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How to size a condensate return unit

Facilities with their own boiler plant almost always have a closed loop system and require condensate to be as hot as possible upon return to the boiler. Conversely, steam condensate return pumps require subcooling to prevent cavitation or condensate flashing to vapor at the pump impellers' suction eye. The degree of subcooling varies with the hydraulic design and pump characteristics.

We've previously mentioned the effect of temperature on NPSHA vs. NPSHR of the pump. Forgetting that effect when you pick a condensate return unit is a sure path to trouble. So, what do you need to know when sizing a condensate return pump?

Start with the load.

Boilers are rated to tell you how much steam they can put out, in terms of boiler horsepower, pounds per hour of steam, BTUs or other ratings. It makes sense to convert the information you get from the engineer or customer into common terms across the system. When everything is said and done, what comes back from the boiler as condensate is .000496 gpm per 1 sq ft EDR. Rounding off, the boiler puts out half a gallon per minute of water in the form of steam per 1000 sq ft. EDR. When the steam cools and turns back to water, that's the condensate you have to deal with.

Some common conversion factors:

Multiply Boiler Horsepower (BHP) **by** 34.5 **=** Lb. of steam (water per hour (lb/hr)

Multiply Boiler Horsepower (BHP) **by** 0.0069 **=** Gallons of water per minute (gpm)

Multiply Boiler Horsepower (BHP) **by** 33,479 **=** BTU

Multiply Boiler Horsepower (BHP) **by** 139 **=** Square feet of equivalent direct radiation (sq ft. EDR)

**Hoffman Specialty
Watchman WCD 30 30B-MA**

Look at the evaporation rate.

Knowing how much water, or water as steam, the boiler can put out is good, but don't pick a pump size yet. ASHRAE recommends sizing your return pump for two to three times the boiler's evaporation rate—so the return unit can return condensate faster than the boiler can put it out.

Think about it: All boilers have a marked water line and optimum steaming levels. If the boiler starts pushing out steam, and your system can return condensate only as fast as the boiler puts it out, then as the water level falls and condensate returns, you can only keep up at the lower water line…not good for the boiler. Your optimum steaming level goes out the window, and the boiler soon after. If you send extra makeup water into the boiler, you must deal with it at some point, or you'll flood the boiler when the boiler stops and the condensate plus the extra water return. Even worse, adding cold city makeup water to a steaming boiler will cause the steaming process to shut down quicker than the mouth of a toddler facing a spoonful of peas.

What about temperature? Condensate return units are designed to collect the returns and move the condensate along quickly and efficiently, minimizing heat loss and thus the energy required to heat it back to steam. With prices for light sweet crude hovering around $50 to $60 a barrel, saving energy can put a pretty penny in your pocket. So hotter is better, right?

Hold on. Remember what we said about NPSHA and NPSHR. First, when temperature goes up, NPSHA goes down. And when the NPSHR (required) of the pump is greater than the NPSHA (available) of the condensate, our old friend cavitation appears. The pennies you "saved" by making the returned condensate as hot as possible will probably go to pump repair. We'll come back to this. For now, the next step is to figure out your discharge pressure requirement.

Calculate required discharge pressure.

The required condensate unit discharge pressure includes:

- the static head lift,
- the friction loss in the piping (including pipe, fittings and valves),
- and any pressure that has to be overcome in the receiving vessel.

Manufacturers and ASHRAE generally recommend that when these values total less than 50 psi, you add 5 psi. For totals over 50 psi, add 10 psi.

This can be a daunting calculation; you have to find out how much pipe there is, what size it is, and the number of elbows, unions, etc. Don't forget the isolation valves, check valves and plug cock (see previous article on balancing). As water flows through each of these, friction slows condensate and reduces pressure.

Refer to the charts, submittals and anything else you can grab to determine the value for each of these (sometimes called or expressed as a Δp), and total it all up. The result is generally expressed in feet of head. If you're transferring back to a vented boiler feed unit, add the 5 (or 10) psi to get your required discharge pressure for the condensate unit.

But remember—required discharge pressure also includes any pressure in the vessel that you're pumping into. If that vessel is a pressurized deaerator, you have to add the maximum deaerator pressure plus the pressure drop across the spray nozzle (on some types), because that must be overcome to get condensate into the deaerator. If you're pumping directly into the boiler (a rare and less desirable option that we'll discuss in another article), add the maximum boiler pressure.

Determine condensate return temperature.

So, we now know what size pump by gpm, and what discharge pressure to size for. As we mentioned earlier, temperature's effect on NPSH can affect which unit you pick. That means you need to determine condensate return temperature—not an easy task. If you're selecting a new unit for an existing system, you can measure the temperature of the actual condensate at your desired recovery point. But for a new or redesigned system, you have to make the calculation before you actually turn on the system.

The return temperature matters because hotter means less NPSHA, and some pumps don't like that. The hotter the water, the more limited the choices. Most pumped condensate return units operate from a vented tank. Remember, steam heating applications using thermostatic traps drain condensate around 160 to 180 degrees. At 180 degrees, a condensate pump mounted to a collection tank at the same level as the pump will have about 15 feet of NPSHA in the water. Most pumps handle this from a vented tank with no problem. But if the trap fails, and the temperature in the condensate tank rises to 212 degrees f., there is zero NPSH available. NPSH is still required, however, because it's a function of the pump design. Having some NPSH **required** vs. no NPSH **available** is a problem at 212 degrees: The pump that could discharge condensate at 180 degrees will now cavitate.

Domestic® Pump Series CB

See how this changes things? Up to about 200 degrees, a standard centrifugal pump design generally works if properly sized for the duty point and NPSHA. From 200 to 210 degrees, you need more specialized (and somewhat more expensive) low NPSH pumps. From 210 to 212 degrees, about all you can do is move the tank above the pump to add NPSHA, in the form of a static column of water above the pump suction. That's right, raising the tank provides additional NPSHA and lets you pump hotter water. Why not raise the tank even more? Because that takes more material, which costs more money, erasing the savings. Besides, return piping is seldom located high in the equipment space. It's a matter of picking the right tool for the job.

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Consider condensate tank sizing.

You usually want one minute net storage in a condensate tank; remember, the sooner you collect and return condensate, the less heat it loses and the less energy required to heat back to steam. Keep in mind that "one minute of net storage" refers to one minute of pumping capacity in storage. If you size for one minute of return rate, the tank is undersized and forces the pump to short-cycle. That accelerates on/off frequency as well as the wear on the pump.

Putting it all together. You know the boiler can put out half a gallon per 1000 sq ft EDR per minute. Sizing for two times that to get the pump capacity means sizing your pump for 1 gpm per 1000 sq ft EDR. Let's apply that to some typical boiler sizes.

For a boiler rated 100 BHP: Use the formula above to convert boiler horsepower: BHP X 139 = sq ft EDR. 100x139=13900. When you calculate the amount of steam put out, you get 6.9 gpm of water as steam. Let's round that up to 7 gpm. Sizing the pump for twice the return rate means we'll size for 14 gpm. Now apply the 1 gpm per 1000 sq ft EDR rule of thumb. Sizing the tank for the pumping capacity based on one minute net storage, you need a tank that is 14 gallons. If the manufacturer you use doesn't offer a 14-gallon tank, choose the nearest size—but beware: In this example, a tank smaller than 14 gallons will not only collect condensate quicker and pump it back to the boiler hotter, but also lack the mass to provide the degree or two of sub cooling required to address NPSHA issues. Going smaller can also set the pump up to short cycle. It's better to go to the nearest larger size than your 1 minute storage—in our example, 15 or 18 or 20 gallons.

The right equipment matters.

Before the mid-1970s, most manufacturers sized for three times the boiler's evaporation rate. Bigger was better—and boy, what a safety factor! Sizing for three times the evaporation rate meant the pumps were sized for 1.5 gpm per thousand square foot EDR. But when oil shortages hit the United States, and people lined up around the block to buy a tank of gasoline, and the cost of making steam rose, manufacturers gradually moved to sizing for two times the evaporation rate.

You can see how that makes a difference. A 15,000 sq ft EDR system puts out 7.44 gpm of condensate as steam. Sizing for twice that, you need a 14.88 gpm pump. Sizing for one minute net storage leads you to a 14- to 15-gallon collection vessel. In the Domestic/Hoffman pump products, you'd choose a 15 gpm unit with 14-gallon tank and, if you're looking at a 20 psi requirement, the hp in 3500 rpm is 1/3 HP. Compare that to sizing for three times the evaporation rate. You're forced to go to a 22 gpm pump and 23-gallon tank, and the HP increases to 1/2 HP. You end up with a bigger, more expensive unit. What's more, since the evaporation rate doesn't change, the condensate sits there longer until enough is collected to be pumped, giving up heat (energy) that has to be added back in at the boiler. The pump comes on less frequently, but the 1/2 HP pump costs more in electricity to run than the 1/3 HP pump.

That wraps up our tips on sizing condensate units. Watch for a future article on sizing boiler feed units—similar to the above, but with important differences.

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Ten Reasons Steam-Heating Boilers Flood

Having problems with that steam-heating boiler's water line? Is that boiler constantly flooding? And does that make your customer complain about not having enough heat?

Before you get mad at the automatic water feeder, look at what may be causing the flooding. Good troubleshooters never make decisions until they've examined all the clues.

Here are 10 common reasons steam-heating boilers flood.

1. The water line surges, turning the automatic water feeder on and off. Surging begins when dirt and oil accumulate on the boiler water's surface. As the steam tries to break free, it lifts the water, creating the surge. You can see this in the gauge glass. Since steam systems are open to the atmosphere, you occasionally need to clean them. Get rid of the surging, and you usually get rid of the flooding.

WFE UniMatch Water Feeder

2. The water's pH is too high. When steam condenses, it produces carbonic acid that can eat through wet-return lines. So service technicians often add chemicals to steam boilers to keep the pH from getting too low. But it can be just as bad if the pH gets too high; that causes foaming, and foaming leads to trouble. Too much water flows from the boiler with the steam. That water loss sends the automatic feeder into action. Then the condensate returns, and the boiler floods. A good pH for a steam system ranges from 7 to 9. When the pH reaches 11, the water foams. The old-timer's cure? Add vinegar to the boiler. Vinegar is acidic and helps bring the pH down.

3. The boiler has a tankless coil, and it's leaking. City water pressure is greater than the pressure in a steam heating system. Even the smallest leak in a tankless coil will flood a boiler. Close the cold-water valve leading to the coil for a few hours and watch the gauge glass. If the flooding stops, you've probably found the culprit. Replace the tankless coil.

4. The system has a gravity return and motorized zone valves. When a motorized zone valve closes on a boiler that's under pressure, the water backs into the closed zone's return line. That brings on the automatic water feeder. The next time the motorized zone valve opens, the condensate returns and floods the boiler. Install quarter-inch bleed lines around the tops of the motorized zone valves. This lets through enough pressure to keep the water from backing out of the boiler, without letting through so much steam that the zone overheats.

5. The boiler is overfired. If the flame is too big, the steam's exit velocity carries water from the boiler into the system. The automatic water feeder then replaces the "missing" water. When that water works its way back into the boiler, the boiler floods. Fire boilers to the connected piping-and radiation load. No more, and no less.

6. The automatic water feeder is positioned too high on the boiler. Some installers try to cover a tankless coil during the summer by adding nipples and elbows to the McDonnell & Miller Quick-Hook-Up fitting. That causes the feeder to sit too high on the gauge glass.

Normally, the feeder should open when the water line drops just above the low-water cutoff's operating position. But if the feeder is too high, so is the low-water cutoff. That means the feeder will add too much water, and the returning condensate will flood the boiler every day.

7. The feed line is clogged with sediment. If you're using a float-operated feeder/cutoff combination, such as McDonnell & Miller's 47-2, a plugged feed line can create a back-pressure that keeps the feed valve from shutting tightly. City water pressure will bleed through and flood the boiler. You can diagnose this problem by doing a broken-union test (see M&M's instructions). If you find a plugged feed line, replace it.

8. The feeder-bypass valve isn't holding. The bypass around the feeder lets you fill the boiler quickly. But if the shutoff valve in that line doesn't hold tightly, the boiiler keeps taking on water until it floods. Again, the broken union test lets you quickly see whether that important valve is doing its job. If it's not, replace it.

9. The piping around the boiler doesn't meet the boiler manufacturer's specs. Modern boilers make steam quickly . If the piping around the boiler is wrong, the boiler throws water into the piping. The automatic water feeder then replaces that water—and before long, the boiler is flooded. Take the time to check the piping on the job against what the boiler manufacturer calls for. If it doesn't meet the specs, you have to repipe that boiler. Tough medicine, but it's often the only cure.

10. Someone is adding water when you're not there. Never dismiss this as a possible cause. If someone adds water to the boiler in the middle of the steaming cycle, the returning condensate will push the water level even higher, and the boiler will flood.

Talk to the homeowner or building superintendent. Make sure they understand how a steam system works, and what it needs in the way of feed water.

Remember:
Your McDonnell & Miller representative is always willing to help you solve your steam heating problems. Call them next time you need help.

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