April 2012
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LOW-WATER PROTECTION FOR BOILERS

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1.0 SCOPE

This data sheet provides guidance on reducing the hazard of boiler dry-firing. The guidance covers the application, installation, testing, and maintenance of low-water protection equipment/systems on boilers.

Related Data Sheets are:

Data Sheet 6-2, *Pulverized Coal-Fired Boilers*
Data Sheet 6-7, *Fluidized Bed Combustors*
Data Sheet 6-13, *Waste Fuel-Fired Facilities*
Data Sheet 6-14, *Heat Recovery Boilers*
Data Sheet 6-21, *Chemical Recovery Boilers*
Data Sheet 6-22, *Firetube Boilers*
Data Sheet 6-23, *Watertube Boilers*
Data Sheet 7-45, *Safety Controls, Alarms, and Interlocks*
Data Sheet 9-0, *Asset Integrity*
Data Sheet 7-109, *Fuel Fired Thermal Electric Power Generation Facilities*
Data Sheet 10-8, *Operators*

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

For any boiler where “two low-water cutoffs” are recommended, low-water protection provided in accordance with one of the following arrangements meets the intent of two low-water cutoffs:

A. Provide two independent dedicated low-water tripping devices connected so that a trip occurs if either one detects a low-water condition.

B. Provide one dedicated low-water tripping device and one cutoff activated through the feedwater control system. A trip occurs if either detects a low-water condition.

C. Provide one low-water trip through the use of the drum level signal developed by an auctioneering system used in the feedwater control system.

D. Provide one low-water trip through the use of a state-of-the-art instrument that utilizes internal redundancy, self-checking internal diagnostics, redundant power supplies, and which provides an audible and visible alarm in the control room when internal diagnostics detect a fault condition in the instrument.

E. Provide three differential pressure drum level measurements for low-water protection using a two out of three tripping logic.

2.1 Equipment and Processes

Since a major contributing factor in failure of low-water fuel cutoff devices include sludge and scale buildup, mechanical breakage, and improper installation/maintenance, reliability of the cutoff will be enhanced when it is properly tested and made part of a drum-level indicating system because the operator can see at any time that drum level is being sensed.

A summary of the Application Recommendations is given in Table 1.

Table 1. Summary of Boiler Low-Water Protection Application Recommendations

Type of Boiler	*Minimum No. of LWCOs*	*Data Sheet Section*	*Comments*
Power Generation			
Natural Circulation	1	2.1.1.1	
Controlled (Forced) Circulation	1 Level & 1 Flow	2.1.1.2	
Once Through	1	2.1.1.3	
Chemical Recovery			
Kraft			Refer to DS 6-21
Soda			Refer to DS 6-12
Magnesium Sulfite/Red Liquor	1 or 2	2.1.2.2	
Industrial			
100% Operator Attendance	1 or 2	2.1.3	See Figure 1
<100% Operator Attendance	2	2.1.4	
Stoker Fired	1 or 2	2.1.5	
Bagasse and Hog Fuel	1 or 2	2.1.6	
Waste Fuel	1 or 2	2.1.7	
Fluidized Bed	1 or 2	2.1.8	
Waste Heat	1 or 2 if practical	2.1.9	
HRSGs	1 or 2	2.1.10	Where needed
Hot Water Heating and Supply	1	2.1.11	
Small Automatically Fired	1 or 2	2.1.12 and C.3	See Table 3
Coil-Type Water Tube	1 or 2	2.1.13	See Section C.3.1, items 6 and 7

2.1.1 Power Generation Drum Type and Once-Through Steam Generators

Ensure steam generators located at electric power generating stations have the following:

A. Constant operator attendance in control rooms

B. Control rooms equipped with multiple means for monitoring steam drum water level (for drum-type units) and alarms for low-water level and/or flow

C. The water treatment program effectively controls potential damage mechanisms that can impact the boiler system, downstream equipment and/or processes. Water treatment carefully controlled and monitored

D. Operators who are well-trained and well-versed in emergency operating procedures

2.1.1.1 For natural circulation steam generators, provide one low-water fuel cutoff that meets all the following criteria:

A. Is independent of at least one of the low-level alarms

B. Is integrated with an auctioneered drum level sensing system or is part of a state-of-the-art electronic drum level monitoring device with internal redundancy, dual power supplies, and self-checking diagnostics

C. Compares the level of all level-sensing devices and provides a high-differential alarm when the difference exceeds normal variations by more than 1 in. (25 mm)

D. If climatic conditions and instrument design warrant, provide freeze protection in accordance with DS 9-18, *Prevention of Freeze-Ups*.

2.1.1.2 Controlled (forced) circulation steam generators—provide one low-water level fuel cutoff and one low-water flow fuel cutoff. Use the minimum safe drum level and circulation rate established by the boiler manufacturer.

2.1.1.3 For once-through (forced flow) steam generators, provide one low-water flow fuel cutoff and a separate low-flow alarm. The low-water flow fuel cutoff is preferably integrated with a remote flow indicator so operators can monitor that it is sensing flow. Additionally, provide a high steam temperature alarm ahead of each attemperator/desuperheater (spray station) and at the superheater outlet. Keep the high temperature alarm independent of any temperature monitoring devices used to control either firing rate or spray water flow.

High temperature alarms integrated with a remote temperature indicating system allow operators to monitor that temperature is being sensed. Where practical, when multiple temperature measurements are made at a given location, provide a high differential alarm that annunciates when the difference exceeds 10°F (6°C).

2.1.2 Chemical Recovery Boilers

2.1.2.1 Refer to DS 6-21, *Chemical Recovery Boilers*, for low-water protection recommendations for recovery boilers in the Kraft (sodium sulfate or alkaline) process and for recovery boilers in the Soda (sodium sulfite) process.

2.1.2.2 For magnesium sulfite/red liquor chemical recovery boilers, apply low-water protection consistent with that for industrial boilers with steam generating capacities equal to or greater than 100,000 lb/hr (45,000 kg/hr).

2.1.3 Industrial Boilers

(See Fig. 1 for summary.)

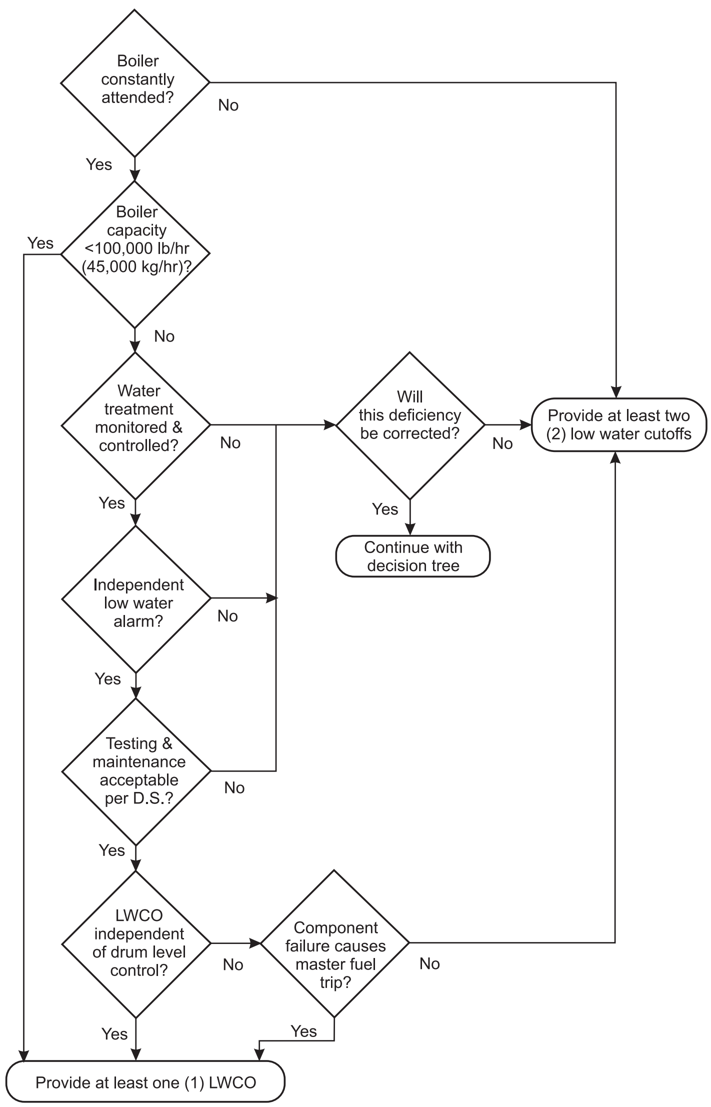

Fig. 1. Industrial boiler low-water protection. (Reference Sections 2.1.3 and 2.1.4)

2.1.3.1 Industrial boilers with steam generating capacities less than 100,000 lb/hr (45, 000 kg/hr) and having full-time boiler operator attendance, provide one low-water fuel cutoff and alarm. For boilers in this size range with less than full-time operator attendance, provide two independent low-water cutoffs.

2.1.3.2 For industrial boilers with steam generating capacities equal to or greater than 100,000 lb/hr (45,000 kg/hr) and having full-time boiler operator attendance, provide one low-water fuel cutoff (see ‘‘exception’’ at end of this section) when all the following conditions are satisfied.

a) Water treatment is carefully monitored and controlled.

b) A low-water level alarm is provided independent of any alarms associated with the low-water fuel cutoff.

c) The low-water fuel cutoff is independent of the system used for normal drum-level control or is integrated with drum-level control and a component failure causes a master fuel trip (MFT).

d) Testing and maintenance programs for the low-water fuel cutoff (LWCO) are established and records maintained in accordance with recommendations in Sections 2.2.1 and 2.2.2 of this data sheet.

Exception: If a boiler has had a history of low-water problems or sludge/scale accumulation, provide two independently connected low-water fuel cutoffs, preferably of different design, and, with the assistance of a qualified feedwater treatment consultant, adjust the feedwater treatment program to mitigate the source of the sludge and scale.

2.1.4 Industrial Boilers with Total Heat Inputs (Firing Capacity) Greater Than 12.5 Million BTU/hr (3,660 kW) [10,000 lb/hr (4,500 kg/hr)] Steam having Less Than Full Time Boiler Operator Attendance

Provide two low-water fuel cutoffs and alarms. Ensure at least one LWCO isindependent of the system used for feedwater flow control.

2.1.5 Stoker-Fired Boilers

Provide one or two low-water fuel cutoffs in accordance with Figure 1. Terminate all fuel feed (solid fuel supplied by the stoker and any support, startup, and alternate fuels) when a low-water condition is detected.

Additionally, for boilers with a large inventory of fuel on the grate (fuel continues to burn for more than five minutes when fresh fuel supply is stopped), implement one or both of the following as permitted by equipment design and boiler manufacturer instructions:

A. Increase grate speed to maximum to dump fuel from grate as soon as possible.

B. Reduce undergrate air to the minimum required to keep the grate from overheating.

With (A) and/or (B), maintain normal draft above the grate by keeping the ID fan in service. Overfire air can also remain in service provided it does not contribute to burning remaining fuel on grate.

2.1.6 Bagasse and Hog Fuel Fired Boilers

Provide one or two low-water fuel cutoffs in accordance with Figure 1.

In the absence of specific guidance from the boiler manufacturer, follow the guidance for stoker boilers. Trip the undergrate air fan and increase grate speed to maximum to remove burning and unburned bagasse from the boiler as quickly as possible. Keep the ID fan in operation to purge pyrolysis gases from the boiler. If overfire air is provided by a separate fan, it is preferable to also trip that fan. Keep dampers in the undergrate and overfire air systems open.

2.1.7 Waste Fuel Boilers

Provide one or two low-water fuel cutoffs in accordance with Figure 1. When waste fuel, such as blast furnace gas or coke oven gas, is fired, a means to divert this fuel source may be necessary to avoid an unacceptable interruption to process operations. When burning solid waste fuels, fuel inventory in the boiler may require special procedures to minimize residual burning while preventing flammable vapor accumulation. Always follow the boiler manufacturer’s recommendations for safe emergency shutdown when a low-water condition occurs.

2.1.8 Atmospheric Fluidized Bed Boilers

Provide one or two low-water fuel cutoffs in accordance with Figure 1. When a low-water condition is detected, do the following:

A. Stop all fuel feed.

B. Shut down primary air (fluidizing air).

C. Keep secondary air (overbed air) and ID fans in operation.

Also, if it is known or discovered that the low-water condition is the result of a tube rupture, isolate the feedwater supply.

2.1.9 Waste Heat Boilers

When a waste heat bypass system is installed, provide low-water protection consistent with the guidelines for industrial boilers and divert the hot stream in the event of a low-water condition. Waste heat boilers may or may not have supplementary fuel firing. When so equipped, also terminate supplementary fuel firing. Each waste heat boiler needs to be separately evaluated to determine the feasibility of providing automatic low-water protection.

2.1.10 Heat Recovery Steam Generators for Combined Cycle Operation

Provide one or two low-water fuel cutoffs in accordance with Figure 1 for steam drums with boiler banks located where gas temperature at maximum load can cause tube damage during a low-water condition.

2.1.11 Hot Water Heating and Supply Boilers

Provide one low-water cutoff any place above the lowest safe permissible water level established by the boiler manufacturer. If installed in external piping, ensure the chamber will drain properly under a low-water condition. Include provision for testing and written procedures for conducting the test.

2.1.12 Automatically Fired Boilers with Total Heat Inputs (Firing Capacity) Not Exceeding 12.5 Million BTU/hr (3660 kW)

Provide low-water protection in accordance with ASME Standard CSD-1, *Controls and Safety Devices for Automatically Fired Boilers*. (See Appendix C, Section C.3.)

2.1.13 Coil-Type Watertube Boilers

Provide low-water protection in accordance with in Appendix C, Section C.3, items 6 and 7 of this data sheet. A variety of flow and temperature actuated devices, as well as conventional floats and probes, can be used for low-water protection on this type of boiler. Follow the boiler manufacturer's recommendations.

2.1.14 Gage Glasses

2.1.14.1 Ensure gage glasses are installed in accordance with code requirements.

2.1.14.2 For boilers with one or more gage glasses, provide at least one gage glass that allows operators to easily recognize if the glass is full or empty when no water line is visible.

2.1.14.3 Gage glasses may be shut off when permitted by the applicable boiler code, but such gage glasses need to be kept in serviceable condition.

2.1.15 Indirect Level Measurement

Reliable low-water protection systems based on process measurements of flow, temperature, and/or pressure have yet to be demonstrated.

2.1.16 Installation

2.1.16.1 Where available for the service intended, use FM Approved low-water fuel cutoffs.

2.1.16.2 Confirm low-water fuel cutoff devices conform with the design, fabrication, and installation specifications in the ASME Boiler and Pressure Vessel Code or accepted comparable code and that installation is in accordance with the manufacturer's instructions and good engineering practice. Verify water is visible in the gage glass at the level the LWCO functions.

2.1.16.3 Bypass switches, either locally mounted or in the control room, are acceptable if required to permit blowdown and testing of a water column incorporating a low-water fuel cutoff, and to permit bypassing of the low-water fuel cutoff during boiler startup.

A. Provide switches to permit blowdown and testing of a water column incorporating a low-water cutoff only when interruption of the boiler fuel supply causes an unacceptable interruption in operation or creates a dangerous condition.

Provide spring-return, push button, or other type of momentary open switch that returns to the open position when released. The bypass is actuated only while the button or switch is pushed.

Include an alarm or light that is activated when the low-water fuel cutoff senses a low-water condition during column blowdown so the operator can verify device operation. Also provide a light or indicator at the switch that confirms the bypass is active when the switch is in use and has returned to its normal position when the switch is released.

Testing the low water cutoff using a momentary open switch verifies the functionality of the low water cutoff's electrical system. Full functional testing as described in Section 2.2.1 includes the entire system, resulting in a fuel trip shutting down the boiler.

B. When used to permit bypassing of the low-water cutoff during startup:

1. A multi-position switch with a keyed bypass is acceptable. The key is intended to discourage indiscriminate use of the bypass during unexpected drum level upsets.

2. Do not keep key(s) in the switch when the bypass is not in use. Store key(s) in a separate location accessible by only the shift supervisor, power superintendent or a person with similar responsibility.

3. This type of bypass switch, when installed to permit startup, can also be used to permit blowdown and/or testing of the low-water fuel cutoff when interruption of the boiler fuel supply causes an unacceptable interruption in operation or creates a dangerous condition.

4. Activate an audible alarm and a separate, specially designated, non-cancelable flashing light when the bypass switch is engaged.

5. Activate an audible alarm and separate, specially designated, non-cancelable flashing light when the low-water fuel cutoff senses a low-water condition, regardless of the bypass switch position. (See Recommendation No. 2.1.16.5)

2.1.16.4 Time delays in the fuel tripping sequence of low-water protection systems are acceptable provided: (a) the time delay is in accordance with the manufacturer's recommendation; and (b) during the time delay, the drum water level is not expected to drop below the minimum safe operating level established by the boiler manufacturer. Do not use time delays in the fuel tripping sequence for low-water flow protection on once-through steam steam generators.

2.1.16.5 Activate an audible alarm and a separate, specially designated, non-cancelable flashing light when the low-water fuel cutoff senses a low-water condition. Design audible alarms to be distinctly audible above ambient noise level. Locate alarms where they will quickly alert the operator or other properly trained individual so that action can be taken to avoid a low-water condition. For boilers with less than full-time attendance, locate alarms and lights at the boiler control panel as well as in a location that is always occupied when the boiler is in operation.

2.1.16.6 Design the low-water protection system to be fail-safe (i.e., de-energized to trip). This will prevent continued operation of the firing system if an electrical failure inhibits proper functioning of the low-water fuel cutoff(s).

For boilers where two low-water fuel cutoffs are recommended, independently pipe and connect the two LWCOs so if either device senses a low-water condition a boiler trip sequence will be automatically initiated.

2.1.16.7 Low-water fuel cutoffs that incorporate an electronic processing unit (EPU) generally have flexibility in the way alarms and cutoffs can be activated. Since it is intended that the cutoffs always be operative while the boiler is in service, take precautions to ensure it is not easy to bypass the cutoff, to change the cutoff to an alarm-only function, or to change the level at which the cutoff operates. To prevent unauthorized tampering, solder wiring connections or, at a minimum, provide a means to prevent unauthorized access to the wiring terminals. (See Appendix C, Section C.1.5.)

2.2 Operation and Maintenance

2.2.1 Testing

If either the slow drain test described in Recommendation 2.2.1.1 or the quick drain test in 2.2.1.2 show the low-water cutoff is inoperative, do not return the boiler to service until the problem is corrected.

2.2.1.1 Slow Drain Tests

Except as noted below, conduct slow drain tests on steam boilers following a written procedure at least semi-annually, at the time of commissioning, when removing boilers from service for a planned outage, and following any work performed on the control system and wiring associated with low-water protection. If a semi-annual test shows the LWCO is inoperative due to scale, sludge, or dirt accumulation, determine and correct the cause of the problem and increase the slow drain test frequency to at least quarterly. Log all slow drain tests, including any corrective action taken. Independently test dual low-water fuel cutoffs.

2.2.1.1.1 Exceptions:

1. For power generation steam generators, refer to Data Sheet 7-109, *Fuel Fired Thermal Electric Power Generation Facilities*, for functional testing recommendations for all safety systems including low-water protection and, where provided, high drum-level alarms and trips.

2. For boilers in locations where a process safety program is in place and the boilers are included in the process safety program, use the frequency for testing the low-water protection system as defined by the process safety program and as acceptable to the authority having jurisdiction.

Testing the low water cutoff using a momentary open switch verifies the functionality of the low water cutoff's electrical system. Full functional testing as described in Section 2.2.1 includes the entire system, resulting in a fuel trip shutting down the boiler.

3. For boilers with low-water cutoffs incorporated into probe-type water columns or differential pressure level transmitters where it can be readily verified the system is effectively monitoring and responding to changes in drum level, the semi-annual slow drain test frequency can be changed to annual.

2.2.1.1.2 Provide written slow drain test procedures.

2.2.1.1.3 If, during a slow drain test, the water level in the gage glass or the remote indicator stops decreasing, stop the test immediately by tripping the boiler. Allow the boiler to cool and then investigate and correct the cause of this problem.

2.2.1.1.4 An actual operational low-water trip is an acceptable substitute for a slow drain test provided the drum level at the time of the trip is documented and a first-out indication confirms the trip was caused by the low-water condition.

2.2.1.2 Quick Drain Tests

A. Check gage glass accuracy at the beginning of each shift the boiler is operating by blowing it down and noting the promptness with which the water level is restored.

B. Unless the manufacturer's instructions specify otherwise, blow down externally mounted low-water fuel cutoffs, float or probe type, that are not part of a continuous water-level indicating system at least daily.

C. Blow down other water columns and low-water cutoffs in accordance with manufacturer recommendations and the historic frequency of scale and sludge buildup that can cause malfunction. Include the frequency of testing in the boiler operating procedures. In the absence of a manufacturer recommended frequency, conduct blowdown quarterly.

D. When it is not acceptable to interrupt boiler operation during a quick drain test, use momentary open switches. (See Recommendation 2.1.16.3.)

E. Probes installed through the shell of a firetube boiler or the drum of a watertube boiler cannot be quick drain tested. Perform quarterly slow drain or other manufacturer defined tests in lieu of quick drain tests.

F. Do not perform quick drain tests on differential pressure type water level/LWCO devices.

2.2.1.3 Ensure operators are trained in testing procedures and proper precautions to take when performing tests. Record all tests.

2.2.2 Inspection, Testing, and Maintenance

2.2.2.1 Calibrate low-water protection systems, such as those that use differential pressure transmitters to monitor drum level or water flow, at least annually. Use calibration procedures that are in accordance with manufacturer instructions. If annual calibration checks show the device has an error of more than 1 in. (25 mm) water level or 5% flow rate, increase calibration frequency until accumulated drift is within these limits.

2.2.2.2 Establish and implement an inspection, testing, and maintenance program. Stock routine replacement parts for all safety controls as recommended by the manufacturer of the device. See Data Sheet 9-0, *Asset Integrity*, for guidance on inspection, testing, and maintenance programs.

Establish and implement a documented water treatment program". See Data Sheet 6-23, *Watertube Boilers*, for additional guidance on water treatment programs.

2.2.2.3 Open, internally inspect, and clean float-type low-water fuel cutoffs at least once each year. Remove any scale or sludge accumulations prior to returning the boiler to service. If buildup is appreciable, increase the frequency of such inspections and use a qualified water-treatment resource to determine the cause and corrective actions. Follow the manufacturer's inspection frequency guidelines for probe-type low-water cutoffs. In the absence of manufacturer guidelines, inspect and clean at least annually.

2.2.2.4 Except for inspection, keep covers of all electrical connections in place and properly fastened. Remove covers annually for a visual inspection of terminals, wiring, mercury tubes, etc., and for any evidence of heat exposure, moisture, dust or other foreign matter that might affect dependable operation of the control. If unsatisfactory conditions are found during the annual inspection, increase the frequency of inspection.

2.3 Training

2.3.1 Train operators on standard and emergency operating procedures. See Data Sheet 10-8, *Operators*, for guidance on developing operator programs. Provide training for operators on how to recognize a low-water condition and on the proper action to take when a low-water condition occurs. Actions include, but may not be limited to, initiating an MFT or equivalent to shut down all fuel/heat input and not adding water to an overheated boiler. Provide documented standard and emergency operating procedures and have them readily available in the boiler control room.

2.3.2 Provide both initial and annual refresher training.

2.3.3 Include testing or other means to verify the adequacy of the training program.

2.3.4 Provide written documentation of training.

3.0 SUPPORT FOR RECOMMENDATIONS

Low-water protection is essential on all boilers to avoid overheating and dry firing losses. Steam drums on larger boilers can be completely emptied in less than one minute if the feed water supply is lost. There is little time for an operator to respond to a low-water alarm, assess the condition, and take the proper corrective action during such an extreme upset.

Before a steam drum reaches an empty condition, steam is drawn into the downcomer circuitry either by having the downcomer drum penetrations become exposed above the water line (likely for downcomers in a boiler bank) or by drawing steam in through whirlpool action (likely for downcomers located on the bottom of the steam drum such as is commonly found on single drum boilers where the steam drum is located in a penthouse).

Once steam enters the downcomers on natural circulation boilers, the head supplied by saturated/subcooled water in the downcomers is reduced and the circulation slowed or eliminated. Without adequate circulation, furnace wall tubes, screen tubes and boiler bank tubes rapidly overheat. For boilers with mechanically pumped (forced) circulation, steam in the downcomers will cause cavitation in the circulating pumps with the consequential loss of pumping capacity and possible pump damage due to overheating. As with natural circulation boilers, a loss of circulating water flow will lead to rapid overheating of the furnace wall and screen tubes.

Continued fuel firing with an empty or near empty steam drum will cause the steam drum to overheat if it is exposed to combustion gases. On single drum boilers, however, it is unlikely that the steam drum would be damaged except in the most severe of dry firing incidents. Generally, the upper furnace wall tubes and the boiler bank or screen tubes exposed to direct furnace radiation will be the first to overheat during a low-water condition. Tube failure, however, is a function not only of the instantaneous operating temperature increase, but of many other operating conditions which include external and internal corrosion and erosion, age, and tube material. Once a water wall or steam generating tube rupture occurs as a result of a low-water condition, continued firing will cause rapid overheating of superheater circuitry and subsequent boiler destruction.

In addition to the damage that is clearly perceptible by dry firing the unit, there can be extensive but less visible damage done to other boiler components caused by the very abnormal expansion of the waterwalls. Very large stresses can be developed in the connecting points as this unpredicted expansion movement occurs. Some examples would be the lower waterwall headers and downcomer connections, the lower support hangers, welded attachments for buckstays, and expansion joints.

4.0 REFERENCES

4.1 FM

Data Sheet 6-2, *Pulverized Coal-Fired Boilers*
Data Sheet 6-7, *Fluidized Bed Combustors*
Data Sheet 6-14, *Heat Recovery Boilers*
Data Sheet 6-13, *Waste Fuel-Fired Facilities*
Data Sheet 6-21, *Chemical Recovery Boilers*
Data Sheet 6-22, *Firetube Boilers*
Data Sheet 6-23, *Watertube Boilers*
Data Sheet 7-45, *Safety Controls, Alarms, and Interlocks*
Data Sheet 9-0, *Asset Integrity*
Data Sheet 7-109, *Fuel Fired Thermal Electric Power Generation Facilities*
Data Sheet 10-8, *Operators*

4.2 Other

Molvie, Peter. (Cleaver Brooks). “Water column and level device blowdown: a word of caution,” *National Board Bulletin*, Fall 1999.

Waltz, R. J. *Drum Level Instrumentation for Reliable Boiler Operation*. ASME, 1981.

APPENDIX A GLOSSARY OF TERMS

Boiler: A closed vessel in which water is heated, steam is generated, and/or steam is superheated in any combination, under pressure or vacuum by the direct application of heat.

Boiler vs. steam generator: These terms can be used interchangeably.

DCS: Distributed control system.

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 list of products and services that are FM Approved.

Low water cutoff (LWCO): A boiler safety device designed to shut off the burner or fuel supply when the water level drops below a certain level. This prevents the boiler from operating in a low-water condition, which could result in overheating and dry firing of the boiler. Also referred to as a low water fuel cutoff (LWFCO).

MFT: Master fuel trip.

Power boiler: A boiler in which steam is generated at a pressure of more than 15 psi (100kPa).

Power generation boiler: A boiler used exclusively or primarily for producing steam in an electric power-generating facility.

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.*

January 2021. Interim revision. Minor editorial changes were made.

January 2019. Interim revision. Minor editorial changes were made.

April 2012. The following changes were made:

1. Changed the title of this data sheet from *Low-Water Protection* to *Low-Water Protection for Boilers* to better identify the scope of the document.

2. Relocated low-water protection guidance for chemical recovery boilers to DS 6-21, *Chemical Recovery Boilers*.

3. Added a recommendation for a light or indicator on deadman switches for LWCO testing to indicate bypass is engaged when button switch is activated, and to verify the switch has returned to its normal condition when the switch is released.

4. Revised low-water protection guidance for stoker-fired boilers to differentiate between quick (5 minute) fuel isolation and burn-out and boilers with longer remaining fuel burn-out times.

5. Added low-water protection guidance for fluidized bed boilers.

6. Added low-water protection guidance for hot water supply boilers.

7. Added low-water protection guidance for heat recovery steam generators (HRSGs) used in combined cycle service with gas turbines.

8. Added low-water protection guidance for bagasse boilers.

9. Revised guidance for slow drain tests to address special considerations for power generation (utility) steam generators, cautions regarding operator response during tests, and recognition of a documented low-water trip in lieu of a test.

10. Revised guidance for quick drain tests to recognize various arrangements and components where a daily quick drain test should not be performed.

11. Differentiated internal inspection guidance for float-type cutoffs vs. probe types.

12. Added recommendations for operator training with regard to recognizing and responding to a low-water condition.

13. Appendix C was updated to be consistent with the 2009 edition of ASME CSD-1, *Controls and Safety Devices for Automatically Fired Boilers.*

In addition, editorial changes have been made to recommendations to provide a consistent format.

January 2003. No technical changes were made to this data sheet.

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

APPENDIX C SUPPLEMENTAL INFORMATION

C.1 Types of Low-Water Protection Devices and How They Operate

C.1.1 Float Type

The first separate low-water cutout device was introduced in 1926. This model incorporated a float, bellows, and mercury tube operating principle. A current low-pressure model is shown in Figure 2.

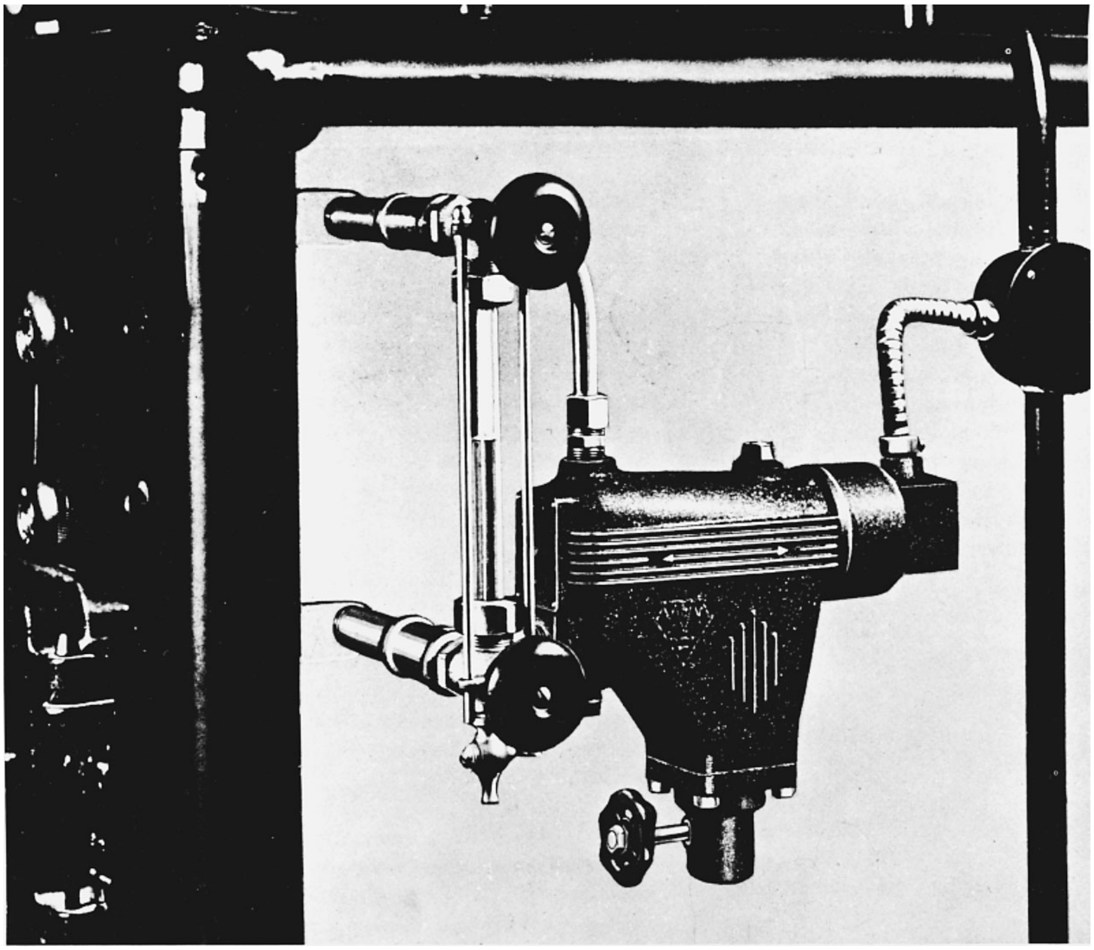

Fig. 2. Typical float type low-pressure low-water cutoff

In the high-pressure (greater than 15 psig [1.0 bar gage]) field, a combination feedwater pump control, low-water cutoff, and alarm switch has served as a very versatile control to operate a boiler feedwater pump and function as a low-water safety limit device (Fig. 3). Mounted so as to operate at the corresponding boiler water level, it starts and stops the pump as the boiler water level dictates.

Some of its design features include a two-piece fully enclosed electrical junction box, which keeps out dirt and dust, sealed switches to prevent tampering or accidental damage while permitting easy wiring, special Monel bellows, which eliminate packing, a float constructed of high tensile strength alloy for long service, and Mercury switches specially designed for high-temperature service.

One of the first companies to design safety controls for steam boilers manufactures the model shown in Figure 4. An important feature of the cutoff when originally designed was its use of the mercury switch. All such low-water cutoffs use a single-throw mercury switch to break the electrical circuit to the burner. The entire switch mechanism is simple and has a minimum of mechanical wearing parts. A control employing a slightly different concept of float actuated control uses a magnetic principle, which eliminates all bellows, packing glands and diaphragms. Only three elements are involved: the magnet, the magnet-attracting sleeve and the nonmagnetic enclosing tube (Fig. 5). The operating principle is as follows: The magnet and switch are assembled on a swinging relay arm that operates on socket-type precision stainless steel pivots. At normal operating level, the stainless steel magnetic piston (3), being within the magnetic field (2), holds the permanent magnet (1) snugly against the non-magnetic enclosing tube (5). In this position, the mercury-to-mercury switch (4) maintains a closed electric circuit between the middle and right hand legs of the switch (burner control) and an open circuit between the middle and left legs (alarm).

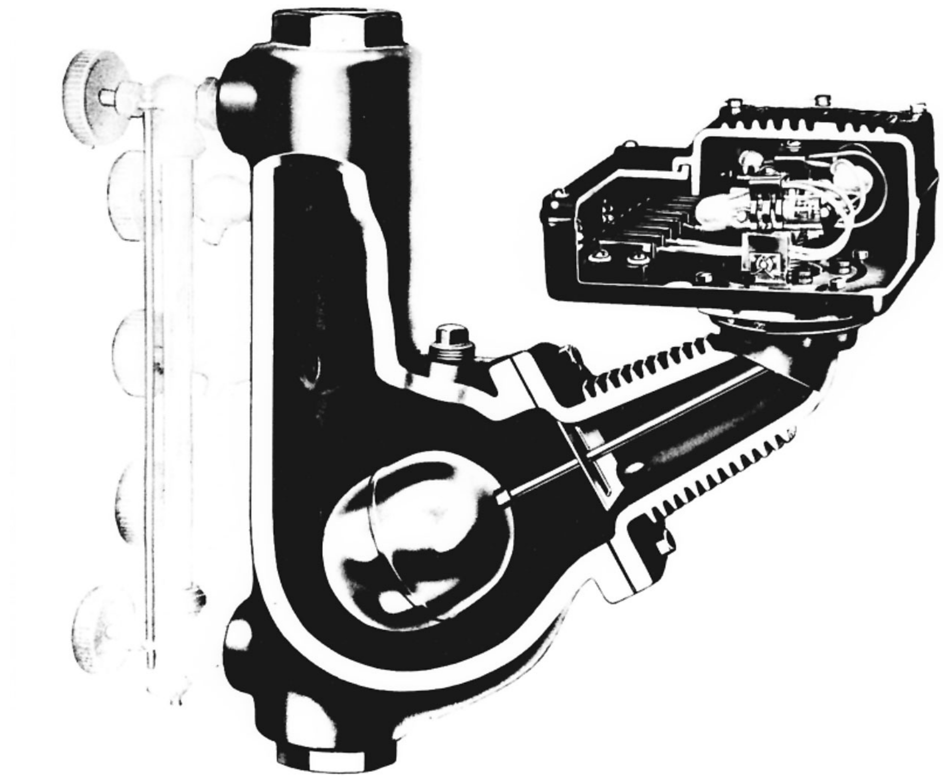

Fig. 3. Cross section of typical float-type high-pressure combination feedwater pump control, low-water cutoff, and alarm switch

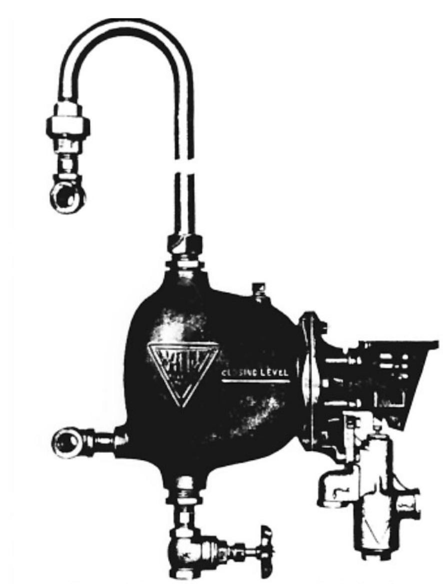

Fig. 4. Typical float type mercury switch feedwater pump control and low-water cutoff

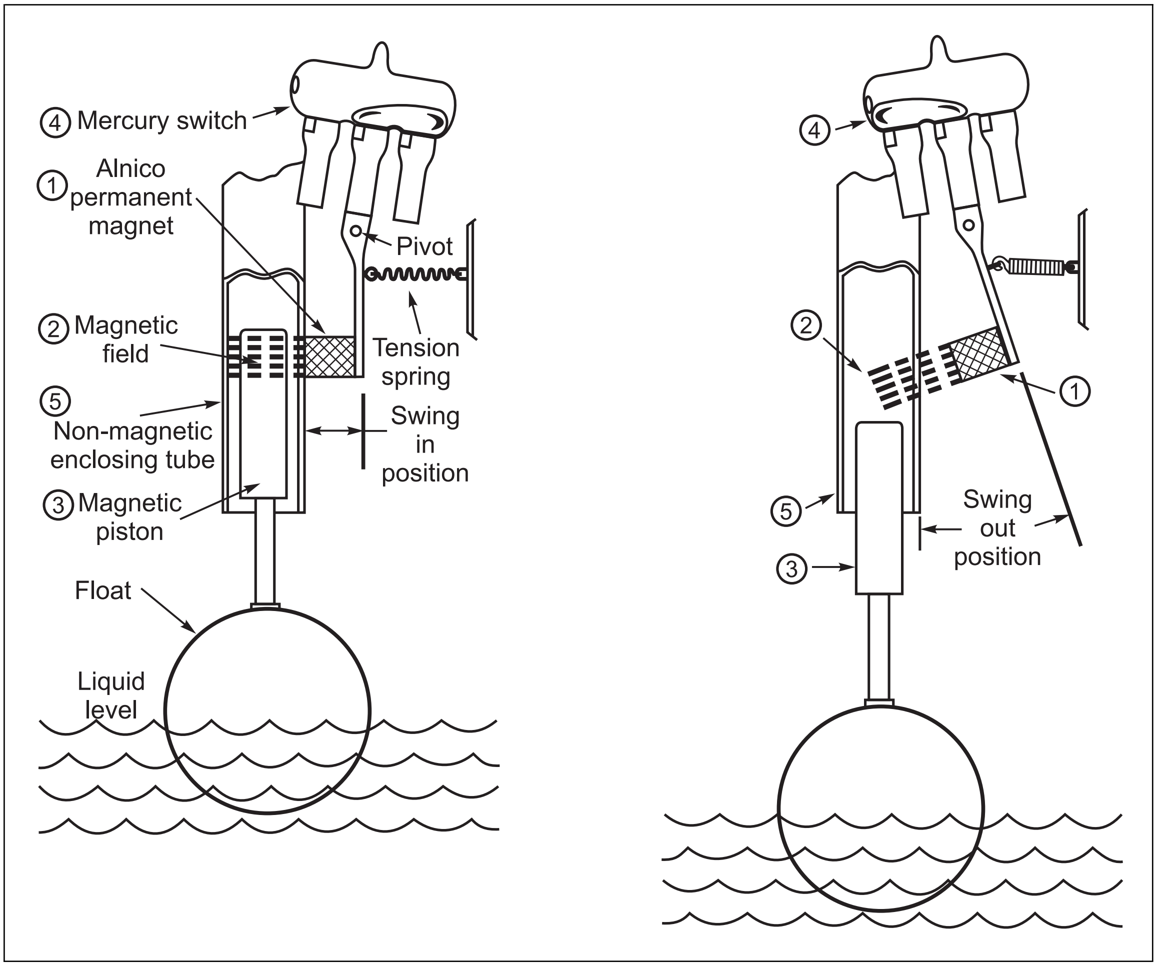

Fig. 5. Operating principle of magnetic control; at normal operating level (left) and at low level (right)

As liquid level recedes, the float is drawn down. When the predetermined low position is reached (right), the magnetic piston has been drawn down and below the influence of the field of magnetic force (2) releasing the magnet to swing outward and away from the enclosing tube. This positive movement, accomplished by gravity and assisted by the tension of an inconel spring, provides ‘‘snap-action’’ of the switch. Tilting the mercury switch in this opposite direction causes the switch to break the middle-to-right leg circuit and ‘‘make’’ the middle-to-left leg circuit.

As water is replaced in the boiler the float rises, pushing the magnetic piston (3) upward. As the piston enters the magnetic field, the magnet (1) is immediately pulled in and held against the nonmagnetic enclosing tube (5) causing mercury switch (4) to assume its original position, establishing the normal electrical circuit.

C.1.2 Probe Type

A typical electrode type of liquid level alarm and fuel cutout is illustrated in Figure 6. It operates alarms, actuates the fuel cutout, and starts and stops the boiler feedwater pump to maintain boiler water level within prescribed limits. Boiler water acts as an electrolyte for closing a circuit between electrodes. Terminals on the electrode fittings are wired into power circuits as required to energize and de-energize electrical load devices. This technique for drum level control and protection is typically known as conductance-actuated control. A transformer provides the current, which passes through the water when the ends of two or more electrodes are immersed.

Another type of conductance probe utilizes the vessel in which it is contained to complete the electrical circuit. These containers are typically referred to as ‘‘grounded.’’ This type of device may have one or more electrodes. AC power energizes each of the electrodes, and when the electrode tip is immersed in water a

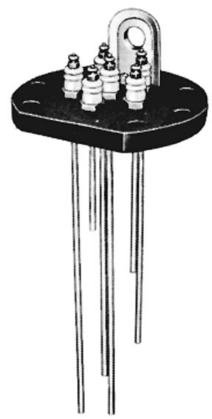

Fig. 6. Typical electrode type cutoff employing a water column cap with electrode fittings and rods

path is created for electrical current to flow between the electrode tip and the enclosure. Depending on the nature of the circuit, the current can either open or close a contact.

Figure 7 is an example of a two electrode low-water cutout. In this case both electrodes are the same length. When the electrode tips are immersed in water, the resulting current through the contacts of one of the electrodes causes the alarm relay to be open. For the other electrode, the current causes the burner control relay to be closed. When the water level drops below the electrodes, the loss of current causes the burner control relay to open, shutting down the burner, and the alarm relay to close, actuating the alarm. This arrangement is considered fail-safe because on loss of ac power to the device, the burner control relay will open and the alarm relay will close.

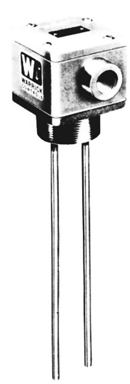

Fig. 7. Two electrode low-water cutoff and alarm

Electrode probes of this type can be different lengths to cause a pump to start and stop or to provide an alarm at one level and a fuel trip at a different level.

Probes can also be installed horizontally as indicated by Figure 8. A series of horizontal probes can be installed on a vertical water column to provide remote indication of water level as well as alarm and trip functions.

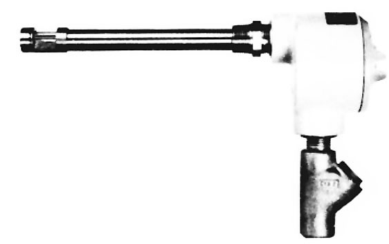

Fig. 8. Horizontally mounted liquid level interface probe (FCI Fluid Mechanics)

C.1.3 Hydraulic Remote Level Indicator with Low-Water Fuel Cutoffs

Hydraulically connected remote level indicators combine two major components: a sensing element, which responds to differential pressure, and an indicating system, which gives a remote visual reading of drum level. The sensing element is a constant head chamber that measures and compares the variable head of drum water to the constant head maintained in the sensing element. The indicating system, located outside the pressure zone, is activated through a permanent magnet coupling. Figure 9 is a schematic representation of this type of device and identifies some of the installation requirements which must be satisfied in order for the device to function properly.

Switches mounted on the remote liquid level indicator are activated by movement of the indicator pointer and can be used to provide alarm and trip functions for low and high water levels.

An advantage to this type of device in comparison to a float or single probe for low-water protection is that the ability of the device to accurately sense drum level is readily verified. A possible disadvantage at some locations is that the liquid in the connecting tubing may be subject to freezing during extremely cold weather. Should freezing occur, automatic low-water protection is lost.

C.1.4 Pneumatic or Electronic Remote Level Indicator with Low-Water Fuel Cutoffs

Pneumatic and electronic remote level indicators operate on the same principle as the hydraulic remote level indicator. The sensing element is a constant head chamber that measures and compares the variable head of drum water to the constant head maintained in the sensing element. Through the use of an appropriate transducer, the output of the sensing element is converted to either a pneumatic signal (typically 3-15 psig [20-103 kPa]) or an electronic signal (typically 4-20 ma or 12-24 volts). The transmitter signal is converted in the control room to a gage, chart, or digital readout for operator use. A low-water fuel cutoff can be integrated into a pneumatic system by using a pressure switch attached to the leg of a Tee connection in the line from the transmitter to the control room. At a preset low pressure, the switch is de-energized (fail safe design philosophy), and fuel input to the boiler is terminated. With an electronic system, a device such as a current transformer monitors signal current. At a current corresponding to a preset low-water level a relay connected to the current transformer de-energizes and fuel input to the boiler is terminated.

C.1.5 Self-Checking Electronic Level Indicator with Low-Water Fuel Cutoff

With an electronic level indicator, an example of which is shown in Figure 10, a number of horizontal probes are located in a water column. The probes sense the presence or absence of water and transmits that information to a locally mounted Electronic Processing Unit (EPU). The EPU processes the signals and provides level indication locally and at a remote indicator by illuminating red and green lights on level-indicating panels. The indicated level is also compared in the EPU to operator set alarm and fuel cutoff levels, and the appropriate action is initiated when these levels are reached.

FM Approved electronic low-water protection devices will have some or all of the following features, which offer advantages in terms of reliable low-water protection.

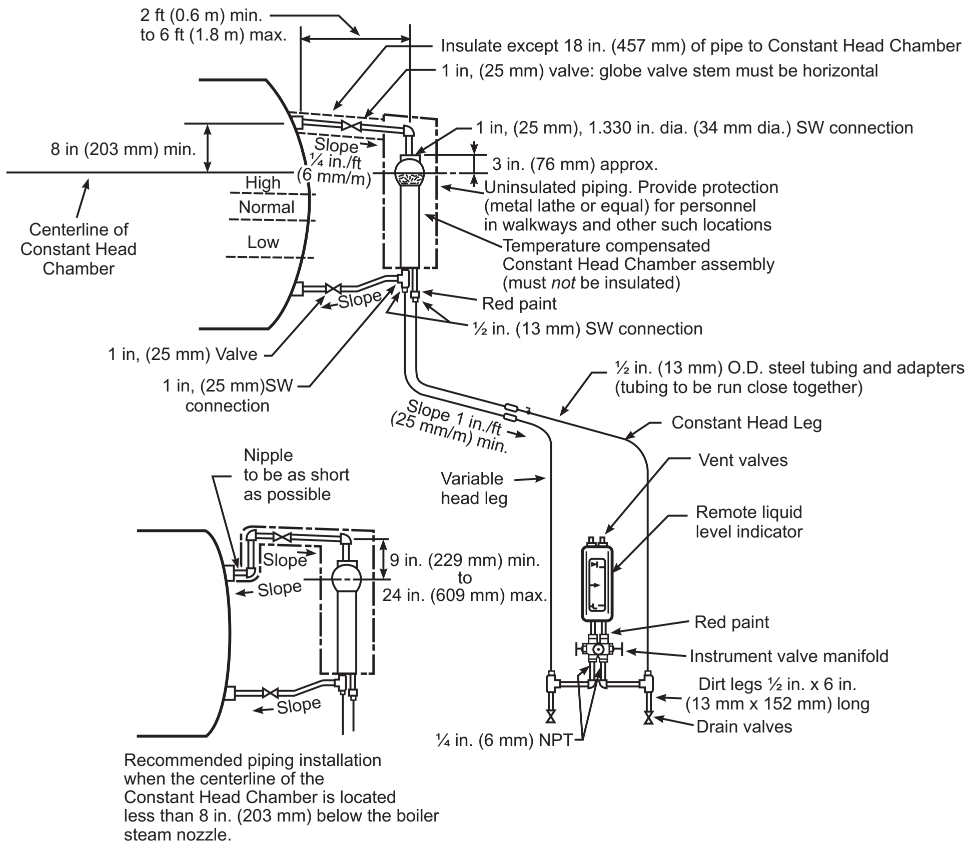

Fig. 9. Typical installation of a remote drum level indicator incorporating high- and low-water level alarms/trips (Yarway Corp.)

1. The electronic probes operate at a lower voltage than many conventional probes, and this appears to decrease the tendency for deposits to accumulate on them. Deposits can result in grounding of the probe, which causes it to ‘‘sense’’ water whether it is present or not.

2. The electronic processing unit validates incoming signals and will alarm if a probe sensing water is higher on the column than one sensing steam.

3. Redundant circuitry is provided in conjunction with two power supplies. If power to one circuit is lost or one circuit malfunctions, level indication is not lost and an alarm sounds. Level alarm and trip action is maintained.

This type of device represents a significant advance in the reliability of drum-level indication and low-water protection. As such, use of FM Approved devices of this type is encouraged.

One area of concern with these devices is that they are made to be adaptable to meet many requirements. For example, some units may be configured to have a high level trip in addition to a low-water fuel cutoff. Others may be installed with low and low-low level alarms and no cutoff. Still others may incorporate a time delay. On many units, these changes can be accommodated by making simple internal wiring changes. When screw terminals, spring clips, plugs, or other similar mechanical terminals are provided, changing the wiring to eliminate (or reconnect) a low-water fuel cutoff or other alarm/trip can be done quickly and easily. In these cases, configuration security is a serious concern. Wiring connections should be soldered, or as a minimum, a means should be provided for preventing unauthorized access to the wiring terminals.

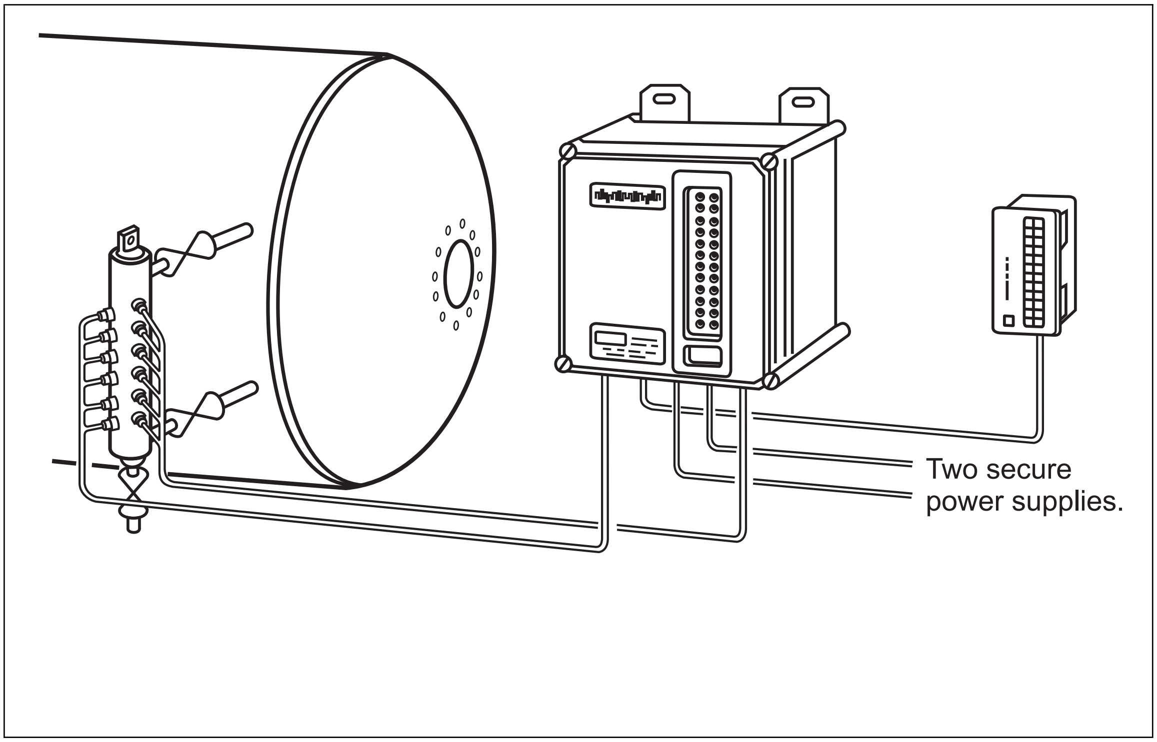

Fig. 10. Electronic water level transmitter incorporating low-water cutoff and self-checking diagnostics (Solartron Protective Systems)

C.2 Feedwater Flow/Drum Level Control

The type of feedwater flow/drum level control employed on a boiler is a function of numerous parameters, which include water-holding capacity of the drum or boiler, steam generation rate, frequency and rate of load change, etc. The following sections describe the three types of feedwater control normally encountered.

C.2.1 Single Element Control

Single element control is the simplest method of maintaining drum level. Its application is limited to boilers where drum level changes occur slowly. This includes industrial and power generation boilers when they are operating at low load such as during startup and shutdown and when on standby. It is the type of control generally used on firetube boilers.

Two variations of single element feedwater flow control are found. One uses two drum or boiler level switches. When water level falls to the level of the lower switch, the feed pump is started or the feedwater valve is opened. Water continues to enter the drum/boiler until the level reaches the upper switch, at which time the feed pump is stopped or the feedwater valve is closed. This type of on/off control is typically found on firetube boilers. The second type of single element feedwater control provides modulated feedwater flow. As drum level changes, feedwater flow is increased or decreased to restore drum level to its set (or zero) point. This type of modulated control is typically used on drum type boilers with a large drum-holding capacity and which are not subject to rapid or frequent load changes. It is also used on large industrial and power generation boilers during periods of low steam generation rates (generally not more than 25% of design load).

C.2.2 Two-Element Control

Two-element feedwater flow/drum level control finds application on industrial boilers which have a fairly large drum- holding capacity and are subject to frequent but relatively slow load changes. Usually these units will have a two- drum arrangement (steam drum and water drum), although other similar multi-drum configurations will also be encountered. Package-type shop-assembled watertube boilers are very common users of two-element drum level/feedwater flow control.

With two-element control, the feedwater is modulated as required to restore drum level to its zero point, but in addition, steam flow is monitored and feedwater flow is decreased or increased in direct response to changes in steam flow. The purpose of this ‘‘feed forward’’ input to feedwater flow control is to adjust water flow in response to changes in load prior to detecting an ‘‘error’’ in steam drum water level, thereby providing tighter control on drum level variations.

C.2.3 Three-Element Control

Three-element feedwater flow/drum level control is the most sophisticated control scheme commonly found on boilers. Its use is primarily on field-erected boilers with high steam generation capacities and short drum hold-up times. (See Section C.2.4.) It may also see application on smaller boilers subject to rapid, large fluctuations in steam demand.

The three-element control scheme measures steam flow and feedwater flow. These two are compared and, with an allowance for blowdown, the feedwater flow is adjusted to match steam flow. Drum level is also monitored and provides final adjustment of feedwater flow to restore drum level to its zero point (normal level).

The best location for steam flow measurement depends on boiler design and auxiliary steam requirements. For boilers where the steam drum has one or two saturated steam outlets, flow measurement should be made in the saturated steam pipe(s) using an orifice or flow nozzle. Power generation boilers generally have a large number of saturated steam lines carrying steam from the drum to the superheater circuitry. In this case, measurement of saturated steam flow is not practical, and measurement is usually done in the main steam outlet piping to the turbine. Depending on the amount of auxiliary steam usage (for example sootblowing) and spray water attemperation, these quantities may have to be added to or subtracted from the measured steam flow to provide a good measure of saturated steam leaving the drum. An example of a three-element control scheme is shown in Figure 11.

If steam temperature and/or pressure at the point of flow measurement varies appreciably over the operating range of the boiler, compensation is required so that an accurate steam flow measurement is used when comparison is made to feedwater flow. Boiler feedwater density is quite insensitive to variations in pressure. However, temperature changes can cause significant density variations. If boiler feedwater temperature at the point of flow measurement changes significantly over the boiler operating range, temperature compensation should be made to the measured flow. Significant temperature variations are often found on power generation boilers where the feedwater is preheated by various levels of turbine extraction steam in low-pressure and high-pressure feedwater heaters.

Three-element feedwater flow/drum level control will only function when steam and water flow is high enough to create a measurable pressure drop across an orifice or flow nozzle. Since pressure drop varies as the square of flow, turndown on these devices is generally limited to 3:1 for orifices and 4:1 for flow nozzles. Below these limits, drum level is controlled simply by drum level monitoring (single-element control).

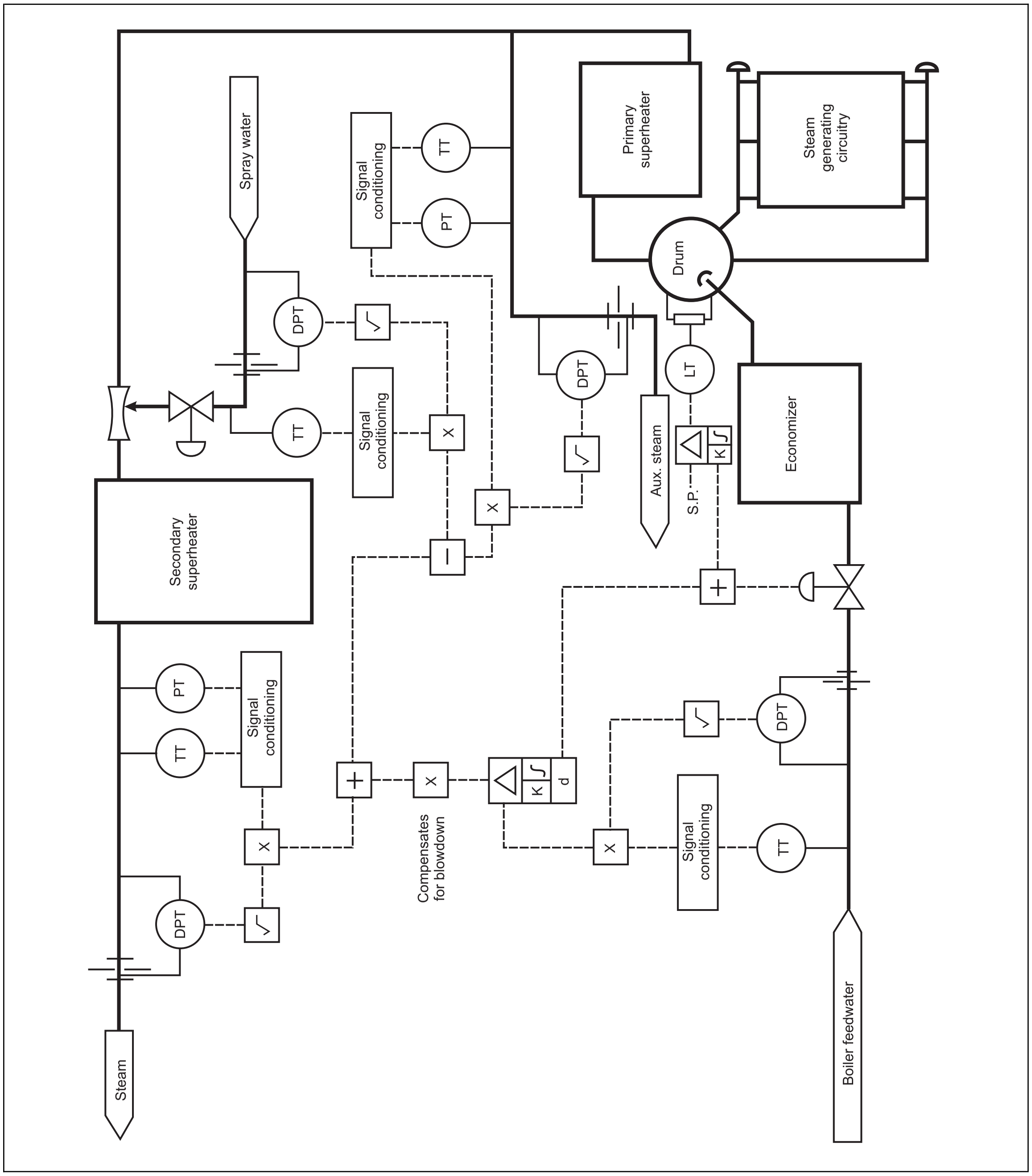

Fig. 11. Example of three-element feedwater control

NOTES: DPT—Differential pressure transmitter
TT—Temperature transmitter
PT—Pressure transmitter
K—Proportional control
∫—Integral control
d—Derivative control
S.P.—Setpoint
LT—Level transmitter

C.2.4 Drum Holding Capacity or Hold-Up Time

Drum (or boiler) hold-up time (holding capacity), as used in this appendix, is the time required at the maximum design steam generating rate for the water level to decrease from its normal level to an empty condition (an empty steam drum or empty firetube boiler) assuming feedwater flow is zero. Hold-up times vary widely depending on size and type of boiler. Some examples are given in Table 2. Of course, low-water fuel cutoffs would terminate fuel input well before either a firetube boiler or steam drum reached an empty condition. However, the relative times do give an indication of how quickly a low-water condition can develop and why low-water fuel cutoffs and more sophisticated feedwater/drum level controls are required on larger boilers.

Table 2. Typical Range of Boiler Water Hold-up Times for Various Boilers

COMPARISON OF WATER HOLD-UP TIMES			
Type of Boiler	*Rating*	*Steaming Rate*	*Hold-up Time*[1]
Firetube	200 hp (2 MW)	7,000 lb/hr (3,200 kg/hr)	1-¼ to 3 hours
Small Watertube	—	50,000 lb/hr (22,700 kg/hr)	6 to 8 minutes
Large Industrial	—	300,000 lb/hr (136,000 kg/hr)	2 to 3 minutes
Moderate Power Generation	200 MW	1,425,000 lb/hr (646,000 kg/hr)	30 to 60 seconds
Large Power Generation	550 MW	3,800,000 lb/hr (1,720,000 kg/hr)	25 to 40 seconds

[1]Hold-up Time:

Firetube boiler: Time for water level to drop from its normal operating level to an empty condition.

Watertube boiler: Time for water level to drop from its normal operating level to the bottom of the steam drum. It is assumed that normal operating level is at the drum centerline. Actual normal level could be within ± 4 in. (100 mm) of the drum center line depending on boiler manufacturer and drum internals.

For all the above boilers it is assumed that steam is being generated at the stated steaming rate and feedwater flow is zero.

Note: Hold-up time should not be confused with time delays. They are *not* the same. See Recommendation No. 2.1.16.4 and Section C.2.4 in this data sheet.

C.3 Low-Water Protection Recommendations for Boilers Not Exceeding Total Fuel/Heat Inputs of 12.5 Million BTU/hr (3660 kW) [10,000 lb/hr steam (4,500 kg/hr)]

The following recommendations for low-water cutoff devices apply to small, automatically fired boilers in the size range covered in ASME/ANSI Standard CSD-1-2009 (*Controls and Safety devices for Automatically Fired Boilers*) and are in general agreement with that standard.

C.3.1 Application

The following application recommendations are summarized in Table 3.

1. Provide each automatically fired low-pressure steam or vapor system boiler with at least two automatic low-water cutoffs, one of which may be a combined feeder/cutoff device. (See Item 2 following for exception.) Each device should be attached to the boiler by a separate pipe connection.

   a) An automatically fired boiler is defined as a boiler which cycles automatically in response to a control system.

   b) A low pressure steam or vapor boiler has a pressure not exceeding 15 psig (103.4 kPa gage).

2. Provide each automatically fired high pressure steam boiler, except miniature boilers, with at least two automatic low-water fuel cutoff devices.

   a) A high-pressure steam boiler is defined as a boiler in which steam is generated at a pressure exceeding 15 psig (103.4 kPa gage).

   b) A miniature boiler is defined as a boiler that does not exceed any of the following limits:

      - 16 in. (406.4 mm) inside shell diameter
      - 20 ft^2 (1.86 m^2) of heating surface
      - 5 ft^3 (0.142 m^3) of gross volume, exclusive of casing and insulation

(Gross volume is the volume of a rectangular or cylindrical enclosure into which all the pressure parts of the boiler in their final assembled positions could be fitted. Projecting nozzles or fittings need not be considered.)

- 100 psig (689.5 kPa gage) maximum allowable working pressure.

3. Provide each miniature boiler with at least one low-water fuel cutoff device.

4. Provide each automatically fired hot water heating and supply boiler with at least one low-water cutoff intended for hot water service.

a) A hot water heating boiler is defined as a boiler in which no steam is generated, and from which hot water is circulated for heating purposes and then returned to the boiler.

b) A hot-water supply boiler is defined as a boiler that furnishes hot water to be used externally to itself at a pressure less than or equal to 160 psig (1 100 kPa gage) or a temperature less than or equal to 250°F (120°C) at or near the boiler outlet.

5. Provide each automatically fired forced circulation boiler with no definitive water line with an accepted safety control to prevent burner operation at a water flow rate inadequate to protect the boiler unit against overheating.

a) An accepted device is defined as a device which is listed, labeled, or otherwise determined to be suitable and safe by a nationally recognized testing agency. Field installations are accepted when Approved by the authority having jurisdiction.

b) A forced circulation boiler could be a low-pressure steam or vapor boiler, a high-pressure steam or vapor boiler, a hot water heating boiler or supply boiler, or a miniature boiler. Forced circulation boilers may be of the watertube or coil type construction.

6. Provide each automatically fired forced circulation boiler with a definitive water line with a low-water cutoff in addition to the flow sensing fuel cutoff device.

7. Provide electrically heated boilers where uncovering of the electrical element can lead to an unsafe condition with low-water cutoff(s) as required by other sections in this appendix based on the type and service of the boiler. The boiler feedwater control may be in a common control with one low-water cutoff.

a) For electrode type boilers, where the reduction in water level provides a self-limiting control on input, low-water cutoffs are not required.

C.3.2 Installation

C.3.2.1 General Installation Recommendations for Low-Water Fuel Cutoffs on Automatically Fired Boilers

1. Use devices accepted by a nationally recognized testing agency for each low-water fuel cutoff or combined feeder/cutoff device when available for the intended service.

2. Install low-water fuel cutoff(s) that have a pressure rating at least equal to the maximum allowable working pressure of the boiler.

3. Install probe type low-water cutoffs so that an open circuit, failure, break or disconnection of the electrical components or conductors in the safety circuit prevents continued operation of the firing mechanism.

4. Provide alarms that are distinctly audible above the ambient noise level.Indicating lights may be used in conjunction with audible alarms. In addition to locally mounted alarms also locate alarms in a constantly attended location to alert an operator or other trained individual when a potentially dangerous situation is developing.

5. For steam boilers, arrange the water inlet to the boiler such that the feedwater does not flow through the float chamber or its connection to the boiler.

6. The low-water fuel cutoff(s) may be internally or externally mounted.

7. For external mounting:

a) Install each device in its own chamber (water column) attached to the boiler by separate pipe connections below the waterline. A common steam connection is permissible.

b) Piping connections for the low-water fuel cutoffs may be: independent of all other connections to the boiler; combined with a water column or gage glass; or the low-water fuel cutoff may be contained in a water column. When connected with piping for a gage glass, locate the gage glass closest to the boiler and be connected through the run of the tee fitting.

c) There should be no shutoff valves in the connecting piping.

d) A cross, or equivalent fitting, should be placed in the water piping connection at each right angle to facilitate cleaning and inspection.

e) When a low-water fuel cutoff is installed in a column or separate chamber, provide blowdown piping with a valve connected to the lowest point of the chamber or water connecting piping to permit testing of the low-water fuel cutoff and flushing of the chamber or column and piping.

8. For steam boilers, a time delay may be used to prevent short cycling. When used, provide a time delay that does not exceed the boiler manufacturer's recommended time or 90 seconds, whichever is less. Ensure water is visible in the gage glass when the low-water fuel cutoff terminates the fuel supply.

C.3.2.2 Additional Installation Recommendations when at least Two Low-Water Fuel Cutoffs are Provided on a Steam Boiler

1. Install each cutoff device to prevent startup and to stop the boiler fuel supply automatically when the water falls to a level not lower than the lowest visible part of the gage glass.

2. Connect the electrical circuit so that either low-water fuel cutoff will shut off the fuel supply to the boiler when a low-water condition develops.

3. Set one low-water fuel cutoff to function ahead of the other.

4. Wire the lower of the two low-water fuel cutoff's to cause a safety shutdown requiring manual reset (safety shutdown with lockout) when it detects a low-water condition not detected by the higher cutoff.

C.3.2.3 Additional Installation Recommendations when One Low-Water Fuel Cutoff is Provided

1. Connect the cutoff device to the safety system so as to prevent startup during low-water conditions and to stop the boiler fuel supply automatically when water is still visible in the gage glass.

2. Ensure a safety shutdown requiring manual reset (safety shutdown with lockout) occurs when the low-water cutoff functions.

C.3.2.4 Installation Recommendations for Low-Water Cutoffs on Automatically Fired Hot Water Heating Boilers

1. The low-water fuel cutoff may be located any place above the lowest safe permissible water level established by the boiler manufacturer.

2. When the low-water fuel cutoff is installed in system piping;

a) Arrange the chamber containing the low-water fuel cutoff to drain properly during a low-water condition.

b) Ensure water flow is in the upward direction when a float chamber is used.

3. Electrically connect the low-water fuel cutoff to cause a safety shutdown requiring manual reset when a low-water condition is detected.

4. Provide a means for testing the operation of the low-water fuel cutoff without resorting to draining the entire system.

C.3.3 Testing

1. For high pressure boilers, test the low-water fuel cutoffs and alarms daily using a quick drain test. Additionally, FM recommends a slow drain test be conducted at least every six months.

2. For low-pressure boilers, test the low-water fuel cutoff(s) weekly using a quick drain test. Additionally, FM recommends a slow drain test be conducted at least every six months.

3. No testing frequency is provided for hot water heating and supply boilers in CSD-1. FM recommends testing quarterly following manufacturer's instructions.

C.3.4 Inspection, Testing and Maintenance

Complete inspection, testing and maintenance in accordance with Section 2.2.2 in the main body of this data sheet.

Table 3. Low-Water Protection Application Recommendations for Automatically Fired Boilers With Total Heat Inputs Not Exceeding 12.5 Million BTU/hr

Type of Boilers	*Min. No. LWCOs*
Low-Pressure Steam Boilers	2
Not exceeding 400,000 Btu/hr (422,000 kj) heat input with gravity return	1
Other low pressure steam boilers	2
High-Pressure Steam Boilers	2
Miniature Boilers	1
Hot Water Heating and Supply Boilers	1
Forced Circulation Boilers	
With no definitive water line	1 (flow)
With definitive water line	1 (flow) & 1 (level)
Electrically Heated Boilers	
Not self-limited on heat input	1
Self-limited on heat input	NONE