6 Common Questions about Boilers Used in Process Heating Applications

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Photo credit: Western Technologies Galvanizing

Engineering and technical support from the design stage to troubleshooting can be one of your best resources when it comes to questions about boilers and boiler systems.

Boilers are used to heat a variety of liquid solutions for different processes via heat exchangers. Heat exchangers keep the boiler water (or steam) from direct contact with the solutions being heated. It is important to maintain this fluid separation because process solutions will be either acidic or caustic, and the fluids can damage the boiler if they migrate into the boiler system piping through a cracked heat exchanger or other means.

Video Not Available

Steam boilers include a gauge glass, which is the most obvious way to differentiate between steam boilers and hot water boilers.

Boilers fall into two ASME Code classifications: Section 1 and Section 4. ASME Section 1 boilers include high pressure steam boilers operating above 15 psi steam and hot water boilers operating above 250°F (121°C) or 160 psi. Section 4 boilers include low pressure steam boilers operating below 15 psi and hot water boilers operating at less than 250°F (121°C) and below 160 psi.

The design of the heat exchanger will determine whether a hot water or steam boiler is required as well as the classification. The size of the boiler will be determined by how many BTUs (or lbs/hr steam) the heat exchanger(s) require. Boiler size usually is defined in one of three ways:

- BTUs per hour (BTU/hr).
- Boiler horsepower (BHP).
- For steam boilers, pounds of steam per hour, or PPH.

They equate to each other this way:

33,475 BTU/hr Output = 1 Boiler Horsepower = 34.5 pounds of steam per hour

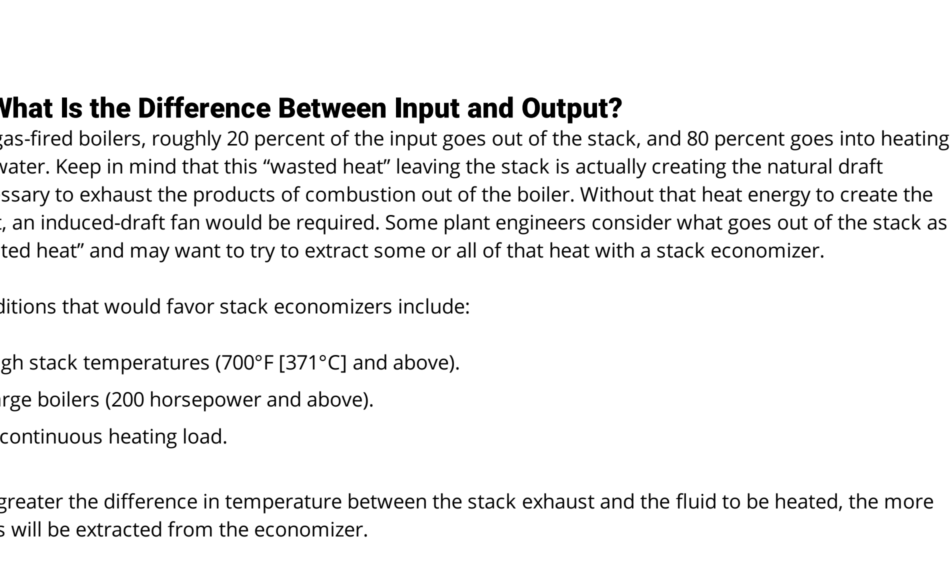
Output is underlined above because that is what the heat exchanger requires — not the BTU/hr input of the boiler.

When sizing a boiler, determine the BTUs required by the heat exchanger(s) and then select a boiler based on output rating, not input rating. For closed-loop hot water boilers, here is another simple sizing formula:

BTU/hr Boiler Output = 500* x ΔT x Flow Rate (gal/min)

***where 500 is 1 gallon of water @ 8.3 lb x 60 minutes**

Keep in mind that a boiler can provide either hot water or steam. But, without the addition of a heat exchanger, it cannot supply both.



This skid-packaged boiler includes pumps and an expansion tank.

Photo credit: Rite Engineering

1. What Is the Difference Between Input and Output?

For gas-fired boilers, roughly 20 percent of the input goes out of the stack, and 80 percent goes into heating the water. Keep in mind that this "wasted heat" leaving the stack is actually creating the natural draft necessary to exhaust the products of combustion out of the boiler. Without that heat energy to create the draft, an induced-draft fan would be required. Some plant engineers consider what goes out of the stack as "wasted heat" and may want to try to extract some or all of that heat with a stack economizer.

Conditions that would favor stack economizers include:

- High stack temperatures (700°F [371°C] and above).
- Large boilers (200 horsepower and above).
- A continuous heating load.

The greater the difference in temperature between the stack exhaust and the fluid to be heated, the more BTUs will be extracted from the economizer.

Before investing in a stack economizer, fully understand what the ROI will be. (Do not forget the installation, maintenance cost and life expectancy of the economizer.) Also, calculate what impact the economizer will have on the boiler-draft system. The addition of a stack economizer may require an induced-draft fan and a change from Category 1 (non-condensing negative pressure) to Category 3 (non-condensing positive pressure) vent material.

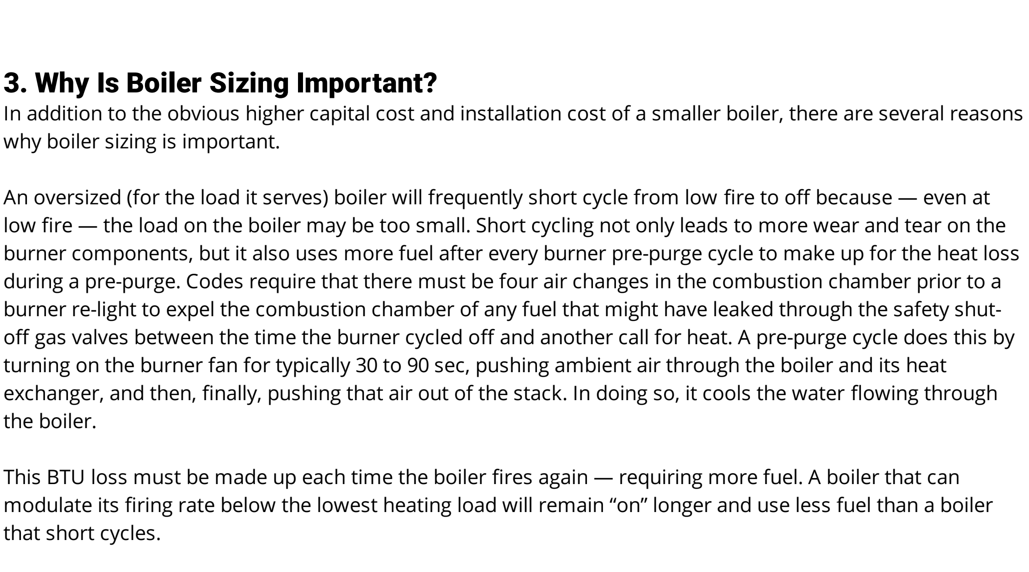
2. What Is the Difference between Startup Load and Operating Load?

When it comes to boiler sizing, it is important to understand the difference between startup load and operating load. An example of a startup load would be heating all of the batch tanks up from a cold start on a Monday morning. An example of the operating load would be the heat input required to maintain temperature after the system is already up to temperature.

After everything has heated up, the BTU/hr loss from normal operation is not that significant. Therefore, a cold startup load will almost always require more BTUs per hour than the operating load. It is the amount of time it takes to get the tanks up to the temperature, however, that is key to sizing the boiler.

Going back to the sizing formula for hot water boilers, when the flow rate is doubled, the BTU/hr requirement doubles. And, likewise, if the flow rate is reduced by half, the BTU/hr requirement is also halved. So, for instance, by changing the heatup time on a Monday morning from 1.5 to 3 hours, the boiler size can be reduced by half.

There are a few caveats to this, however. The boiler should always be sized 15 to 20 percent over the operating BTU/hr load requirement. Also, if the boiler fails to automatically come online on Monday morning, and there is no one there to reset it, the extended startup time may interfere with production.



Hot water boilers are used in a paint line system application.

Photo credit: Therma-Tron- X

3. Why Is Boiler Sizing Important?

In addition to the obvious higher capital cost and installation cost of a smaller boiler, there are several reasons why boiler sizing is important.

An oversized (for the load it serves) boiler will frequently short cycle from low fire to off because — even at low fire — the load on the boiler may be too small. Short cycling not only leads to more wear and tear on the burner components, but it also uses more fuel after every burner pre-purge cycle to make up for the heat loss during a pre-purge. Codes require that there must be four air changes in the combustion chamber prior to a burner re-light to expel the combustion chamber of any fuel that might have leaked through the safety shut-off gas valves between the time the burner cycled off and another call for heat. A pre-purge cycle does this by turning on the burner fan for typically 30 to 90 sec, pushing ambient air through the boiler and its heat exchanger, and then, finally, pushing that air out of the stack. In doing so, it cools the water flowing through the boiler.

This BTU loss must be made up each time the boiler fires again — requiring more fuel. A boiler that can modulate its firing rate below the lowest heating load will remain "on" longer and use less fuel than a boiler that short cycles.

Another reason is stack emissions. NO_X rules (and the maximum allowable limits of other pollutants) are based on the BTU/hr input of the boiler. The permitting of a smaller boiler can, therefore, make the difference between a more expensive low NO_X burner and a less costly standard emissions burner.

4. Should You Install Two Boilers or One?

If the operation is critical, a backup boiler is advisable. Two boilers can each be sized for anywhere from 60 to 100 percent of the total load, depending on whether full or partial backup is required. With two boilers each operating at 60 percent capacity, they can come online together to reduce startup run time. Then, one boiler can be taken offline, leaving the other to maintain the operating load with less chance of short cycling. In addition, in the event that one boiler is not operational, the other boiler can still provide 60 percent production capacity.

There are lead-lag systems available to automate equal run time for both boilers. Having two identical boilers also means less spare parts inventory, and control parts can be swapped relatively easily. In some cases, the emissions requirements for one larger boiler may trigger a more expensive low NO_X burner than is required for two smaller boilers. One disadvantage, however, is that the purchase and installation cost for one large boiler will usually be less than for two smaller ones.

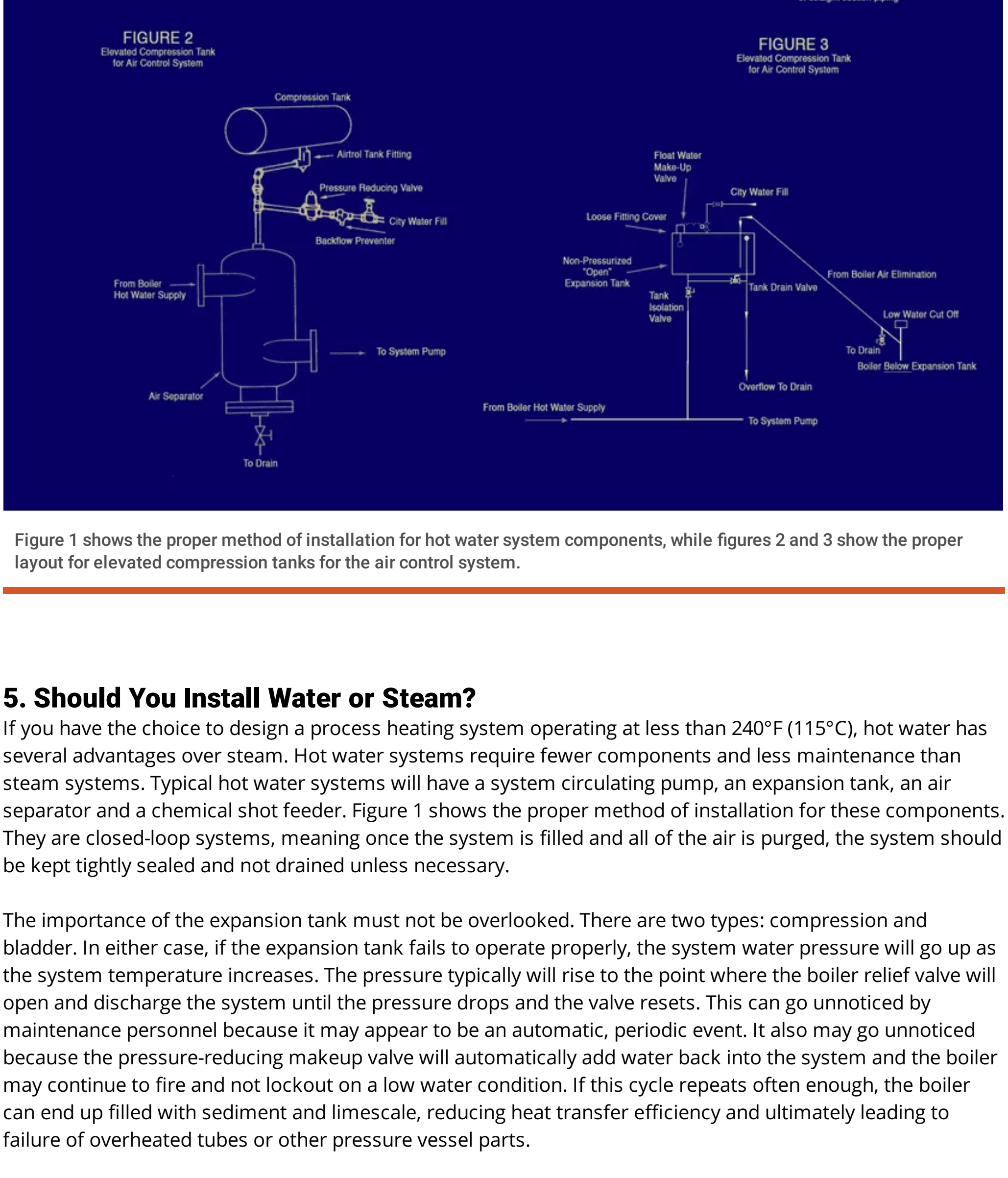


Figure 1 shows the proper method of installation for hot water system components, while figures 2 and 3 show the proper layout for elevated compression tanks for the air control system.

5. Should You Install Water or Steam?

If you have the choice to design a process heating system operating at less than 240°F (115°C), hot water has several advantages over steam. Hot water systems require fewer components and less maintenance than steam systems. Typical hot water systems will have a system circulating pump, an expansion tank, an air separator and a chemical shot feeder. Figure 1 shows the proper method of installation for these components. They are closed-loop systems, meaning once the system is filled and all of the air is purged, the system should be kept tightly sealed and not drained unless necessary.

The importance of the expansion tank must not be overlooked. There are two types: compression and bladder. In either case, if the expansion tank fails to operate properly, the system water pressure will go up as the system temperature increases. The pressure typically will rise to the point where the boiler relief valve will open and discharge the system until the pressure drops and the valve resets. This can go unnoticed by maintenance personnel because it may appear to be an automatic, periodic event. It also may go unnoticed because the pressure-reducing makeup valve will automatically add water back into the system and the boiler may continue to fire and not lockout on a low water condition. If this cycle repeats often enough, the boiler can end up filled with sediment and limescale, reducing heat transfer efficiency and ultimately leading to failure of overheated tubes or other pressure vessel parts.

Adding a water pressure switch to the boiler or in the system piping to signal excessive pressure is one way of detecting expansion tank failure. Routine visual checks that the boiler pressure gauge is reading normal and well below the pressure-relief valve setting are recommended. The pressure-reducing valve should be set to supply enough water pressure to reach the top of the system piping with an additional 4 to 5 psi cushion. There is no reason or advantage to operate a water heating system with a higher cold fill pressure than that.

The chemical shot feeder typically is used to add corrosion inhibitors into the system to help offset the dissolved oxygen entrained in the water during the initial fill. If freezing is a possibility, glycols (ethylene or propylene) can be added through the shot feeder.

Keep in mind that glycols reduce heat transfer efficiency, so consider adding only enough glycol by volume for burst protection and not freeze protection. Weekly checks for system water pH are a good idea. In a water heating boiler, pH should be between 8 and 9 on the pH scale. If acids or caustics that are being indirectly heated get into the boiler system through a faulty heat exchanger or some other means, the damage to the boiler can be severe.

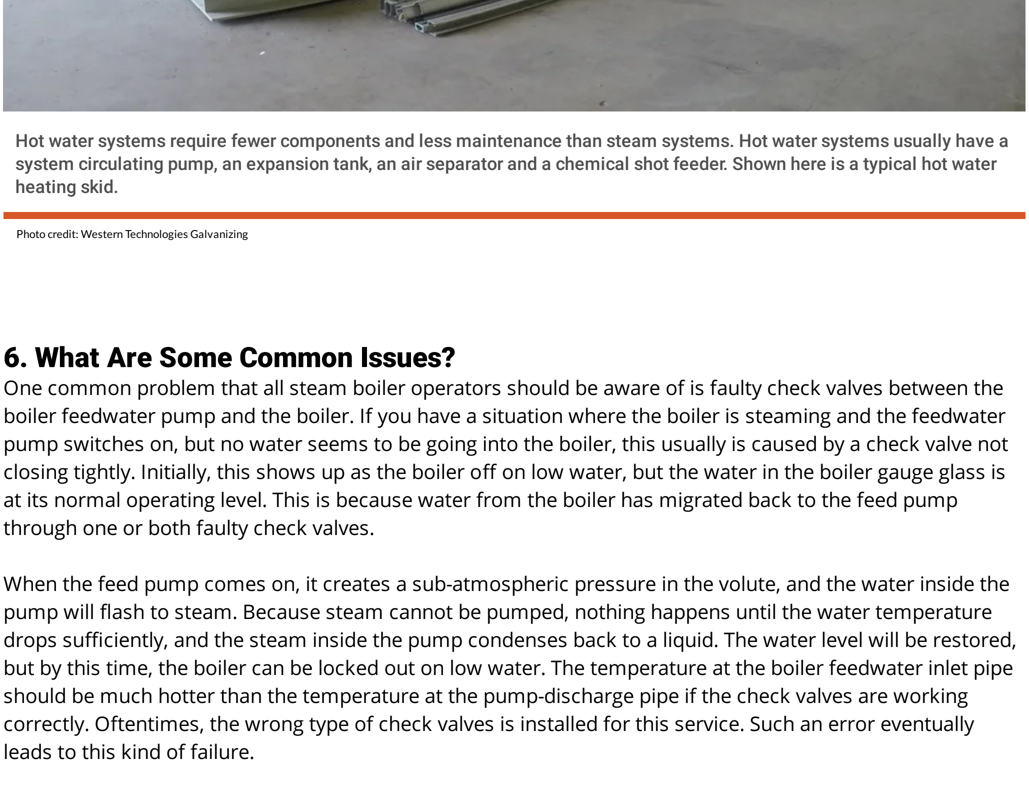
Steam boilers do not require circulating pumps because steam will travel to the heat exchangers under its own power. Steam systems will require traps at the end of the steam header and at the outlets of all heat exchangers. Low pressure steam systems may require one or more condensate transfer stations to get the condensate leaving the traps back to the boiler feed unit. High pressure steam systems usually have enough pressure at the traps to lift and push condensate back to the boiler feed unit. One psi of steam pressure at the inlet to a trap can lift the condensate up 2.3'. For large plants with long steam runs, high pressure steam lines can be significantly smaller in diameter than low pressure steam lines.

If two or more steam boilers are piped into the same steam header, check valves or stop-check valves should be installed in each boiler's steam supply line before it reaches the steam main to prevent steam backflow and condensing into the other line. Softened water makeup with no more than one to two grains of hardness per gallon and "zero" grains preferred is a must.

Chemical treatment in conjunction with blowdowns is also a must. Chemical treatment requires a sample cooler to test the boiler water on a regular basis and is usually monitored by a water treatment specialist. High pressure steam boilers are required to be opened and inspected on the waterside once a year and it is recommended that low pressure steam boilers be opened after one year of operation to make sure the water treatment program is effective. An effective water treatment program is one that prevents limescale buildup and corrosion of waterside surfaces inside the boiler. Changes to the water treatment program should be made immediately if limescale or corrosion (usually oxygen) are discovered.

Every time a steam boiler is turned off and cools down, it will draw a vacuum because steam has 1,700 times the volume of water. The vacuum can be broken by either a vacuum breaker or through the seals of the boiler gauge glass. If the vacuum is not broken, it can be strong enough to pull feedwater out of the condensate receiver/boiler feed unit and into the boiler. A full boiler gauge glass on a Monday morning after a shutdown is an indication of this. Failure to drain enough water out of the boiler until some air is visible in the gauge glass could result in water carryover into the steam line.

Adding a vacuum breaker will siphon water out of the boiler feed unit, but doing so introduces air into the boiler and piping and raises the probability of oxygen corrosion. There are various strategies for dealing with these issues such as leaving the boiler on all the time — with or without night setback — as well as amine treatments for above-the-water-line protection against corrosion. These should be discussed with your water treatment specialist for your specific operation.



Hot water systems require fewer components and less maintenance than steam systems. Hot water systems usually have a system circulating pump, an expansion tank, an air separator and a chemical shot feeder. Shown here is a typical hot water heating skid.

Photo credit: Western Technologies Galvanizing

6. What Are Some Common Issues?

One common problem that all steam boiler operators should be aware of is faulty check valves between the boiler feedwater pump and the boiler. If you have a situation where the boiler is steaming and the feedwater pump switches on, but no water seems to be going into the boiler, this usually is caused by a check valve not closing tightly. Initially, this shows up as the boiler off on low water, but the water in the boiler gauge glass is at its normal operating level. This is because water from the boiler has migrated back to the feed pump through one or both faulty check valves.

When the feed pump comes on, it creates a sub-atmospheric pressure in the volute, and the water inside the pump will flash to steam. Because steam cannot be pumped, nothing happens until the water temperature drops sufficiently, and the steam inside the pump condenses back to a liquid. The water level will be restored, but by this time, the boiler can be locked out on low water. The temperature at the boiler feedwater inlet pipe should be much hotter than the temperature at the pump-discharge pipe if the check valves are working correctly. Oftentimes, the wrong type of check valves is installed for this service. Such an error eventually leads to this kind of failure.

Negative room pressure inside a plant can adversely affect boiler operation. Boilers often are installed inside process plants with little or no room separation. Plants that utilize high volume exhaust fans can turn negative with regard to room pressure, especially in winter when the roll-up doors are closed. This negative pressure can be strong enough to negatively impact the way a boiler "breathes" and lead to flame rollouts and reverse flow of exhaust gases down the stack instead of out the stack.

For new plants, this should be accounted for in the design phase by considering such measures as adding an adjacent structure next to the main building(s) with a common wall in order to maintain a separate boiler room environment from the rest of the plant. For existing plants subject to this problem, an induced draft fan may be the only solution if there are no other means of correcting the negative plant pressure.

Boiler manufacturers and their representatives that specialize in process heating applications can provide valuable engineering and technical support from the design stage to troubleshooting. They can be one of your best resources when it comes to questions about boilers and boiler systems.

About the Author

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