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Rise of the Super Boiler

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Each day, the United States consumes a vast amount of energy — almost 25 percent of the world's supply.[1] With this consumption comes consequences: a high degree of dependence on unpredictable foreign fuel supplies, rapid depletion of known energy reserves, growing concerns about air cleanliness and global warming. The nation is at a crossroads and must act swiftly on a variety of fronts to curb its energy consumption, clean its air, and become more energy-independent, lessening the threat to its socioeconomic status. The boiler/burner industry has accepted its share of the challenge and is making significant strides. This article is a brief synopsis of the boiler industry's direction and accomplishments to date.

Public Meets Private

In the U.S. industrial sector, steam is an important carrier of energy and will remain such, but the current stock of boilers is aging rapidly, and there is a clear need for advanced technologies to enable the more efficient, cost-effective, and environmentally friendly generation of steam. That was a conclusion drawn in “Industrial Combustion Technology Roadmap,”[2] submitted to the U.S. Department of Energy (DOE), which facilitated the document, in April 1999. Another conclusion was that U.S. boiler manufacturers, though large in number, are mostly small to medium in size, with limited ability to invest in research and development. If breakthroughs in steam-generation technologies were to be achieved, the report concluded, public/private alliances would be needed.

Following a review of the recommendations contained in “Roadmap,” the DOE initiated the Industrial Technologies Program, reaching out to the public and private sectors for assistance in advancing the document's findings.

In 2000, the Gas Technology Institute (GTI) was named an allied partner by the DOE and started developing the concept for a “super” boiler, one combining a proven efficient packaged boiler system and a highly efficient combustor to deliver ultralow emissions and inordinately high fuel-to-steam efficiencies, all within an acceptably compressed footprint. This development focused on:

- Efficiency improvement through the extraction of sensible and latent heat from stack gases and the quantitative return of extracted heat to the boiler.
- Emissions reduction through the application of staged combustion with intensive interstage cooling, optimized fuel-air mixing, and engineered internal recirculation of combustion gases.

- Boiler-size reduction through the use of extended convective surfaces, which increase heat transfer and more uniformly distribute radiative heat in the furnace.
- Application of state-of-the-art controls to optimize boiler performance, particularly that related to combustion.

During this concept-development phase, others joined the effort as sponsoring and performing entities: the Gas Research Institute, Southern California Gas Co., Pacific Northwest National Laboratory, Utilization Technology Development Co., Cleaver-Brooks Inc., the GTI's Sustaining Membership Program, the California Energy Commission, the California Air Resources Board, and the South Coast Air Quality Management District.

Test Boilers

In 2002, work on the building and testing of two 80-hp high-pressure steam boilers — one using a highly efficient single-stage-firing burner and the other employing a two-stage configuration — began. Both boilers featured extended convective surfaces and contained the latest in programmable-logic-controller- (PLC-) based control technology.

Equipped with advanced external heat-transfer equipment (two stack economizers, a transport-membrane condenser, and combustion air heater) to raise fuel-to-steam efficiency beyond their boiler/burner package's capability, the “super boilers” were tested at the GTI's laboratory facility in Chicago.

After extensive testing and modification in the GTI laboratory, the super-boiler concept was extrapolated to a 300-hp high-pressure-steam configuration for placement in a beta test facility: Specification Rubber Products Inc. in Alabaster, Ala. The single-stage unit uses advanced controls and a full heat-recovery system. Results since July 2006 indicate nitrogen-oxide (NOx) levels below 9 ppm and fuel-to-steam efficiency consistently in the 93-to-94-percent range, which translates to annual-fuel-cost savings of 10 to 15 percent.

Startup of a 300-hp high-pressure super boiler with two-stage firing, advanced controls, and the full complement of heat-recovery equipment employed at the Specification Rubber Products facility was expected during spring or summer of 2008 at a second beta test site: the Ontario, Calif., plant of Clement Pappas & Company Inc., producer of fruit juices, fruit drinks, and cranberry sauces. Less-than-9-ppm NOx and 96-percent fuel-to-steam efficiency are anticipated.

Market Potential and Requirements

Considering the U.S. industrial sector's annual consumption of 24.7 quadrillion Btu,[1] a super boiler with full heat recovery has the potential to save $4 billion in fuel and facility costs and prevent more than 140,000 tons of NOx and more than 20 million tons of greenhouse gases.

In the United States, more than 210,000 firetube-type boilers in the 100-to-2,000-hp high-pressure-steam range are in operation. Conservatively speaking, 60,000 of those units are more

than 25 years old. Those boilers normally are in the 75-percent fuel-to-steam-efficiency range, with NOx emissions of approximately 120 ppm.

Factors Impacting Buying Decisions

Factors found to influence a customer's decision to improve fuel-to-steam efficiency and/or reduce emission levels include:

- Return on investment (ROI). Generally speaking, the ROI is three to five years in the industrial sector and five to seven years in the institutional sector.
- Safety/reliability.
- Comparable or reduced footprint.
- Ease of operation.
- Fuel flexibility, including natural gas and No. 2 oil.
- Environmental compliance (e.g., the U.S. Green Building Council's Leadership in Energy and Environmental Design [LEED] Green Building Rating System).

Commercialization

Recently, an “optimized boiler package” featuring a four-pass firetube boiler was introduced for process-steam applications. It includes:

- PLC-based burner- and combustion-control logic.
- An integrated two-stage condensing economizer.
- A precisely matched blower and fan assembly for combustion-air delivery and waste-heat reclaim.

This completely packaged offering is suitable for an array of industrial applications, delivering up to 90-percent fuel-to-steam efficiency.

Conclusion

Since 1999, the DOE and its allied partners have accomplished much in forging a clear direction in our quest to reduce our dependence on foreign oil, conserve our finite resources of oil and gas, and improve the air we breathe.

In recent years, global warming has become quite acute in the public's consciousness. Even though debate continues as to its cause, reducing carbon-based fuel consumption and, thus, the amount of carbon dioxide emitted to the atmosphere can only help.

With at least 60,000 firetube boilers over 25 years old in the U.S. marketplace, the time is right to begin retrofitting those units or replacing them with new boilers that conserve significant amounts of energy while substantially reducing noxious pollutants emitted to the atmosphere.

The time is right to think globally and act locally.

References

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2. Energetics. (1999). *Industrial combustion technology roadmap*. Washington, DC: U.S. Department of Energy. Available at http://www1.eere.energy.gov/industry/combustion/pdfs/combustion_roadmap2.pdf

About the Author

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