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A New Breed of High-Efficiency Boiler

Roles of systems view and intelligent monitoring

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Among building owners, facility managers, and consulting-specifying engineers who design hot-water systems, the last 10 years perhaps best can be described as the "efficiency decade." As more attention has been paid to green initiatives, LEED points, and the like, the efficiency ratings of boilers have become an all-important consideration.

As the market now understands, however, there is much more to lowering operating costs and optimizing system performance than a boiler's published efficiency. The application, how well the boiler integrates with other system components, and the controls are important factors as well. With greater knowledge of system optimization, engineers and facility professionals are taking more of a system-level approach to operation.

Today, boilers must be "smart" enough to fit in an intelligent water-heating system that allows basic self-diagnostics and proactively makes system adjustments. Software tools and other technologies are becoming a larger part of a boiler's "brain," solving challenges related to efficiency and reliability presented by today's facilities.

Improved Boiler Designs

Of course, the boiler is vital to the overall operation of a heating system. Modulation allows a boiler's firing rate to meet the actual heating demand of a system. For example, a 2-million-Btuh-capacity boiler can run with as little as 100,000-Btuh, or 5-percent, input. Drawing only enough fuel to meet actual load changes, the unit gradually will increase its capacity—in 1-percent increments—up to 100-percent capacity.

Modulation optimizes fuel savings and enhances heat transfer at partial loads. While constant operation maintains temperature within the heat exchanger, reduced input increases the time combustion gases are in contact with the heat-exchanger surface, promoting greater energy transfer and cooler exhaust gases. Boilers with this design, then, have an inverse efficiency curve, performing best at the lowest loads, where they spend most of their operating time.

Another advantage of modulation is that less strain is placed on boiler elements, which enhances uptime reliability. Design with only a few moving parts and construction with high-grade materials, such as 439 stainless steel, further extends the life of heat exchangers.

Over the last few years, this capacity has been achieved in boilers with increasingly smaller footprints. When these compact boilers are coupled with tankless water heaters, mechanical rooms require less square footage, creating more usable space in a building.

Trim Technology

To help make condensing boilers used in conventional commercial systems operate more efficiently and to realize faster returns on investment, advanced oxygen- (O_2-) trim technologies that are much less expensive than legacy systems are being developed.

Traditionally used in large commercial and industrial non-condensing designs, O_2-trim systems continuously maintain the optimal air-to-fuel ratio in the boiler combustion zone. Boilers that operate with minimal

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excess air usually are more efficient. Real-time monitoring of the oxygen level in the exhaust-gas flue allows minor adjustments to the air-fuel ratio to be made to compensate for combustion variables, such as air temperature and density, barometric-pressure change, air humidity, venting, and fuel-quality variances. This continual compensation reduces inefficiencies.

The following equation shows why combustion efficiency is a good indicator of boiler-system efficiency:

$$\eta_{\text{Thermal Eff.}} = \eta_{\text{c.e.}} - (\text{radiated losses}) - (\text{off-cycle energy losses})$$

Table 1 highlights the effects of air on combustion efficiency in a non-condensing boiler system. Condensing equipment operates with much lower net stack temperatures and higher combustion efficiencies, so the benefits will be even more pronounced.

Condensing occurs when return-water temperature drops below the dew point of exhaust gases, which is approximately 135°F. For every pound of water forced into a liquid state, 970 Btu of energy in the form of heat is released. Approximately 13 percent of flue-gas energy is this latent heat.

Air directly affects the dew-point temperature at which flue gases condense. Maintaining the right excess-air/oxygen level is critical to ensuring maximum condensing occurs at less than 135°F return-water temperature. Systems incorporating these new O_2-trim technologies to achieve and maintain desired air/oxygen levels yield 0.5 to 2 percent in savings. In terms of the bottom line, operational costs will be reduced by hundreds of dollars per unit, creating thousands of dollars in savings for multiboiler systems.

Complementing the operational savings is the fact these new O_2 technologies are one-third the cost of conventional trim solutions. The lower entry point means one of these new O_2-trim systems can pay for itself in approximately three to four years. Table 2 compares a condensing system with O_2 trim to one without.

Air temperature, °F	Hours	Supply water, °F	Return water, °F	Firing rate, %	Standard efficiency, %	Efficiency with trim, %
65	740	120	119	5	92.0	94.0
60	783	124	122	13	90.8	92.8
55	762	129	125	19	90.0	92.0
50	715	133	128	26	89.8	91.8
45	687	137	130	32	89.3	91.3
40	685	141	133	38	88.9	90.9
35	683	146	136	45	88.7	90.7
30	647	150	139	51	88.3	89.3
25	561	154	142	58	88.1	89.1
20	435	159	145	64	88.9	89.9
15	301	163	148	70	88.5	89.5
10	184	167	151	77	88.4	89.4
5	101	171	154	83	88.2	89.2
0	51	176	157	90	87.8	88.8
–5	43	180	160	96	87.3	88.3

TABLE 2. Comparison utilizing an outdoor-air-reset schedule.

Excess air, %	Excess 02, %	Combustion efficiency at net temperature difference, %								
		170°F	220°F	270°F	330°F	380°F	430°F	480°F	530°F	580°F
0	0	86.3	85.3	84.2	83	81.9	80.8	79.7	78.6	77.5
4.5	1	86.2	85.1	84	82.7	81.6	80.5	79.3	78.2	77
9.5	2	86.1	84.9	83.8	82.4	81.2	80.1	78.9	77.7	76.5
15	3	85.9	84.7	83.5	82.1	80.9	79.7	78.4	77.2	75.9
21.1	4	85.7	84.5	83.2	81.7	80.5	79.2	77.9	76.6	75.3
28.1	5	85.5	84.2	82.9	81.3	80	78.6	77.3	75.9	74.5
35.9	6	85.3	83.9	82.5	80.9	79.5	78	76.6	75.2	73.7
44.9	7	85	83.5	82.1	80.3	78.8	77.3	75.8	74.3	72.8
55.3	8	84.7	83.1	81.6	79.7	78.1	76.6	74.9	73.3	71.7
67.3	9	84.3	82.7	81	79	77.3	75.6	73.9	72.2	70.4
81.6	10	83.9	82.1	80.3	78.2	76.4	74.5	72.7	70.8	68.9
98.7	11	83.4	81.5	79.5	77.2	75.2	73.2	71.2	69.2	67.1
119.7	12	82.7	80.6	78.5	75.9	73.8	71.6	69.4	67.2	64.9
145.8	13	82	79.6	77.3	74.4	72	69.6	67.1	64.7	62.2
179.5	14	81	78.3	75.7	72.4	69.7	67	64.2	61.5	58.7
224.3	15	79.6	76.6	73.5	69.8	66.7	63.5	60.4	57.2	54

Source: Dyer, D.F. (1991). Boiler efficiency improvement. Auburn, AL: Boiler Efficiency Institute.

TABLE 1. Effects of air on combustion efficiency.

Systemwide Approach

Technologies such as cost-efficient O_2 trim are one way condensing-boiler systems have become more efficient. Another is the practice of seeing the boiler as an element within an entire hot-water solution responsible for space heating and domestic hot water. This philosophy allows for single-source suppliers that can design and assemble entire systems.

Reliability is improved as a team of experienced professionals familiar with boiler design and application configures a system for lower maintenance costs and maximum efficiency. Additionally, the water-heating system can be designed in parallel with the overall project, saving valuable time for engineers, contractors, and building owners.

Lastly, the approach considers how a boiler will operate with a water heater to reduce system waste. This "combination plant" method will help to ensure the boiler receives the coldest-possible return water. The boiler would be used for water heating, with a percentage working with the water heater for domestic water, which can create a savings of up to 10 percent during heating season.

Inbound/Outbound Remote Tools

In addition to viewing boilers in the context of entire heating systems, engineers, building owners, and facility managers are seeing the value of remote tools.

Conventional remote-monitoring services use state-of-the-art computer tracking to observe, record, and analyze boiler and/or water-heater systems. Problems in systems are identified in real time for quick resolution and to prevent lost revenue caused by undetected faults. Early detection and alerts sent by the monitoring system can help to avoid lengthy and expensive service interruption.

In addition to comprehensive e-mail alerts notifying facility managers of issues or faults, these remote tools provide monthly reports generated from the data captured. These reports allow users to track performance trends, maintain reliability, reduce the cost of ownership, and identify opportunities to increase efficiency.

All of the scenarios outlined are based on current remote-monitoring tools, which collect only outbound data, such as temperature and setback elements. A new generation of solutions will add inbound capabilities, such as diagnostics, soft calibration, and changing set points, so adjustments can be made proactively to maximize boiler operation and improve overall system life.

Conclusion

The quest to optimize boiler systems continues to evolve. A new mindset among engineers, building owners, and facility managers that considers how a boiler fits into an entire water-heating system, coupled with advances in O_2-trim technologies and remote-monitoring tools, will help to create a faster return on investment through lower operating costs.

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