Features, Advantages of Condensing Boilers

How new-breed boilers are simplifying hydronic-heating-loop design

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Much of what characterizes "traditional" hydronic-heating-loop design—greater-than-140°F return-water temperatures, conservative 20°F ΔT, primary/secondary piping, temperature control at terminal units, ducting and venting accommodations—has been strongly influenced by the operating limitations of gas-fired boiler equipment. This article will discuss how a new breed of boiler is challenging conventional practices and supporting new approaches to improve the cost and energy efficiency of hydronic heating loops.

INCREASED EFFICIENCY

Conventional hydronic-heating-loop design practices represent an interrelated effort to prevent direct-fired boilers from condensing in heat exchangers.

Condensation occurs when water vapor within a boiler's combustion gases falls below its dew point and is forced into a liquid state. Releasing approximately 1,000 Btu of heat for every pound of liquid created, this change of state occurs naturally—as a result of exposure to a cool heat-exchanger surface—when lower-than-135°F return water enters a boiler.

Though desirable from a system-efficiency perspective—as much as an 11-to-12-percent increase is possible—condensing operation can be damaging to conventional boilers. When latent energy is extracted from water vapor, acidic condensate will be left behind on the surface of heat exchangers. Unless built from the highest-quality materials and designed to drain freely, a heat exchanger will corrode over time. With non-condensing equipment typically manufactured from lower-quality materials (copper, cast iron, carbon steel, etc.), system designers must rely on ancillary components, such as dedicated boiler pumps, mixing valves, and temperature-averaging components, to pre-warm entering water to above 140°F.

Today's high-efficiency boilers are engineered to condense. Their heat exchangers are made of high-quality materials and designed to drain freely, which allows them to withstand years of condensing operation with no significant corrosion. Some equipment even can withstand thermal shock caused by rapid temperature changes. Consequently, condensing equipment can be incorporated into a main loop directly. Without piping, pumps, mixing valves, and other components historically used to protect boilers from cool return water, condensing boilers simplify hydronic loops and reduce project and maintenance costs.

IMPROVED COMFORT AND CONTROL

Conventional boilers operate with an on/off temperature switch (aquastat) or a somewhat crude temperature controller providing a modest (3-to-1, 2-to-1) burner turndown. As a result, calls for heat are met with the full (or nearly full) capacity of a boiler sized for peak design-day conditions. This causes a boiler to cycle on and off and can lead to valve hunting and poor temperature control at terminal units. Consequently, engineers design systems to reliably handle a 10°F-to-20°F variance in supply-water temperature, while customers see higher-than-necessary seasonal fuel bills.

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Another drawback of on/off operation are the cycling losses incurred each time a unit shuts down. Heat exchangers cool and must be fully "re-heated" before heat transfer can begin. Also, once a unit re-starts, its 100-percent firing rate may be far more than what is required to meet a building's load. In contrast, today's high-efficiency boilers typically feature full modulation (burner turndown) at ratios as high as 20-to-1. Not only does such smooth and constant operation maintain temperatures within a heat exchanger, firing at reduced input increases the time combustion gases are in contact with heat-exchanger surfaces, promoting greater energy transfer and cooler exhaust gases. Fully modulating boilers typically feature an inverse efficiency curve (Figure 1), performing best at lower loads. With the majority of a boiler's operating hours under "part-load conditions," fully modulating units promise greater seasonal efficiency.

The highest-efficiency boilers combine accurate temperature control with high burner turndown to precisely and cost-effectively match plant output to heating demand. These boilers may use a PID controller to maintain supply-water temperature to within ±2°F. After load and temperature requirements are determined, these PID controllers modulate high-turndown burners in 1-percent increments. This allows boilers to change input/output to match load exactly. There is no temperature overshoot, and these boilers can operate over their entire range in a matter of seconds. Such high turndown, coupled with latent energy recaptured during condensing, can generate as much as a 30-to-40-percent increase in efficiency, compared with conventional hydronic systems.

Fully modulating products typically are more fuel-efficient at part load. While a boiler plant consisting of five 2-million-Btuh units, each with 20-to-1 turndown, can deliver 100,000 to 10 million Btuh, it requires less fuel when all five units are operating at 60 percent of capacity to meet a 6-million-Btuh load than it does when just three of the units are operating at 100 percent. Such part-load efficiency can be leveraged even further with a boiler-management system (BMS). In some cases, both a BMS and individual unit controllers provide access to comprehensive operating information to support advanced energy-management programs, allowing system designers to leverage indoor/outdoor-reset schedules, remote set points, and even full integration into building-automation software to maximize fuel savings.

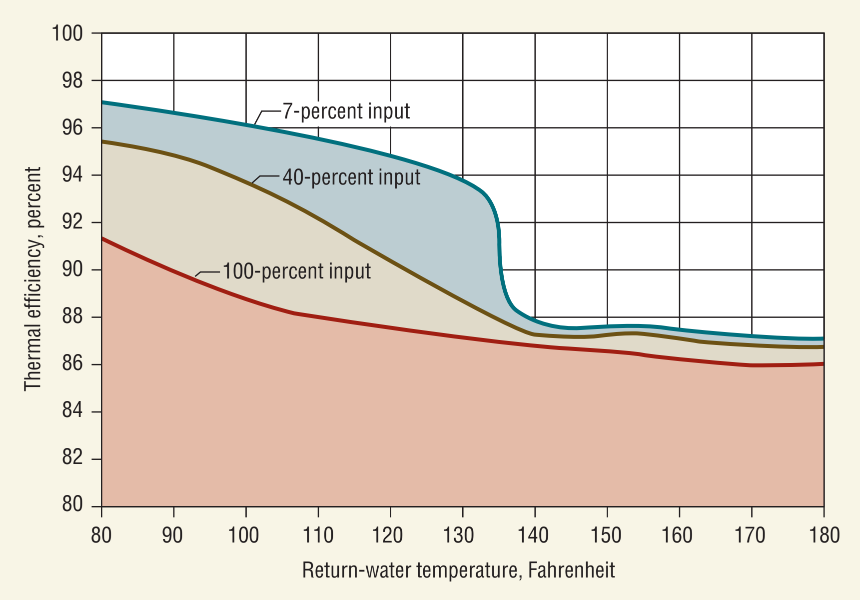

FIGURE 1. Inverse efficiency curve.

SAVING SPACE

Setting aside adequate building and mechanical-room space to support conventional boilers has been a long-standing challenge of building design. While the emergence of modular equipment has helped, there still are significant material and construction expenses associated with the atmospheric intake ducting, natural-draft exhaust venting, and fixed-flow pumping requirements of conventionally designed boilers.

Today's high-efficiency boilers offer a variety of venting options. Units can be common-vented through a ceiling or individually vented through a sidewall, with the forced-draft design of some equipment able to dramatically reduce the length and diameter of flue runs. This translates to reduced project costs and more "usable" building space. Even within the confines of a mechanical room, most equipment is doorway sized, with a small installed footprint. The ability to support variable flows (and withstand no-flow conditions) eliminates the need for dedicated pumping equipment, saving both money and space.

CONCLUSION

This article examined some of the traditional weaknesses of hydronic-system design. When condensing, fully modulating, intelligent boilers are inserted into loops, systems are simplified and produce better results.

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