Energy Efficient Operations and Maintenance Strategies for Boilers

Large, complex and widely used, industrial boilers are major consumers of fuel. Proper operations and maintenance (O&M) procedures must be followed to ensure safe and efficient operations. Without proper O&M energy consumption can increase by as much as 10 to 20 percent as the system slowly gets out of adjustment.

Maintenance includes keeping physical components in good working order and within design specifications. This includes cleaning heat transfer surfaces, controls tuning and maintaining insulation. Operational practices include equipment adjustments, handling and analysis of boiler log information and identification of boiler performance goals. Good operations and maintenance practices can be expected to save 5 to 10 percent of the energy a boiler normally consumes.

How Operations and Maintenance Strategies Can Save Energy

Efficiency losses are avoided by maintaining clean heat transfer surfaces, optimizing the air-to-fuel ratio of the burner, keeping steam vessels and pipes properly insulated, minimizing steam and boiler gas leakage, following good blowdown procedures, and minimizing steam pressure in keeping with load requirements. It is also important to match the boilers in use to the steam or hot water load. For facilities with multiple boilers and variable loads, achieving the most efficient combination of boilers may mean occasionally shutting down some to allow others to operate at a more efficient firing rate. Controls must be properly adjusted and coordinated for continuous delivery of steam or hot water to processes that are likely to be dynamic.

Proper operation and maintenance of boilers will help derive useful work from as much of the fuel as practical, by avoiding unnecessary efficiency losses and matching boilers to loads. It is important to establish operational goals and to maintain accurate logs for each boiler so that variances can be quickly identified and remedied.

Energy-Saving Operations and Maintenance Strategies

Boiler maintenance refers to keeping the boiler itself in efficient working condition. Boiler operation refers to adjustments and procedures that ensure the boiler meets its loads efficiently and safely.

Boiler Maintenance

Boiler maintenance must be systematic to minimize energy consumption and downtime due to un-anticipated failures. Responsibility should be assigned for performing and keeping written records with checklists of daily, weekly, monthly and annual maintenance tasks. Maintenance items that you should incorporate into your boiler’s routine include inspections, cleaning of fire- and water-side heat transfer surfaces, and insulation upkeep.
Boiler System Diagnostics and Inspection

A tune-up helps identify and address off-design equipment performance or undesirable site-specific operating practices/constraints before attempting to optimize boiler performance.

Negative-draft boilers should be checked for air leakage using smoke-generating sticks, a lighter flame, or ultrasonic equipment. High oxygen readings caused by air leaks can lead operators to reduce the air-to-fuel ratio, resulting in wasted fuel in the stack.

Check for steam and water leaks using ultrasonic probes for steam leaks in water-tube boilers. Any boiler with a water storage tank can be checked by shutting off the make-up water supply and observing the water level in the tank over a specified period of time. Prior to testing, the operator must be absolutely certain that low-water cutoff controls are functioning properly.

Air leaks and combustion non-uniformity should be checked for by a specialist.

Maintain Clean Heat Transfer Surfaces - Fire Side

Soot can build up on the fire-side of heat transfer surfaces even in gas-fired boilers. Elevated stack temperatures may indicate fouling of surfaces and inhibition of heat transfer. It is estimated that each 40°F rise in stack temperature cuts efficiency 1 percentage point. Alternatively, a 1/32-inch layer of soot reduces boiler efficiency an estimated 2.5 percent and a 1/8-inch layer an estimated 8.5 percent. As a general rule, stack gas temperature should not be more than 150°F above the temperature of saturated steam at the boiler operating pressure. The most likely causes of fouling are low air-to-fuel ratios, improper fuel preparation or malfunctioning burners.

Maintain Clean Heat Transfer Surfaces - Water Side

Scale deposits on the water-side of boiler tubes also inhibits heat transfer and lowers efficiency. If the fire-side remains clean, the tubes absorb heat without any means of dissipation. This can lead to tube failure, especially in water-tube boilers. In addition, scale accumulation may cause even more severe efficiency losses than soot accumulation.

The best way to deal with scale is not to let it form in the first place. This is accomplished by a combination of properly treating the boiler water in water softeners before it enters the boiler, by the injection of chemicals into the boiler water, and by blowing down the system. Scale that has already formed can be removed by mechanical means like water treatment or acid cleaning. Mechanical and acid cleaning require care to avoid damaging the tubes; water cleaning requires care not to remove scale too quickly. Removing scale too quickly can result in large pieces of removed scale restricting water flows, leading to localized overheating and possible catastrophic failure.
Maintenance of Insulation

The primary mechanism for heat loss through the skin of an uninsulated boiler is radiant heat loss. The higher the temperature of the boiler skin (insulated or not), the greater the radiant heat loss to the surroundings. The first inch of insulation reduces heat loss by about 90 percent. Each additional inch obviously will have much less impact. One rule of thumb is that any surface above 120°F should be insulated, including boiler surfaces, steam or condensate piping and fittings. Removable insulating jackets are available for valves, flanges, pressure-reducing valves, steam traps and other fittings. In addition, damaged, missing or wet insulation should be repaired or replaced.

Boiler Operations

Natural gas-fired boiler operational problems commonly fall into three major categories:

- Operation at non-optimum air-to-fuel ratios
- Lack of combustion uniformity
- Combustion controls/instrumentation placement issues

Air-to-Fuel Ratio

Efficient operation of any combustion equipment is highly dependent on a proper air-to-fuel ratio. Due to the mechanics of combustion, it is necessary to provide more air than would be required to provide exactly the right quantity of oxygen (O2) to burn all the fuel without any O2 left over. Because air is comprised of approximately 21 percent O2 and 79 percent nitrogen (N2), in delivering the right amount of O2, nearly four times as much N2 is also delivered. Nitrogen absorbs heat and carries it out the stack, resulting in a loss to the system. Minimizing excess air, consistent with complete combustion, minimizes this heat loss.

Complete carbon combustion forms carbon dioxide (CO2) as heat is released. Incomplete combustion forms carbon monoxide (CO) and less than one-third as much heat is released. CO is an un-burned combustible and, in the stack gas, an efficiency loss to the system. Figure 1 shows the relationship of excess (or deficient) air to unburned combustibles, CO2 and O2 in the flue gas. Many stack gas analyzers combine the measurement of either O2 or CO2 with the concentration of CO. Most systems will also display a calculated combustion efficiency value. Even with continuous monitoring of the flue gas, non-optimum air-to-fuel ratios may result due to air leaking in upstream of the analyzer; infrequent or incorrect analyzer calibration; insufficient combustion air supply at full load; or an analyzer placed at a non-representative location.
Combustion Uniformity

Complete combustion at efficient excess air levels requires the fuel and air to be uniformly mixed throughout the primary combustion zone. In multi-burner gas boilers, non-uniform combustion can result if the fuel and air are not evenly distributed due to a malfunctioning burner. The natural tendency when encountering noticeable CO levels is to raise excess air levels for the whole boiler, causing the other burners to operate at unnecessarily high O2 levels.

Uniform combustion can quite often be achieved by simple adjustments to the air register or damper settings. In other cases, further diagnostic testing is required. Considerable insight into combustion uniformity can be obtained by mapping the O2 profile at the economizer exit. Systems exist that will automatically measure and map O2 concentrations on a continuous basis. A complete combustion uniformity assessment typically involves an evaluation of combustibles and oxides of nitrogen (NOx) emissions.

Oxygen Analyzer Location

Occasionally, boilers with O2 analyzers have them placed at a non-representative location in the flue gas duct. This can be identified by diagnostic tests where the O2 analyzer sample plane is traversed with a probe connected to a portable O2 analyzer.
Reduce Steam Pressure

To the extent practical, steam should be generated at the lowest pressure that will meet the highest-pressure demand. Less fuel is required and lower stack temperatures result, improving efficiency. Savings may be as much as 1 or 2 percent, but actual savings depend on the starting pressure and the pressure reduction that is realized.

Blowdown Management

Blowdown is essential for maintaining low concentrations of dissolved solids in the water (skimming blowdown) or removing solids that have settled out of the water (bottom blowdown). Both practices result in unavoidable energy losses as hot water is wasted to the drain, and a balance must be maintained between acceptable results and energy losses. Skimming blowdown is best used as a continuous process, bottom blowdown is best done periodically as several short blowdowns. Continuous blowdown makes the use of heat recovery devices more feasible.

Load Management

When multiple boilers serve many loads, it is important to manage them as efficiently as possible. Individual boilers achieve maximum efficiency over a specific firing range. Units with high excess air requirements or significant radiation losses at low loads will have peak efficiency at a high load. Boilers with constant excess air levels and small radiation losses over the load range will exhibit peak efficiency at a lower load. Efficiencies should be determined over the full range of firing rates. More efficient boilers should be brought on line first as loads increase, and less efficient units should be taken off-line first as loads drop. Where possible, scheduling of loads can help achieve optimum system performance.

Energy Savings Feasibility

Look for the following factors to determine how you can improve the efficiency of your boiler system:

- **Too much excess air** will show up as elevated stack temperatures, because the hot gases are being forced through the boiler too quickly, without time for adequate heat transfer. Generally, stack temperature should not be more than 150°F above the temperature of saturated steam at the boiler operating pressure.

- **Boiler operation logs** should indicate whether excess air is too far out of limits of good practice. Gas-fired boilers should be able to operate at 5 to 10 percent excess air. This range corresponds to 1 to 2 percent O2, 11.9 to 12.3 percent CO2, and, depending on stack temperature, efficiencies of 85.2 to 85.4 percent.

- **On balanced-draft boilers**, normal O2 readings coupled with high combustibles and/or low stack temperatures may indicate air leakage into the system or air preheater seal leakage, situations that need to be remedied. Air leakage may also be indicated if high O2 readings are coupled with normal or even low stack temperatures.
• **Missing or degraded insulation** on boiler, steam and condensate lines and fittings.

• **Multiple boilers running at low fire simultaneously** may indicate potential improvements through load management. Low-fire conditions can be determined by asking the operator or comparing steam flow rates, as indicated by gauges or readouts at a control panel, to boiler ratings.

**More Information**

Contact your PG&E representative or call 1-800-468-4743 for more information about PG&E’s energy efficiency programs and other services.