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Optimizing Efficiency WITH Multiboiler Systems

Heat when it's needed, energy savings when it's not

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With the current strong emphasis on energy conservation, there is a great deal of interest not only in selecting the most energy-efficient products, but properly applying them to obtain the greatest energy savings. Multiple-boiler systems are very helpful in achieving this goal.

Multiple-boiler systems can be optimized with the selection of low- mass boilers, primary/secondary pumping, variable flow, and hybrid boiler systems. One of the more significant advantages of multiple-boiler systems is the fact that only the required capacity need be online at a given time. Peak heating-season loads occur a very small percentage of the time—typically, 5 percent or less. The rest of the time, the load is less than peak, and most of the time the load is less than 50 percent. Thus, if we use a four-boiler system as an example, one or two boilers will carry the load for most of the season.

During those times, two to three of the four boilers can be unfired. For best results, these standby boilers should be isolated from the circulating system. The easiest and most energy-efficient way to achieve this is to use a primary/secondary piping system in conjunction with low-mass, high-recovery boilers. Load matching that tracks rapid climate swings (shifting to or from condensing-boiler lead mode) can be virtually instantaneous when high-recovery boilers are utilized. The reason to decouple inactive boilers from a primary system loop is that if they are kept online or in the loop they will be wasting heat continuously. Consider that even a high-quality thermos bottle filled with hot coffee eventually will get cold. That means it is losing heat, just as all boilers filled with hot water will, regardless of insulation. The more water stored in a boiler, the greater the loss. And the worst energy waste is to continue flowing water though a standby boiler that does not need to be online. Knowing that the heat in a boiler will be lost when it goes offline, it follows that having less heat in the boiler is highly desirable. This is the case with low-mass, high-recovery boilers. These boilers are ideally suited for taking advantage of savings that can be gained by decoupling them from a system when in the "off" mode, because there is a very small amount of British thermal units to be lost per cycle.

High-mass, low-recovery boilers also will lose heat stored in them each time they are decoupled—but they will lose more of it. When not decoupled, which often is the case in a primary-loop-only system, they will lose heat continuously. Beyond that, high-mass boilers frequently are kept hot the entire heating season to prevent thermal shock and long restart delays. The simple solution for decoupling an unfired boiler is primary/secondary pumping. When done correctly, there will be no flow in the boiler when its dedicated pump is off. You also will save the pump energy that would be needed to pump water through the unfired boiler.

In primary-only pumping designs, the primary pump must be sized large enough not only to pump the system, but all of the boilers in that system. In primary/secondary systems, the primary system pump is sized for the system only and will be considerably smaller than a primary-only pump. The energy draw of a large system pump often exceeds the combined draw of a smaller system pump and much smaller boiler pump(s), especially during lighter loads, when some of the boilers are off much of the time.

Other advantages of multiple-boiler systems include redundancy and the ability to service a boiler without interrupting system operation. Right sizing is more attainable and provides backup without excessive oversizing when more than one boiler is utilized. A multiple-boiler system also offers greater turndown capability for variable-flow systems than does a typical single-boiler system with higher minimum-flow re-

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quirements. Variable primary flow can be applied in both primary and primary/secondary systems to minimize electrical power consumption. It takes more heat (and, thus, more water flow) to meet peak loads. It is not necessary to pump at that same flow rate all year when it only is needed for the 5 percent peak-load period. However, there are practical minimum acceptable flow rates for any variable-flow system. Hydronic engineers historically have suggested minimum flow velocities not less than about 1.5 fps. Lower velocities increase the potential for air locks. This is especially true in parallel loops, where all of the flow may go into only one loop.

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A hybrid variable-primary-flow system with wall-mounted sequencing controller plumbed for primary/secondary pumping using one condensing boiler and two non-condensing boilers.

The practical flow turndown ratio in a variable-flow system is about 5:1. With care, system designs with higher turndowns may be possible, but greater turndown ratios generally do not achieve significant enough advantages to make them worthwhile. This 5:1 flow turndown is achievable only if the minimum flow velocity of 1.5 fps and maximum flow velocity of 7.5 fps are the design parameters. If the American Socity of Heating, Refrigerating, and Air-Conditoning Engineers' maximum-velocity guideline of 5 fps for occupied spaces is required for the design, acceptable flow turndown will be limited to 3.3:1. Pumps also have a limitation as to how slowly they can run smoothly.

When using variable-flow-primary pumping, ensure the system flow is never less than the flow through the online boilers. To make sure of this, the target design minimum system flow rate should be at least 10 percent more than the online boiler flow rates. This generally will not be an issue when more than two boilers are used. However, with one or two boilers, the individual boiler pump may overpower the system pump at its minimum flow rate. If this is the case, a small buffer tank installed between the primary and secondary loops will decouple the system and solve the problem. The boiler pump, when on, will circulate flow to and from the boiler to the buffer tank. Meanwhile, the system flow will flow through the buffer tank and deliver the heated water to the system. When the boiler associated with the buffer tank is off, the hot water in the buffer tank still will be of full use in the system loop. The boiler will be decoupled from the system, but not the buffer tank. Hybrid boiler systems (a combination of condensing and non-condensing boilers) can further optimize a boiler heating system with the performance advantage of condensing boilers and the first-cost advantage of non-condensing boilers. To take advantage of high-efficiency condensing boilers, the system return temperature must be kept well below 130ºF, the lower the better. This often is not practical for the rare peak-load day but, with aggressive outdoor reset, can be achieved much of the heating season. Becuase the low return temperatures needed for high-efficiency condensing operation do not occur during heavy or peak loads, there is little to no advantage gained by running condensing boilers during these periods. Thus, a hybrid system can achieve excellent fuel savings while minimizing upfront equipment costs.

Using the previous four-boiler-system scenario, two condensing boilers along with two non-condensing boilers usually will work very well. For three-boiler systems, typically only one needs to be condensing. Condensing boilers should be the lead boilers any time the system return water is low enough to allow the boiler to operate in condensing mode. The rest of the time, the non-condensing boilers can be utilized as the lead. All of the boilers will provide near-maximum-attainable non-condensing efficiencies during heavy loads. In addition to energy and installed cost savings, a hybrid system will have lower maintenance cost than a multiple all-condensing-boiler system.

Clearly, it is critical for a specifying engineer to look beyond a manufacturer's listed single-boiler efficiency, which may or may not be independently tested using actual American National Standards Institute test procedures. Truly comparable single-boiler efficiencies are as listed by the Air-Conditioning, Heating, and Refrigeration Institute. These data, along with all the aforementioned best practices for energy-saving systems, must always be considered. Local seasonal-temperature data and overall system design-temperature parameters also must be included to verify the number of condensing vs. non-condensing units to be specified will achieve maximum job-site system efficiency.