Property Risk Consulting Guidelines

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LOW WATER PROTECTION FOR BOILERS

INTRODUCTION

Operating without enough water, or dry firing, is the greatest single cause of accidental boiler damage. The outside of a dry-fired boiler may heat up enough to ignite its surroundings. If water enters a severely overheated boiler, the water will flash to steam. The weakened metal parts may rupture because of the sudden pressure increase, resulting in a steam explosion. Any dry-fired boiler will be out of service until possibly expensive repairs are completed. Many dry-fired boilers cannot be repaired.

This section recommends boiler low water protection equipment. Although the recommendations in this section satisfy most jurisdictional requirements, consult the local codes and ensure that the completed installation complies with them. The jurisdictional rules are primary in all cases.

There is no technological reason for the large number of low water incidents. Many properly-equipped boilers suffer these incidents because the boilers and their safety devices are not properly maintained. Therefore, this section also explains how management loss prevention programs should address low water protection equipment and what test frequencies are needed.

POSITION

Ensure that boiler parts or equipment installers are properly certified by the jurisdiction, if necessary, and that the installers are familiar with the jurisdictional requirements for certified devices, parts and installation procedures.

Ensure personnel who operate and maintain boilers are trained about the dangers of low water in an operating boiler and about the serious losses a low water accident can cause. Ensure that equipment, operating procedures, training programs and management systems adequately address the risk presented.

Provide all boilers, water or liquid and steam or vapor, with two low water fuel supply cutout devices (LWFCOs). The exceptions where a single LWFCO are acceptable are for hot water heating boilers and on gravity return units installed in residences. Arrange the LWFCOs to automatically shut off all boiler fuel or heat input sources if the boiler water level drops to the minimum level required for safe operation. For liquid, gaseous or pulverized fuel boilers, shutting off the fuel is normally sufficient. For solid fuel-fired boilers, particularly those with grates or stokers, stopping fuel input will not stop heat input; therefore, arrange the LWFCO to automatically close the under-fire air or primary air dampers or otherwise minimize the burning rate. For heat recovery boilers arrange the LWFCOs to automatically operate bypass or venting dampers.

Provide automatic LWFCOs for all boilers, even those with full-time operators. Human error causes many low water incidents. Also, problems can occur while boiler operators are involved with other tasks. Water level can drop quickly in a boiler. For example, if the feedwater flow stops while a large water tube boiler is under full steam load, the steam drum can empty in less than one minute.

Provide two independently-piped LWFCOs for each steam boiler. The cutouts must be electrically connected in series, so that either cutout will shut down the boiler. The second cutout is not required for small heating boilers in tight, closed systems having a heat input capacity of 400,000 Btu/h (115 kW) or less. A closed system returns all system fluid, whether water or condensate, to the boiler during all operating conditions. A tight system has no visible steam or condensate leaks.

Provide the LWFCO with the lowest level setting for each boiler with a manual reset. This LWFCO should have no purpose other than low water shutdown and, if desired, remote low water shutdown alarm. The manual reset should not engage if electric power is lost, unless a low water condition occurs before or during the power outage. A different LWFCO on each boiler should provide a low level alarm, which, for unattended boilers, should alert personnel in a normally manned area.

Install LWFCOs using straight-through piping, not less than 1 in. (25 mm) pipe size, with cross fittings so the piping can be cleaned and inspected. Do not locate isolation valves between the boiler and the LWFCO. Do not install any piping that allows feedwater to flow through the cutout device.

When installing two LWFCOs on the same boiler, provide separate connecting pipes for each cutout and locate one cutout on each side of the boiler. This is done to prevent a single clogged connecting pipe from affecting both cutouts. Figure 1 shows one way of piping two LWFCOs.

As an alternative, one cutout may be an internally-mounted type; however, internally mounted cutouts generally cannot be flushed or fast-drain tested.

Install LWFCOs on hot water boilers, such that rapid drain tests will not drain large amounts of water from the system.

The only boilers which do not require LWFCOs are:

- Forced flow steam generators having no fixed water level;
- Waste heat or waste gas boilers designed to tolerate dry-firing.

Waste heat or waste gas boilers that cannot safely be shutdown quickly should either be designed to tolerate dry firing, or should have provisions to automatically divert the process stream to a stack or flare in case of low water.

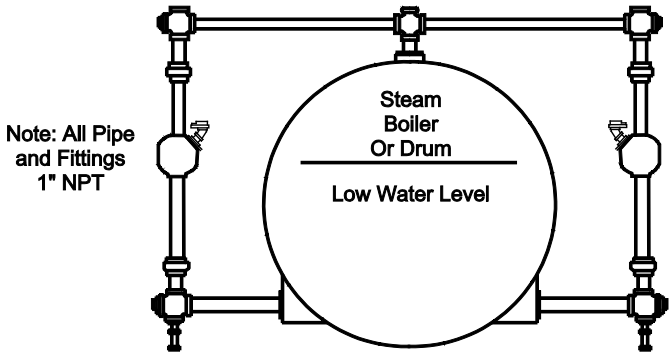

Figure 1. Typical Piping For Two LWFCO Units.

TABLE 1
LWFCO Testing Frequencies

	Rapid Drain Test	Slow Drain Test
Steam Heating (1)	Weekly (2)	Quarterly
Steam Power or Process (3)	Daily or at shift change (4)	Quarterly
Hot Water (5)	Monthly	When drained (6)

Notes to Table 1:

1. Boilers 15 psi or less serving closed systems; vapor-phase heat transfer fluid boilers.
2. For tight systems only. If there is visible steam or condensate leakage, test daily.
3. Any boiler over 15 psi or any boiler serving any process that does not return 100% of condensate to the boiler.
4. Daily for boilers that “idle” or serve only heating loads at night; every shift otherwise. A “deadman” bypass switch may be used, if necessary, to avoid actually shutting down the boiler.
5. Includes all heating and high temperature hot water boilers and all liquid heat transfer fluid boilers.
6. Perform the slow drain test while draining the boiler for internal inspection. Check the cutout with a rapid drain test first.

Provide devices for forced circulation boilers and forced flow steam generators, including coil-type boilers, which will shut down heat input if steam flow is lost. A pump interlock may provide supplemental loss-of-flow protection; however, provide at least one device that senses flow directly. Arrange forced flow steam generators and coil-type boilers to shut down when the temperature gets too hot at the outlet.

Ensure that digital electronic controls for low water and low flow protection are the triple-redundant, voting-logic type with a back up power supply from an independent source. Arrange all boiler safety controls to fail in the shutdown condition when electric power or control air is lost.

Provide LWFCOs even when the normal water level control system has emergency features. Keep LWFCOs and the normal level control system separate.

LWFCO Maintenance and Testing

Scale and sediment are factors in many low water losses. Scale and sediment can accumulate in LWFCOs and prevent them from functioning when the water level drops to an unsafe level. Therefore, boiler water chemistry control, which helps control scale and sediment, is a crucial element in boiler low water protection. Consider boiler low water protection an integral part of a boiler maintenance management program that includes water chemistry control and steam and condensate system integrity monitoring. Log all LWFCO test and maintenance activities. Monitor these activities through the management loss prevention inspection program.

Dismantle all LWFCOs and connecting piping on steam boilers for inspection and cleaning at least annually and whenever the boiler is opened for inspection or cleaning. For hot water boilers and steam heating boilers in tight closed systems, if the jurisdiction permits, inspect the devices every other year. If dismantling reveals significant amounts of scale and sediment, clean the devices more often.

Table 1 lists LWFCO recommended testing frequencies. If significant solids are drained during any test, immediately repeat the test until clear water drains, and the device being tested works properly. Immediately investigate the source of the solids, and double the test frequency until the source of the solids is found and corrected. If any LWFCO fails any test, or performs sluggishly, shut down the boiler immediately and correct the condition. If the boiler cannot be shutdown immediately, and it has another, properly functioning LWFCO, continuously-monitored operation can continue for up to 24 hr so an orderly shutdown can be planned. If there is no properly functioning LWFCO, do not operate the boiler.

Perform all tests when the boiler is in service; observe that the boiler actually shuts down when the LWFCO is drained. Record all tests and maintenance activities in the boiler log. After performing any test, remain with the boiler long enough to restore it to normal conditions, particularly normal water level.

Thoroughly and immediately investigate the circumstances of any low water level which occurs to determine why the low water condition occurred. A boiler in a closed system will neither require makeup feedwater nor shutdown on low water unless the system is leaking or otherwise losing water. A thorough investigation may reveal:

- Vents, pump packings or return lines leaking;
- Condensate tanks overflowing;
- Condensate tank vents allowing steam to escape because of leaking steam traps;
- Water-logged hot water system expansion tanks;
- Improper valve lineup.

Do not allow continued boiler operation if normal water level cannot be re-established.

DISCUSSION

Boiler low water level is a frequently-occurring hazardous condition. The usual consequence of a low water incident is immediate loss of boiler service for at least one day, probably three to five days, and possibly more than 30 days. At least one day is normally required to drain, inspect, refill and hydrostatically test a boiler that has no more than surface damage. At least three to five days are generally needed to partially or fully retube a smaller boiler. Thirty days or more may be needed to repair or replace a large boiler.

An unscheduled boiler outage can cause:

- Production loss;
- Fire protection, condensate, service water, domestic water, cooling water and other piping system or component freezing and rupture;
- Product stream solidification or freezing.

Many varieties of LWFCOs are available. Some are installed directly in the boiler, although most are connected to the boiler by external piping in the same way as a water column.

Most LWFCO devices on heating boilers have mechanically operated valves or contacts connected to electric pumps or valves to provide normal or emergency feedwater. Although such combinations are satisfactory, the lowest set device on each boiler should have no function other than shutting down the boiler and, if desired, providing remote notification that this has occurred.

Eliminating any of the common causes of boiler water loss will enhance boiler efficiency in addition to helping prevent boiler damage. Less heat loss to the atmosphere, lower scale and sediment accumulation rates, better fuel economy, simpler water chemistry and easier cleaning all improve boiler operation. Preventing scale and sediment and improving boiler water quality along with proper maintenance and testing reduces the probability of LWFCO failure.

Keeping steam boiler water at the proper level requires coordinating the steam production rate with the feed and/or makeup water addition rate. In a heating system, this requires sizing the condensate tank so the volume of water in the tank is less than the volume difference between the lowest and highest safe water levels. Unless a properly-sized tank leaks, the water level in the boiler will not drop below the operating range between condensate pumping cycles.

Hot water boilers are always filled with water during operation. The level “floats” in a system expansion tank. If the expansion tank is the correct size and the air cushion in the tank is the correct size, the water level in the tank rises when the system heats and falls when the system cools, and no makeup water enters the system. If, because of leakage, too much water gets into the expansion tank, the tank effectively becomes too small, or “water-logged.” If this happens, heating the water in the system overpressurizes the system, opening the relief valve and voiding water. Cooling the water in the system drops the system pressure and allows makeup water to enter the system.

An emergency feeder is normally installed on a heating boiler. This device usually feeds domestic water directly to the boiler if a low water condition develops. In a closed heating system, this feeder should never operate. If heating system leakage, an improperly-sized steam system condensate tank or a water logged hot water system cause it to operate, the feeder puts raw water into the system. Regular raw water addition adversely affects water chemistry and promotes corrosion and scale.

Most LWFCOs are of the probe or float type. Either can provide good service; however, both will fail if they are improperly installed or maintained.

A float-type cutout has a chamber containing a float. If the water level drops, the float drops. The float is connected by a linkage to switches and possibly a mechanical feedwater valve. If the float chamber accumulates enough scale and sediment to prevent the float from dropping, or if corrosion of the pivot point causes the device to bind, this type of cutout fails. Figure 2 is a float-type LWFCO with a manual reset. Figure 3 is a combination float-type LWFCO and water feeder. Either of these units could be connected to a boiler with external piping. Float-type cutouts designed to be installed directly in the boiler shell are available.

A probe-type cutout takes advantage of boiler water electrical conductivity. A drop in water level will open a circuit between probes or between a probe and ground. If scale or sediment covers the insulation between the probes, or the probe(s) and ground, or bridges over the gaps, this type of cutout cannot indicate low water. Figure 4 is a probe-type LWFCO. This kind of unit can be installed in a separate chamber piped to the boiler or directly in the boiler shell.

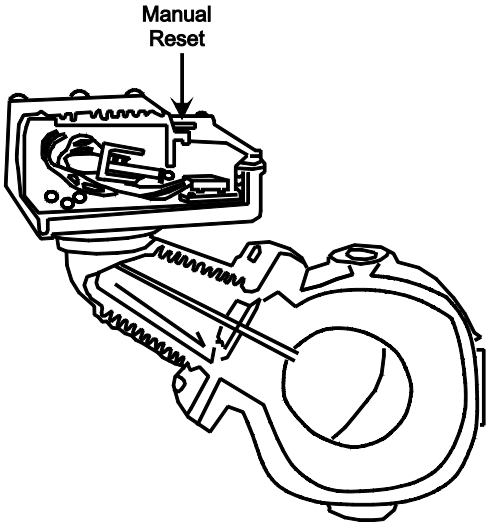

Figure 2. Float Type LWFCO With Manual Reset.

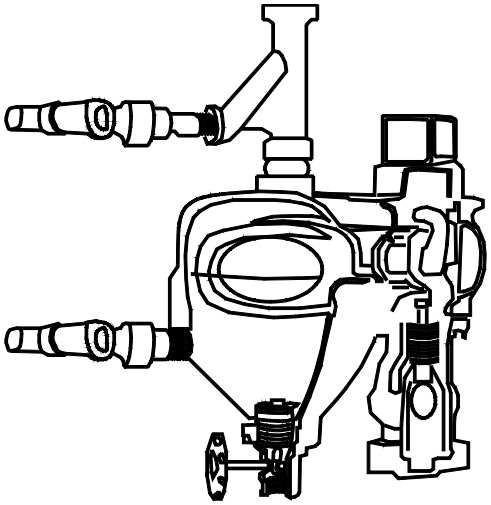

Figure 3. Combination LWFCO And Boiler Water Feeder.

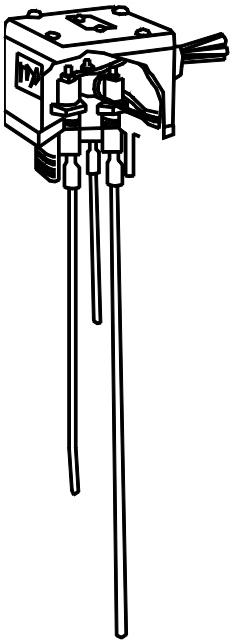

Figure 4. Probe-Type LWFCO.

Any type of cutout located in a separate chamber will fail to protect the boiler if scale or sediment plugs the connecting piping and traps water in the chamber.

Switch, relay or wiring faults will keep any LWFCO device from protecting the boiler. Corroded mercury in devices with mercury switches is another problem that can occur.

Insulation failure can prevent boiler controls from working. Ground-circuit devices, e.g., devices that use the boiler as a current return path, are undesirable, because a single insulation failure in the wired portion of the circuit will prevent the devices from protecting the boiler.

Boiler water level can drop for many reasons, and LWFCOs can fail to protect the boiler for many reasons. Therefore, these devices need proper maintenance and testing, which includes opening and cleaning and performing rapid and slow drain tests. Boilers which need frequent cleaning because of scale or sediment problems will also require more frequent LWFCO maintenance.

Rapid and Slow Drain Tests

To be meaningful, any LWFCO test requires the burner to be operating at the time of the test.

LWFCO rapid drain tests are done frequently to verify basic control function and to remove as much loose debris from the control chamber as possible. Rapid drain tests can only be applied to externally-piped units.

A rapid drain test is performed by fully opening the drain valve on the probe or float chamber to flush the chamber and simulate a low water condition. The burner must shut down. All other functions, such as emergency feed valve opening, pump operation, and remote alarms should be verified. Each installed LWFCO should be tested separately.

Slow drain tests are necessary to detect more subtle malfunctions, such as binding, which may not be detected by a rapid drain test.

A slow drain test is performed by manually reducing or shutting off the feedwater to the boiler and allowing the boiler to steam down. The test actually creates a low water condition. Lightly loaded steam boilers may need slow blowdowns to complete the test in a reasonable time period. The boiler must be continuously manned during the test and the water level must never be permitted to drop below the gauge glass range. All control operation should be verified during the test. If the LWFCOs

do not shut the boiler down before the boiler water level drops below the sight glass, the boiler should be manually shutdown and the cause of the LWFCO malfunction immediately found and corrected.

When drain tests require significant blowdown, the water chemistry may also need adjustment. If a higher-set device needs to be bypassed to test a lower-set device, the bypass must be removed after the test. No boiler should be left unattended if any level control or protective devices are out of service.