Modern Hydronics: Socialized Efficiency

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In the past, boilers weren't expected to interact with other building systems. Today, boilers are socialized. Modern hydronic systems, by design, have transformed boilers into versatile devices that can be plugged into an ever-broadening mechanical landscape. For example, boilers may serve as a back-up source of heat for large geothermal or solar thermal systems, or may be tied to sophisticated variable-air-volume systems as the primary source of hydro-air warmth.

Therefore, system engineers designing a commercial hydronic system should strive to achieve a smart interrelationship of boiler performance and system performance criteria.

There are four key facets of hydronic system design and function that design engineers and building owners should be aware of to create a total system approach: first cost, life-cycle cost, annual efficiency, and value engineering.

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A technician works in a large boiler plant. Boilers are playing new roles in an ever-broadening mechanical system landscape.

First Cost

When planning a boiler installation or replacement, building owners often place a great deal of emphasis on minimizing the initial cost of system components. However, the initial cost of the system should not be the bottom line when it comes to evaluating the best solution. It can turn out that the lowest initial cost may end up costing a building owner more over the operational life of his or her system.

"Today's market has become highly competitive," Bill Root, general manager of Laars Heating Systems, Rochester, N.H., said. "The level of competitiveness has led to a rich field of options when considering which boiler may be best for an application. It can be very helpful to step back to look at a sensible solution that performs superbly, yet perhaps not at the bleeding edge of efficiency."

According to Bob Polizzi, vice president of business development and technical services for California & Columbia Hydronics, the broad availability and acceptance of modulating-condensing boiler technology offers a new hydronic strategy that's smart, cost-effective, and extremely efficient, while also providing building owners with a reliable, long-term solution.

"One of the most sensible recipes for equipment configuration is using a modulating-condensing boiler to handle the low-temperature start-up and circulation phase, then shifting heating and circulation to less expensive, non-condensing systems for routine heating as return fluid temperatures rise to 120°F or 125°F," Polizzi said.

Life-Cycle Cost

Life-cycle costing includes the purchase cost and estimates for maintenance, repair, and energy to operate a boiler system throughout its lifespan.

To be sure comparisons are made in today's dollars, these calculations discount future costs to the time of the purchase and are then added over the operational

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life of the boiler.

"Once the discounted life cycle cost is known for the different options, the payback period can then be calculated," Chuck O'Donnell, Laars product marketing manager, said. "This shows the amount of time it takes to recoup one boiler system's initial cost vs. another design based on operating costs."

Often, when the life-cycle calculations are completed, a mixed installation of condensing and near-condensing boilers is shown to be the most cost-effective solution for the building owner over the life of the boilers.

Annual Efficiency

The best measure of system efficiency is annual efficiency. Just a few years ago, many in the industry considered combustion efficiency and thermal efficiency to be the most important factors in determining overall system performance.

Every packaged boiler design must be tested to government standards in order to determine its nominal efficiency. However, the performance of a boiler's installed thermal efficiency is based on its design and its operation within a specific hydronic system and the controls applied to that system.

Transferring heat from a boiler into a total system, in just the right amount and at just the right time, is a key component of annual efficiency.

To create a system with a high annual efficiency, it makes sense to start with a truly efficient "engine." Manufacturers can build boilers that maximize heat transfer to water, and that efficiency is a critical aspect of a boiler's performance. However, many applications do not call for the highest levels of combustion efficiency (condensing equipment) because the water temperatures are too high. Designing systems with staged firing, modulation, and/or multiple boilers often can produce higher system efficiencies than systems that rely on single condensing boiler—no matter how high its combustion efficiency.

Value Engineering: A Total Systems Approach

How effectively a boiler relates to the total system is determined by capacity to deliver heat quickly or slowly depending on the needs of the system, and the ability of the boiler to adjust to changes in the system's demand for heat. The common term is "to size to the load." Also, total system performance is greatly enhanced when the equipment works at peak performance—with fuel consump-

PHOTO COURTESY OF LAARS

A technician commissions boiler systems at a ski resort in California. The boilers shown are non-condensing, but the system's lead boiler is a condensing unit to handle the very cold return water.

tion happening at the highest levels of combustion efficiency—at all levels of heat demand.

Another important factor is PID (proportional – integral – derivative) controls that sample changes over time and "learn" the responses of a system to changes in conditions such as heating load, outdoor air temperatures, and firing stages of the boiler(s).

Modulating and staged-fired boilers, for example, reduce fuel consumption by sizing to the load so that the amount of heat produced by the system precisely matches the need.

In addition, there's the system's response to outdoor temperatures, water-storage temperatures, and system loop temperatures. These, too, are very important contributors to overall system performance. Control systems should be sufficiently advanced to take these key variables into consideration.

Efficiency is only one of the advantages of installing a condensing boiler as the lead boiler, supported by a near-condensing boiler or boilers. A condensing boiler's resistance to thermal shock and the ability to accept low-return-water temperatures opens up many new possibilities for high-volume, cold-start systems. A condensing boiler takes low inlet temperatures in stride. In fact, the lower the incoming water temperature (or a water/glycol mix as is often the case), the higher the combustion efficiency of the boiler. And because all condensing boilers use combustion-air fans, many have an exceedingly long vent reach.

Modulation goes hand-in-hand with the ability to operate in a condensing mode. When a boiler can operate with low-return-water temperatures and low firing rates, the relationship of heat-transfer surface to fuel consumed, and the combustion efficiency itself, are optimized.

When multiple boilers are installed, each one handles only a portion of the heating load; that drives system efficiency even higher. Some systems that require higher operating temperatures often may still benefit from a condensing lead boiler, while the remaining boilers that provide the bulk of the heat are non-condensing.

"In the business of matching a commercial boiler with an application, there's usually a 'spec' at which point a rep firm may offer its best brand or product," Root said. "But it's during the second round, a discerning specifier may ask, 'What are we really trying to accomplish?' Perhaps a hybrid system would best suit the need. Such a system could mate a lead, condensing boiler with a non-condensing or 'near-condensing' system that may only fire four or five days a year when load conditions are at their height.

"This is an ideal arrangement for large buildings with cold return-water temperatures at start-up," Root added. "The condensing boiler takes that initial cold, high Delta-T return-water rush in stride."

"Near-condensing" refers to fan-assisted, non-condensing boilers that may offer a performance level—for example, 85 percent AFUE—with operational efficiencies only a few points lower than fully condensing equipment.

Success Stories

"We've had great success using condensing boilers with standard efficiency boilers," Polizzi said. "Our customers have found that under low loads and low-water-return temperatures they can run the condensing boiler as the lead system. As the load increases along with the return-water temperature, the standard boilers then fire, and operate at efficiency levels equal to higher-cost modulating-condensing boilers because of the increase in circulation temperatures.

PHOTO COURTESY OF LAARS

Modern hydronics systems can incorporate any number of similar boilers or different types of boiler types to achieve the greatest possible overall system efficiency.

Polizzi added that this configuration must be used in conjunction with outdoor reset control on the water set-point to take advantage of low-load and low-return-water temperatures.

"Low-load with high-return temperatures wouldn't take best advantage of a condensing boiler's ability to harvest British thermal units from condensate within the system because as the hydronic load is reduced, the outdoor reset control system lowers the set point; this allows the modulating-condensing boiler to condense," Polizzi said. "A standard boiler without outdoor reset control will modulate down while operating at high temperatures. This would provide only minimal gain in efficiency."

Polizzi also encourages designers to use the condensing boiler as a cold-start boiler. This allows the heating system to be shut down without affecting the standard- efficiency boilers. "The condensing boiler would bring the system up to safe operating conditions for the standard efficiency boilers, somewhere in the 120°F to 140°F range, before the conventional boiler is fired," he said.

Similarly, Andy Culberson, president of Elyria, OH-based Geisel Mechanical Services, sees the advantage of applying a modulating-condensing boiler as the start-up precursor to non-condensing commercial boiler systems.

Geisel crews recently completed a number of projects that tap a modulating-condensing system as the lead, low-temperature boiler, including the Lutheran Home of Concord Reserve, a senior life facility in Westlake, OH.

"The Lutheran Home was in need of a comprehensive overhaul to its hydronic systems," Culberson said. "TES Engineering designed the new system beginning with the demolition and removal of two massive, 30-plus-year-old cast-iron boilers. We repiped the mechanical room and replaced the old boilers with three much smaller systems." These systems were one 850-MBH boiler and two 1,000-MBH boilers, both rated at 85 percent AFUE.

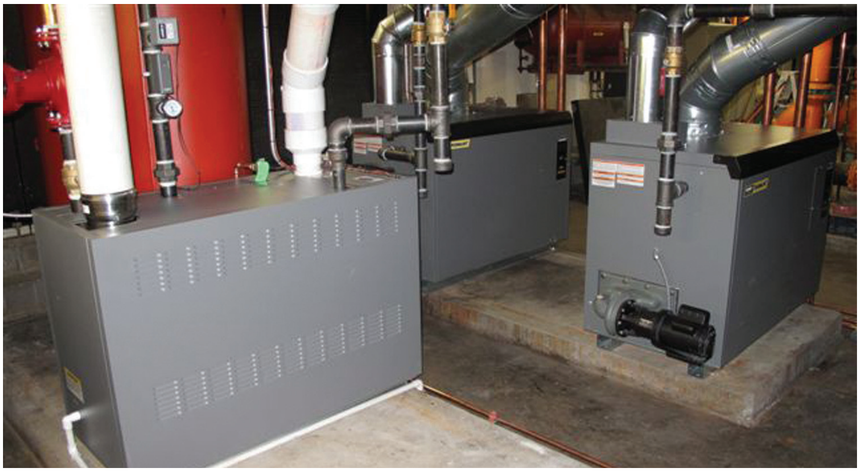

PHOTO COURTESY OF ANDY CULBERSON

One of two 30-year-old cast-iron boilers removed from the Lutheran Home of Concord Reserve in Westlake, OH.

Culberson chose the lead cold-start condensing boiler because it offered a fully packaged hydronic solution with 94 percent thermal efficiency. The boiler is a direct-vent, sealed-combustion system with a 10:1 turndown and low 10-ppm NOx emissions. The two second-in-command boilers are sealed-combustion, fan-induced, two-stage units with low NOx emission ratings.

"Typically, multi-boiler systems like the one we designed for installation at the Lutheran Home are first-fired in the fall," Dieter Hausmann, director of mechanical engineering at TES Engineering, said. Of course, the fall start-up conditions are ideal for the lead, condensing boiler. As the season progresses, the system is programmed to operate at the lowest possible temperatures, which is also ideally suited to the main, condensing boiler. Also, the partial-load conditions continue to favor the highly efficient condensing system and, if the weather becomes dramatically colder, there's plenty of capacity for additional heat in the non-condensing boilers. There simply aren't any downsides to the system design or performance."

According to Culberson, a system design such as that used at the Lutheran Home typically results in energy savings of around 25 percent. At the Lutheran Home, a reduction in energy costs of about $53,076 was attributed chiefly to the boilers between the winters of 2010 and 2011.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The new hydronics system at the Lutheran Home of Concord Reserve features one 850-MBH cold-start condensing boiler and and two 1,000-MBH sealed-combustion, fan-induced, two-stage boilers.

There were several factors that contributed to the savings, including replacement of space heating and domestic water heating, and a mild winter in 2011.

"We saw a 50 percent reduction in fuel use for our campus' Heritage Preserve building," said Ray Leszkowicz, director of environmental services, Lutheran Home at Concord Reserve. "We speculated that the savings might be that high, but when the numbers came in, it was great to see them. At this rate, the overhaul will pay for itself within two and-a-half years, making it an amazingly good investment."

"We see a line of questioning and specification with great frequency," Root said. "The recurring question seems to be, 'Why spend the funds for an all-condensing power plant?' After all, condensing boilers require much more maintenance."

A final advantage when considering the condensing/near-condensing recipe is the ability to control two different types of technology with one control system.

When reduction of first-costs is an important factor in a project, consider specifying a lead modulating-condensing boiler to work in concert with non-condensing boiler systems. This new hydronic recipe could offer a building owner a fair and competitive first cost for equipment that requires minimal maintenance and provides good annual efficiency and has a relatively low life-cycle cost. The initial cost would be substantially higher to apply ultra-high-efficiency equipment entirely to meet the same British-thermal-unit need.