Instantaneous Heaters - Technical Discussion

Steam fundamentals

When make-up water enters the boiler room or power plant, its first stop after treatment is the deaerator. Here it is sprayed over heated trays to drive out dissolved gases. The water is usually heated from 40F to 205F by adding sensible heat. It takes about 1 BTU to raise a pound (or pint) of water by 1F. These BTU's are supplied by steam in the trays.

Smaller package boilers might not utilize a deaerator, in which case, the boiler provides this same sensible heat demand.

Here is one place where the Maxi-Therm system makes a difference. Why is make-up water needed in the first place? Some losses are due to boiler blow-down and some to make up for leaks. The other loss is from "flash steam". That's the steam puffing out of vent pipes all around the condensate return system.

The steam boiler takes water from the deaerator, heats it to the boiling point by adding more sensible heat, and then adds latent heat to vaporize the water into steam. How much sensible and latent heat are needed? That depends on the steam pressure desired.

Fig 3 Flash steam puffing from vents

A sophisticated system for a university, food processor, or chemical plant will generate steam at 600 psig or higher, because steam is used to generate power before distribution. The steam is normally distributed at 100 or 150 psig. Some industrial plants (usually with turbine drives) will distribute steam up to 600 psig.

Systems are designed around higher pressure distribution because of the steam volume.

High pressure distribution is used to minimize pipe sizes, and reduce the drop in pressure experienced by flowing steam.

Intermediate pressure steam is normally 60 or 80 psig. It is used for sterilizers, autoclaves, wash mixers, and pumping stations. This steam is usually generated from distribution pressure by a pressure reducing station.

Low pressure steam is normally 10 to 15 psig. It is used for heating air and water. The water heating systems are either "service" or "domestic". Domestic water is for the hot side of sinks and showers. Service water is first heated by the steam, then it circulates through coils and baseboard to heat air. It's usually mixed with glycol to avoid freezing.

Between service and domestic, most facilities use at least 50% of their steam for heating water.

Condensate system pressure is normally 0 psig. Industrial process dryers sometimes use intermediate 30 to 60 psig return systems, which then "cascade" down into a 0 psig system.

Pressure	Temperature	Sensible Heat	Latent Heat
0 psig	212°F	180 Btu	970 Btu
15 psig	250°F	218 Btu	945 Btu
60 psig	308°F	277 Btu	905 Btu
100 psig	338°F	308 Btu	880 Btu
150 psig	366°F	338 Btu	857 Btu
600 psig	486°F	472 Btu	732 Btu

Fig 4 Pressure compared to heat content

Pressure	Temperature	Volume
0 psig	212°F	27 ft3
15 psig	250°F	14 ft3
60 psig	308°F	6 ft3
100 psig	338°F	4 ft3
150 psig	366°F	3 ft3
600 psig	486°F	1 ft3

Fig 5 Steam pressure compared to volume

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Conventional Heaters

When heating air or water, the conventional control method is to use a modulating valve on the steam inlet. Its job is to throttle the steam pressure feeding the heat exchanger. By raising and lowering the pressure, the steam temperature changes in response to the sensor which controls the valve. A person could even do it manually. Just watch a thermometer in the leaving fluid. If the temperature is too high, then start closing the inlet steam valve. If it's too low, open the valve.

This is called the "feedback" method. In a storage tank or service water application it works well from a temperature control standpoint. From the steam management side, it's complicated. Also, it does not work well for domestic water heating without a storage tank.

What's the problem with conventional "feedback" control? For one thing, its very nature is "after the fact". The modulating valve only reacts after it sees a variation in outlet temperature. If that leaving water is too hot, that's too bad; it's out into the system already.

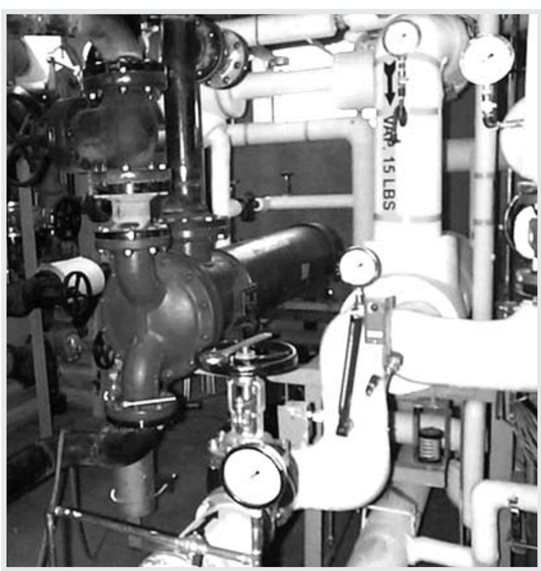


Fig 7 Complicated steam and drainage piping

The other problems can be summed up in one word... vacuum. The inlet modulating valve typically has 15 psig steam supplied to it. We often forget that this is really 30 psia steam. The modulating valve doesn't know that 14.7 psia is what we call 0 psig. It will throttle the steam pressure to whatever satisfies the temperature sensor. If it needs 200°F steam to satisfy the sensor, it's no problem. It will throttle the pressure down into vacuum, and "presto!" there is 200°F steam.

(See following appendix VACUUM)

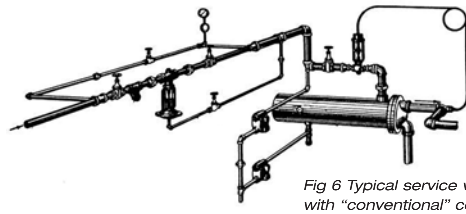


Fig 6 Typical service water heater with "conventional" control

That's where the problems start. Because the condensate return system is at 14.7 psia, the heat exchanger can't drain. Water hammer, valve hunting, and uneven control result. The solution is simple, fortunately, but the design becomes much more complicated.

The solution is to install a vacuum breaker. It sucks air into the exchanger, breaking the vacuum. The system can then drain by gravity.

That solves the problem, but three factors make the system design complicated.

- There is now air in the heat exchanger
- The pressure is very low (0 psig) and condensate is still being created
- An overhead return line can't be used without a pump

Between larger steam trap selection, air vent placement, and adding a condensate pump, the design gets expensive.

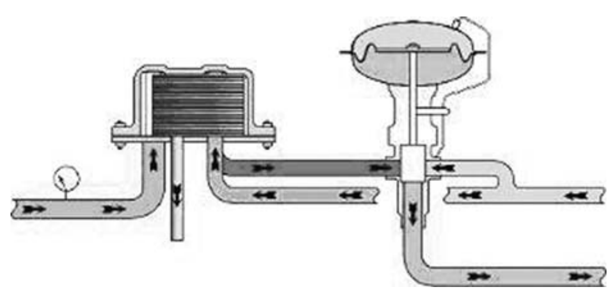
Blending Heaters

A way to address some of these problems led to the development of "feed-forward" devices. They are not suitable for "service" water applications. They need a minimum rise of 40°F to be effective, which is why they can only be used for "domestic" applications.

The temperature control is moved from the steam side to the water side. A blending valve determines how much water should flow through the heater, and how much to bypass.

The blending valve is actuated by water flow instead of a temperature sensor. The valve drops the supply pressure by about 10 psi as it functions. If water enters the heater at 60 psig, it will leave the unit at 50 psig. This solves the problem of the heater reacting "after the fact", but sets up other issues.

The first issue with "feed-forward" units is temperature. **They don't sense the water temperature**, so it is "assumed" to be constant. The unit is specially adjusted with a minimum of two separate position settings required on the blending valve. Each unit should be started by a trained technician.



Instantaneous Heaters - Technical Discussion

Blending Heaters

Seasonal variation in water supply temperature is a problem that requires readjustment of the blending valve. Recirculation systems require a second temperature sensing valve to keep the recirculation loop from cooling off.

The second issue is **minerals.** On 15 psig steam, the water residing in the exchanger during low flow can easily reach 245°F. **This higher temperature water can easily liberate six (6) times more minerals** than a heater running at 140°F. This style heater generally has water in the tubes, so plugging of the tubes is a frequent occurrence if the water is hard.

At full load, a Maxi-Therm style is designed to discharge condensate at 200°F. Compared to a conventional or a blending heater at 250°F, this saves 50 BTU's for every pound of steam consumed. Furthermore because the condensate is less than 212F, it will not create flash steam.

The third is **piping.** Any cross connects out in the system can leak cold water into the hot side, since the blending valve drops the hot water side by 10 psi. Low pressure steam is required, so a pressure reducing station is needed.

Lifting condensate to an overhead return is not recommended, so a condensate pump may be needed. Hot water can potentially work its way back into the supply, so thermal "U loops" are needed on the water side.

Maxi-Therm Vertical Design

This is a new twist on a proven design. Vertical exchangers were called "Calorifiers" years ago. They used the conventional control method with the inherent design problems.

Maxi-Therm Principle of Operation

The Maxi-Therm system uses a control valve **on the condensate side** for temperature control. This difference allows two advantages. First, high pressure steam can be used. A pressure reducing station is not needed, and steam piping is smaller and lighter. Second, the heater utilizes the latent and sensible heat of the steam.

This design means that two significantly different temperatures exist on the hot side of the exchanger. To smooth out the temperature profile of the water side, a recirculation pump moves water through the exchanger constantly. This pump is relatively high volume, and is close coupled to the water inlet and outlet. It consumes little energy since the head loss of a short loop is negligible.

When flash steam is formed, it flows up through the vent on the condensate return station. It's lost in the atmosphere through the vent pipe. In the deaerator discussion above, remember that makeup must be added, treated, and heated when flash steam is lost.

The condensate pump station behaves better with the cooler condensate. Hot condensate cavitates as the pump pulls it into the volute. The pump will sound like it's full of gravel, and the internals will wear out quickly. In addition, the unbalanced impeller wobbles and causes the shaft seals to leak.

Fig 7 Worn impeller from condensate pump

The Maxi-Therm eliminates the need for a dedicated condensate pump. The 200F condensate has high pressure behind it, so it does not need a pump. This piping is sized like a water line, so smaller and lighter pipe can again be used.

In order to deliver these benefits, the control valve on the condensate side is a vital component. Every precaution is taken to be sure it does not leak. The system is normally furnished with a temperature controlled steam regulator to prevent high water temperatures in the rare event that the control valve leaks. A steam trap is also provided to prevent a leaking control valve from discharging live steam.

Fig 6 Maxi-Therm Skid

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In summary, the Maxi-Therm steam heater has many advantages:

- Lower installed cost than other fluid heaters
- Utilize steam that is wasted by other heaters (Save 20% of energy usage at 125 psig steam, save 5.4% of energy usage at 15 psig steam.
- Smaller footprint
- No dedicated condensate pump required
- No dedicated PRV station required
- No vacuum breaker required
- Control liquid leaving temperature at ± 2F on building heat, at ± 4F on domestic
- High quality T-316L stainless steel exchanger

You can use the Maxi-Therm for:

- Domestic Hot Water
- Heating Water / Glycol for Building Heat
- Hot Oil or other Heat Transfer Fluids
- Wash Stations
- Emergency Showers
- Reactors, Pasteurizers, Jacketing

Instantaneous Heater Appendix

It is surprising to people how much steam flow is happening when a heat exchanger has no pressure for drainage. Most of us have a preconceived notion that when the pressure gage is zero... that no flow is happening. In fact, the modulating valve is delivering vacuum pressure steam when it is anywhere from closed, all the way to 60% open. Let's look at how vacuum is formed so readily in heat exchangers.

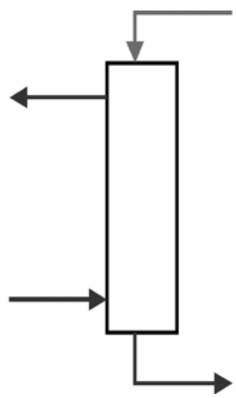
There are two calculations that engineers make to determine how much heat is being transferred through a water heater. By plotting the numbers, we can calculate the steam temperature (and pressure) when the load changes.

The first looks at the heat flowing through the tubes in the exchanger: Q = U x A x delta (across tube).

By plotting the known temperatures, we can determine the steam flow rate when the steam pressure hits vacuum.

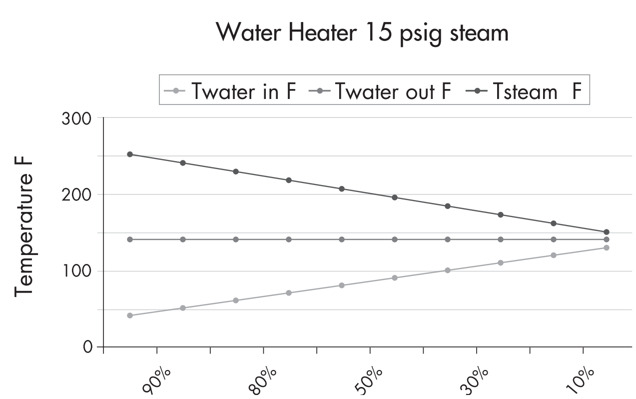
This first graph shows entering water temperature (40°F and up), leaving temperature (constant at 140°F), and the steam temperature required (variable from 250°F (15 psig steam and less)) to make the outlet temperature happen.

Average Water Temp



The second looks at how much heat the flowing fluid is picking up, by virtue of how much the temperature rises: Q = GPM x 500 x delta (water flow)

In each case the temperature difference (delta T) is the variable that is proportional to the amount of heat being transferred. The material, surface area, and properties of water don't change significantly at all.



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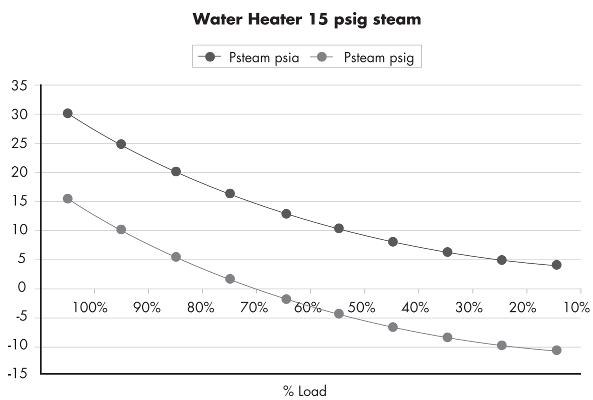
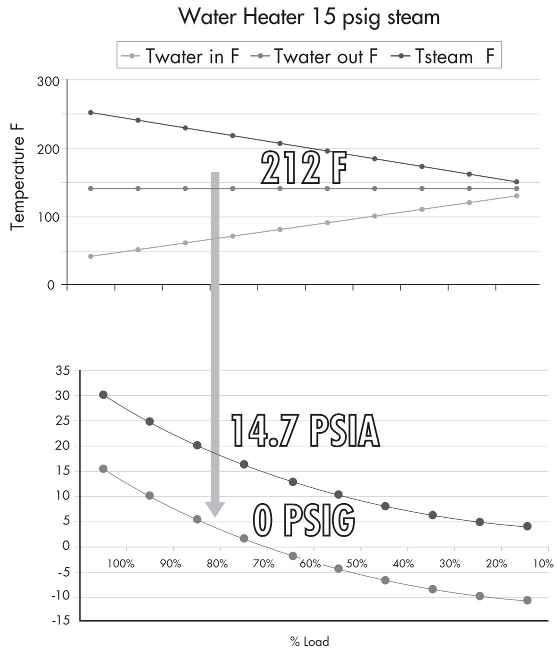
Now this is the important graph! We plot the steam pressure according to the steam temperature required in the first graph.



This is the pressure that the control valve will deliver to make the required steam temperature happen. Note that there are two curves. The first is in PSIA. It makes sense that absolute pressure drops down to zero as the valve closes. But now for the "eye-opener"... the second curve is PSIG. Note that at about 70% of full load, the required steam pressure falls below zero.

Next, let's line up the two graphs. See that as the steam temperature curve falls below 212°F, that the steam pressure also falls below zero.

Also note that the steam load is above 60%. Steam is still rushing into the exchanger and condensing, but there is now NO PRESSURE in the exchanger to push it through the trap.



We now have (essentially) a plumbing system. The "plumber's rule" says that "Water flows downhill..." If there is a lift ahead of the condensate return line, the exchanger will have flooded already.

Poor control, water hammer, corroded tube bundles are the result.

Maxi-Therm Heaters solve this problem by running the system above vacuum. If you have to run your system in a vacuum, ask us for Drawings MT – 10, 13 and 14. They show piping guidelines for trapping and piping of condensate pumps.

For more specific recommendations, to download drawings, or schedule a seminar on steam management, see our website.