"The Ultimate Gas Fired Heat Source"

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A critical notion if hydronic technology is to maintain a leading role in residential construction.

If you're like me, you've probably worked with a wide range of hydronic heat sources on various projects. In some cases, the choice was limited by the availability or local cost of fuels. In others it has been "mandated" by the owner. Today, the options have been influenced by the desire to operate the system, at least in part, from renewable energy sources. One of the delights of working with hydronics is the flexibility to select heat sources that accommodate all these constraints and preferences.

Have you ever pondered — what is the ultimate hydronic heat source? Does our industry already have this heat source, or are there still details and characteristics that would further improve current heat sources?

This month I'll offer up some opinions on this question, and support them with concepts that are imperative if hydronic technology is to maintain a leading role in future residential and light commercial buildings. I will limit the discussion to heat sources that operate on gas (natural gas, propane or perhaps a future "biogas" blend).

Most Wanted

To me, the ultimate gas-fired heat source must have five characteristics (in no particular order of importance):

1. High combustion efficiency. In low-temperature applications, gas-fired hydronic heat sources must continue to provide combustion efficiencies in the low- to mid-90-percent range. In systems with medium design supply water temperatures (120-150 degrees F), the heat source should maintain efficiencies in the high 80s to low 90s. It should also have a built-in outdoor reset control to reduce supply water temperatures and encourage condensing mode operation whenever possible.

2. Low head loss. Many boiler manufacturers, both here and abroad, apparently view dedicated boiler circulators as a necessary compromise when building a compact, condensing boiler. That compromise was not necessary in most previous-generation cast-iron and steel boilers.

Perhaps we've thrown away something we really shouldn't have. I believe the industry needs to re-examine the energy use associated with pushing water through the heat source. Here's why:

Consider a typical 200-watt boiler circulator that operates 3,000 hours each year. In an area where electricity currently costs 12 cents/kwhr, the current annual operating cost of that circulator can be estimated as:

$$\text{annual cost} = 200\text{watt}\left(\frac{3000\text{hr}}{\text{yr}}\right)\left(\frac{1\text{kwhr}}{1000\text{watt}\bullet\text{hr}}\right)\left(\frac{\$0.12}{\text{kwhr}}\right) = \$72/\text{yr}$$

If the cost of electricity is assumed to inflate at 4 percent per year, the total operating cost of this circulator over a 20-year design life is $2,144! This is in addition to the cost of installing the circulator (probably around $500), and any maintenance that might be required. Is this additional $2,600 (and the associated carbon footprint if you're into that frame of reference) justified for the sake of a compact heat exchanger?

We can do better. Why not retain the high thermal efficiency of a condensing-capable system, but design the heat exchanger for significantly lower head loss? Low enough that there's no need for a separate boiler circulator.

3. Low standby heat loss. All hydronic heat sources spend time full of heated water with their burners off. Ideally, they should act like thermos bottles under such conditions. Higher levels of insulation are needed to reduce standby heat losses to a small fraction of a degree per hour. Heat traps should be included to stop thermal migration to connected piping. Remember, the goal of a hydronic system is to deliver heat when and where it's needed, not to overheat the mechanical room.

Extraneous heat loss from heat sources and distribution equipment needs to be seen as a priority in future product design. Manufacturers can choose to ignore this, pointing out that their competitors don't seem to be concerned about it. Or they can seize the current opportunity to promote an ultra-low heat loss feature to "green-savvy" consumers.

4. Thermal mass. Modulating burners help match the output of a heat source to the load, but they don't eliminate short-cycling in systems with many small-capacity zones. Consider, for example, a homerun system serving several panel radiators with individual thermostatic valve controls. Such systems are well-suited to low-energy-use homes, especially those with passive solar gains. Unfortunately, this type of distribution system can lead to short-cycling of low-mass boilers, even those with only 50,000 Btu/hr. heating capacity. The solution is to add thermal mass to help moderate between heat production and heat release. The ideal thermal mass is more water between the burner and the distribution system.

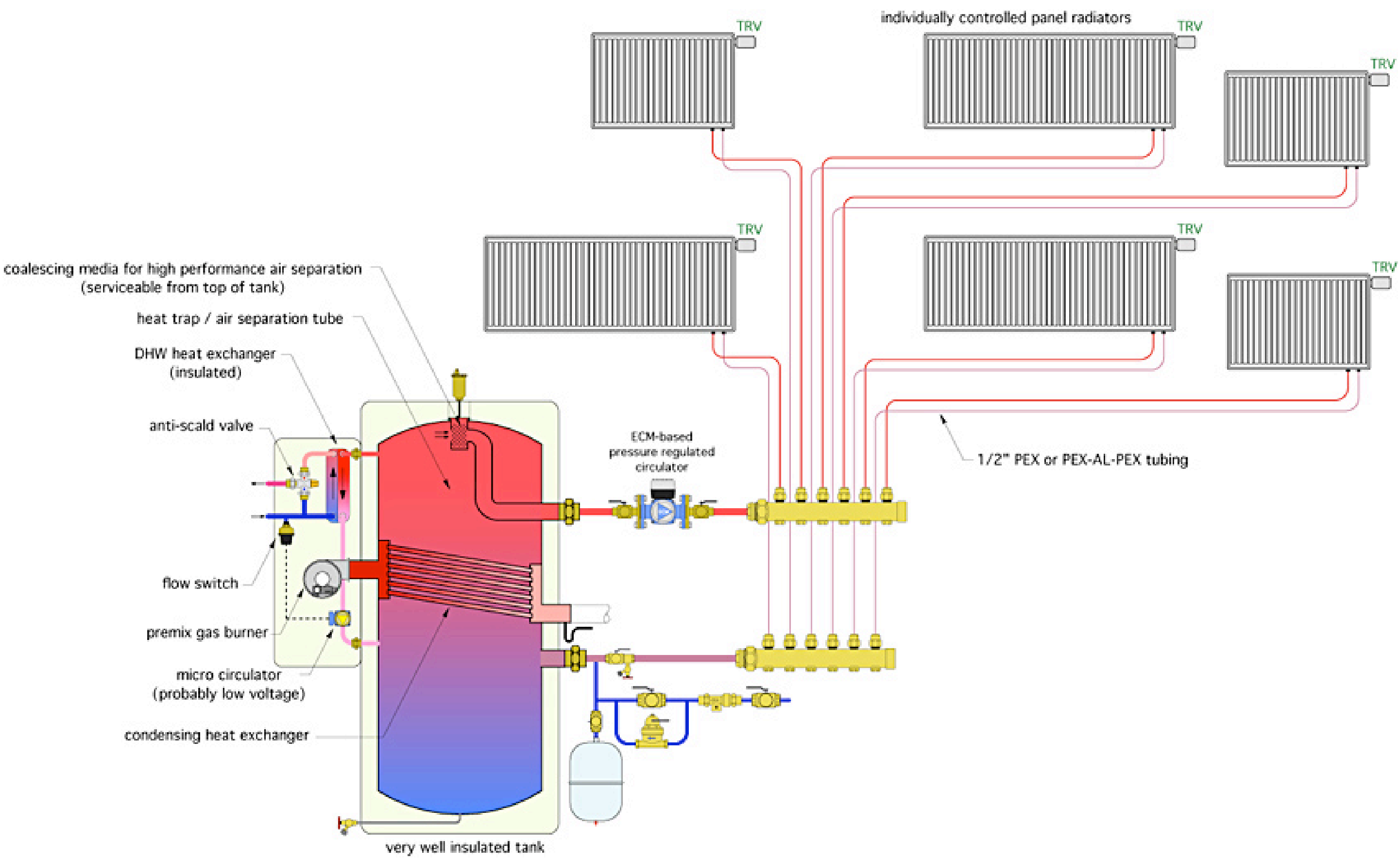
5. Minimum 20-year design life. It's not uncommon for properly installed cast-iron boilers to last well beyond 20 years. Some even go 40 years or more. Given the accelerated pace of technology, it's likely such boilers will be obsolete, or fail to meet some future government-mandated efficiency or emissions standard, before they are literally "worn out." Very few other appliances come close to such life expectancies. This feature has been, and should remain, a significant selling advantage of hydronic systems.

Today, there's increasing concern that some current generation mod/con boilers, and their current venting systems, will fall far short of a 20-year average life. I hear speculation about 10- to 15-year life expectancies, and it's often backed up by very plausible observations. Obviously these products have not been around long enough in the North American market to build a good statistical database on life expectancy. However, with increasing emphasis on "green" and "sustainable" systems, it seems contradictory to promote products with shorter life expectancies than what our industry was cranking out half a century ago.

Part of achieving a 20+-year life expectancy is designing the heat source for easy servicing. Another part, one that's likely to increase cost a bit, is using heavier-duty components and high-grade alloys, especially for components exposed to acidic condensate. Some may flinch at the higher cost part, but 10 years from now I sincerely hope our industry is not looking back at a very disappointing "should of/could of" scenario.

Form Factor

Figure 1



To achieve these characteristics, the ultimate gas-fired heat source will likely take the form of a well-insulated storage tank, coupled with a modulating burner and heat exchanger assembly. Figure 1 shows a concept for such a device. In this case, it serves a homerun distribution system supplying panel radiators. Flow through the heat source is handled by the small variable-speed, pressure-regulated circulator that powers the distribution system. In a residential system, this circulator would typically operate in the range of 10 to 50 watts, depending on the flow. That's it — for the entire distribution system!

A coalescing media mounted in the flow tube within the heat source provides high-performance air separating, and eliminates the need of an externally mounted air separator. This coalescing media is serviceable from the top of the tank.

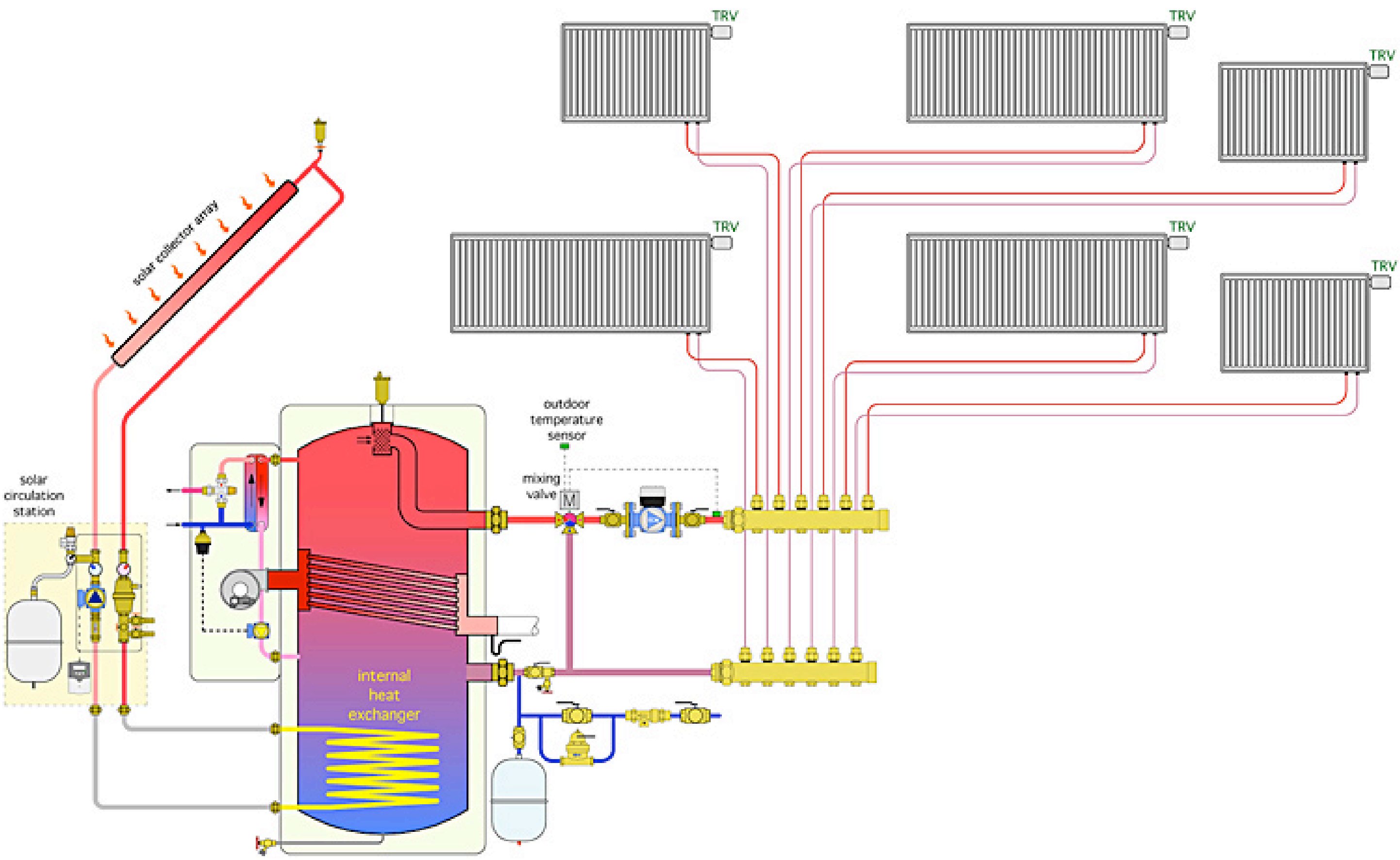
Domestic water would be heated instantaneously within an external brazed-plate heat exchanger mounted within an insulated shell on the side of the heat source. Keeping the DHW heat exchanger outside the heat source allows for easy serviceability in cases where local water might scale or otherwise compromise the heat exchanger over time. This approach also minimizes the stored volume of DHW, and thus minimizes the potential for Legionella growth.

A flow switch detects domestic water flow as soon as a fixture is opened and turns on a very low wattage "micro-circulator" (probably less than 10 watts) to move water from the heat source through the heat exchanger. Cold water is heated instantly as it flows through the heat exchanger. The mass of heated water in the upper portion of the tank stabilizes DHW delivery. A thermostatic tempering valve protects against scalding.

The burner operates as necessary to maintain the top of the heat source at a suitable temperature for domestic water heating — whenever that service is deemed necessary, which is not necessarily 24/7. These temperatures are well-matched to several types of radiant panels as well as generously sized panel radiators. At times when no domestic water service is needed, or in systems that provide space heating only, the burner would operate based on outdoor reset logic. This maximizes the condensing potential of the internal heat exchanger and, thus, maximizes thermal efficiency.

Since this is a closed-loop system, the storage vessel could be carbon steel rather than stainless steel. It would be very well-insulated; probably 3 to 4 inches of polyurethane on all surfaces. There might even be some lightly loaded spring check valves, or thermal breaks on piping connections to reduce heat migration to piping. The head loss through the heat source would be extremely low. I estimate that less than 1 watt of pump input power would be required under design load conditions.

Solar Ready
Figure 2



This design allows the option of having a lower coil for input from an alternative heat source such as an array of solar collectors or a wood-fired boiler (see Figure 2). An external heat exchanger for such heat input is another possibility.

When an uncontrolled, or partially controlled, alternative heat source is added to the system, a mixing device should also be installed in the distribution system to protect against potentially high temperatures within the heat source.

This concept for the ultimate gas-fired heat source is simpler than many current generation gas-fired boilers. It consolidates functionality that's often accomplished through use of separate, field-assembled components. The thermal mass of the heat source makes it virtually immune to changes in distribution system flow rates, and thus ideally matched to variable-flow distribution systems powered by modern high-efficiency ECM-based circulators. In effect, the heat source is "self-buffering" just like the high-mass boilers of yesteryear.

Look around. There are already products on the North American hydronics market that come pretty close to this concept for the ultimate gas-fired hydronic heat source. I think there's room for more.

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