Boiler Facts

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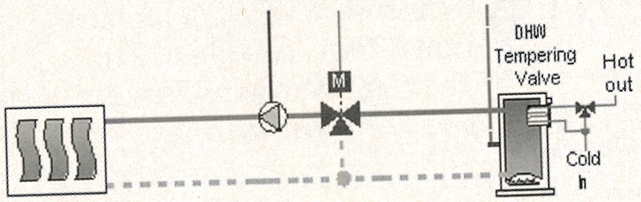
"Thermal shocking" a hot water boiler

Recently, a service manager from a large oil company in the area called and asked me to look at a problem job. It was a large apartment complex that they had recently taken on as a new account. While he was walking through the boiler room, "getting comfortable" with this new account, he noticed something peculiar. Over in the corner, there were three rear boiler sections lined up against the wall. Each one had a crack in about the same place as the others. He was concerned about this and wanted to find out more information before he became responsible for the fourth rear section. We spoke to one of the maintenance personnel from the management company. He explained that for the past three years, the previous oil companies had been replacing the rear section of the boiler each heating season.

The heating boiler provided domestic hot water for the apartment building through an external side-arm water heater as well as baseboard heating for each unit. Because of the external heater, the boiler had to maintain temperature year round. In an effort to prevent overheating in the apartments and wasted fuel costs, someone had installed a reset system about *four years ago* that incorporated a 3-way mixing valve and controller. Therefore, we immediately started looking how the 3-way valve and the boiler piping were configured. (Fig. 1, below).



A reset system adjusts the temperature of the water supplied to the heating system based upon outdoor temperature and optionally by indoor temperature feedback. The 3-way valve has a motor operated actuator that re-positions the valve according to the reset controller and its settings. During mild heating loads the system supply water may be as low as 100°F. This happens by positioning the valve to allow a percentage of hot boiler water to mix with a percentage of the system's return water. The problem with these systems is when they are installed incorrectly, they can impose sudden thermal loads on a hot boiler that can "shock" the boiler. Cast iron boilers end up with cracked and leaking sections, while water tube boilers have their tubes pulled off their tube sheets.

BOILER THERMAL SHOCK

Boiler thermal shock can be loosely defined a sudden thermal changes that occur within the boiler causing rapid and uneven contractions of the boiler's material (cast iron or steel). For example, if you were to take a cold glass from the freezer and run hot water over it, naturally, the glass would crack because of the extreme temperature change occurring too quickly. In thermally shocked boilers, the fractures or cracks occur where the temperature difference is greatest. In cast iron boilers, the stresses usually occur in the back of the boiler near the furnace area where the cold water enters. That's because the surfaces exposed to the cold water are contracting while the other side that is exposed to the fire is trying to expand.

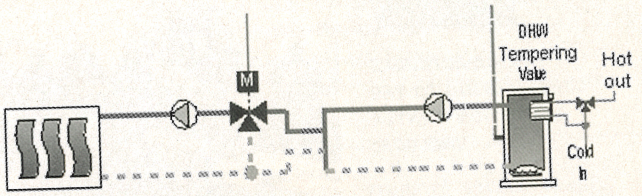
Temperature alone is not the problem but rather the "load-temperature" relationship of too many gallons of cold water entering a hot boiler. This causes a massive load on the boiler, resulting in an extreme temperature change in the boiler. For example, if a commercial cast iron boiler maintaining a temperature of 200°F were to see a couple of gallons of 50°F water, it would not create a problem. However, if several zones in a system suddenly opened and sent several gallons of 80°-90°F water back to the hot boiler, it would cause stressing and possible shocking of the boiler.

Systems that incorporate night setback but maintain boiler temperature for domestic hot water are also susceptible to thermal shock. When the system goes into setback, the water temperature in the zones can drop to ambient. When the system comes out of setback, a large volume of cool water is sent back to the hot boiler. CRACKKK!!!

In fact, a few years ago, the American Boiler Manufacturers Association (ABMA) issued a report on thermal shock. They stated the primary causes of shocking a boiler were due to night and weekend setback and outdoor air reset systems. The report stated that it is necessary to protect the hot boiler from the following conditions:

- Return water at too low a temperature
- Cool return water at too great a flow rate
- Moving to high fire with boiler water at too low a temperature
- High burner cycling rates coupled with high firing rates
- Firing boiler up to temperature before circulator is started

It is evident that to prevent thermal stressing and shocking of boilers, it is necessary to control the load imposed on the hot boiler. By preventing the existence of large temperature differentials between the inlet and outlet, you will prevent the sudden occurrence of temperature changes in the boiler. Boiler load is a function of flow rate and temperature difference. The most effective method of controlling this load is to use a modulating mixing control and a mixing device. Mixing valves or pumps are typically used as the mixing device. In typical outdoor reset systems, like the one we visited, a 3-way valve was employed to provide outdoor reset. However, there was no means of measuring the temperature of the water going back to the boiler. To prevent boiler thermal shock, it is essential to measure and control the return temperature going back to the boiler. To do this effectively, you need to add a second circulator for the boiler loop. As the return temperature becomes too cool for the boiler, the reset control will start to close the valve off to the system and the "boiler loop" circulator will simply re-circulate hot water right back to the boiler. As the water temperature starts to warm up, the return sensor will allow the 3-way valve to re-open, satisfying the system's temperature needs. If the system only used one circulator without the boiler loop circulator, when the return sensor closed the 3-way valve, there would be NO flow across this sensor. This would keep the 3-way valve closed for extended periods causing the heating system to experience wide swings in temperature. By using two circulators there will be two mixing points; one for the supply temperature and one for the returning temperature. Something to be aware of is that the potential exists for these two circulators to operate in series with each other when the valve fully opens to the system. The best way of preventing this from becoming a problem is to hydraulically isolate one from the other by using primary/secondary-pumping techniques. Pipe the supply and return connections from the boiler loop into the system loop at a maximum distance of four pipe diameters apart. (Fig.2, below). This keeps the pressure drop in the piping common to both "loops" at an absolute minimum, preventing any ghost flows in either loop or hydraulic problems with the circulators.



By employing this technique, the boiler will see a constant flow rate, improving its combustion efficiency. And since boiler load is a function of flow rate and temperature difference, the return sensor will effectively measure and limit the amount of cold water allowed back into the boiler. Now the reset control can supply the proper temperature to the system based on its reset schedule while also providing proper boiler return protection! Once the management company agreed to our proposal, the oil company re-piped the boiler room and they haven't experienced any cracked rear sections this season.

If you have any questions please email me at gcarey@fiainc.com or call 1-800-423-7187. ❑