BASIS SAFETY CONTROLS FOR HOT WATER AND LOW-PRESSURE STEAM BOILERS
By: Tom Vana, Factory Representative, McDonnell & Miller, Inc.

HOT WATER SPACE HEATING BOILERS

SAFETY RELIEF VALVES

Good engineering tells us that every hot water boiler must have a safety relief valve that will keep the pressure at or below the maximum allowable working pressure of the boiler. But until recently the methods of accomplishing this objective were not clearly understood. Figure 70F51A shows one method of attempting to provide protection against over-pressure which is unsafe for these reasons:

1. The relief valve does not comply with the ASME Boiler code requirements.
2. Its capacity is unknown.
3. It is installed in the wrong location.
4. It can inadvertently be isolated from the boiler due to lime or scale build-up in boiler feed line.
5. The function of a relief valve has nothing in common with a pressure reducing type fill valve. A combination of the two units is based on price consideration—not performance.

The first basic step in providing correct safety control for a hot water boiler is to make sure that an ASME relief valve is installed. The ASME Code states: “Every hot water heating boiler shall have at least one officially rated pressure relief valve set to relieve at or below the maximum allowable working pressure of the boiler… Relief valve shall be connected to the
top of boilers with the spindle vertical if possible.... No shutoff of any description shall be placed between the relief valve and the boiler, nor on the discharge pipe between such valve and the atmosphere.”

Figure 70F51B shows the correct and safe installation of the relief valve.

**CONDITIONS REQUIRING SERVICE**

1. Waterlogged or undersized expansion tank—It may be necessary to drain the expansion tank so that a new air cushion may be created in order to allow for thermal expansion. Should this not remedy the situation, it may be necessary to determine if the expansion tank is of the proper size for the system.

2. Pressure setting of relief valve too low—Check the boiler manufacturer’s instruction manual or boiler nameplate to determine maximum boiler pressure. Actual operating pressure of the boiler should be several pounds below the relief valve setting.

3. Improperly sized relief valve—Btu capacity of relief valve may be less than the gross boiler output, therefore unable to provide full relieving capacity.

4. Excessive pump or head pressure.

5. Excessive overfiring of fuel burner.


7. Valve not installed on top of boiler.

8. Valve installed backwards.

9. Relief Valve discharge pipe capped or plugged.

**PERFORMANCE AND FUNCTION OF ASME RELIEF VALVES**

To understand how a relief valve should perform, it will be helpful to analyze just what a relief valve on a hot water boiler is supposed to do. Basically of course, its job is to keep the boiler pressure within the designed working pressure of the boiler—usually 30 pounds. But to accomplish this properly the relief valve must be capable of performing satisfactorily under two quite dissimilar conditions:

1. Relieving pressure by discharge of water (Thermal Expansion).

2. Relieving pressure by discharge of steam (Emergency Condition).
Relieving pressure by discharge of water is made necessary by the thermal expansion of water in the boiler, and is considered a normal operating condition. But the relief of pressure by the discharge of steam is the result of abnormal operation and is usually referred to as an “emergency condition.”

The more critical demand placed on a safety relief valve is during the emergency stage, when it must discharge both high temperature water and steam. Whenever the temperature in the boiler is about 212°F, and the relief valve discharges, the sudden pressure drop causes the higher temperature water to flash to steam. Thus the discharge capacity of an ASME relief valve is tested and rated on steam.

Basically the emergency stage is caused by an over-firing of the burner. The heating system cannot dissipate the heat energy as fast as it is developed in the boiler, and temperatures and pressures continue to rise. Over-firing may be caused in numerous ways, such as:

1. Failure of a limit control to stop the burner.
2. Mechanical failure of a fuel valve.
4. Residual heat with coal firing.
5. Burner considerably over-size for boiler and system.

The vast difference between discharging water and discharging steam from a relief valve is illustrated in Figure 70F52. One pound of water occupies a space of only approximately 27.7 cubic inches, whereas a pound of steam at atmospheric pressure occupies more than 1600 times as much space—approximately 26.8 cubic feet. Therefore it is necessary that the relief valve have a very large capacity and yet close drip tight.

ADDITIONAL RECOGNIZE NEED FOR ADDITIONAL BASIC SAFETY CONTROLS

Many consulting engineers and utility companies have been consistently recommending certain basic controls for hot water boilers beyond an ASME relief valve. Many local codes and federal specifications insist on them. Perhaps the best verification of this sound engineering principle is outlined in an excerpt from an article published in a leading trade magazine:

“Then there’s the problem of avoiding firing dry boilers, especially boilers in hot water heating plants. Fired continuously by a run-away burner and carrying no heating load, the boiler may not explode because it has a modern mechanical device (ASME relief valve) to protect against explosion caused by excessive pressure. But the boiler may be ruined because it goes dry, or tries to operate as a steam boiler though it is not arranged for this.

“In these connections, excellent arguments come up regarding the need to increase safety of boiler operation through the increased use of automatic feeders and low-water controls, not only for steam boilers but also for the boilers used in both open-type and closed hot water heating plants.”

Therefore it can be seen that while ASME rated pressure relief valves are absolutely essential to boiler safety, there is also a great need for boiler feeders and cut-offs.
LOW WATER CUT-OFFS

Can a low water condition occur in a hot water boiler? Emphatically, yes! The record clearly indicates that most hot water boiler damage and boiler losses can be traced to low water.

Essentially the construction of a hot water boiler and a steam boiler are the same. Most of the reasons why low water can occur in a steam boiler will also hold true for a hot water boiler.

It is a common misconception that a pressure reducing valve, used to fill a hot water system initially, will keep the boiler and system full under all circumstances. But when it is realized that a pressure reducing valve is normally set at 12 or 18 pounds, and a safety relief valve opens at 30 pounds and closes at 26 pounds, it becomes obvious that the pressure reducing valve is ineffective during the time the relief valve is functioning. Figure 70F53A shows an ASME relief valve discharging due to excessive pressure in the boiler; without makeup water replacing the loss through the relief valve a hazardous low water condition can result.

If a hand fill valve is used, then of course any leak in the system can quickly cause a low water condition.

Here are some of the reasons why a hot water boiler and system can lose water so that a low water condition can result;

1. Loss of water due to carelessness.
   - draining boiler for repair or summer lay-up without eliminating possibility of firing.
   - drawing hot water from boiler.

2. Loss of water in distribution system.
   - leaks in piping caused by expansion breakage or corrosion.
   - leaks in boiler.
   - leaks through pump or other operating equipment.

3. Relief valve discharge caused by over-firing.

Figure 70F53B shows the action of the low water cut-off when an emergency condition arises. The falling boiler water line and simultaneous falling of the water line in the float chamber causes the float to drop, thus opening the electrical circuit and stopping the automatic burner.
CONDITIONS REQUIRING SERVICE

1. Improper wiring isolating cut-off from circuit—Check manufacturer’s wiring diagrams and trace circuits to insure proper electrical hook-up.

2. Switch overload causing fused contact points—Excessive electrical load due to a short or improper wiring may cause burnt or fused switch contact points.

3. Switch damaged by water—Water residue or water itself may be present in the switch causing improper switch performance.

4. Fuel valve stuck open thus allowing burner to remain operative.

FEEDER CUT-OFF COMBINATIONS

The following statement, which is based on considerable experience in the heating field, appears in a booklet on “Recommended Practices for Installation,” published by a leading utility company:

“A low water cut-off which will cut off the fuel supply before the water level reaches a low danger point, or a water feeding device with cut-off, shall be attached to all steam and hot water boilers.”

If we could rely absolutely on the low water cut-off to stop the automatic burner each time a low water condition developed, then the problem would be solved completely. However, experience has proved that under certain circumstances the low water cut-off cannot fulfill its duties. Here are several emergency conditions for which a low water cut-off is inadequate:

1. Over hand-firing a coal fire boiler.

2. A fuel feed valve mechanically held in an open position—that is, stuck open.

3. The burner system manually placed in the “on” position.

4. Closing of zone controls isolating the boiler from the system with a residual fuel bed in the boiler.

The best recommendation to cover all installations, and to provide the most complete measure of safety, is to use a combination Boiler Water Feeder and Low Water Cut-off. Such a combination is shown operating under an emergency condition in Figure 70F54A and safely shutting off the burner in Figure 70F54B. Note the feeder continues to feed water into the boiler to keep the boiler safe.
This combination provides:

**Mechanical Operation**—feeding water to the boiler as fast as it is discharged through the relief valve;

**Electrical Operation**—stopping the burner when low water occurs.

**CONDITIONS REQUIRING SERVICE**

1. Improper piping arrangement—Check with boiler or control manufacturer’s specifications regarding proper control piping.

2. Insufficient water supply pressure—City water or supply pressure should exceed relief valve setting by at least 10 psi in order that the water feeder can operate properly. Check control manufacturer’s capacity data to assure that there is adequate supply pressure or that the control is of a sufficiently large size to satisfy boiler requirements.

3. Float collapse due to excessive steam pressure—Hydrostatic testing at pressures greatly in excess of control operating pressures may cause float collapse. Also pressure relief valve setting or boiler operating pressure may be higher than maximum operating pressure of feeder cut-off combination.

4. Control of improper size—Control capacity may be less than necessary to satisfy boiler requirements. Check control manufacturer’s catalog to determine proper size control for specific application.

**LOW PRESSURE STEAM BOILERS**

**LOW WATER CUT-OFFS**

Every steam boiler can run into a low water condition from causes like these:

1. Defects in system
   a. Leaking air valves.
   b. Pump stoppage.
   c. Leaky supply or return.
   d. Faulty check valves.
   e. Foaming or priming.
   f. Returns not pitched properly.
   g. Boiler leaks.
   h. Automatic control failure.
   i. Process use of steam; no condensate returned.
2. Over-firing of boiler.
   
a. Loss of water through safety valve discharge.

3. Carelessness or inattention.
   
a. Not watching water glass.
   
b. Leaving blow-off valves open.
   
c. Drawing hot water from boiler.
   
d. Draining boiler without stopping firing.

The danger that accompanies a low water condition is recognized by all leading authorities and insurance companies. The ASME Code for Low Pressure Heating Boilers specifies:

"Each automatically fired steam or vapor system boiler shall be equipped with an automatic low-water fuel cut-off so located as to automatically cut off the fuel supply when the surface of the water falls to the lowest safe waterline. If a water feeding device is installed, it shall be so constructed that the water inlet valve cannot feed water into the boiler through the float chamber and so located as to supply requisite feed-water. The lowest safety water line should be not lower than the lowest visible part of the water glass."

It can be seen that the most basic protection against damage caused by low water to the boiler is the installation of a float operated low water fuel cut-off, as shown in Figure 70F55A.

**CONDITIONS REQUIRING SERVICE**

1. Sediment holding float in up position—Control has not been flushed regularly. Also the boiler water may itself be exceptionally dirty or full of foreign matter or sediment.

2. Control damaged by excessive pressure—Boiler operating pressure or safety valve setting exceeds maximum operating pressure of control.

3. Electrical overload resulting in fused contact points—Excessive electrical load due to a short or improper wiring may cause burnt or fused switch contact points.

4. Switch damaged by water—Water residue or water itself may be present in the switch causing improper switch performance.

5. Fuel valve stuck open allowing burner to remain operative.

**Figure 70F55A** - This cut-off is mounted on the boiler so the switch will break the current to the burner when the boiler water drops to an unsafe level.

**Figure 70F56A** - Installation of a cut-off and electric water feeder provides automatic control of the boiler water level... but not that both controls are electrically operated.
**ELECTRIC WATER FEEDER**

When a cut-off stops the firing it also puts a stop to the automatic operation of a heating system. The boiler will not operate—and loss of heating or possibly even damaging freeze-up will result—until boiler water line is restored to a level again.

For this task of adding water automatically to the boiler as needed an Electric Water Feeder can be added to the cut-off installation, as shown in Figure 70F56A. The feeder is controlled by a second switch provided in the cut-off, which operates at a higher level than the cut-off switch. If boiler water should fall to this first operating level an electrical circuit is completed which energizes the solenoid-operated feeder; when boiler water level is restored the circuit is broken and feeder is closed drip-tight.

At all times the second cut-off switch stands ready to stop the burner if for any reason boiler water level drops into the water zone.

**FEEDER CUT-OFF COMBINATIONS**

The best method of boiler water control is a mechanical boiler water feeder and an electrical low water cut-off, shown in Figure 70F56B. A mechanical boiler water feeder will maintain sufficient water in the boiler to prevent it from being overheated—even though power failure might occur, a fuel regulating device might become inoperative, or a burner might be placed on manual operation. An electrical low water cut-off is constantly standing by to stop the automatic burner in case a lower water condition should occur.

A mechanical boiler water feeder will maintain sufficient water in the boiler to allow it to operate under any normal conditions. This assures fully automatic heating, reduces the hazards of operator carelessness, and prevents the possibility of piping freeze-ups. Further, feeding water to the boiler only as it is needed maintains the most efficient water level and steam space, reduces scale formation and makes the boiler water level as automatic as the firing.

**CONDITIONS REQUIRING SERVICE**

1. Partially plugged feed line.... Feed line from feeder to return header has become partially plugged with lime or sediment. This decreases the inside diameter of the feed pipe creating a back pressure which in turn can cause a flooding of the boiler. Replacement or at least cleaning of this pipe will remedy the situation.

2. Incorrect hook-up.... Check with boiler or control manufacturer's specification regarding proper control piping.

3. Excessive boiler pressure.... Safety valve setting or boiler operating pressure may be higher than maximum allowable operating pressure of feeder.

4. Sediment holding float in UP position…. Control has not been flushed regularly.

5. Dirty water…. This can cause priming in the boiler and result in erratic feeder operation as well as the possibility of a flooded boiler.
6. Too small differential pressure.... City water or feeder supply pressure does not exceed the safety valve setting on the boiler by a sufficient amount to supply adequate city makeup water.

7. Faulty swing check in return header....

**PUMP CONTROLLER, FEEDER CUT-OFF COMBINATION & MAKE-UP WATER FEEDER**

On heating systems where process steam is used—often by refrigeration absorption units—a different method of control is used. A pump control and low water cut-off is installed at the normal boiler water line. This is a float operated device similar to the low water cut-off discussed before, except that it is designed to operate at both high or low pressures. The pump controller is wired directly to the boiler feed pump so that an accurate and efficient water line may be maintained in the boiler. In this system the condensate is re-used for make-up, thus helping to minimize sediment build-up in the boiler.

A second set of electrical contacts provided in this control acts as a low water cut-off, stopping the burner in the event of a low water condition in the boiler.

The condensate receiver tank has mounted on it a float actuated make-up water feeder to maintain sufficient make-up water to answer any demand for water from the boiler. Note that this make-up feeder is installed 1/3 of the way from the bottom of the receiver tank, to allow sufficient room for returning condensate.