

sustainableplant

Refine Fuel Consumption

Control combustion and improve operating efficiencies of fired equipment.

By Paul Studebaker

A SINGLE INDUSTRIAL FACILITY can consume millions of dollars in fuel each year to generate steam and to heat occupied space, water and process equipment, making fuel a significant portion of operating and product costs as well as a major contributor to environmental impact and carbon emissions. The bad news for energy, environmental and sustainability managers is that fuel-consuming equipment often includes complex burner, heat exchanger, heat recovery and control systems that deteriorate over time due to high temperatures and combustion byproducts. These may require a high level of expertise and attention to optimize efficiency.

The good news is that much of this equipment could be a lot more efficient. For example, “Eight out of 10

boilers are more than 30 years old,” says Steve Connor, director of marketing and training, Cleaver-Brooks. “They run less efficiently, often are unreliable and might even be in violation of U.S. federal pollution standards.”

Most industrial facilities have at least one boiler, and the principles of boiler efficiency and control generally apply to other industrial combustion systems, so that’s where we start our overview. Then we’ll talk about process heating and steam systems, followed by opportunities in cogeneration, district energy and alternative fuels.

BOILER VERSUS STEAM AUDITS

A steam audit is a comprehensive analysis of energy used within a facility, process or equipment, including



recommendations for energy conservation measures. Connor says there are two types of steam audits: a simple boiler system audit and a complete facility audit. In a simple audit, a professional evaluates the boiler room, boiler and accessory support equipment, possibly extending the evaluation somewhat into the facility. With a complete site audit, auditors evaluate the boiler system as well as components throughout a facility, including steam traps, piping, valves and steam users.

“A simple boiler system audit costs about \$1,000, whereas a complete site audit, depending on the number of steam traps, other equipment and the size of the plant, could cost a few thousand dollars,” Connor says. The essential steps are:

- Data acquisition: Identify where and how a facility, process or equipment uses energy, along with costs and utility issues affecting the energy consumption.
- Data analysis: Identify energy conservation measures to make energy use more efficient, less expensive and more environmentally friendly.
- Recommendations: A final report details what was found, a list of areas that need improvement, and recommended actions, usually accompanied by some type of economic justification.

A FACILITY NEED NOT SHUT DOWN FOR A STEAM AUDIT – IT’S BETTER THAT IT CONTINUE AS USUAL SO THE AUDITOR CAN EASILY SPOT STEAM LEAKS AND OTHER ANOMALIES.

A steam audit can take several days to complete, depending on the type of audit and the size of the facility. A facility need not shut down for the procedure; it’s better that it continue as usual so the auditor can easily spot steam leaks and other anomalies during daily operations.

During a boiler room audit, “Your mild-mannered auditor will check the boiler controls, the boiler, blowdown and feedwater conditioning to identify inefficiency issues,” Connor says. “Auditors use their uncanny abilities to do an inventory of key equipment, looking for energy-saving methods, areas to implement better engineering practices, and health and safety concerns.”

In a complete facility audit, an inspector not only checks the inventory of key equipment in the boiler room, but also focuses on potential improvements

Cogeneration Cuts CO₂ and Energy Costs

Pratt & Whitney's Middletown, Connecticut, jet engine manufacturing, assembly and test facility faced a number of operational challenges in its plant powerhouse. The existing boilers burned only #6 fuel oil and were oversized for current steam requirements, resulting in inefficiencies. Boiler maintenance and repair costs were increasing, and it was becoming more difficult to meet ever-changing environmental requirements. Electricity and energy prices were rising, and the state of Connecticut offered opportunities and incentives to help offset capital costs of "behind the fence" generation. The company also recognized intrinsic efficiency and security benefits of cogeneration.

The facility decided to replace two Erie City Boilers (100,000 pounds per hour) that had been built in 1956 and a Keeler Boiler (150,000 pounds per hour) installed in 1975 with a Solar Turbine Taurus 70 combined heat and power (CHP) plant and an associated heat-recovery steam generator. The CHP plant can produce 7.5 MW. Two quick-start Rentech boilers (40,000 pounds per hour) also were installed to balance the steam load. "This new line-up of equipment provides all our steam needs and nearly two-thirds of our annual electricity requirements of 90 million kWh at the site," says Mark Kopera, Pratt & Whitney energy services manager. Natural gas replaced #6 oil as the primary fuel, with #2 oil as an alternate. "This environment-friendly solution reduced our greenhouse gas footprint by over 10% in just one year and has been operating since January of 2008," says Kopera.

throughout the energy-using facility. The evaluator inspects the boiler, steam flow, pressures, temperatures, air handling, steam trapping, piping ancillaries including valving and insulation, condensate handling and heat recovery. Energy savings are sought through:

- Locating steam leaks
- Heat recovery
- Conservation of flash steam
- Return of condensate

START AT THE FIRE

One of the first things an auditor needs to determine is the condition of the boiler system. "The decision to replace a boiler shouldn't be based solely on the boiler's age," Connor says. "Some boilers, even at 70 years old, remain in good condition. However, if the boiler is leaking, heavily scaled, or has outdated burners and controls, it's probably time to replace it."

Typically, efficiency improvement alone doesn't justify a complete boiler replacement. However, coupling that with spending otherwise necessary for a burner retrofit or boiler heat exchanger repair may. The specifics of your existing equipment and your current and future needs will determine what can be done, what this entails and the cost.

In many cases a retrofit, that is, modernizing your current boiler, makes the most economic sense. "Often it's easy to justify upgrading the control system with a state-of-the-art programmable logic controller and a new servo-based burner-management system," says Andy Wales, western regional manager, Clayton Industries. "Adding an economizer usually is a viable way to boost efficiency. However, repairing a boiler that's too small or inefficient may not be the best use of your capital budget."

Efficiency retrofits such as an updated burner or combustion control system "can save 50% on capital costs compared to a new boiler unit and provide significant fuel savings at least equal to the retrofit cost during the first year," says Connor.

Auditors also investigate whether the boiler has been overheating. If the boiler overheats, there might be problems with either the boiler's insulation or gasketing, which could lead to damaged and unsafe equipment. The cost of repairs to correct these types of problems are relatively nominal when compared to the consequences of letting conditions exist that result in serious safety or mechanical repair issues.

TUNE OUT EXCESS AIR

The auditor will perform a combustion test using stack gas analysis equipment to quantify boiler efficiency. This could lead to the recommendation of an oxygen sensor/transmitter in the exhaust gas.

The sensor/transmitter continuously senses oxygen content and provides a signal to the controller, which adjusts the air damper and gas valve, maintaining a consistent oxygen concentration in the flue. This minimizes excess air while optimizing the air-to-fuel ratio. "Oxygen trim systems typically increase efficiency by 1% to 2%, which, if you're looking at energy bills in the millions, means saving \$10,000 or more each year."

Plants typically supply air instead of oxygen for combustion, which means four parts of nitrogen for each part of oxygen. The excess nitrogen picks up heat and leaves the stack at an elevated temperature, contributing to stack-gas losses.

Minimizing stack gas loss is done by minimizing both the quantity and the temperature of the gases. "If these factors are higher than required, stack losses also are

higher and heater efficiency is reduced,” says Veerasamy Venkatesan, general manager, VGA Engineering Consultants. “Controlling the quantity of stack gases is the most-talked-about savings opportunity for process heaters. However, at 80% of the process plants I visit no significant efforts have been undertaken.”

So the first step in process heater optimization is to control the quantity of excess air supplied to the burner. Most burner manufacturers recommend about 10% excess air. Many plants add a further safety margin, increasing this to 20% or more. “At some sites, either operators are unaware of excess air levels or burner control systems are too primitive to make changes,” says Venkatesan. “In any case, it’s worthwhile to evaluate the opportunity to trim excess air.”

Burners firing natural gas typically require about 1% excess oxygen (or about 5% excess air) to achieve complete combustion. So, if the level exceeds 2%, the first step is to reduce it. If a heater already is maintained at 2% oxygen in stack gas, it still may be possible to trim further. For some heaters, you can reduce excess air without significant capital investment.

Field-tune each major heater to meet a target operating level: combustion efficiency exceeding 80% with 1% to 2.5% oxygen and near 0% combustibles in the flue gas. “This target range is neither new nor unrealistic,” Venkatesan says. “The tough part of the task is convincing plant operators to shift from their comfort zone to the optimum operating zone.

“The results usually are measurable at the end of the first year — and can add up to significant savings if the annual purchased fuel bill exceeds \$25 million,” Venkatesan adds. “Typically, the first year payoff is five times more than the cost of the first year efforts.”

SOAK UP WASTED HEAT

It’s very common to see stack temperatures above 400°F in process heaters that were designed prior to 1980. More recent designs may operate with stack temperatures of around 250°F. “Approximately 1% additional fuel is consumed for every 40°F rise in the stack temperature at the same process heating load,” Venkatesan says. To bring down those temperatures:

- Always keep the process heater’s heat recovery surfaces clean. Add soot blowers or improve maintenance of existing soot blowers.

Soot can be mechanically removed with a flue brush. “Once the soot is gone, a professional will be needed to recalibrate the burner,” Connors says. “The return on your investment to reduce stack temperature is quick, usually in less than one year.”

On boilers, another cause of elevated stack temperature is scale formation on the waterside surfaces caused by improper water treatment. The remedy might be either acid cleaning or tube replacement, depending on the severity of the scaling condition. “In either case, the fix, though more expensive than cleaning the fireside, is often paid back through energy savings in a year or less, depending on boiler size,” Connors adds.

- Look for heat sinks in nearby processes. If the inlet process temperature is limiting how low you can get the stack temperature, consider pinch technology, where multiple heat sources and heat sinks are integrated to recover more heat.

“In one of the heaters at a client site, we replaced its low pressure (LP) steam generating coil with an economizer coil to preheat the fresh makeup water from ambient to moderate temperatures before sending it to the deaerator,” says Venkatesan. “The stack

The High Price of Escape				
Equivalent orifice diameter	Steam loss (lbs/yr)	Steam cost per 1,000 lbs		
		\$5.00	\$7.50	\$10.00
1/16 in.	115,630	\$578	\$867	\$1,156
1/8 in.	462,545	\$2,313	\$3,469	\$4,625
1/4 in.	1,848,389	\$9,242	\$13,863	\$18,484
1/2 in.	7,393,432	\$36,967	\$55,451	\$73,934

At 100 psig. Cost multipliers for other steam pressures:	
16 psig: 0.26	200 psig: 1.87
50 psig: 0.56	300 psig: 2.74
150 psig: 1.43	600 psig: 5.35

temperature of the heater dropped from 400°F to about 310°F. Also the deaerator's reduced LP steam use more than compensated the LP steam generation loss from the old coil."

- Explore options for alternative use of low-level heat. If you can't find additional heat recovery opportunities, consider using an adsorption chiller to provide chilled water for cooling.

"In a Wyoming refinery, we came across a situation where process condensers cooled by tower water were insufficient to recover all the light ends from the refinery fuel gas stream — especially in the summer. Our recommendation to install an absorption chiller to complement the condenser cooling was well received," Venkatesan says. "In that refinery, LP steam is generated by additional heat recovery from the process heaters, and the excess LP steam is used to run the absorption chiller." Absence of critical non-moving parts in absorption chillers keeps their maintenance costs low.

IF STEAM PRESSURE CAN BE REDUCED, FEWER BTUS PER HOUR WILL BE USED IN THE PROCESS, SAVING THE FACILITY THOSE ENERGY DOLLARS.

EXAMINE THE STEAM CIRCUITS

Moving outside the boiler room, an auditor will determine what the steam is used for, how it's applied and if it's possible to lower the system pressure to reduce the heat required to produce a pound of steam. "The heated process is reviewed along with the piping to see whether the diameters of the piping, controls, steam traps and control valves allow operation at lower pressure, knowing velocities and pressure differentials will be changing," Connors says. "If it's concluded that the pressure can be reduced, fewer BTUs per hour will be used in the process, saving the facility those energy dollars."

Survey the steam piping for energy losses through radiation and steam leaks. "More than half of process plants lack pipe insulation or the insulation has deteriorated to the point of uselessness," Connors says. The larger the pipe diameter and greater the length, the more insulation can help in saving energy.

Reducing steam leaks caused by piping corrosion and compromised flanging can be another significant energy saver. He adds, "The leaks appear as wisps

of condensed steam, and, once secured, result in considerable dollars saved."

Steam traps are typically part of a complete facility site audit. Look for traps that blow through, pressurizing the condensate line and causing waterlogging and inefficient process performance. Traps are normally checked using heat-sensitive or ultrasonic instrumentation. A steam trap audit will gather information on the number of steam traps in the facility, test and tag the steam traps, record findings, and calculate energy-saving measures and potential ROI.

CONDENSATE AND FEEDWATER

Boiler feedwater should be free of dissolved gases such as oxygen and carbon dioxide, which can cause destructive corrosion to the boiler and condensate lines. If you're using a water softener, be sure it's working properly. "Without a water softener, scale builds up in the heat exchanger, and it doesn't take much scale to cause fuel usage to skyrocket," Connor says. "A quarter-inch of scale increases fuel use as much as 15%."

Condensate should not be dumped down the drain. Along with raising concerns about wastewater quality, the practice discards treated water that contains a significant amount of energy.

Steam contains two types of energy: latent and sensible. When steam is supplied to a process application (heat exchanger, coil, tracer, etc.) the steam vapor releases the latent energy to the process fluid and condenses to a liquid condensate. "The condensate retains the sensible energy the steam had," says Kelly Paffel, technical manager, Swagelok Energy Advisors and a member of the U.S. Department of Energy's (DOE) Steam Best Practices and Steam Training Committees. "The condensate can have as much as 16% of the total energy in the steam vapor, depending on the pressure."

Condensate is hot, so it takes far less heat and fuel to turn it back into steam than it would to produce steam from an equal quantity of cold water. "Reusing condensate can lead to hundreds of thousands of dollars in savings, depending on the size of the boiler and its operating hours," Connors says.

You can also save energy by raising the temperature of feedwater with recovered heat. "An auditor will probably suggest an economizer if your facility hasn't already invested in one, because an economizer can reduce the steam boiler's fuel requirements by transferring heat from the flue gas to incoming feedwater," Connor says. "An economizer can often reduce fuel requirements by 5% to 10%, and if you're looking at \$1 million to \$3 million in annual energy costs, this retrofit can save \$50,000 to \$300,000 a year."



IT DOESN'T TAKE MUCH HEAT EXCHANGER SCALE TO CAUSE FUEL USAGE TO SKYROCKET – A QUARTER-INCH OF SCALE INCREASES FUEL USE AS MUCH AS 15%.



COGENERATION IS A HOT TOPIC

Defined here as generating both heat and electric power from a single combustion event, cogeneration is a hot topic in North America due to the recent relatively low price of natural gas, and everywhere because it offers a practical way to significantly improve total energy yields.

Cogeneration typically uses internal combustion engines or gas turbines to drive electric power generators, with the exhaust and/or cooling system heat recovered to produce steam and/or process heat. “For diesel generators using natural gas or diesel fuel, absorption chillers capture the energy available in exhaust and the jacket water for heating and cooling,” says Farhad Ghahremani, P.E., president and founder, Cogeneration Planners. “Alternatively, the exhaust heat recovery system of a gas turbine generator can produce steam.”

Cogeneration offsets other forms of energy production, such as power grid generation and localized firing of natural gas or oil in a boiler. According to the DOE, if cogeneration were to supply 20% of U.S. electricity generating capacity by 2030, the projected increases in carbon dioxide emissions would be cut by 60%. Overall emissions of carbon dioxide, oxides of nitrogen and sulfur dioxide from grid-provided

electrical production are reduced as more onsite cogeneration systems are installed.

The advantages don't stop with efficiency and emissions. “Power reliability is cogeneration's greatest benefit,” says Tim Baur, P.E., senior program manager, Vericor Power Systems. “No plant can afford blackouts from storm damage, poor utility operation or transmission line failures. Onsite cogeneration systems equipped with sufficient redundancy, such as standby grid connection and uninterruptible power supply systems, can far exceed the reliability of some local utilities.”

CONSIDER ALTERNATIVE FUELS

The current low price of natural gas in the United States makes it a tough competitor, but where you're using oil or coal, or in parts of the world where natural gas isn't cheap, and in the future, most likely everywhere, waste streams and renewable fuels offer viable and economical alternative fuels.

Renewables such as biogas from landfills and organic waste streams, and biomass as a byproduct or end product of agriculture and forestry are reducing the carbon footprints of many facilities.



Scottish distilling icon William Grant & Sons (Grant's) uses a combined heat and power system at the Grant's Girvan Distillery in Girvan, Scotland. Operating on biogas from residual malt materials used in distillation to produce alcohol, a set of four gas engines can generate about 7 MW. The engines' exhaust provides heat to produce steam used in the distilling process.

Located in Whittlesey, Peterborough, the UK's largest French fry factory produces a wastewater output rich in potato starch, which must be cleaned and treated before it's properly discharged from the site. A covered anaerobic lagoon (CAL) is the first stage in the site's wastewater treatment process and produces biogas (which has a high methane content) as a by-product. The biogas qualifies as a renewable fuel.

Large, integrated facilities such as paper mills, steel mills and chemical plants have long used waste product streams as alternative fuels. The advance there is making more intelligent choices about which fuel to use when. Today, this is done based on availability, demand and spot prices, but it's easy to envision a future where certain products' carbon footprint specifications will call for renewable fuel, where others' might not.

Tata Steel's plant in Port Talbot, Wales, recently upgraded the controls on its largest steam boiler using new energy-management principles, technologies and services by Emerson Process Management. However, unlike most run-of-the-mill boiler upgrades, these new

principles and controls are enabling Tata to increase its energy efficiency, maximize waste fuels, cut emissions and reduce its reliance on purchased fuels.

The heart of the system is control technology that calculates and adjusts burners for the actual BTU values of fuel sources. "Our True BTU combustion control platform reinvents the current model of combustion management, which has been around since the 1920s and is still in practice today," says Chip Rennie, director of Emerson's Industrial Energy Group. "This brings about nothing short of a reinvention of combustion models, which will make the prevalent use of low-cost fuels like biomass achievable and sustainable."

At Tata Steel, "The boiler upgrades are helping us make better use of indigenous waste fuels, such as blast furnace gas, BOS gas and coke oven gas, which are byproducts of our manufacturing process," says Andrew Rees, manager of the mill's upgrade project. "The improved controls are part of a comprehensive energy management project that's expected to reduce powerhouse energy consumption by 3% to 5% and help us achieve our vision of becoming energy self-sufficient." ♦

Access a set of resources referenced in and related to this article at bit.ly/SustainablePlantCombustion.

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