FIRETUBE BOILERS

Table of Contents

Page

List of Tables

1.0 SCOPE

This data sheet covers firetube boilers used to supply steam for a given process, except those used in marine and locomotive applications. It does not cover space and hot water heating firetube boilers. Recommendations provided are intended to prevent losses involving firetube boilers.

1.1 Changes

April 2025. Interim revision. Minor editorial changes were made for additional clarity referencing water treatment program guidance in Data Sheet 6-23, *Watertube Boilers*.

2.0 LOSS PREVENTION RECOMMENDATIONS

2.1 Operation and Maintenance

2.1.1 Establish and implement a firetube boiler inspection, testing and maintenance program. See Data Sheet 9-0, *Asset Integrity* for guidance on developing an asset integrity program. Provide periodic testing and verification of controls and safety devices in the maintenance program. Table 1 shows the recommended frequency of testing and verification. Records or logs of such maintenance should be kept by the owner or boiler operator. Investigate and record the cause and corrective action taken for all cracking incidents. (See also Appendix C.2).

a. Flush water columns and gage glasses at least once each shift Flushing removes accumulation of sludge or deposits that could cause a false boiler water level indication. Check the accuracy of a water column (blow down the column) more frequently if boiler water conditions (surging, foaming) cause the indicated water level to be unreliable.

b. Provide, maintain and periodically test low-water fuel cutoff devices and feedwater regulators in accordance with recommendations in Data Sheet 6-12, *Low-Water Protection.*

Check low-water cutoffs to make sure they are free of scale and sediment. Open, internally inspect, and clean these devices at least once each year. Additional information on operation and maintenance is in Data Sheet 6-12.

c. Periodically blow down (bottom blowdown) the boiler to prevent accumulations of sediment. Sediment can insulate the heating surfaces of the boiler and lead to overheating. Frequency of blowdown depends on water quality.

d. Periodically inspect the boiler fireside in accordance with the National Board Inspection Code (NBIC). When the exit flue gas temperature exceeds 100°F to 175°F (38°C to 80°C) above normal operating temperature, perform a fireside cleaning immediately upon shutdown. Follow the boiler manufacturer's recommended procedures for all fireside maintenance.

Inspect all refractory for excessive cracking, chipping, erosion or loose sections. Perform this inspection when the boiler is open for cleaning, or at least once a year. If refractory has not been properly installed or repaired, the boiler may be severely damaged by overheating.

e. Check interior baffles (if provided) on both the waterside and fireside during unit shutdowns to make sure the baffles are still intact and properly located.

f. Check the area around tube ends at both tubesheets for cracks or leakage problems.

g. Periodically check all stays to make sure they are in place, securely attached and in proper tension.

h. To ensure prevention of boiler water backflow, inspect check valves in the boiler feedwater and treatment chemical feed piping thoroughly. Inspect the valve disc and seat for signs of wear and corrosion and replace the valve if any defect is found. Inspections for any foreign matter that may have entered boiler feedwater piping should be completed at the same time.

If backflow occurs, shut off the burner(s) immediately and close the feedwater stop valve tightly. If boiler water has entered the feedwater system or treatment chemical feed system in any significant amount, cool down the system for a few hours and inspect for damage (especially of plastic fittings in the chemical feed system) before restarting.

Table 1. Frequency of Testing

Item	*Frequency*
Calibration of gages, monitors and instrument and equipment settings	Per Data Sheet 6-4
Firing rate control	Per Data Sheet 6-4
Fuel valves: 1. Pilot valves 2. Main gas valves 3. Main oil valves	Per Data Sheet 6-4
Combustion safety controls: 1. Flame failure 2. Pilot turn down tests	Per Data Sheet 6-4
Low-water cutoff, feedwater regulator/pump controls	Per Data Sheet 6-12
Low combustion air flow interlock	Per Data Sheet 6-4
Atomizing air/steam interlock	Per Data Sheet 6-4
High and low gas pressure interlock	Per Data Sheet 6-4
Low oil pressure interlock	Per Data Sheet 6-4
Low oil temperature interlock	Per Data Sheet 6-4
Fuel valve proof-of-closure switch	Per Data Sheet 6-4
Purge timer	Per Data Sheet 6-4
Burner position switch (multi-fuel only)	Per Data Sheet 6-4
Low fire-start interlock	Per Data Sheet 6-4
Automatic changeover control (dual fuel)	Per Data Sheet 6-4
Safety valves	Per NBIC or Data Sheet 12-43

2.1.2 Provide proper water treatment to prevent formation of scale and prevent corrosion from harmful elements that may be in the water supply (make-up and return condensate). Feedwater can contain many impurities that can cause damage. Atmospheric gases, minerals, and organic matter may be present in solution. Maintain boiler water quality within limits recommended by the boiler manufacturer. (See Section C.2, item 3 water treatment.)

Establish and implement a documented water treatment program to effectively control potential damage mechanisms that can impact the boiler system, downstream equipment and/or processes. Maintain boiler feedwater quality (external to the boiler - raw/make up water supply/condensate) quality, boiler water quality (internal to the boiler) and steam purity is maintained within the boiler original equipment manufacturer's recommended parameters and chemistry limits and/or industry guideline limits. See Section C.2.3 for additional guidance. Also see Data Sheet 6-23, *Watertube Boilers*, for additional guidance on water treatment programs.

Oxygen is a direct cause of pitting damage to feedwater heaters, condensate lines and corrosion of the boiler proper. Make dissolved oxygen tests during boiler operation on a regular basis. Standby or out-of-service equipment is more susceptible to oxygen corrosion than on-line equipment. Control of oxygen is of vast importance.

2.1.3 Check all piping systems for proper installation.

a. Design and install steam and water piping between the boiler and Code-required stop valves in conformance with the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code and local and state ordinances.

b. Install gas piping as recommended in Data Sheet 7-54, *Natural Gas and Gas Piping*, and as required by state or local codes. After installation, test the gas lines for leaks. Size the gas line to provide the maximum gas flow required at the proper pressure. Inadequate gas line capacity results in the inability to fire the boiler at its maximum capacity. Provide a pressure regulator at each boiler to assure gas delivery at a constant pressure.

c. Install oil piping at the burner front according to the manufacturer's instructions. Install oil transfer piping as recommended in Data Sheet 7-32, *Ignitable Liquid Operations*. Install oil tanks as recommended in Data Sheet 7-88, *Ignitable Liquid Storage Tanks.*

For additional recommendations on the installation of fuel piping at the burners, refer to Data Sheet 6-0, *Elements of Industrial Heating Equipment* and Data Sheet 6-4 *Oil- and Gas-Fired Single-Burner Boilers*. (See also Section C.2, item 6, Operating Checks.)

2.1.4 Install all boiler and boiler room wiring in compliance with the National Electrical Code and any state or local requirements. For information on control circuit wiring, refer to Data Sheet 6-0. Periodically check electrical contacts on such items as starters, contactors and controls for cleanliness and arc burns.

2.1.5 Package-type firetube boilers may be factory test fired prior to shipment to verify proper operation of all controls and safety devices. Damage or instrument drift may have occurred during shipping and installation. Test all safety devices and controls during the initial boiler startup. Set controls to the requirements of the specific installation at this time. (See also Sections C.1 and C.2, items 1 and 3.)

a. The purpose of *water level controls* is to maintain the water inside the boiler at a proper operating level. All water level controls have a range of operation rather than one set point. Set the water level controls and alarms so that both the low- and high-water level limits are within the visible range of the gage glass.

The water level control that is most frequently found on a packaged firetube boiler is a combination pump control and low-water fuel cutoff that is often incorporated in a water column arrangement. This combination control may be designed to cycle the operation of a boiler feed pump to maintain a uniform range of water level. The control also interrupts electricity to the burner control circuit if water level drops below the minimum safe level established by the boiler manufacturer.

b. Select and install *safety valves* or *safety relief valves* as required by Section I or IV of the ASME Boiler and Pressure Vessel Code. These valves should be maintained as required by the NBIC and as recommended by Section VI or VII of ASME Code.

c. Follow the manufacturer's recommendations for initial *startup, firing rates* and *curing times* for refractory.

2.1.6 Follow the requirements of the NBIC, current edition, for any boiler alteration or repair. Permit only organizations having a National Board of Boiler and Pressure Vessel Inspectors' (NB) repair authorization to perform welding on boiler pressure parts. If an NB-authorized repair organization is not available, qualify the repairing organization in accordance with the NBIC. Outside North America, follow the local code or if there is none, follow the NBIC. Review other codes and references such as ASME Section I or IV; ASME/ANSI B31.1, *Power Piping*, and any technical advisory bulletins from the boiler manufacturer to assure the repair or alteration will achieve long-term economical results.

2.1.7 Design and construct new firetube boilers to meet or exceed the requirements in the current edition of ASME Section I or Section IV. Outside North America, implement any similar construction code promulgated by a jurisdiction. If there is no local code, implement the appropriate ASME Code section.

Complying with the ASME Code will better ensure pressure part integrity over a reasonable operating lifetime. The ASME Code provides minimum design and construction rules. Specific boiler application may require design that exceeds these minimums. For boiler construction outside North America (where the ASME Code may not be accepted by the jurisdiction) a comparable code, acceptable to the authority having jurisdiction, should be used.

2.2 Training

2.2.1 Train operators on standard and emergency operating procedures. See Data Sheet 10-8, *Operators*, for guidance on developing operator programs. Provide proper training for all operators in the general operation of boilers on documented standard and emergency operating procedures that are readily available in the boiler control room. Train operators for the specific firetube boiler including responses to typical emergency situations. Proper training may be accomplished at the boiler site through instruction by qualified operators, contract instructors or manufacturer's representatives.

2.3 Contingency Planning

2.3.1 Equipment Contingency Planning

When a firetube boiler breakdown would result in an unplanned outage to site processes and systems considered key to the continuity of operations, develop and maintain a documented, viable firetube boiler equipment contingency plan per Data Sheet 9-0, *Asset Integrity*. See Appendix C of that data sheet for

guidance on the process of developing and maintaining a viable equipment contingency plan. Also refer to sparing, rental, and redundant equipment mitigation strategy guidance in that data sheet.

3.0 SUPPORT FOR RECOMMENDATIONS

The continual search for higher efficiencies by the manufacturer and maximum outputs by the user has created situations that can lead to serious trouble while the boiler is in service. As the limit of peak efficiency and output is reached for a given design, the necessity for all the auxiliary systems to perform reliably becomes greater. The most critical performance criteria are heat input conditions, circulation, and feedwater purity.

Typical boiler problems are:

- overheating;
- cracking at the tube ends;
- cracking at the furnace ends;
- collapsing of furnaces;
- cracking of tubesheets;
- cracking of welds.

Although the heat input may be a main contributing factor, it is not always the primary cause of failure. Physical, chemical, and metallurgical tests may be required to properly diagnose the precise cause. Heat is conducted through boiler surfaces in rather a complex way and the amount transmitted is dependent on a number of factors which include the following:

- the specific conductivity of the boiler material;
- temperature differential between the heat transfer surfaces;
- thickness of boiler material;
- foreign matter (scale, deposits) on the heat transfer surfaces.

When a boiler is initially designed, these factors should be in harmony with its thermal characteristics. Operating conditions can and do vary significantly. This may affect the heat transfer, and result in overheating failures.

A survey of design practices was conducted of several leading package boiler manufacturers in regard to the heat input in Btu/hr-cu ft Years ago, furnaces contained a large amount of refractory and the heat input rate to the furnace was limited to about 25,000 Btu/hr-ft^3 (930 J/hr-m^3). Later, the amount of refractory was reduced and the heat input increased to 35,000 Btu/hr-ft^3 (1400 J/hr-m^3). With practically all refractory eliminated, today's designs provide better heat transfer and the heat release rate in the furnace has increased to as high as 250,000 Btu/hr-ft^3 (9300 J/hr-m^3).

Cracking at the ends of furnaces, tubes, and at the ligaments is usually the result of overheating. Excessive overheating can be caused by several conditions, such as these:

- low water;
- excessive scale;
- concentrated heat causing the steam bubbles to act as insulators;
- excessive heat from too high a firing rate, which in turn causes more expansion and contraction than normal;
- excessive temperature change during purge cycle;
- unit started up too fast (overfiring);
- soot plugged tubes.

Overheating due to low water can cause cracking, collapse of the furnace in the case of internally fired units, or shell distortion in the case of externally fired boilers. Expansion and contraction from temperature changes,

coupled with the tubesheet movement caused by pressure changes, also cause cracking. The movement caused by temperature appears to be more critical than that caused by pressure.

Any concentration of intense heat on a small section of the rear tubesheet can lead to the formation of steam bubbles even though the average water temperature is less than that of saturated steam. When these steam bubbles are blanketed by layers of cooler water on the upper part of the tubesheet, they cannot rise. They remain in position until the latent heat is transferred to the main mass of water by conduction. The layer of steam bubbles serves as an insulator, resulting in overheating of this section of the tubesheet. Scale buildup can also act as an insulator and lead to overheating. Conditions of this type can affect the entire rear tubesheet, which in turn affects the ends of the tubes and the furnace.

Radiant heat from refractory on the rear door can create a similar condition during boiler operation and during intermediate firing cycles. A firing cycle is usually preceded and followed by a purge period. During this period the tubes are subjected to a blast of cool air while the boiler shell remains hot. As the tube walls are relatively thin compared to the tube sheet, they contract rapidly when cooled. Radial contraction pulls the tube wall away from the tube hole and can eventually cause cracking or leaking.

If there is a lack of proper instrumentation, it is not always possible to obtain the information necessary to identify these problems. If the problem is serious, proper instrumentation should be provided to obtain the required information. Loss experience indicates that cracking at the rear tubesheet, tube ends, and furnace ends is a major problem. In some instances, there are so many cracks that welding repairs cannot be made and the entire tubesheet must be replaced.

By carefully monitoring the internal condition of the boiler and taking time to observe operating data, these types of failure can be prevented.

Additional hazards for firetube boilers include a steam explosion from collapse of the furnace tube due to severe overheating, and fire hazards that can arise from an event such as fuel leakage coinciding with the presence of oxygen and an ignition source. A discussion of those hazards can be found in data sheets dealing with the subjects of furnaces and boiler fire hazards. (See Data Sheets 6-0 and 6-4.)

4.0 REFERENCES

4.1 FM

Data Sheet 6-0, *Elements of Industrial Heating Equipment*
Data Sheet 6-4, *Oil-and Gas-Fired Single-Burner Boilers*
Data Sheet 6-12, *Low-Water Protection*
Data Sheet 6-23, *Watertube Boilers*
Data Sheet 7-32, *Ignitable Liquid Operations*
Data Sheet 7-54, *Natural Gas and Gas Piping*
Data Sheet 7-88, *Ignitable Liquid Storage Tanks*
Data Sheet 9-0, *Asset Integrity*
Data Sheet 10-8, *Operators*
Data Sheet 12-43, *Pressure Relief Devices*

4.2 Others

National Board Inspection Code.
American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code.
ASME/ANSI B31.1, Power Piping.

APPENDIX A GLOSSARY OF TERMS

This document does not have any defined terms.

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).

April 2025. Interim revision. Minor editorial changes were made for additional clarity referencing water treatment program guidance in Data Sheet 6-23, *Watertube Boilers*.

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

January 2022. Interim revision. Minor editorial changes were made.

January 2021. Interim revision. Updated contingency planning and sparing guidance.

January 2000. This revision of the document has been reorganized to provide a consistent format.

APPENDIX C SUPPLEMENTAL INFORMATION

C.1 Installation Guidance

Boilers should be positioned in the boiler room to allow for tube cleaning and future tube replacement. Adequate space for these purposes should be provided.

Aisle space should be provided around the entire boiler and between boilers on multiple installations. Sufficient space should be provided above the boiler to accommodate access to the breaching, steam header, and other necessary piping.

The boiler room should be properly vented to provide an adequate amount of air to the burner(s) for proper combustion of the fuel. Automatic dampers on ventilation systems should be provided with electrical interlocks that will prevent any automatic burners from operating when the dampers are in the closed position.

In cold climates the boiler room should be constructed and insulated to protect pipes, pumps, vessels, controls and other equipment against freezing.

C.2 Operation and Maintenance

The following material is a guide for operation and inspection, testing, and maintenance of packaged firetube boilers.

1. Preliminary Checkout

All manufacturers supply operating instruction manuals for their equipment. Before starting the boiler, the instruction manual should be thoroughly read and understood. It is important that operating personnel carefully study and follow the procedures in the manual, particularly the safety precautions, before attempting equipment activation.

Before initial operation of a new boiler, certain procedures should be followed to ensure high operating efficiency, long life, and reliability. Even when the boiler has been test fired by the manufacturer, the following procedures should be performed:

a. The unit should be thoroughly examined on both the waterside and the fireside to make sure that no foreign material is present;

b. Blowdown piping, steam piping, feedwater piping, and all other piping should be checked to ensure that it has been properly installed to eliminate any possibility of damage. Items such as gages, gage glasses, controls and the like should be checked for any evidence of damage or breakage during transportation or installation;

c. Motors should be checked for correct rotation. Solenoid valves, interlocks, motorized valves, and limit switches should be operationally checked to ensure proper function;

d. All fuel lines should be checked for proper installation.

After completing these and any other inspections recommended by the manufacturer, boiler startup may be initiated.

2. System Cleaning

System cleaning must be completed prior to connecting the boiler to the system. A boiler can experience severe damage because of system contaminants such a pipe dope, cutting oil and metal shavings or chips.

Much of the dirt and contamination in a steam system can be flushed out prior to boilout of the system. This is accomplished by first flushing the system to waste with clear water. The boiler and circulating pump are isolated with valves, and city water is allowed to flush through successive zones of the system carrying chips, dirt, pipe joint compound, etc., with it. This is followed by a chemical flush. Removal of pipe chips and other debris before opening the isolating valves to the boiler and pump help to protect this equipment from damage.

After the flushing process is complete, the usual boilout procedure is done. If one zone is flushed and boiled out before other zones are completed or connected, this flushing process should be repeated on completion of additional zones, loops, or sections of piping.

The boilout should be done at approximately 50% of the unit operating pressure for a period long enough to ensure that all oils and materials to be removed by the boilout process have been dislodged. Manufacturer's recommendations for boilout should be followed.

3. Water Treatment

The water treatment program effectively controls potential damage mechanisms that can impact the boiler system, downstream equipment and/or processes. This includes:

- prevention of the accumulation of scale and deposits in the boiler;
- removal of dissolved gases from the water;
- protection of the boiler against corrosion;
- elimination of carryover (steam only);
- maintenance of proper pH levels;
- maintenance of the highest possible boiler efficiency;
- decrease of boiler downtime for cleaning.

There is a tendency for any sediment or sludge to settle at the bottom of the boiler. Salts, silt and solids are usually introduced into a boiler with raw feedwater. Chemicals introduced into the system can also contribute to these deposits. The continual supply of makeup water to replace leakage, process losses and unusable condensate results in accumulation of these undesirable solids. The removal of these solids is of utmost importance. Bottom blowdown valve connections are provided at the bottom of the boiler shell to provide a means of controlling sediment buildup.

Water released from the boiler during blowdown must be reduced to atmospheric pressure and cooled to permit disposal. Blowdown tanks vented to atmosphere are used for this purpose. The frequency and amount of blowdown is dependent on the amount of makeup water required and on the type of boiler water treatment program used.

4. Removal from Service

When cool-down of a boiler is required, the manufacturer's recommendations should be followed.

Some boilers may be subject to freezing temperatures, or may be idle for long periods (more than 30 days) if used on a seasonal basis. These boilers should be laid up dry and the following procedures performed to prevent damage during periods of inactivity:

- The boiler should be thoroughly drained, cleaned (both fireside and waterside) and then dried out;
- Lime or other water absorbing substance should be placed in open trays inside the boiler shell, fireside and flue gas pass. The waterside should be closed tightly to exclude all moisture and air. A sign that reads **Fill Boiler and Remove Desiccant Trays Prior to Firing** should be attached to the boiler front;
- All allied equipment such as condensate tanks, pumps, etc., should be thoroughly drained.

During short idle periods, a boiler should be laid up wet in the following manner:

- The boiler should be filled to overflowing with hot water. The water should be approximately 120°F (50°C) to help drive out the free oxygen. The water should also be chemically treated to minimize corrosion;

- All boiler connections should be checked for leaks, and a weekly sample should be taken to ensure that the water is chemically neutral.

Upon restarting a boiler that has been laid up dry, laid up wet, or has been cooled down for repairs, the startup procedure recommended for a new boiler should be followed.

5. Burner System

Package-type boilers are supplied with engineered fuel combustion equipment that must be maintained through a regular maintenance program to keep it in satisfactory operating condition.

Oil nozzles, igniters, electrodes and burner internals should be checked on a regular maintenance schedule. Specific instructions as to the methods of cleaning and adjustment are contained in the instruction manual furnished by the boiler manufacturer.

Such items as linkages and other mechanical fastenings and stops should be periodically checked for tightness and visually checked for any movement or vibration. Any items that are loose or that have changed in position should be thoroughly checked and readjusted if necessary.

Fuel solenoid valves and motorized valves should be visually checked by observing the fire when the boiler shuts down. If the fire does not cut off immediately, the valve could be fouling or showing wear. If this occurs, the valve should be repaired or replaced immediately to avoid any serious problems.

All switches, controls, safety devices, and other equipment should be periodically checked. Do not assume that all safety devices, switches, controls, etc. are operating properly. These devices should be checked on a planned maintenance schedule and any malfunctions noted and promptly repaired. See Data Sheet 6-4.

All filters, screens, and strainers should be periodically cleaned to prevent any restriction or malfunction.

Oil tanks should be checked annually for the presence of water and sludge. Filling connections should be checked for tightness of covers and proper gaskets after each delivery. The fill box must be above grade to prevent water seepage into the tanks. Vent pipes should be checked periodically for obstructions.

Oil heaters should be checked annually for the presence of water or sludge and for ‘‘coking’’ on the heat exchanger surfaces.

Condensate removal systems from oil heaters should be checked for proper operation and that condensate is discharged to a satisfactory place. Condensate from oil heaters should not be discharged into the boiler feedwater system.

Pumps should be checked for leaky shaft seals and worn or loose drive mechanisms at least monthly.

Oil lines should be checked for external leaks and damaged insulation at least monthly.

The oil line pressure gages should be checked daily. Gage readings that increase or are erratic indicate potential trouble. If this occurs, strainers should be checked and cleaned, and oil lines checked for obstructions or internal sludge buildup.

6. Operating Checks

The following periodic checks should be conducted to prevent boiler malfunction:

- Check to ensure that cold makeup water is not being fed into an operating boiler. Feedwater temperature should be kept above 80°F (26°C).
- Check the feedwater treatment equipment to make sure it is operating properly.
- Check such items as feed pumps, valves, and other equipment to ensure proper performance.
- Check safety valves according to the requirements of the ASME Boiler and Pressure Vessel Code, Sections I or IV and VI or VII and the NBIC. Weeping safety valves may indicate valve malfunction.
- Check for excessive amounts of system makeup water by means of a water meter on the inlet line.

Particular instructions and recommendations made in the instruction manual should be observed to ensure a long life for the boiler.

When draining a boiler for inspection, it is recommended that a flow of water be maintained into the boiler with a high-pressure hose to keep any sediment thoroughly agitated and in solution. This prevents caking of the sludge, which can be extremely difficult to remove if permitted to harden in place.