconds (4 sec. flame response and 1 sec. valve closing). Remove the flame scanner during the trial-for-ignition period. A flame failure shutdown should occur after the trial-for-ignition period.

b. Main flame proved: Remove main flame scanner or flame rod during normal operation. After a short delay (4 seconds maximum), the boiler should go into safety shutdown. It should then go into post purge, if applicable, and then shut down. It should not go into pre-ignition purge or initiate the ignition cycle until the combustion safeguard is manually reset.

E. Other Interlocks

1. High temperature limit: Reduce temperature setting or disconnect a wire. The purge should be interrupted.

2. High steam pressure cutout: Reduce switch setting or disconnect a wire. The purge should be interrupted.

3. Low water cutout: Perform rapid drain and slow drain tests in accordance with Data Sheet 6-12, *Low Water Protection.* Slow drain tests are preferred. Testing is often done during firing. If done during purge, the boiler should not light off after the low water cutout switch contacts have opened; a meter can be used to see at what water level the switch operates.

Note: Some of these tests may not be applicable depending on the type and size of the boiler.