



## TECH TIP #18

### WATER LEVEL CONTROLS FOR STEAM BOILERS

#### Steam Boilers

They've been with us for over two hundred years, and most of the time they're so reliable most folks don't give them much thought. They sit in buildings all over the world, transferring heat from fuel to water, allowing us to warm our buildings or complete our processes.

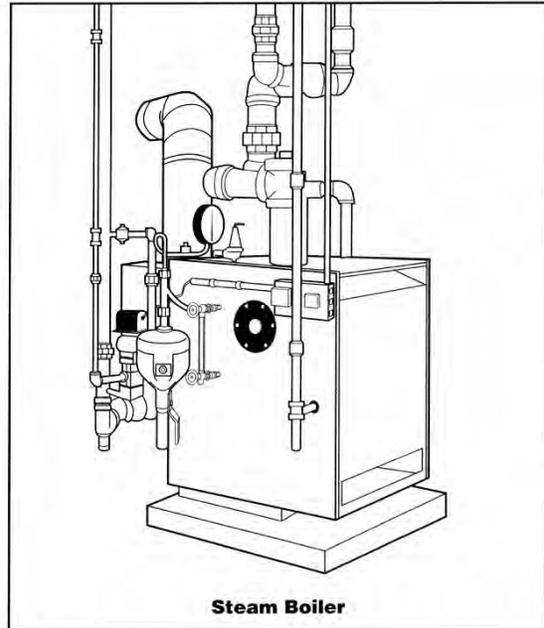
Steam boilers are simple, efficient and reliable. No machine does a better job of moving BTUs from one place to another. We've used them for space heating since before the United States Civil War in 1861.

Even before the Civil War, we used steam boilers for industrial processes. Today we use them to run factories, press clothes, wash dishes, pasteurize milk, sterilize medical equipment, and to heat entire cities! Their capabilities seem endless.

But despite its simplicity, any steam boiler can run into trouble if its control system doesn't act properly. If the energy you put into the boiler exceeds what the boiler can absorb, the boiler can rupture. So you must always be on guard.

A simple safety relief valve of the right capacity and relief-pressure setting protects the boiler from over pressure. But over pressure isn't the only thing that can threaten a steam boiler. There are also the dangers of dry firing.

Should the internal water level drop too low, the boiler can burn out. So here too, you must always be on guard. You see, a steam boiler needs its water to move the heat away from its metal surfaces. Without the right internal level of water, heat quickly accumulates. Too much heat creates a very dangerous operating condition.





## TECH TIP #18 (Cont.)

Boiler manufacturers have always set up minimum safe water level requirements for their equipment. Our controls help enforce those requirements in two ways:

- By maintaining a minimum safe water level in the boiler.
- By signaling the burner to stop should the water level drop below that point.

In this brief Systems Guide we will explain how we do these two very important jobs.

### What's a "Normal" Water Level?

The proper steam boiler water level varies from manufacturer to manufacturer, but generally we can say that it's "normal" to start by manually filling the boiler to the two-thirds-full point on the gauge glass. As the boiler operates, the water will quickly turn to steam and head out toward the system.

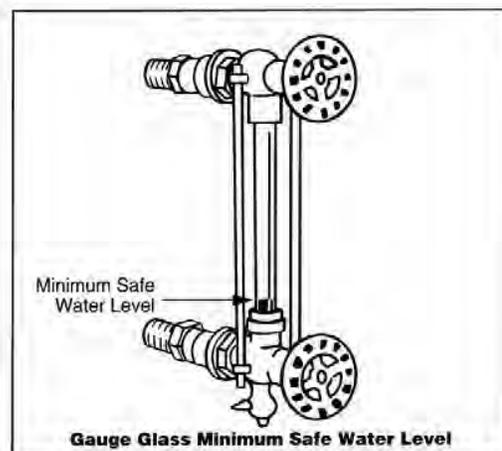
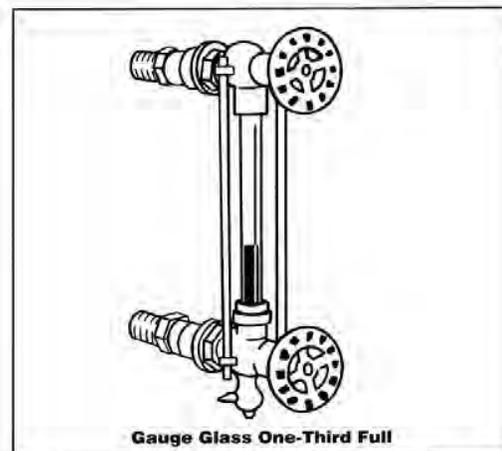
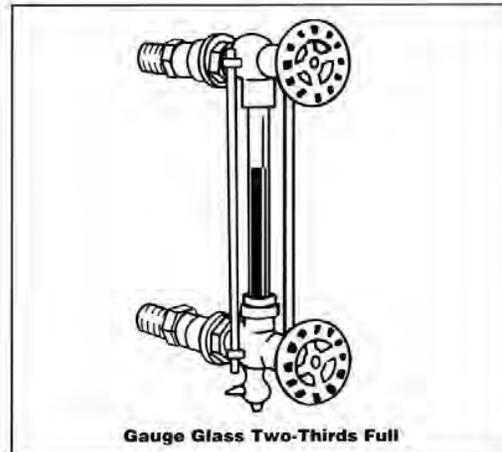
Steaming takes place at a constant rate of about one-half gpm per 240,000 BTU/HR (D.O.E. heating capacity rating). This is a law of physics, so it doesn't vary from manufacturer to manufacturer. If you're working with a boiler with a rating of say 1,000,000 BTU/HR, you can be assured the water is turning to steam and leaving that boiler at the rate of about two gpm. And it's leaving at speeds measured in miles per hour (sometimes exceeding 60 mph!). So it's very important for your near-boiler piping to be correct. If it's not, the fast moving steam will pull water out of the boiler and create problems for you in the system and the boiler.

As the water (in the form of steam) heads out toward the system, the water level in the boiler will, of course, drop. How far it drops depends a lot on the size and condition of your piping system. You see, *ideally*, the water should begin to return to the boiler before the boiler's internal water line drops to a critical point. That's the point at which the low water cut-off will cut power to the burner, or an automatic water feeder will open.

Because the water is in the system piping and radiating during operation, the "normal" water level becomes a point that's somewhere in the lower-third of the gauge glass.

Remember that you're working with a *range* of operation here, not a fixed point. If the water were to stay at the top of the gauge glass all the while the burner was firing, you probably wouldn't be making steam! So don't get too caught up with the word "normal" because the only thing that's normal is that the water level will rise and fall.

Boiler manufacturers, as we said before, *do* establish a minimum safe water level for their boilers, however. That point





## TECH TIP #18 (Cont.)

is usually just out of sight of the bottom of the gauge glass. Should the water level drop to this point, the boiler may be in danger of overheating. We have to find a way to protect the boiler from itself.

All leading authorities and insurance companies recognize this need. The ASME Code for Low Pressure Heating Boilers, for instance, specifies, "Each automatically fired steam or vapor steam boiler shall be equipped with an automatic low water fuel cut-off." The device the code refers to is what most people in the field commonly call a "low water cut-off." Its job is to stop the burner and protect the boiler.

### What Causes a Low Water Condition?

Because it's an open system, some evaporative water loss is normal for a steam system. How much depends on the size and condition of the system. If you're losing too much water, however, it's time to begin troubleshooting. There are many places to look

Here are a few good places to start:

- The air vents are dirty, not seating properly, and passing steam to the atmosphere.
- Someone left the boiler blowdown valve partially open.
- Someone, for whatever reason, has been drawing hot water from the boiler.
- The relief valve has discharged.
- The condensate pump isn't working as it should.
  - The float may have come loose.
  - The condensate may be too hot to pump. (Check those steam traps!)
- Improper near-boiler piping may be throwing water up into the system, or causing the waterline to tilt during operation.
- The wet returns may be leaking. (Always suspect any buried pipe).
- A check valve may be stuck closed or partially closed.
- The boiler may be foaming and priming.
  - Check the pH of the water. It should be between 7

and 9.

- Check the condition of the water. Dirty water will prime and foam.
- Check the burner's firing rate. Over-firing can cause priming.
- The pipes may not be properly pitched.
- The automatic feeder may not be working properly.
  - Its chamber may be filled with sediment.
  - Its feed line may be clogged.
- All of the condensate may not be returning from the system (a common problem with process applications).
- The boiler metal may be corroded and leaking at the water line.
  - Flood the boiler to its header to check for leaks.

Good troubleshooters take the time to look over the entire system before deciding what's wrong. Take the time to do it right, and you'll be the person with the answers

### Watching the Water Level

The best way to prevent overheating damage to a boiler is to stop the burner if the water level falls too low. This is the low water cut-off's job. There are several types of low water





# TECH TIP #18 (Cont.)

cut-offs you can use. Let's look at them.

## Float Operated Low Water Cut-Offs

Float operated low water cut-offs have been around since the 1920s and have earned a reputation worldwide for reliability. Usually you'll mount this type of low water cut-off directly in the boiler's gauge glass tappings. We make "quick hook-up" fittings for these units to simplify installation.

The water level in the low water cut-off's chamber will mimic the water level in the boiler. As the water level drops in the boiler during steaming, the level in the chamber, and the cut-off's float drops with it. Should the float drop to the boiler's critical low water cut-off point, the float will trip an electrical switch that's wired in series with the burner. The burner instantly stops firing. It will stay off until the water level rises to a safe operating point.

This happens when the condensate returns from the system or when an automatic water feeder or a boiler attendant adds water to the boiler. When the level reaches a safe position, the low water cut-off will make its electrical connection and the burner will restart.

When a steam system is well balanced, the low water cut-off's job is to stand by and wait. The situation we just described suggests that there's something out of balance in that system. We'll look at this again in a few minutes.

## Probe and Float Type Built-In Low Water Cut-Offs

There are some jacketed boilers that don't easily accept quick hook-up fittings. These boilers will often have a tapping for a built-in low water cut-off. These built-in units do the same thing as the external units we just looked at, but instead of being in a chamber, the "built-ins" are right inside the boiler where they can sense the water level directly.

We make two types of built-in low water cut-offs:

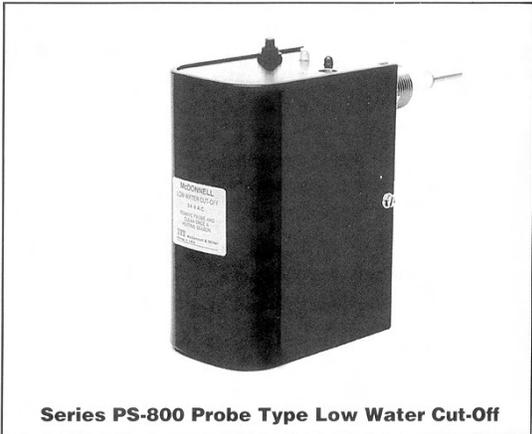
*Probes* -The boiler manufacturer will specify the point where they'd like to have this type of low water cut-off inserted. It will usually sit just below the water line, at a point above the boiler's crown. A probe uses the boiler's water to complete an electrical circuit past an insulator (the center portion of the

probe) back to a ground (the threaded portion of the probe). As long as water covers the probe, an electronic "go" signal will travel to the burner. When water drops off the probe for a continuous ten seconds, an electronic "stop" signal goes to the burner, shutting it down and protecting the boiler from a low water condition.

At ITT McDonnell & Miller, we manufacture several different types of probe low water cut-offs to meet any of your job applications.

One of those applications might involve the boiler's water level. The water capacity of today's boilers is considerably less than that of boilers from decades ago. Along with this, the water level operating range of today's boilers is smaller. Further, the amplitude of surging water levels is increasing. As a result, the low water cut-off must be "smart" enough to recognize these variations and react appropriately. We have done this by incorporating delay features in the probe's operating logic. These include a delay on break feature (DOB) which keeps the burner lit for 10 seconds after water leaves the probe. This minimizes the effects of a surging water line. Another addition - the delay on make feature (DOM) - allows an additional feed time of 15 seconds once water comes in contact with the probe. This minimizes rapid burner and feeder cycling by slightly elevating the water level so that water lost to steaming will return (in the form of condensate) before the water level drops below the probe.

*Float Type* - in operation, these are similar to the external, float operated low water cut-offs we looked at before. The difference is that instead of sensing a duplicated water level *outside* the boiler, these units sense the level directly inside



Series PS-800 Probe Type Low Water Cut-Off



## TECH TIP #18 (Cont.)

the boiler. We make them for you in five mounting-barrel sizes (Series 69) to accommodate different boiler insulation thicknesses. When you select a built-in float type control, make sure it fits as far as possible into the boiler without the float shield coming in contact with the boiler.

When a low water cut-off stops a burner, it also stops the entire heating system. Nothing will happen until the water in the boiler returns to a safe operating level.

While this is very good for the boiler, it may not be the best thing for the system. If the heat in the building is off for too long a time, water pipes may begin to freeze.

This is where automatic water feeders come in. An automatic feeder will maintain a safe minimum water level in the boiler and keep it operating, even if the system is leaking. It keeps the system operating automatically until you can make the repairs.

### Hot Water Boilers

Low water protection isn't just for steam boilers. Hot water boilers face the same perils of overheating damage if the water line drops too low. Many people don't think of this as often as they should because hot water boilers serve "closed" systems. They have pressure-reducing valves that are supposed to feed water automatically should a leak develop.

The truth, however, is that a pressure reducing valve is no substitute for a low water cut-off. Pressure reducing, or "feed" valves, often clog with sediment and wind up not feeding at all. A buried pipe can corrode and spring a leak that flows faster than a "feed" valve can satisfy. Relief valves can pop and, while dumping water at a great rate, actually prevent the feed valve from operating.

Let's take a closer look at how we can protect these boilers.

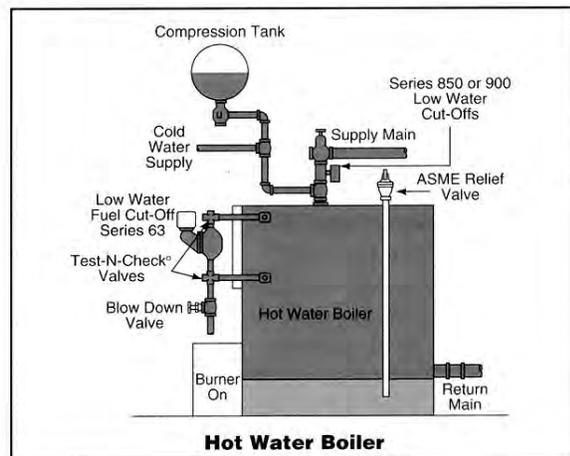
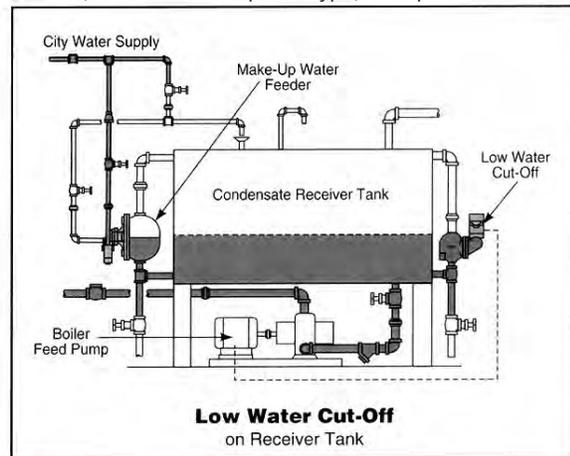
### Hot Water Systems

As we said, the things that affect steam boilers also affect hot water boilers. If you run them with too much water, the

relief valve will open. If you run them with too little water, they'll overheat and suffer damage.

A low water cut-off is the only sure way of protecting a hot water boiler from sudden loss of water. The ASME boiler code recognizes this by requiring all hot water boilers of 400,000 BTU/HR or more input to have low water fuel cut-off devices.

ASME doesn't call for low water cut-offs on smaller, residential boilers, but we think *all* hot water boilers, regardless of their size, must have protection. However, the International Mechanical Code requires low water cutoffs on ALL hot water and steam boilers. ITT McDonnell & Miller make several devices, both float and probe type, that protect and meet





## TECH TIP #18 (Cont.)

the needs of any boiler whether it's cast iron, steel, or copper construction.

Hot water systems regularly lose water through faulty air vents, loose valve stem packing, cracked boiler sections, loose nipples, corroded pipes, broken or loose pump seals, leaking gaskets, or dripping relief valves, to name just a few places. Most installers depend on their pressure reducing or feed valve to replace the lost water automatically. But feed valves often clog with sediment, especially in hard water areas. And it's very easy to close the supply valve to a feed valve and forget to open it again.

On systems with buried pipes (say a radiant heating system) a feed valve will open if a pipe breaks. It will feed fresh water continuously until it either clogs (and stops feeding) or destroys the ferrous components of the system with oxygen corrosion. A simple feed valve can wind up costing a lot more than its purchase price. This is why major suppliers of feed valves, such as ITT Bell & Gossett, recommend you close the feed valve once you've established your initial fill pressure. This is also why we strongly recommend you use a low water cut-off on every hot water boiler. Feed valves are not a substitute for low water cut-offs. They can't protect your boilers from a low water condition. Feed valves are fine for filling the system initially, and for helping you vent air from the radiators, but once the system is up and running, you shouldn't look to them for protection.

### Over firing

There are times when hot water boilers don't lock-out on safety. Whether by control failure or human error, things go wrong. And when they go wrong in a hot water heating system, the water temperature can rise quickly to a point where the expansion tank can't take up the expansion of the water. This causes the relief valve to discharge.

When the relief valve opens, there's a sudden drop in system pressure. The water, which at this point is probably much hotter than 212°F (100°C), will flash into steam. This is why ASME insists that relief valves for hot water boilers carry steam-discharge ratings. If a feed valve doesn't open to replace this rapidly exiting water, a low water condition will quickly result. The only thing that can protect the boiler at this point is a low water cut-off. The feed valve can't protect the boiler because its typical setting is 12 psig (.83 bar). In



**Series 67 Float Type Low Water Cut-Off**



**Series PS-851 Probe Type Low Water Cut-Off**



**Series RB-24 Probe Type Low Water Cut-Off**



## TECH TIP #18 (Cont.)

other words, the system pressure must drop below 12 psig (.83 bar) before the feed valve will open.

The trouble is that while the relief valve is open and flashing steam to atmosphere, the internal system pressure never drops anywhere near 12 psig (.83 bar). A relief valve with a 30 psig (2.1 bar) setting, for instance, will open at 30 psig (2.1 bar) and close again when the pressure drops to about 26 psig (1.79 bar). The result is a loss of water with no make-up. Repeat this cycle enough times and the boiler will be in a dangerous low water condition. Keep in mind, steam exerts pressure. It can easily fool a feed valve, and that's why feed valves offer very little protection at all against low water.

### Feeder/Cut-Off Combinations for Cast Iron and Steel Hot Water Boilers

To protect a boiler from dry firing, the low water cut-off must be located above the boiler's crown. After the low water cut-off shuts off the burner, you should have a way to add water to the system to ensure the crown stays under water.

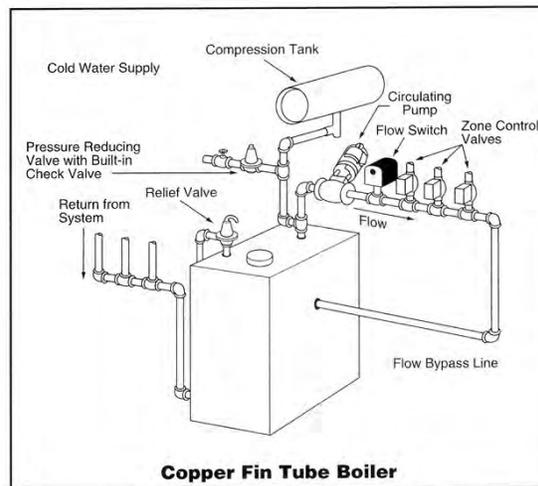
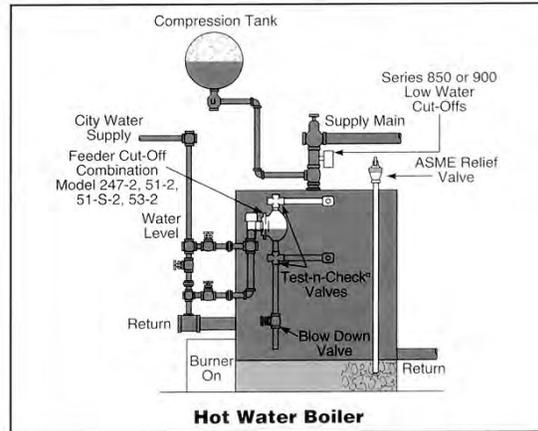
A combination water feeder and low water cut-off can do this for you. If you position the feeder above the boiler's crown, it will mechanically feed water if the level should drop to that point. This is an important consideration because even if the electricity is cut off, it's possible for the firing cycle to continue if the fuel feed valve is mechanically locked open. The combination unit's cut-off switch will act as a back-up to the primary low water cut-off, providing the boiler with additional protection.

### Protecting Copper Fin Tube Boilers

Copper fin tube boilers move heat from the flame to the water almost instantly. This type of boiler depends on the proper flow of water across its heat exchanger to move the heat quickly out of the boiler and into the system. Should flow stop while the burner is operating, heat will quickly build and cause the water in the heat exchanger to flash into steam. This condition is similar to a dry firing in a cast iron or steel boiler. A McDonnell & Miller flow switch, installed on the copper fin tube boiler's hot water outlet, protects it from this danger. The burner cannot fire unless water is moving across the flow switch. When the flow stops for whatever reason, the McDonnell & Miller flow switch immediately cuts electrical power to the burner and protects the boiler from overheating.

### Pressure Relief Valves

Good engineering practice calls for every hot water boiler to have a pressure relief valve. This spring loaded valve must





## TECH TIP #18 (Cont.)

be able to release the boiler's entire load at the boiler's maximum operating pressure. Here are some things that can cause a relief valve to open in a hot water heating system:

- *The automatic feed valve fails, allowing higher than normal pressure to enter the system.*
  - *Someone leaves a hand bypass line open after filling the system.*
  - *Someone hydrostatically tests the system at a pressure greater than the relief valve's setting.*
  - *The air cushion in the diaphragm type compression tank doesn't match the system's static fill pressure. Keep in mind most tanks come from the factory precharged at 12 psig (.83 bar). If the system needs more than 12 psig (.83 bar) pressure, you have to add more air to the tank, and you have to do this while you have the tank disconnected from the system.*
  - *The compression tank may be too small for the system.*
  - *The boiler's aquastat is in a well without heat transfer grease. When this happens, the boiler's temperature will quickly exceed the aquastat's setting, causing rapid rise in system pressure.*
  - *The circulator may be on the return side of the system with the compression tank at its suction. If it is, the circulator's head pressure will appear inside the boiler as a net increase. It may be enough to open the relief valve.*
  - *The burner limit may be jumped-out or stuck in a manual position.*

The main thing to keep in mind when you're troubleshooting this one is that relief valves pop when any of these three things happen:

- *The compression tank loses its air cushion*
- *The system takes on more water.*
- *The system temperature increases.*

Think methodically, and keep your eyes wide open!

We hope this Basic System Operation Guide has given you insight into the systems on which you're now working or will face in the future. We welcome any questions or comments you may have about the Guide, or about our products.

Thanks for your support, and for your continuing business.



**McDonnell & Miller**