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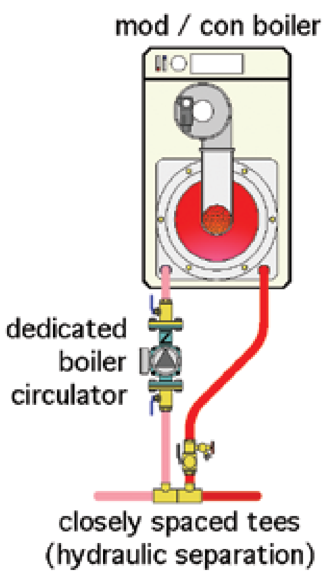
Trade-offs

Two boiler characteristics that need to make a comeback.

Figure 1



North American hydronic professionals can now choose from dozens of modulating/condensing (mod/con) boilers. Many are designed for wall-mounting. Those who design these boilers strive for small enclosures and low weight. After all, who can't appreciate a boiler that one installer can lift onto wall brackets, compared to the struggle required to move a 400-lb. boiler down a set of basement stairs?

To make boilers small and light, the heat exchanger in them has to be small and light. This can be done several ways using materials such as stainless steel, aluminum and copper. The results can be impressive. Imagine a heat exchanger that can move 100,000 Btu/hr. from combustion gases to water, while weighing only a few pounds and taking up less space than some of those three-ring product information binders sitting on your office shelves.

Unfortunately, many of these heat exchangers had to sacrifice two very desirable qualities in the interest of being small and light.

One of those qualities is low head loss. Those who have installed cast-iron sectional boilers know that pumping several gallons per minute through them doesn't require a dedicated circulator. The same circulator that drives flow through a zone, or the coil of an indirect water heater, also can move adequate flow through such a boiler.

The head loss of sectional cast-iron boilers is typically so low that some suppliers don't bother listing it along with corresponding flow rates in their technical specifications. When I asked about this, one manufacturer suggested treating the head loss of its cast-iron boiler as if it were equivalent to three 90° elbows of the same size as the boiler connections.

For a residential boiler, this would be equivalent to about 12 ft. of 1 1/2-in. pipe. The equivalent head loss at a flow rate of 10 gpm would be about 0.1 ft. The electrical power required to drive 10 gpm through this boiler, assuming a standard wet rotor circulator with 22% wire-to-water efficiency, is about 0.8 watts. To put that in perspective, a standard incandescent night light bulb operates on about 4 watts.

Too bad that many current-generation mod/con boilers can't make the same claim. Instead, some boiler manufacturers specify use of a dedicated boiler circulator requiring from 80 to 200 watts. This circulator is installed between the boiler and some form of hydraulic separation, such as a pair of closely spaced tees as shown in Figure 1.

The sole purpose of this circulator is to create flow through the boiler. Other circulators are required to create flow through the distribution system.

So watts the big deal?

Consider a circulator that operates 3,000 hours per year and requires 100 watts when running. Assume the current cost of electricity is \$0.12/kWhr. The first-year operating cost will be:

$$100w\left(\frac{3000hr}{yr}\right)\left(\frac{1kwhr}{1000whr}\right)\left(\frac{\$0.12}{kwhr}\right)=\$36$$

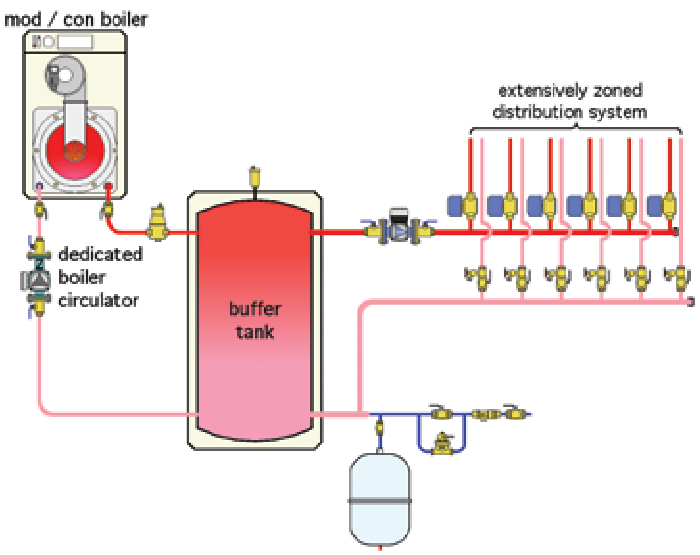
Now assume that circulator lasts 20 years and the price of electricity inflates by 4% each of those years. The total operating costs over 20 years (TC) would be:

$$TC=C_1\left(\frac{(1+i)^n-1}{i}\right)=36\left(\frac{(1+0.04)^{20}-1}{0.04}\right)=\$1,072$$

If it's a 200-watt circulator, just double these amounts.

The total cost of having this circulator in the system is the estimated operating

Figure 2



cost plus the cost to purchase, install and maintain the circulator. Factoring in labor, accessories such as isolation flanges, closely spaced tees, tube stubs, fittings and wiring, even a small dedicated boiler circulator is likely to cost $400 to $500 installed.

These costs go away if the circulator goes away. The circulator goes away if the head loss goes back down to where it was with cast-iron sectional boilers. We need hydronic heat sources that retain the high thermal efficiencies of mod/con boilers but present very little head loss and thus enable designers to eliminate dedicated boiler circulators.

This can be achieved by using heat exchangers with lower head loss characteristics or going to tank-type heat sources, where the water passes through relatively large spaces at very low flow velocities and very low head loss. I have seen positive signs of this transformation in the North American market over the last three years. Thanks to those who have recognized the need for this and please keep up the efforts.

Had it, lost it

Another desirable characteristic of many older boilers is that they are self-buffering. The thermal mass of a cast-iron boiler heat exchanger weighing 400 lb. and containing 10 gal. of water is 14 times greater than that of a 5-lb. stainless-steel heat exchanger holding 1 gal. of water. That higher thermal mass helps prevent burner short-cycling when only one or two zones are active.

In making boilers small and light, most of the metal and water content that made older boilers self-buffering went away. The result: Connect almost any compact mod/con boiler to a highly zoned distribution system and you're likely to get times when the burner short-cycles.

This happens even with boilers that can reduce their heat output by a factor of five. All it takes is a small zone calling for heat on a relatively mild day. The boiler simply can't dial down its output low enough to match the heating requirement. The situation is only made worse by boiler oversizing.

The industry's common solution to this has been to add mass in the form of an external buffer tank. The tank often sits between the boiler and distribution system as shown in Figure 2.

This approach works but obviously adds significant cost and likely requires more floor space than one of those older self-buffering boilers.

Why not add the mass back to the heat source? Preferably as water added once the boiler is in place, rather than metal added at the factory. Incorporate a small mass tank as the anchor component in combination with a low-mass modulating/condensing burner assembly. This is the approach I have seen used on many residential hydronic-heating appliances sold in Europe. The physics works just as well on this side of the pond.

Double duty

One of the benefits of incorporating sufficient thermal mass in the heat source is that it can buffer both highly zoned space-heating loads as well as small draws of domestic hot water. The latter eliminates the need for the burner to fire each time a hot water faucet is opened for a short draw. The system shown in Figure 3 illustrates a common configuration.

In this heating appliance, a small, well-insulated tank holds 20 to 30 gal. of water. Heat is added to the tank by a very low-mass modulating/condensing burner assembly mounted above the tank. The tank temperature is maintained high enough to fully heat domestic water making a single pass through a generously sized stainless-steel heat exchanger coil.

Figure 3

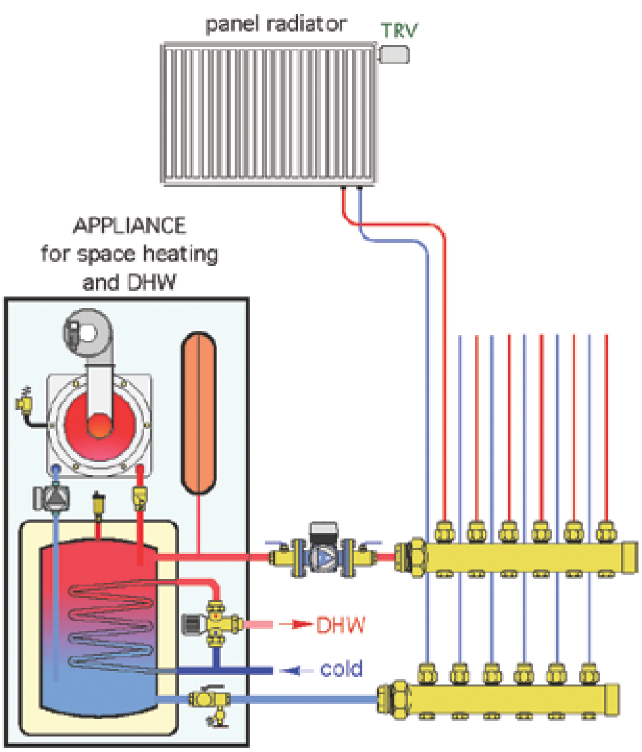


Figure 4

A thermostatic mixing valve protects against the possibility of water being delivered to fixtures at temperatures that could cause burns. The orange component within the enclosure is a pancake-type expansion tank.

Figure 4 shows a European product that uses this approach. You can see the small tank at the bottom of the unit. The tank has been cut open to show an internal heat-exchanger coil for heating domestic water.

Adding thermal mass to the heat source is a simple solution for space heating and DHW.

This heat source provides the thermal efficiency of a mod/con burner, the very low head loss of a tank-type heat source and the thermal stability of a self-buffering heat source. It's a simple solution for space heating and domestic hot water.

The distribution system is as simple as a variable-speed, pressure-regulated circulator supplying a manifold that in turn supplies home-run piping circuits to panel radiators. Each panel radiator is equipped with a wireless thermostatic valve, which allows room-by-room temperature control. It doesn't get much simpler than this.

We need more products such as this in North America.

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