



Firetube Boilers

The packaged firetube boiler is the most common boiler design used to provide heating or process steam in industrial and heavy commercial applications. The American Boiler Manufacturers Association (ABMA) surveyed high-pressure (15 to 350-psig) firetube and small watertube boiler sales between 1978-1994. ABMA found that firetube boilers comprised over 85% of the sales of these boilers to industry.

Although firetube boilers are available in ratings up to 85,000 pounds of steam per hour, they are generally specified when the required steam pressure is under 150 psig and the boiler capacity is less than 25,000 pounds per hour. Watertube boilers are designed for larger, high-pressure, and superheated steam applications.

Steam Tip Sheet information is adapted from material provided by Brock Turbulators and Fuel Efficiency, LLC and reviewed by the DOE BestPractices Steam Technical Subcommittee. For additional industrial steam-system efficiency improvement information, refer to the Improving Steam System Performance—A Sourcebook for Industry (“Steam System Basics: Generation” section). The document is available from the EERE Information Center at 877-337-3463.

Consider Installing Turbulators on Two- and Three-Pass Firetube Boilers

In a firetube boiler, hot combustion gases pass through long, small-diameter tubes, where heat is transferred to water through the tube walls. Firetube boilers are categorized by their number of “passes,” or the number of times that the hot combustion gases travel across the boiler heat-exchange surfaces. For example, a two-pass boiler provides two opportunities for hot gases to transfer heat to the boiler water. Hot combustion gases enter the tubes in a turbulent flow regime, but within a few feet, laminar flow begins and a boundary layer of cooler gas forms along the tube walls. This layer serves as a barrier, retarding heat transfer.

Turbulators, which consist of small baffles, angular metal strips, spiral blades, or coiled wire, are inserted into the boiler tubes to break up the laminar boundary layer. This increases the turbulence of the hot combustion gases, and the convective heat transfer to the tube surface. The result is improved boiler efficiency. Turbulators are usually installed on the last boiler pass.

Turbulator installers can also balance gas flow through the tubes by installing longer turbulators in the uppermost tubes. This practice increases the effectiveness of the available heat-transfer surface by eliminating thermal stratification and balancing the gas flow through the firetubes.

Applications

Turbulators can be a cost-effective way to reduce the stack temperature and increase the fuel-to-steam efficiency of single-pass horizontal return tubular (HRT) brick-set boilers and older two- and three-pass oil and natural-gas-fueled firetube boilers. Turbulators are not recommended for four-pass boilers or coal-fired units. A four-pass unit provides four opportunities for heat transfer. It has more heat exchange surface area, a lower stack temperature, higher fuel-to-steam efficiency, and lower annual fuel costs than a two- or three-pass boiler operating under identical conditions. New firetube boilers perform better than older two- and three-pass designs.

Turbulators can also be installed to compensate for efficiency losses when a four-pass boiler is being converted to a two-pass boiler because of door warpage and loose and leaking tubes.

Turbulators are a substitute for a more costly economizer or air-preheater. They are simple, easy to install, and low cost. Their installed cost is about \$10 to \$15 per boiler tube. Current turbulator designs do not cause significant increase in pressure drops or contribute to soot formation in natural-gas-fired boilers. Turbulators are held in place with a spring lock and are easily removed to allow for tube brushing.

Turbulators come in various lengths and widths and should be installed by a qualified installer. To avoid combustion problems, the boiler burner should be retuned after the turbulators have been installed. The installer must also verify that the stack temperature does not fall below the flue gas dew point.

Price and Performance Example

A manufacturing facility installed 150 turbulators into their firetube boiler. Tests, conducted both before and after turbulator installation, indicated a reduction in the stack gas temperature of 130°F. More combustion heat was being transferred into the



boiler water. Because each 40°F reduction in the boiler flue gas temperature results in a 1% boiler-efficiency improvement, overall boiler efficiency is improved by about 3.25%. Fuel costs decrease by approximately 4%.

Example

Consider a two-pass firetube boiler that consumes 60,000 million British thermal units (MMBtu) of natural gas annually, and that produces 15,000 pounds per hour of 100 pounds per square inch gauge (psig) saturated steam. What are the annual energy and cost savings, given that the installation of turbulators improves the boiler efficiency from 79% (E1) to 82% (E2)? Natural gas is priced at \$4.50/MMBtu.

$$\text{Energy Savings} = \text{Annual Fuel Consumption (MMBtu)} \times (1 - E1 \div E2) \\ \text{or } 60,000 \text{ MMBtu} \times (1 - 79 \div 82) = 2,195 \text{ MMBtu/year}$$

$$\text{Annual Cost Savings} = \$4.50/\text{MMBtu} \times 2,195 \text{ MMBtu/year} = \$9,878$$

If the boiler has 250 tubes and the installed cost for the turbulator is \$15 per tube, the simple payback on the investment in the energy efficiency measure is:

$$\text{Simple Payback} = (250 \text{ tubes} \times \$15/\text{tube}) \div \$9,878/\text{year} = 0.38 \text{ years}$$

Suggested Action

Consider installing turbulators in your two- or three-pass firetube boiler tubes if your stack gas temperature is 100°F or more above your steam or hot water temperature.

About DOE's Industrial Technologies Program

The Industrial Technologies Program, through partnerships with industry, government, and non-governmental organizations, develops and delivers advanced energy efficiency, renewable energy, and pollution prevention technologies for industrial applications. The Industrial Technologies Program is part of the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy.

The Industrial Technologies Program encourages industry-wide efforts to boost resource productivity through a strategy called Industries of the Future (IOF). IOF focuses on the following eight energy and resource intensive industries:

- Aluminum
- Forest Products
- Metal Casting
- Petroleum
- Chemicals
- Glass
- Mining
- Steel

The Industrial Technologies Program and its BestPractices activities offer a wide variety of resources to industrial partners that cover motor, steam, compressed air, and process heating systems. For example, BestPractices software can help you decide whether to replace or rewind motors (MotorMaster+), assess the efficiency of pumping systems (PSAT), compressed air systems (AirMaster+), steam systems (Steam Scoping Tool), or determine optimal insulation thickness for pipes and pressure vessels (3E Plus). Training is available to help you or your staff learn how to use these software programs and learn more about industrial systems. Workshops are held around the country on topics such as "Capturing the Value of Steam Efficiency," "Fundamentals and Advanced Management of Compressed Air Systems," and "Motor System Management." Available technical publications range from case studies and tip sheets to sourcebooks and market assessments. The Energy Matters newsletter, for example, provides timely articles and information on comprehensive energy systems for industry. You can access these resources and more by visiting the BestPractices Web site at www.eere.energy.gov/industry/bestpractices or by contacting the EERE Information Center at 877-337-3463 or via email at eereic@ee.doe.gov.

BestPractices is part of the Industrial Technologies Program Industries of the Future strategy, which helps the country's most energy-intensive industries improve their competitiveness. BestPractices brings together emerging technologies and best energy-management practices to help companies begin improving energy efficiency, environmental performance, and productivity right now.

BestPractices emphasizes plant systems, where significant efficiency improvements and savings can be achieved. Industry gains easy access to near-term and long-term solutions for improving the performance of motor, steam, compressed air, and process heating systems. In addition, the Industrial Assessment Centers provide comprehensive industrial energy evaluations to small- and medium-size manufacturers.

FOR ADDITIONAL INFORMATION, PLEASE CONTACT:

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