OIL- AND GAS-FIRED MULTIPLE BURNER BOILERS

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1.0 SCOPE

This data sheet is concerned primarily with the hazards associated with the firing of natural gas and standard grades of fuel oil in multiple-burner boilers. 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, suitability of the equipment, and need for special protection.

The boilers addressed in this data sheet cover a broad range of sizes. In general, industrial boilers have a steam capacity ranging from 50,000 lb/hr (22,000 kg/hr) to 200,000 lb/hr (9 x 10^4 kg/hr), and electric utility boilers range from 500,000 lb/hr (220,000 kg/hr) to 7,000,000 lb/hr (3.2 x 10^6 kg/hr).

Single-burner boilers are covered in Data Sheet 6-4, *Oil- and Gas-Fired Single-Burner Boilers.*

1.1 Changes

July 2023. Interim revision. Minor editorial changes were made.

2.0 LOSS PREVENTION RECOMMENDATIONS

2.1 Construction and Location

2.1.1 When located indoors, situate boilers in buildings of noncombustible construction.

2.1.2 Do not locate boilers and fuel piping in below-grade locations. When below-grade installations are unavoidable, provide adequate access for manual firefighting efforts based on consultation with the local fire service.

2.1.3 Locate fuel system components, other than those directly associated with the burner fuel train, outside of the boiler room, and arrange and protect them in accordance with Data Sheets 7-32, *Ignitable Liquid Operations;* 7-54, *Natural Gas and Gas Piping;* 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 occupancy, and provide construction features, containment, and emergency drainage in accordance with Data Sheets 7-32, *Ignitable Liquid Operations;* 7-54, *Natural Gas and Gas Piping;* 7-88, *Ignitable Liquid Storage Tanks*, or other applicable data sheets.

2.1.4 If fuel oil piping within the boiler room is not designed in accordance with this data sheet (see Section 2.3.2) such that the potential exists for an oil 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 Protection

2.2.1 Gas-Fired Boilers

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

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

2.2.2 Oil-Fired Boilers

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

2.2.2.2 Design the sprinkler system as follows:

A. Where the equipment and piping is designed in accordance with this data sheet (i.e., 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 (see Section 2.3.1), provide automatic sprinkler protection in accordance with Data Sheet 7-32, *Ignitable Liquid Operations.*

2.2.2.3 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.

2.2.3 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.

2.3 Equipment and Processes

2.3.1 FM Approved Equipment

Use FM Approved equipment when available for the intended service. When FM Approved equipment is not available, use equipment that has proven reliability in the operating environment and process conditions under which they will be used.

2.3.2 Fuel Supply

Arrange fuel supply, transfer, and piping systems in accordance with Data Sheets 7-32, *Ignitable Liquid Operations;* 7-88, *Ignitable Liquid Storage Tanks;* 7-54, *Natural Gas and Gas Piping;* and other FM recommended practices for handling, piping, and storing 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

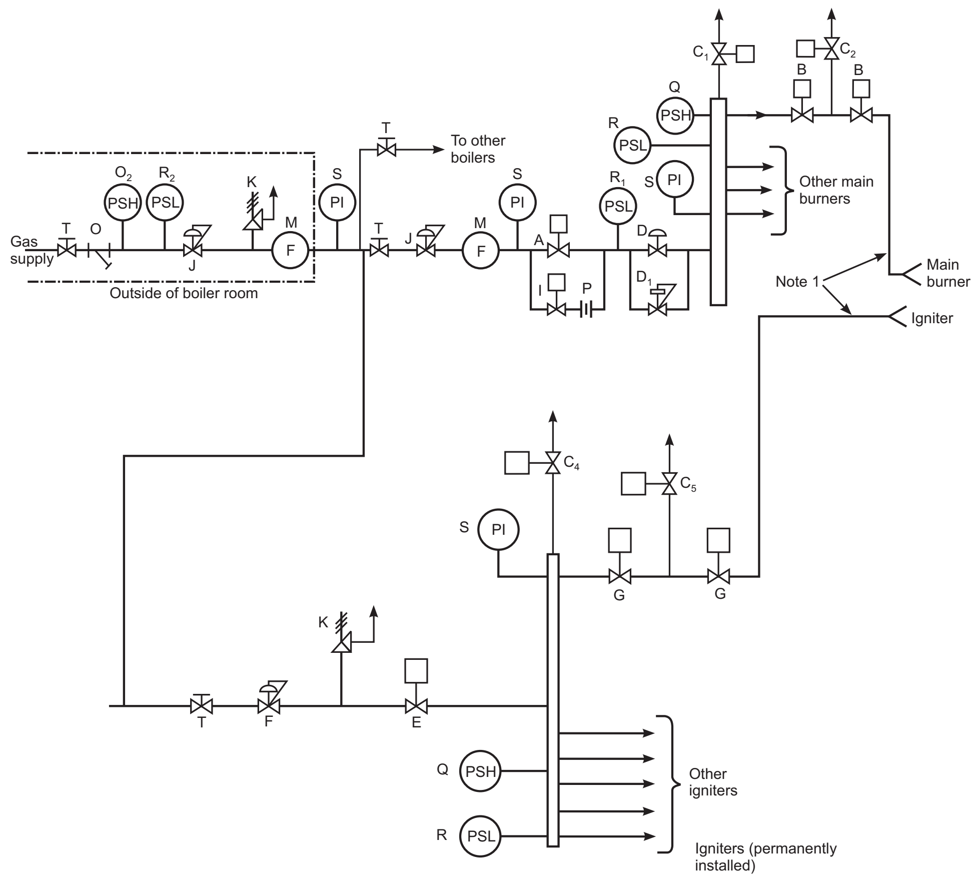
C. Provision of valves to ensure proper system control and regulation

D. Use of emergency shutoff valves

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

2.3.3 Purge Interlocks

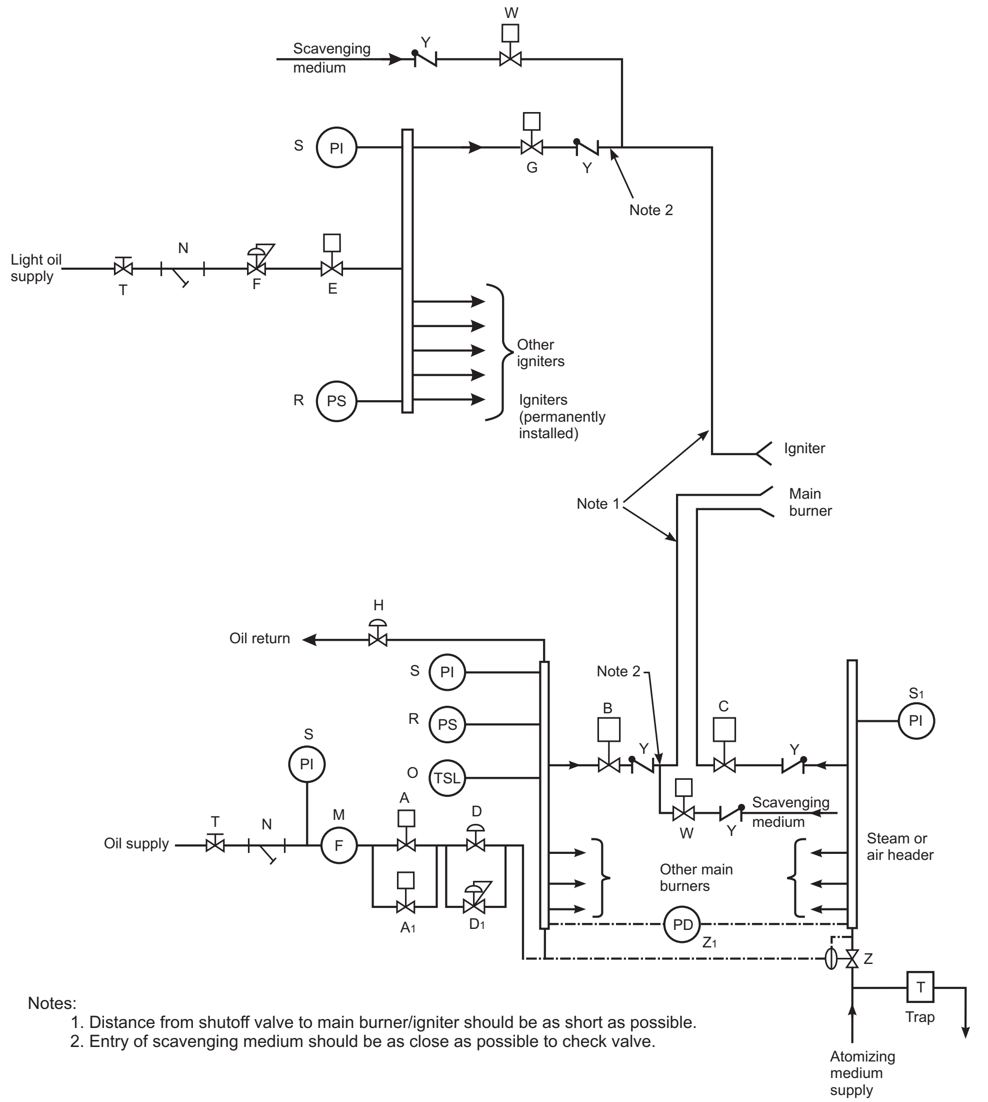
Table 1 provides a summary of recommended safety controls and interlocks. Figures 1 and 2 are schematics for multiple burner gas and oil fuel trains respectively and are provided to support the recommendations for interlocks and SSOVs in this data sheet.



Note 1: Piping between fuel SSOV and burner/ingiter should be as short as possible.

A Main safety shutoff valve
B Individual burner safety shutoff valve
C_1 Burner header atmospheric vent valve
C_2 Individual burner atmospheric vent valve
C_3 Igniter header atmospheric vent valve
C_4 Individual igniter atmospheric vent valve
D Main fuel control valve
D_1 Main fuel bypass control valve (optional)
E Igniter header safety shutoff valve
F Igniter fuel control valve
G Individual igniter safety shutoff valve
I Charging valve (optional) (must be self-closing)
J Constant fuel pressure regulator
K Pressure relief valve
M Flow meter
O Cleaner or strainer
P Restricting orifice
Q High fuel pressure switch
Q_2 High fuel supply pressure switch
R Low fuel pressure switch
R_1 Burner header low fuel pressure switch (alternate location)
R_2 Low fuel supply pressure switch
S Fuel pressure gauge
T Manual shutoff valve

Fig. 1. Typical fuel train for a gas-fired, multiple-burner boiler



Notes:

1. Distance from shutoff valve to main burner/igniter should be as short as possible.
2. Entry of scavenging medium should be as close as possible to check valve.

A Main safety shutoff valve
A_1 Circulating valve
B Individual burner safety shutoff valve
C Atomizing medium individual burner shutoff valve, automatic
D Main fuel control valve
D_1 Main fuel bypass control valve (optional)
E Igniter safety shutoff valve
F Igniter fuel control valve
G Individual igniter safety shutoff valve
H Recirculating valve (optional for unheated oil)
M Flow meter
N Cleaner or strainer
O Low-temperature or high-viscosity interlock
R Low fuel pressure interlock
S Fuel pressure gauge
S_1 Atomizing medium pressure gauge
T Manual shutoff valve
W Scavenging valve
Y Check valve
Z Differential pressure valve
Z_1 Differential pressure alarm and trip interlock

Fig. 2. Typical fuel train for light oil igniter system with heavy oil main burner fuel system

Table 1. Summary of Recommended Safety Controls and Interlocks

Control/Interlock	*Recommendation*	*DS 6-5 Section*
FM Approved controls and interlocks	Use when available for intended service	2.3.1
Purge time	5 minutes	2.3.3
Volume air changes	5	2.3.3
Purge rate	25% minimum	2.3.3
Air register/damper position	If automatic	2.3.3
Fan motor interlock & air flow/pressure/fan speed	All fans	2.3.4
Header, igniter, main SSOVs	Fuel gas	2.3.6
	Fuel oil	2.3.6
Proof-of-closure	All SSOVs	2.3.6
Non-recycling combustion safeguard	Yes, if intermittent pilot, separate supervision needed unless class 1	2.3.8
Pilot trial-for-ignition	10 seconds, 15 seconds heavy oil	2.3.8
Limited main flame trial-for-ignition	10 seconds (max.), 15 seconds (max.) heavy oil; 5 seconds after fuel enters furnace	2.3.8
Low/high gas pressure switch	All gaseous fuels	2.3.10
Low oil pressure switch	All fuel oils	2.3.11
Low oil temperature switch	All heated fuels	2.3.11
Atomizing steam/air pressure switch	All steam/air atomized fuels	2.3.11
Electric igniter proved fully inserted	All retractable electric igniters	2.3.8
CO analyzer	Interlocked or alarmed	2.3.9
Furnace low/high pressure switches	If balanced draft or induced draft, high pressure only for pressurized boilers	2.3.9
Manual master fuel trip	Yes	2.3.9
Low water cutout	Refer to Data Sheet 6-12	2.3.9

2.3.3.1 Provide a timed preventilation period to purge the boiler enclosure prior to admitting fuel into the boiler. Ensure the purge consists of at least five volume changes of the boiler enclosure, with fresh air for a continuous period of not less than five minutes. Ensure the purge airflow rate is at least equal to 25% of the full load volumetric flow. Simultaneously, purge (with not less than five volume changes) any other components downstream of the boiler that contain an ignition source.

2.3.3.2 Provide a complete purge after an emergency shutdown or master fuel trip (MFT). If airflow is less than the purge rate, maintain the existing rate for at least 5 minutes and then gradually increase to the purge rate. If the airflow is higher than the purge rate, it can be gradually decreased to the purge rate. If any or all fans need to be restarted to complete the purge, wait a minimum of 15 minutes before attempting to restart the fan(s), then gradually increase the air flow to purge rate.

2.3.3.3 Ensure the purge period is controlled by the combustion safeguard so the ignition system will not activate and the safety shutoff valves will not open before the purge has been completed. (On older systems, an FM Approved time delay switch wired into the safety control circuit may be used.)

A manual reset of the MFT relay, which can only be done after purge has been completed, meets the intent of this recommendation.

2.3.3.4 Provide interlocks to prove the following conditions are satisfied prior to initiating purge. If any permissive interlock is lost during the purge timing, a re-initiation of the purge is needed.

A. Main fuel and igniter header safety shutoff valves, and all individual burner and igniter safety shutoff valves are closed. When provided with FM supervisory cocks, all cocks must be proved closed prior to and during the purge period. The FM cocks can be interlocked with the combustion safeguard, main safety shutoff valve, or purge timer to serve as a purge permissive. Refer to Data Sheet 6-18, *FM Cock Safety-Control System.*

B. All required burner registers or dampers are open to the purge position (for automatic boilers).

C. At least one set of induced-draft and forced-draft fans is running.

D. Air flow is not less than 25% of full load volumetric air flow.

E. Drum level is satisfactory.

F. Fuel pressure and temperature are within normal operating limits.

2.3.4 Fan and Air Flow Interlocks

Provide interlocks as follows for startup and firing protection, to ensure properly sequenced operation, to shut off fuel and ignition systems if interlock functions are not satisfied, and to interrupt the startup process if hazardous conditions develop prior to completing the purge.

A. Provide interlocks to prevent starting a forced draft fan until after its associated induced draft fan is in operation, unless boiler operating instructions direct otherwise.

B. Ensure the failure of a fan (or fans) shuts down any fan (or fans) following it, in the order of actuation.

C. Shut off and lock out all fuel and ignition systems upon loss of a fan. Exception: Where two induced-draft fans or two forced-draft fans (or both) are provided, it is acceptable to continue firing the boiler if only one fan or one set of fans is lost, provided an automatic fuel cutback system is installed. For example, when only one of two induced draft fans is lost, its associated forced-draft fan is tripped and the fuel to the unit automatically reduced to provide the proper fuel-air ratio for the reduced air flow that is still available.

D. Provide a low air flow interlock set at not more than 5% below the minimum purge rate air flow of 25% of full load volumetric air flow (i.e., at not less than 20% full load volumetric air flow). If the normal purge rate air flow is greater than 25% of full load volumetric air flow, provide an additional minimum airflow interlock set at the purge rate air flow. Ensure this additional interlock is in service during purge and initial burner light-off.

2.3.5 Igniters

2.3.5.1 Provide permanently installed igniters that have sufficient capacity to ensure prompt ignition of the main burner. Ignition energy requirements will vary depending on the location of igniter with respect to the main burner, main burner fuel input, and the firing conditions for which igniter operation is required (i.e., interrupted, intermittent, or continuous operation). An igniter is a fixed device that provides the energy required to ensure prompt ignition of the main burner. A pilot is a type of fuel-fired igniter.

2.3.5.2 Provide flame supervision for each fuel-fired igniter. Separate flame supervision from that used for the main burner flame is required if a Class 2 igniter is operated beyond the trial-for-ignition period (i.e., flame supervision of the main burner is positioned so as to not see igniter flame).

2.3.5.3 Install igniter(s) and flame sensing element(s) securely so the position of each with respect to the others and the main flame will not change. Provide observation ports so these positions can be seen while the igniter and/or main burner are firing. Ensure these units are readily accessible for inspection and cleaning.

2.3.6 Safety Shutoff Valves

2.3.6.1 Ensure there is a visual indication at the valve to verify valve position, open or closed. Additional valve position indication may be provided in the control room and/or at the local operator panel.

2.3.6.2 Gas-Fired Boilers

2.3.6.2.1 Install at least one safety shutoff valve (SSOV) with valve seal overtravel proof-of-closure in each main and igniter fuel supply header.

For gas-fired power generation boilers that use energize-to-close safety shutoff valves, install a motorized main manual shutoff valve (energize to open and close). Install end switches on the main manual gas valve arranged to indicate the closed and wide open positions in the control room.

2.3.6.2.2 Install two safety shutoff valve(s) with valve seal overtravel proof-of-closure in the main fuel line to each burner. If the total boiler heat input exceeds 250 MMBtu/hr (73,000 kW), provide an automatic vent valve, piped to a safe location out-of-doors, between the two safety shutoff valves to each burner, Provide logic or electrical connections such that the vent valve is open when the two SSOVs are closed and closed when the two SSOVs are open.

2.3.6.2.3 Install two SSOVs in the fuel line to each igniter. If an igniter is rated at 5,000,000 Btu/hr input or higher, provide proof-of-closure on at least one of the SSOVs and, if rated 12,500,000 Btu/hr input or higher, provide proof-of-closure on both SSOVs.

2.3.6.2.4 Use of an FM Approved automatic leak detection/leak tightness testing system can be used in lieu of proof-of-closure.

2.3.6.2.5 It is permissible to gang burners or igniters together so they are placed into service simultaneously from a single pair of safety shutoff valves. However, each burner and igniter of the group must be reliably supervised so that failure of any one to light or remain lit will cause the fuel to the entire group to be shut off.

2.3.6.3 Oil-Fired Boilers

2.3.6.3.1 Install one safety shutoff valve (SSOV) with valve seal overtravel proof-of-closure in each main and igniter fuel supply header.

2.3.6.3.2 Install one safety shutoff valve with valve seal overtravel proof-of-closure in the main fuel line to each burner,

2.3.6.3.3 Install one SSOV in the fuel line to each igniter.

2.3.7 Emergency Shutoff Valves

2.3.7.1 In addition to the safety shutoff valves recommended in Section 2.3.6, install emergency shutoff valves or equivalent interlocks in the oil supply piping system to ensure the prompt shutdown of liquid 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. Automatic shutdown may be accomplished using one or more of the following methods:

A. Actuation by use of heat detectors (e.g., HADs). Actuation of this device would cause the emergency shutoff valve to close.

B. Operation of the automatic sprinkler system to cause the emergency shutoff valve to close. Arrange the system to permit protection system alarm testing without unwanted equipment shutdown.

C. Operation of an FM Approved fusible link-operated valve. Install the safety shutoff valves in accordance with Data Sheet 7-32, *Ignitable Liquid Operations,* including proper placement of the fusible link(s), to ensure prompt operation when exposed to an oil fire.

2.3.7.2 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.

2.3.8 Combustion Safeguards

2.3.8.1 Provide a flame-supervisory combustion safeguard arranged to first prove the existence of a reliable igniter flame before permitting the main burner safety shutoff valve to open. Limit the igniter flame establishing period to the shortest practical interval, generally not exceeding ten seconds.

Where a high-energy direct ignition spark-igniter assembly (Class 3 Special) is provided, the fuel burning igniter and proof of igniter flame 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.

2.3.8.2 Provide a flame-supervisory combustion safeguard for direct supervision of the main burner flame only, following proof of pilot flame and opening of the main fuel SSOV. Limit the trial-for-ignition of the main burner to the shortest practical time, generally not exceeding ten seconds for gas and light oil, and 15 seconds for heavy oil. Because of the time required for large remote operated valves to open, or the distance from the valve to the burner, longer periods may be required to achieve burner light-off. Best practice for all installations, other than when using a Class 1 igniter, is to limit the main burner trial-for-ignition time to that required for fuel to enter the furnace for not more than five seconds.

Note: When Class 1 igniters are provided, independent main burner flame supervision may be omitted. When interrupted igniters are provided, main burner flame supervision may be provided by the device used to prove igniter flame.

2.3.8.3 Ensure loss of flame at an individual burner flame envelope causes the safety shutoff valves for the individual igniter or burner to trip.

Ensure total loss of flame trips all fuel to the unit and requires a complete furnace purge.

2.3.8.4 Install the combustion safeguard flame-sensing element(s) in accordance with manufacturer's instructions. Locate the main burner flame-sensing element so it reliably senses the main flame at all firing rates. When an igniter is proved by a combustion safeguard, ensure supervision is at a location where the igniter flame will effectively ignite the main burner or burner unit. Ensure the main burner is ignited immediately by its igniter, even when the igniter is reduced to the minimum flame capable of holding the flame-sensing relay of the combustion safeguard in the energized (flame-present) position.

2.3.8.5 Ensure the safe-start check for the combustion safeguard is not nullified by the action of operating or limit controls.

2.3.8.6 When UV scanners are used, provide self-checking UV flame scanners on boilers that are in continuous operation or where an operating cycle exceeds 24 hours. Non-self-checking UV flame scanners can fail in an unsafe manner. Self-checking is not needed on electronic UV scanners that do not use UV cells. Refer to Data Sheet 6-0, *Elements of Industrial Heating Equipment.*

2.3.8.7 Ensure clean air is supplied to flame scanner lenses for the purpose of cleaning or cooling where it is found necessary. This will help to prevent nuisance tripping.

2.3.9 General Interlocks

2.3.9.1 Provide high furnace-pressure interlocks and alarms in accordance with Data Sheet 6-6, Boiler Furnace Implosions, to shut off all fuel and ignition systems if excessive furnace pressure develops. This can also minimize the development of hazardous fuel conditions upon boiler tube rupture or outlet damper failure.

2.3.9.2 Provide low furnace pressure interlocks and alarms in accordance with Data Sheet 6-6, Boiler Furnace Implosions, to protect against a low furnace pressure condition.

2.3.9.3 Provide air flow/pressure switches for all fans; forced draft, induced draft, and/or flue gas recirculation, and provide fan motor electrical interlocks using the extra contact on the motor starter, interlocked to shut off all fuel and ignition systems if a problem develops.

2.3.9.4 Locate the automatic damper or air register position switches for purge and light-off on the damper end of the linkage.

2.3.9.5 Provide a manual trip wired directly to the master fuel trip (MFT) relay.

2.3.9.6 Provide a CO or combustibles analyzer to alarm or shut off all supply of fuel upon detection of high CO or combustibles. See Section 2.3.12.

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

2.3.10 Additional Recommendations and Interlocks for Gas Firing

2.3.10.1 Provide low and high fuel gas pressure interlocks for both main and igniter fuel supplies.

2.3.10.2 Manifolding of vent lines is permitted, but ensure automatic vent lines between safety shutoff valves, when provided, are not manifolded with vent lines from pressure regulator or pressure switch vent lines. Also ensure vents from different pressure ranges (i.e., header, main fuel train, and pilot fuel trains) are not manifolded together. Do not manifold together vent lines from more than one boiler. Terminate the vent lines at a safe out-of-doors location away from any air intakes or ignition sources. Do not manifold vent lines from overpressure relief devices.

2.3.10.3 Provide permanent and ready means for making periodic tightness checks of the header and main burner gas safety shutoff valves and Class 1 igniters.

2.3.10.4 Install a pressure relief valve with full relieving capacity downstream of the gas pressure regulators as needed to protect downstream equipment from overpressure as the result of regulator failure. Alternatively, provide a high fuel pressure trip and safety shutoff valve that isolates the fuel gas supply upstream of the pressure regulator.

2.3.11 Additional Recommendations, Interlocks for Oil

2.3.11.1 Install a safety shutoff valve in the fuel oil recirculating line to each boiler to prevent pressurization of a header if there is a common recirculating system.

2.3.11.2 Provide atomizing-medium interlocks for steam- or air-atomized fuel oil burners to prevent the introduction of fuel oil to the burners upon loss or impairment of the atomizing medium. A differential pressure switch may also be provided to detect an imbalance between the fuel and atomizing medium supplies.

2.3.11.3 Provide a low fuel oil pressure switch.

2.3.11.4 For heated oils, monitor fuel oil temperature and/or viscosity. Provide a low oil temperature interlock and alarm, as high oil viscosity can lead to poor atomization. If the oil temperature is too high, this can cause vapor lock and loss of pump suction. Include a high temperature interlock or alarm if the heating system is capable of heating the oil to a temperature that can cause vapor lock. Ensure operators fully understand fuel oil specifications, especially if the fuel supply is variable.

See Figure 2 for a schematic of a fuel oil system piping arrangement.

2.3.12 Indicators and Alarms

2.3.12.1 On remotely operated units, provide the operator with adequate information concerning the status of operating equipment, position of valves, burner registers, vital damper settings, and other operating conditions that will permit evaluation of the operating situation.

2.3.12.2 Ensure there are adequate annunciators and alarms to aid normal operation and warn operators of the development of abnormal conditions.

A. Provide alarm systems that give both audible and visual indication. Means may be provided to silence the audible alarm, but ensure the visual indication remains until the condition has been returned to normal.

B. Provide “first out” indication, enabling an operator to tell which interlock function initiated a master fuel trip.

C. Also provide alarms to alert operators when off-normal conditions are detected that could result in a boiler trip if left uncorrected. Although not necessarily required as master fuel tripping interlocks, important alarms in this category include individual burner or igniter flame-failure, failure of a burner valve to close following a burner trip, loss of power to combustion control system, and low fuel-oil temperature.

D. Provide carbon monoxide or combustibles and oxygen analyzer-recorders as an operating guide to safe and efficient operation. Provide an alarm to warn the operator of a possible hazardous condition when any measurable combustibles are indicated. Also use other means to prevent poor fuel/air ratio, such as comparing fuel and air flow. Some boilers have a means to trim the fuel/air ratio by sensing the oxygen concentration in the flue gas. This should only be able to vary the air flow a small percentage. Primary control of the fuel and the air normally depends on load demand. When an oxygen analyzer/controller assists with fuel/air ratio trim, it is good practice to alarm when the excess oxygen is out of limits. As the load changes, the excess oxygen will vary as prescribed by an oxygen versus load curve for a particular boiler (more oxygen should be present in the flue gas exhaust at lower loads), and the oxygen level should remain within a certain percentage of this curve.

2.3.13 Flue Gas Recirculation Interlocks

Provide the following interlocks as applicable to the installed flue gas recirculation (FGR) system to prevent unstable combustion due to an FGR system malfunction:

A. An FGR fan motor electrical interlock using motor auxiliary contacts

B. An FGR fan flow switch

C. An FGR control damper position interlock (this is needed in order to compare actual damper position with control position and should not allow the boiler to operate if the damper is not within the limits)

D. An FGR circuit trouble interlock

E. A stack low temperature interlock

Upon actuation of any of these interlocks, close the FGR damper and, when the boiler cannot be operated without the FGR system in operation, initiate a master fuel trip.

2.3.14 Waste Fuel Firing

2.3.14.1 Due to environmental regulations, some industries (e.g., petrochemical, pharmaceutical, pulp and paper) are using boilers to incinerate various liquid and gaseous wastes. Variations in heat of combustion, firing characteristics, composition, and handling methods require that each case be given special consideration. Refer to Data Sheet 6-13, *Waste Fuel-Fired Facilities,* for recommendations.

2.4 Operation and Maintenance

2.4.1 General

Provide adequate means of communication between the control room and the boiler burner front areas. This is especially important on multi-burner, multi-tier boilers, and remotely controlled units. Explosions have occurred because the activities of the equipment operator at the burners and the actions taken by the control room operator were improperly coordinated during critical operation situations such as lighting off, bringing the boiler up to pressure, or during upset operating conditions involving flame instability.

2.4.2 Inspection and Testing

2.4.2.1 Inspect and test safety controls at least annually, whenever maintenance involving the safety controls is performed, and after any modification to safety controls. Conduct inspection and testing in accordance with the manufacturers' instructions. Use properly trained personnel or qualified contractors. Increase frequency of testing when conditions warrant. 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 and loss of production.

Document the inspection/test procedures. Record test results listing date of testing, what was tested, the test results, and who performed the testing. Confirm proper operation of all interlocks. Correct any defects found prior to returning the boiler to service. See Table 1 for a summary of recommended safety controls and interlocks, and refer to Data Sheet 9-0, *Maintenance and Inspection*, for additional guidance.

Inspection and testing includes, but is not necessarily 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. For oil: Fuel pressure and temperature interlocks

E. For gas:

1. Low and high fuel pressure interlocks

2. Gas cleaner and drip leg

F. Igniter and burner components. Ensure smooth, reliable light-off in the required period of time is achieved. Proper flame color and shape, and exhaust color are indicative of good combustion.

G. Combustion air supply system. Check air flow or pressure switches, and damper position interlocks.

H. Flame failure system components (burner trips and master fuel trips). Check flame scanners and all safety components that interlock with the master fuel trip relay and/or safety shutoff valve(s) (SSOV) through the combustion safeguard controller.

I. Piping, hoses, wiring, and electrical connections of all controls and shutoff valves. Check for leaks, bulging, corrosion, fraying, and loose connections.

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

K. Calibration of indicating and recording instruments.

L. Boiler low water protection in accordance with Data Sheet 6-12, *Low Water Protection for Boilers.*

M. Operator manual emergency shutdown switch(es)

N. As required for oil-firing:

1. Disassemble and clean atomizers

2. Clean strainers

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

2.4.3 Maintenance

2.4.3.1 Keep the fuel free from all foreign matter, solid or liquid. Remove welding beads, chips, scale, dust, and debris from both newly installed fuel piping and that which has been opened for alteration or maintenance. Use inert gas, air, or steam to blow lines clean. Do not use natural gas. Refer to DS 7-54 for additional information. Install suitable strainers, filters, drip legs, etc.

2.4.3.2 Maintain all equipment in good condition. Maintenance details and schedules depend on the equipment, the operating conditions, and the environment. Follow a specific routine recommended by the manufacturer and include (at scheduled intervals) maintenance of burner equipment, inspection and cleaning of the electric igniter and/or pilot-burner assembly, and maintenance of all safety controls. Other important maintenance items are (a) linkages and controllers of fuel-air-ratio control dampers and valves, and (b) flame scanner cells, amplifiers, or other control equipment replaced as recommended by the manufacturer.

2.4.3.3 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 cause leaks at threaded connections 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.

2.4.3.4 Inform operators if control adjustments are to be made by plant technicians or outside contractors, and ensure they are on hand to assist and respond in the event of an upset. Upsets may occur when controls are being maintained on-line, and it may be necessary to switch to manual boiler control if upsets occur.

2.4.3.5 Keep instrument air dry and clean. Water, oil, or dirt in a control air line can interfere with the proper operation of pneumatically operated control devices. Alarm refrigeration-type dryers for high temperature, and inspect automatic water traps on air pressure tanks for proper operation. Check and maintain desiccant dryers, if used, as recommended by the manufacturer. If instrument air lines pass through an area subject to freeze-ups, take appropriate precautions. Refer to Data Sheet 9-18/17-18, *Prevention of Freeze-ups.*

2.4.3.6 For oil firing, inspect oil burner tips periodically for cleanliness. Carbon deposits indicate poor combustion, the cause of which needs to be determined. Test oil for sediment if this problem suddenly appears on a boiler that has been burning efficiently.

2.4.3.7 Low load oil firing, which may occur during acid cleaning of boiler internals, often leads to oil deposits inside furnaces. After such an operation, inspect and, if necessary, clean furnaces before reverting to high firing.

2.4.3.8 Verify that manual gas valves are closed when the boiler is shutdown. This is especially important when trouble-shooting a control system or other boiler components and when performing maintenance or hot work on the boiler.

2.4.4 Two-Burner Operation

2.4.4.1 General

Two-burner boilers with a single fuel and air control and separate safety shutoff valves can present special hazards involving fuel/air ratio upsets during light-off, fuel transfer, and trip of one burner. (The following recommendations do not apply to boilers with two burners that operate as one with single controls and common safety shutoff valves.)

Similar hazards and guidance apply to boilers with up to 12 burners, although the impact of a change in operation (starting or tripping) of one burner becomes proportionately less. For boilers with more than 12 burners, the impact of a change in operation of one burner will usually be within the operating tolerance of the remaining burners.

2.4.4.2 Interlocks

If a flame failure is sensed at either burner, ensure one of the following takes place:

A. Trip all fuel.

B. Trip the individual burner safety shutoff valve(s) for the burner experiencing flameout and reduce the total fuel flow by 50%. Do not reduce the air flow to either burner.

C. Trip the individual safety shutoff valve(s) for the burner experiencing flameout and cut out air to that burner. Ensure the fuel input to the other burner does not exceed the burner rating.

2.4.4.3 Burner Operation

Use the following to prevent off-ratio firing during burner light-off:

A. Purge the furnace with both burner registers open.

B. When lighting the first burner, leave the second burner register open.

C. Carefully observe flame stability during register adjustments and also after light-off of the second burner.

D. If it is necessary to operate the boiler on one burner with the air register to the other burner closed, adhere to the following procedures when lighting the second burner:

1. Before opening the air register, manually increase the air supply to the operating burner, or reduce the fuel supply while holding the air supply steady.

2. Open the register slowly and observe the flame stability at the operating burner. If necessary, make fuel or total air adjustments to maintain a stable flame.

3. After lighting the second burner, observe for proper flame stability before switching to automatic combustion control.

2.4.4.4 Transferring Fuel

When switching fuels to one burner, first reduce both fuel and air supply to an amount that can be handled by one burner. Then shut off both fuel and air supply together to the burner for which fuel is being transferred. Follow the procedures in 2.4.4.1 through 2.4.4.3 when lighting the burner with the new fuel.

2.4.5 Flue Gas Recirculation (FGR)

2.4.5.1 Design Considerations

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

2.4.5.1.2 Ensure the rate of recirculation closely follows the rate of combustion air flow on load changes (air leading the fuel when increasing load) so the burner flame will not become unstable during boiler load fluctuations. Verify that the ratio of flue gas to total combustion air is acceptable over the operating range of the boiler and during load changes.

2.4.5.1.3 Provide a gas/oil selector switch for combination-fired boilers to change recirculation rates. The rate of recirculation is lower for oil than for gas.

2.4.5.1.4 Allow a cool down period for the FGR fan by allowing the fan to run after boiler or FGR shutdown.

2.4.5.2 Purging and Starting the FGR System

2.4.5.2.1 Purge, start, and operate the FGR system is accordance with the boiler manufacturer’s instructions.

2.4.6 Low NO_X Burners

Methods of controlling nitrogen oxide emissions will introduce additional risks if precautions are not taken. Adhere to the following recommendations when installing low NO_X burners on new or existing boilers.

2.4.6.1 Perform flame stability tests to verify that transients generated by burner fuel and air subsystems do not adversely affect burner operation.

2.4.6.2 Use CO analyzers for early detection of unburned combustibles.

2.4.6.3 Changes in flame characteristics may require relocation of flame detectors on existing units.

2.4.6.4 When flue gas O_2 levels are measured for trim of fuel/air ratio, provide reliable and accurate O_2 analyzers and use multiple instrumentation and sampling points. Base control on the lowest oxygen level reading rather than averaging. Set control limits so an extreme O_2 deficiency is avoided in the event of a control malfunction. Removal of an instrument from service for maintenance should not affect the operation of other instruments or result in false O_2 readings. Perform instrument calibration in accordance with the manufacturer's recommendations. Take readings at various loads to optimize for low NO_X firing.

2.4.6.5 Burner optimization is critical to safely operating low NO_X burners and must be done by highly trained personnel. Many problems can arise, especially during initial operation, resulting in adjustments to equipment or even a redesign of components.

2.5 Training

2.5.1 Train operators in the proper operation of the boiler and the specific functions of the various safety controls. Ensure training is ongoing and instructs operators on how to respond to various upset scenarios. An upset can cause a rapid chain of events that require an immediate response. Operator awareness is particularly important during the boiler warm-up period and also during shutdown and load changes. Fuel/air ratio may be more difficult to control during these periods, and an explosion is more likely to occur than during normal firing. Retrofitting with low NO_X burner systems and other pollution control equipment requires additional training for operators. Multiple-burner boiler operation involves more human interface than single burner boiler operation, which is one reason why the human error factor is greater for these boilers than malfunction or lack of safety controls.

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

2.6 Human Factor

2.6.1 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.

2.7 Electrical

2.7.1 Design electrical installations in accordance with the National Electrical Code or to the applicable local code.

2.7.2 Ensure both ac and dc safety control circuits are two-wire with one side grounded. Limit all safety control switching to the hot, ungrounded conductor.

2.7.3 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.

2.7.4 In the Unites States and other countries where 120 volt circuits are used, limit control voltage to not more than 120 volts.

2.7.5 In unusual cases where an ungrounded dc power supply cannot be avoided, locate all switching in one conductor and provide ground fault detection.

3.0 SUPPORT FOR RECOMMENDATIONS

3.1 Loss History

Multiple-burner oil-fired and gas-fired boilers are more complex than single-burner boilers. Poor combustion is a factor in many losses, and safety controls as recommended in this data sheet will help mitigate many of the incidents. Operators are usually very involved in the operation of multiple-burner boilers as compared to smaller, automatic single-burner boilers. As a result, human element is also a factor in many of the losses. Following operating and maintenance procedures as recommended in this data sheet will have a positive effect on minimizing losses.

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

When compared to oil- and gas-fired single-boiler explosion losses during this same time period, there were three times as many single-burner boiler losses, but the median gross PD per incident for multiple-burner boilers was more than ten times that for single-burner boilers. A similar trend was evident with single-burner versus multiple-burner boiler fire losses (see Table 2).

Table 2. Causes of Explosion Losses (FM Loss History, 2002-2012)

Loss Factor	*Percentage of Losses*[1]
Inadequate training, operator or contractor error	40%
Lack of, failure of, or inadequate combustion safety system	26%
Inadequate maintenance or testing	20%
Inadequate operating procedures	7%
Equipment failure	7%

[1]The cause of the loss was not identified in approximately 1/3 of the losses occurring between 2002 and 2012. Most losses had more than one factor. The percentages shown are based on the losses for which cause(s) were identified.

3.2 Illustrative Losses

3.2.1 Explosion Loss Examples

3.2.1.1 Boiler with No Combustion Safeguards

A large, tangentially fired, twin-furnace power generation boiler was operating on natural gas. The unit typically operated in cycling mode twice per day, with the load varying between standby at 75 MW and full load at 375 MW (20% to 100% MCR). There were no combustion safeguards installed, but an operator continuously monitored the flame pattern in each furnace from the control room as seen using furnace cameras. During one of the transitions from full load to standby, when the load had been reduced to about 25% MCR, the operator noticed a disruption in the normal flame pattern in one of the furnaces, with flame apparently extinguished at two of the four corner burners. The decision to shut down the boiler was made, but an explosion occurred before operators could isolate the fuel.

Major damage to the boiler casing, lagging and insulation, buckstays, adjacent structural steel, ductwork, and building resulted, with lesser damage to connecting piping and pipe hangers. A follow-up investigation confirmed a waterwall tube leak in one corner of the furnace near the burner elevation. It is believed escaping steam and water from this leak disrupted and extinguished flame at the two corners. With boiler load below 30%, the typical central fireball present in tangentially fired boilers during normal operation was not available to immediately reignite the unburned fuel, allowing the fuel gas to accumulate before being ignited by one of the other burner flames.

3.2.1.2 Boiler with Combustion Safeguards

A 60-year-old, two-burner gas- and oil-fired power boiler at a papermill was being returned to operation on gas when a fuel explosion occurred. The boiler had been taken out of service with one igniter remaining in operation following a paper break on the paper machine. With the igniter in service, normal operating procedures allowed the burner to be restarted without a purge cycle being completed. Following the apparent light-off of the burner by this igniter, boiler steam pressure continued to fall, rather than increase as it should have. An operator was sent to the boiler to start the second burner. An explosion occurred as the operator lit-off the second igniter.

The explosion caused refractory in the furnace area to crack and firebrick to be dislodged. In addition, the rear and both sides of the boiler were deflected outward, the casing cracked in several places, and supporting beams were bent. Explosion doors on the top of the furnace opened and relieved the overpressure, reducing the extent of boiler damage. A follow-up investigation determined that the DCS, added in the late 1990s, had a faulty module that resulted in a false indication of burner/igniter flame at the one igniter that was thought to have been left in service. Poor operating procedures and operator error contributed to the loss by permitting the use of a single igniter to keep the boiler in “operating mode” while paper machine repairs were made, by relying solely on control room indication as confirmation that both the first igniter and burner were operating, and by attempting to start the second burner without first investigating why steam pressure was continuing to fall. Interruption to facility operation was minimized by a second boiler at the mill that was able to meet plant steam demand.

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).

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 performed following the fire estimated 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 put out 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. Because 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.

4.0 REFERENCES

For more information, please refer to the following publications 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 6-4, *Oil- and Gas-Fired Single-Burner Boilers*
Data Sheet 6-6, *Boiler Furnace Implosions*
Data Sheet 6-12, *Low-Water Protection for Boilers*
Data Sheet 6-13, *Waste Fuel-Fired Facilities*
Data Sheet 6-18, *FM Cock Safety-Control System*
Data Sheet 7-32, *Ignitable Liquid Operations*
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 9-18/17-18, *Prevention of Freeze-ups*
Data Sheet 10-1, Pre-Incident Planning

4.2 Other

American National Standards Institute (ANSI) B31.1., *Power Piping.*
National Fire Protection Association (NFPA). NFPA 30, *Flammable and Combustible Liquids Code.*
National Fire Protection Association (NFPA). NFPA 31, *Oil Burning Equipment.*
National Fire Protection Association (NFPA). NFPA 54, *National Fuel Gas Code.*
National Fire Protection Association (NFPA). NFPA 70, *National Electric Code.*
National Fire Protection Association (NFPA). NFPA 85, *Boiler and Combustion Systems Hazards Code.*

APPENDIX A GLOSSARY OF TERMS

FM Approved: References to "FM Approved" in this data sheet mean the 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.

Flue gas recirculation (FGR) system: Used to reduce nitrogen oxide emissions.

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, and any other term for a liquid that will burn.

Igniter: A fixed device which provides the energy required to ensure prompt ignition of the main burner. There are four classes of igniters: Class 1, Class 2, Class 3, and Class 3 Special.

Pilot: A fuel-fired type of igniter.

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).

July 2023. Interim revision. Minor editorial changes were made.

October 2020. 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 NO_X reduction technologies 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's format to be consistent with other data sheets.

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

D. Deleted recommendations referring to manual and supervised manual boilers.

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

F. 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.

G. 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.

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

I. Provided additional guidance on purge to include other downstream components with ignition sources, actions following an MFT, and purge rate vs. minimum air flow.

J. Added a recommendation for local visual indication of valve position, open or closed, for all safety shutoff valves (SSOVs), consistent with all FM Approved SSOVs.

K. Updated the loss history and illustrative losses sections.

May 2006. Minor editorial changes were done for this revision.

May 2003. Figure 5, ''Typical fuel oil piping arrangement',' was added.

January 2003. Editorial changes were done for this revision.

May 2002. A new paragraph was added to section 2.1.4.1, recommending a motorized main gas shutoff valve with position indication where energize-to-trip safety shutoff valves are used. This is to help assure that gas is not admitted to a boiler after shutdown.

September 2001. In section C.1.4, information was added regarding verification of manual gas valves closed after shutdown.

January 2001. The following changes were made:

1. A recommendation was added to address purging after an emergency shutdown (2.1.1.1).

2. The recommendation on automatic safety shutoff valve leak testing was revised to state that it fulfills the requirement for proof-of-closure but not position indication (2.1.4.2). It has also been stated that this system does not eliminate the need for manual leak testing.

3. The recommendation for self-checking UV scanners has been revised to state that electronic UV scanners do not need to be self-checking.

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

October 1993. This revision of Loss Prevention Data Sheet 6-5/12-70 (now Data Sheet 6-5) contains a number of new recommendations and reference material. Recommendations are generally in agreement with NFPA 85C 1992. Some of the existing recommendations, such as for safety shutoff valves, have been changed. The following summarizes the new and changed recommendations.

1. Recommendations for two-burner boilers have been added, as there is additional risk presented by these boilers.

2. The recommendation for gas pressure switches has been expanded to include information on settings.

3. New recommendations for oil firing include information on oil hoses, cleaning of furnaces after low load firing, and cleaning of burner tips.

4. New recommendations for gas firing include an option for automatic safety shutoff valve tightness testing, and using the double block and vent arrangement for boilers with heat inputs greater than 250,000,000 Btuh.

5. Extreme caution has been advised during boiler warm-up and also when control adjustments are made.

6. Tables have been added summarizing new safety shutoff valve recommendations. The previous data sheet recommended a safety shutoff valve for each main and igniter header and for each individual burner and igniter. The new tables, one for gas-fired boilers and one for oil-fired boilers, describe the requirements for manual, supervised manual, and automatic boilers. The recommendations are in agreement with NFPA 85C, with the exception of the automatic vent. Valve seal overtravel proof-of-closure SSOVs are recommended for all main and igniter headers, for each main burner, and also for igniters depending on size.

7. A table has been added for recommended safety controls and interlocks.

8. A recommendation has been added for a manual master fuel trip.

9. The importance of keeping control air clean and dry has been stressed.

10. Recommendations concerning loss of combustion air and damper position switches have been added.

11. Consideration for CO monitoring for the detection of off-ratio firing has been changed to a recommendation.

12. Recommendations and reference material on flue gas recirculation (FGR) and low NO_X burners have been added.

13. Recommendations for burner front fire detection and protection have been added.

14. Information on classes of igniters has been added.

15. A recommendation on self-checking UV flame scanners (from TAB 6-0) has been added.

16. Testing frequency for safety controls has been added.

17. An alarm for loss of flame at individual burners when using a tangential firing arrangement has been recommended.

18. A gas pressure relief valve downstream of gas pressure regulators has been recommended.

19. An allowance has been made for gas device vent piping to be connected to a single roof stack so that only a single penetration through the roof deck is needed.

APPENDIX C SUPPLEMENTAL INFORMATION

C.1 Safe Operating Procedures

C.1.1 General

Well-trained operating personnel following proper procedures are essential to the safe operation of multiple burner power boilers. A fundamental principle or operating procedure is the open-register or fuel-lean startup.

This procedure provides for a continuous and constant airflow rate through the unit during the purge, startup and initial load-carrying period of operation. The same number of burner registers or burner dampers required for purging the boiler are kept open at the normal firing position throughout the starting sequence. However, as a specific burner is being started, its register or damper is usually readjusted to provide the proper, reduced burner air flow just prior to lighting-off. After the burner flame is established, the register is returned to the open position. For some units, modifications on specific burner dampers or registers opened during the startup may be necessary to control temperatures in the boiler passes. However, such modifications should be made only if determined necessary after operating the installed unit.

This open register procedure has the advantages of a highly fuel-lean furnace atmosphere which reduces the probability of explosion if some malfunction occurs, such as burner flameout. It also minimizes the chance of fuel-rich flameout during the startup, and, after the flow of purge air is established, only minor adjustments are required as additional burners are placed in service. The number of manual operations is reduced, decreasing the possibility of operating errors. The hazard of dead pockets of fuel in the boiler gas passes is also minimized.

Follow the specific, detailed operating instructions of the boiler manufacturer. The following paragraphs outline the principal objectives and procedures for safe operation:

C.1.2 Startup

1. Ensure the furnace is in good repair, free of foreign material and fuel accumulation, has been evacuated by personnel, and access doors and inspection ports are closed. Set fan and burner dampers or registers at recommended positions for purging and light-off. Establish proper water level or circulation. Ensure combustibles or CO and oxygen analyzers, if provided, are in operation, indicating zero combustibles or CO and normal atmospheric oxygen concentrations. Ensure power is available to safety control circuits.

2. Prove fuel header and individual burner valves are in the closed position.

3. Start I.D. fans, FD fans, and regenerative air heaters. Operate flue gas recirculation fans, if furnished, in accordance with the boiler manufacturer's instructions. It is desirable to perform the purge with the flue gas recirculation fan not operating and the flue gas recirculation damper open, if possible. This permits a complete system purge without the risk of recirculating flammable gases back into the boiler.

4. Provide a timed preventilation period to purge the boiler furnace, passes, horizontal breaching and stack. The purge should consist of at least five volume changes of the boiler enclosure with fresh air for a continuous period of not less than five minutes. Ensure the purge air flow rate is at least equal to 25% of that required for firing at full load.

5. Following purge, operate recirculation fans and regenerative air heaters as recommended by the boiler manufacturer to establish proper light-off conditions.

6. Open the main fuel header safety shutoff valve and prove that pressures are within limits for safe light-off.

7. For gas-fired units and oil-fired units with fuel-fired igniters, open the igniter fuel header safety shutoff valve and prove that pressures are within established limits for safe light-off. Direct high energy spark igniters may be used to light oil-fired burners.

8. Adjust the air register or damper on the burner to be lighted to the position recommended by the manufacturer. Check that the burner element and igniter are properly positioned. For oil firing, ensure oil guns are made up with proper tip and/or sprayer plate and properly coupled. Check that the atomizing medium is available, and that oil temperature is within limits for proper atomization. Smooth light-off depends on proper draft setting and proper throttling of the fuel input. Control the burner fuel and air supplies to give a smooth, low-fire light-off.

9. Energize the ignition source and open the igniter shutoff valve on the burner to be lit. If flame on the first igniter is not proven within ten seconds, close the igniter shutoff valve, then identify and correct the problem. If air flow has been maintained at purge-air flow rate, a repurge is not required, but allow at least one minute to elapse before attempting to relight this or any other igniter.

10. With oil-fired burners using direct electric igniters, the igniter must be proven to be in position and energized prior to attempting main burner light-off.

11. With the igniter in service, open the main burner safety shutoff valve. Prove the main burner flame within five seconds after fuel is admitted to the furnace. If it is not proven, the burner safety shutoff valve should close; determine and correct the cause of failure to ignite. A repurge of the furnace is required if no other main burners are firing. If other main burners are proven, allow at least one minute to elapse before attempting to relight this or any other burner.

12. With ignition established and the burner fully lighted and stable, slowly open the burner's air register or damper to its normal operating position. (Make sure ignition is not lost in the process.)

13. Follow the same procedure to place additional burners with open registers in service as required to raise steam pressure or carry additional load. Maintain the fuel flow to each burner at a rate that is compatible with the air flow. Operating instructions should define a specific sequence in which burners should be lighted or removed from service.

C.1.3 Normal Operation

1. When changing the firing rate, adjust the air and fuel flows at the proper rates simultaneously to maintain a safe air-fuel ratio. Only one control device should be manipulated to achieve the change in firing rate. This does not preclude the use of an air-fuel lead/lag system where air flow changes lead fuel flow changes when load is increased and air flow changes lag fuel flow changes when load is decreased.

2. Keep individual burner shutoff valves in the full open or full closed position. Regulate the firing rate through a single main fuel control valve rather than by throttling individual burner shutoff valves. Individual burner fuel control is acceptable only when air and fuel to each burner can be measured and controlled.

3. When boilers are fired below approximately 30% of their rating, the number of burners in service must be reduced to avoid having to turn down all burners below the minimum stable firing rate. The actual minimum stable firing rate may vary with different fuel characteristics and fuel firing equipment.

4. Combustion control systems should be changed from automatic to manual operation at firing rates that are too low for the equipment to automatically maintain a safe air-fuel ratio. This is usually necessary during the initial lighting off cycles, extremely low load demand, and normal shutdown. Consult the equipment manufacturer and conduct tests to determine the specific conditions under which changeover to manual operation is necessary for an individual boiler.

5. Total furnace air flow should not be reduced below the minimum necessary for safe firing and the avoidance of stagnant pockets as determined by the boiler manufacturer. This normally will be set at 25 percent of full load volumetric air flow.

6. Loss of an individual burner flame should automatically initiate a trip of that burner’s fuel safety shutoff valve.

7. Periodic soot blowing is necessary to maintain high thermal efficiency in oil-fired boilers. However, if this operation is not performed with high carbon dioxide and low oxygen concentrations in the flue gases, explosions are likely to occur from the formation and ignition of air-soot dust clouds within the boiler.

A. Operate soot blowers only while burners are firing at high rates to avoid extinguishing the burner flames. The fuel-air ratio and combustion air should be adjusted to ensure a high carbon dioxide concentration and low oxygen content in the flue gases so that the soot will not burn. The boiler manufacturer’s instruction manual should be consulted to obtain specific recommended operating procedures when blowing soot.

B. If soot blowing must be done when the boiler is out of service, make certain the boiler is cold and there is no other source of ignition. It is preferable to blow the soot in cold boilers with compressed air rather than steam because condensing steam may dissolve the soot and corrode boiler tubes.

C.1.4 Shutdown

1. Normal shutdown should follow the reverse procedure of that used during startup. Burners should be removed from service sequentially as the load is reduced. Burner registers should be left in the firing position when approaching 25% load and all burners are going to be taken out of service. Fuel-air ratio control should be shifted from boiler flow to burner flow basis.

2. To avoid the admission of unburned fuel, burner igniters should be placed into service prior to removing the burner from service and purging of oil guns into the furnace. Igniters should not, however, be placed into service without proof of main burner flame. Explosions have been caused by turning on igniters when there has been a flameout of an operating burner.

3. With the igniter in service for an operating oil burner, the burner shutoff valve may be closed, and steam or air clearing valves may be opened. After sufficient time has elapsed to remove oil from the burner gun, the clearing valves may be closed and the igniter may be removed from service. When scavenging oil passes into the furnace, igniters should be in service with ignition established.

4. The fuel header safety shutoff valve should trip following closure of the last burner safety shutoff valve.

5. A post-purge of the furnace and flue gas passages should be accomplished by maintaining an air flow of not less than 25 percent of full load air flow for a period of not less than five minutes.

6. For gas-fired manually operated boilers and electric power generation boilers that use energize-to-trip safety shutoff valves, the main manual shutoff valve should be closed after shutdown. Preferably, the manual valve should be equipped with end switches which cause indication of the wide open and closed positions

in the control room. Otherwise, there should be documented procedures for manual verification of the valve position. At least 2 people should verify that the valve is closed and report to the control room. Monitoring gas meters will also help to indicate valve leakage.

C.2 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.2.1 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.2.2 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.3 Igniters

There are four classes of igniters: Class 1, 2, 3, and 3 Special.

A. Class 1 igniters are proven by test to reliably ignite any credible combination of fuel and air under any light-off or operating condition. When a Class 1 igniter is operated in a continuous manner, it will be in operation from the completion of the igniter trial-for-ignition through the entire operating cycle of the main burner until it is shut down. Independent flame supervision of the main burner is not required when a Class 1 igniter is used. 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. A Class 1 igniter may also be used as an intermittent or interrupted igniter. An intermittent igniter can be operated beyond the trial-for ignition of the main burner, if desired, to help stabilize combustion. An interrupted igniter does not remain in operation after the main burner trial-for-ignition period. Typically, Class 1 igniters provide energy in excess of ten percent of burner fuel input.

B. Class 2 igniters are smaller than Class 1 igniters and are proven by test to reliably ignite fuel under normal light-off conditions. They can also help to support main burner ignition under low load and other normal conditions that are within the normal operating range of the burner. Typically, Class 2 igniters provide energy between four and ten percent of burner fuel input. Unlike Class 1 igniters, Class 2 igniters do not have sufficient energy to reliably ignite any credible combination of fuel and air under any light-off or operating condition. Class 2 igniters are generally operated intermittently; i.e., they may be operated beyond the main burner trial-for-ignition period when desired. Separate flame supervision of the igniter and main burner flames is required if a Class 2 igniter is operated beyond the trial-for-ignition period. The main burner flame scanner is positioned so as to not detect igniter flame. The igniter flame scanner will detect both igniter and main burner flames. Class 2 igniters also may be used as an interrupted pilot.

C. Class 3 igniters are small igniters designed to provide energy to reliably ignite main burner fuel under prescribed light-off conditions. This type of igniter can only be operated as an interrupted igniter and must shut off when the main burner trial-for-ignition time is ended. Class 3 igniters are typically less than four percent of burner fuel input.

D. Class 3 Special (electric igniters) are high-voltage igniters that directly light off main burner fuel. Power must be interrupted when the main burner trial-for-ignition is ended. If the igniter is a retractable type, it must be interlocked to be proven fully inserted. Electric igniters require frequent maintenance to ensure a high-energy spark.

C.4 Other Standards

Additional information concerning explosion prevention in multiple-burner boiler-furnaces can be found in the National Fire Protection Association (NFPA) Standard No. 85, *Boiler and Combustion Systems Hazards Code.* It is recommended that this standard be consulted for a more detailed explanation of system design considerations and operating philosophy. See Section 4.2 for a list of other related standards.