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Subject: One approach to setting up *automatic standby* capability of a boiler feed pump running in an On/Off application to support a steam boiler.

Maintaining Proper Water Level Critical [1]

Steam boilers have been with us for over two hundred years, and most of the time, they're so reliable most people 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, steam boilers were used for industrial processes. Today we use them to run factories, press clothes, wash dishes, pasteurize milk, sterilize medical equipment, and to heat entire cities. 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 may rupture. 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. A steam boiler needs water to move the heat away from its metal surfaces. Without the proper internal level of water, heat quickly accumulates. Too much heat creates a very dangerous operating condition. Boiler manufacturers have always set up minimum safe water level requirements for their equipment. Pump controllers help ensure those requirements are satisfied 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.

Leading authorities and insurance companies recognize the need to protect a steam boiler from overheating due to a low water condition. For example, the ASME Code for Low Pressure Heating Boilers states, "Each automatically fired steam or vapor steam boiler shall be equipped with an automatic low water burner cut-off."

The following section briefly explains the general concept (see disclaimer below) of how to set up a standby pump on a boiler feed unit for maintaining the proper water level in a steam boiler if the primary pump should fail for any reason or simply not keep up with the boiler's need for water.

Condensate Unit versus Boiler Feed Unit

If you have a steam system where some steam is used in a process application (meaning, it won't be coming back), or if your system isn't well balanced (meaning the condensate pump does not return sufficient water to the boiler preventing it from dropping to a point requiring makeup water), you should consider using a boiler feed pump instead of a condensate pump to supply water to the boiler. A boiler feed pump serves a similar function as condensate pump in that it provides the "push" needed to move the water back into the boiler. The major difference between a condensate pump and a boiler feed pump, however, lies in the way the pumps are controlled.

On a condensate unit, a float inside the receiver sends a signal to turn the pump on and off as water rises and falls inside the receiver. A level controller mounted directly on the boiler controls the pumps on a boiler feed unit. This controller responds to the water level in the boiler — NOT in the boiler feed unit.

A Common Misconception Regarding Pump Alternation and Standby Control

There is also a common misconception that pump alternation (see Note) on a boiler feed unit provides standby pump control. The use of pump alternation, either manual through use of lead/lag selector switches or automatic through use of an electrical alternator in the control panel, simply alternates pump operation so that the same pump does not run all the time — alternation does NOT provide standby pump control.

Note: For a more comprehensive discussion on pump alternation, see article titled "Understanding options for alternating pumps" that is available on the Shipco® web site under Technical Articles.

Boiler Feed Unit With Standby Feed Pump

Typically, the most practical and economical approach for arranging control of a standby boiler feed pump is to use two combination controllers (see Figure 1) that provide pump control in combination with a burner cut-off control and alarm activation. The pump controllers are used to maintain the water level, under normal operating conditions, in the boiler between the close limits recommended by the boiler manufacturer to maintain maximum steam efficiency. It starts and stops the boiler feed pump[s] based on the boiler's demand for water. The controllers are float actuated that make or break contacts as the water level in the boiler moves up or down.

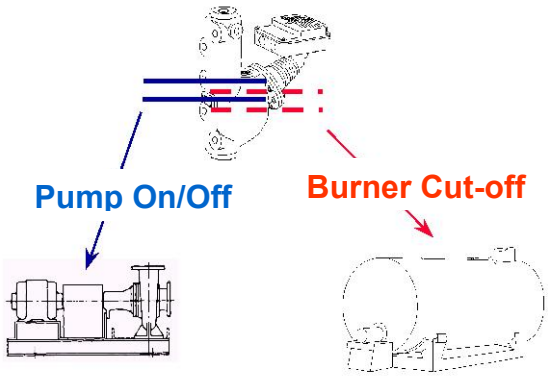

Figure 1
Combination Controller

A second combination controller (see Figure 2) is typically required for the burner cutoff to provide redundancy in order to comply with codes, rules and regulations governing the installation and operation of boilers – even though in the field you might find boilers without a separate mechanism for the burner cut-off control. The secondary controller is mounted at a level a bit lower than the primary controller.

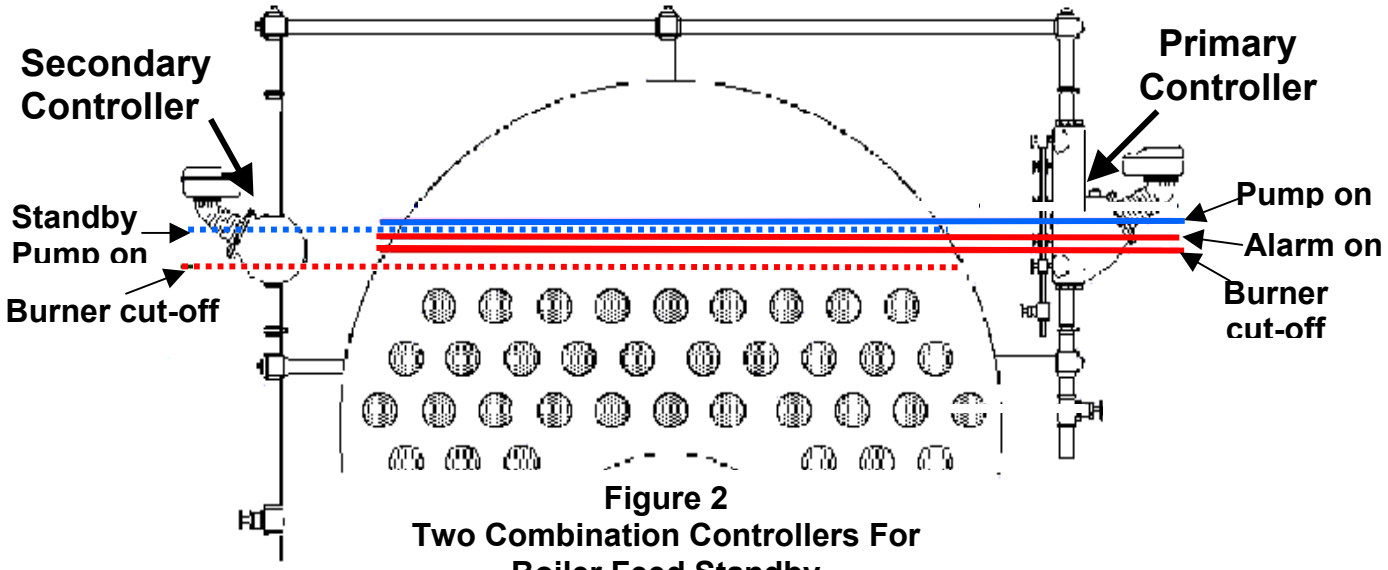

Figure 2
Two Combination Controllers For Boiler Feed Standby

When the water level in the boiler begins to drop, the primary controller senses the drop and sends a signal to start boiler feed pump #1 (see Figure 3). Pump #1 then sends water from the boiler feed tank to the boiler that should restore the water level under normal operating conditions. When the water in the boiler returns to the proper level, as indicated in the gauge glass, the pump controller sends a signal to stop boiler feed pump #1.

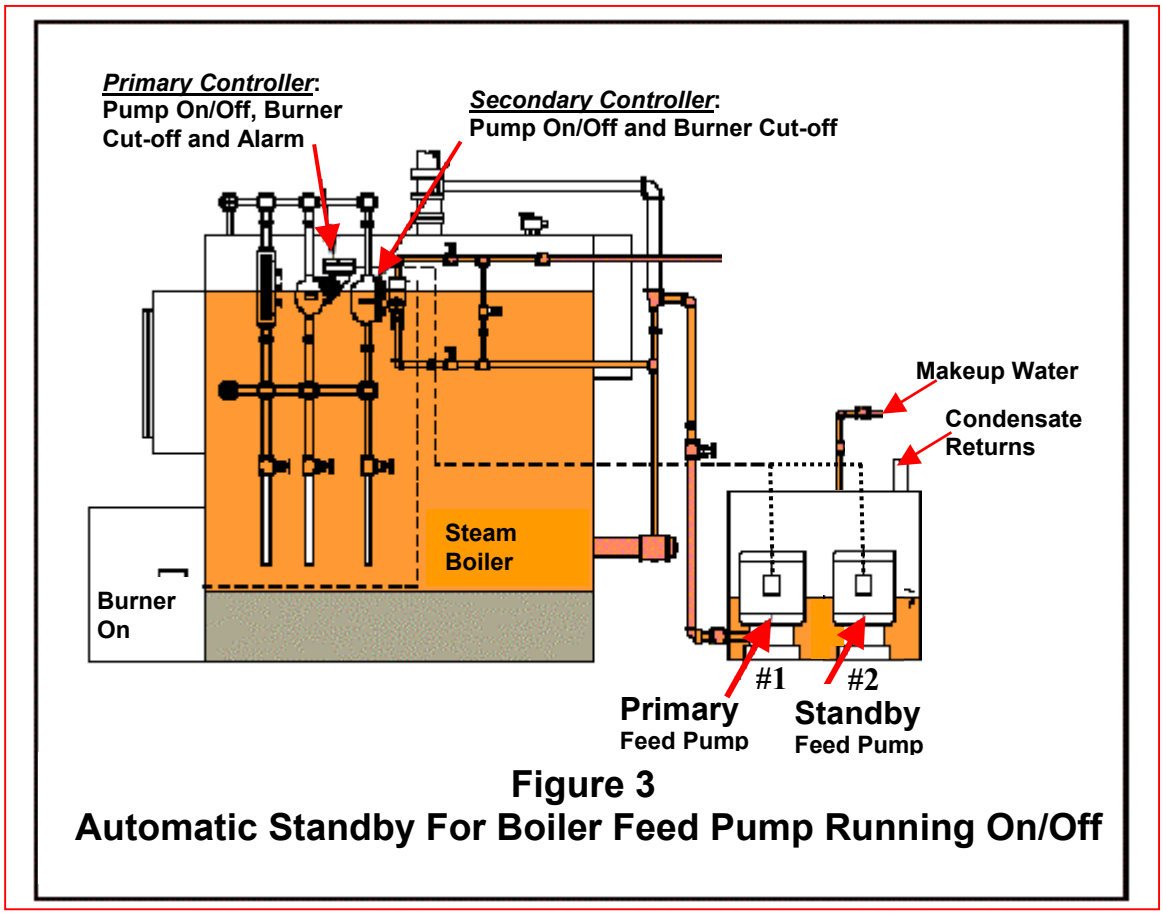

Figure 3
Automatic Standby For Boiler Feed Pump Running On/Off

If for any reason the water level in the boiler continues to drop because pump #1 cannot keep up with the boiler's demand for water, the secondary controller senses the drop and sends a signal to start pump #2 (i.e., the standby pump).

If the water level in the boiler should still continue to drop below the minimum safe operating level, even with both pumps running, or if something should go wrong with the pump controller, the burner cut-off in the primary controller is be used to protect the boiler from a low water condition. If for any reason the burner cut-off in the primary controller fails to cutoff the burner and the water level continues to drop, the burner cut-off in the secondary controller protects the boiler from a low water condition.

The water level in the chamber of the boiler cut-off mimics the water level in the boiler. As the water level drops in the boiler, the level in the chamber also drops. Should the float in the chamber drop to the boiler's critical low water cut-off point, the float will trip an electrical switch that is wired in series with the boiler's burner cutting the electricity to the burner and sounding a low water alarm (if installed in the electrical control panel of boiler). The burner stops firing until the water level is restored to the safe operating point.

A common arrangement for a low-pressure (i.e., 15 psig or lower) boiler application is:

- McDonnell-Miller Model **157or 159** for the Primary Controller:
- McDonnell-Miller Model **93** for the Secondary Controller

A common arrangement for a high-pressure (i.e., above 15 psig up to 150 psig) boiler application is:

- McDonnell-Miller Model **157or 159** for the Primary Controller
- McDonnell-Miller Model **150** for the Secondary Controller

Boiler manufacturers can and do vary the type of controllers and location. While each boiler set-up may be different but the purpose of the controller[s] is the same — to maintain a water level and protect the boiler from low water conditions. *In selecting a controller, it is also critical that the pressure rating of the burner cut-off be appropriate for the boiler's operating pressure. For job specific application consult with Installation, Operation and Maintenance Manual for controller manufacturer and seek advice from a trained, professional manufacturer representative*.

Two other important factors influencing the selection of controllers are cost and environmental concerns. Because mercury is becoming more expensive each year and is considered an environmentally hazardous material, the more environmentally safe "snap-switch" controllers are replacing "mercury-switch" controllers. Mercury switch models continue to be produced, but at a premium price over the cost of a snap-switch model.

In addition, mercury-switch controllers, by their design, are less precise than snap switch units. Because of this, they have more tolerance and the set points are less likely to be affected by the system operating pressure and fluctuating water lines. This is related to the linkages that hold the mercury tubes and the rolling effect of the mercury itself.

Snap switch units are more precise. When the water level rises or falls beyond the set points, the switch quickly changes state. There is no mercury or linkages to compensate for the subtle movements of the float. Because of this precision, the settings appear to be less than they really are.

A final factor to consider when selecting a control for a low water cutoff is that a majority of states in the U.S. (i.e., at last count, 28 states primarily in the North and East) have state codes that require a manual reset on the low water cutoff switch of the boiler.

What is the "proper" water level in a boiler [2]

The proper water level in a steam boiler varies from manufacturer to manufacturer. Generally at startup, a steam boiler is manually filled to the two-thirds point on the gauge glass that indicates the water level in the boiler. As the boiler operates, the water will quickly turn to steam and rise into the steam header and out into the system.

Steaming occurs at a constant rate of one-half gallon per minute (GPM) per 240,000 BTUs/hour. This rate is based on the law physics so it doesn't vary from manufacturer to manufacturer:

This can be shown using the following principles:

- One pound of water weights 8.33 lbs.
- It takes 970 BTUs to convert one pound of water into a one pound of steam at atmospheric pressure.

Therefore:

- ½ gallon of water weighs 4.17 lbs. (i.e., 8.33 lbs / 2)
- Converting ½ gallon of water to steam requires 4,045 BTUs (i.e., 4.17 lbs. x 970 BTUs/lb.)
- Which equates to approximately 240,000 BTU/hour (i.e., 4045 BTUs x 60 mins/hour)

Therefore, a boiler rated at 1,000,000 BTU/HR, will convert water to steam and leave the boiler at the rate of approximately two GPM. The steam leaves the boiler at speeds measured in miles per hour. Consequently it's important for the piping near the boiler to be correct. If the piping is wrong, the fast moving steam may create problems such as "carry over" where the steam pulls water from the boiler.

As the steam (water vapor) heads out toward the system, the water level in the boiler will drop. How far it drops depends on the size and condition of the piping system. Ideally, the condensate (i.e., condensed steam) begins to return to the boiler before the boiler's water level drops to a critical, low water point where the burner cut-off disconnects power to the burner and sets off the low water alarm (assuming an alarm is installed in the electrical control panel).

Keep in mind that the water level displayed in the gauge glass rises and falls as part of "normal" boiler operation. If the water level were to stay constant while the burner was firing, no steam is probably being generated. Also, the minimum safe water level is often just out of sight of the bottom of the gauge glass.

References:
[1] "Basic System Operation", McDonnell & Miller Website, page 12.
[2] "Basic System Operation", McDonnell & Miller Website, page 12-13.

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