Increasing the Energy Efficiency of Boiler and Heater Installations

A systematic approach to improving the energy efficiency of boilers – rather than unsystematic improvements involves a few simplified steps as shown in figure below.

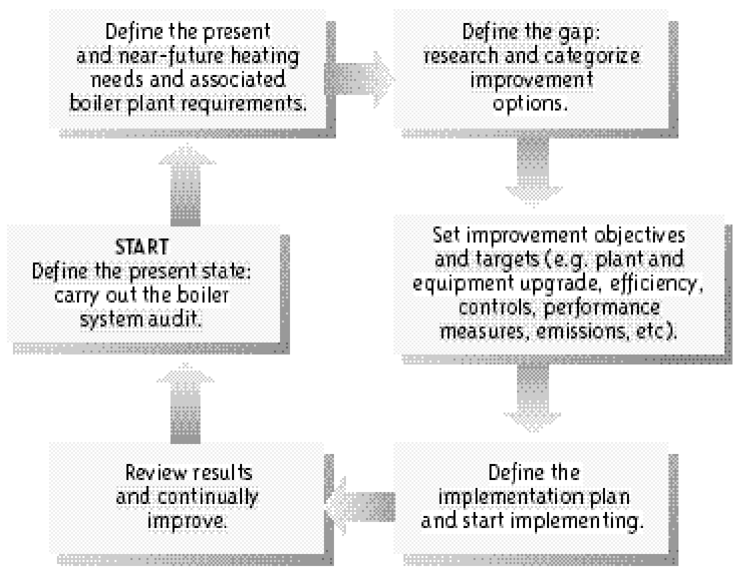

Figure 2. Boiler Efficiency Improvement Program

The following should be checked for further energy-saving and energy-reclaim opportunities:

- the heating needs and energy efficiency aspects of heat-consuming processes, products and equipment; and
- the heat distribution systems (such as steam and condensate).

Heat and energy losses in a boiler system can be reduced in several ways. Some, such as combined heat and power generation (cogeneration), are sophisticated and complex; others can be easily implemented and offer good payback.

The main categories in the energy efficiency improvement drive are the following.

1. PROPER BOILER OPERATION

1.1 Keep the boiler clean:

Except for natural gas, practically every fuel leaves a certain amount of deposit on the **fireside of the tubes**. This is called fouling, and it reduces heat transfer dramatically. Tests show that a soot layer just 0.8 mm (0.03 in.) thick reduces heat transfer by 9.5 percent and a 4.5 mm (0.18 in.) layer by 69 percent! As a result, the flue gas temperature rises – as does the energy cost.

Boilers that burn solid fuels (such as coal and biomass) have a high fouling tendency, whereas those that burn liquid fuels (particularly refined oils) have a low fouling tendency. Maintaining the boiler at peak efficiency requires keeping the boiler surfaces as clean as possible. Large boilers and those burning fuels with a high fouling tendency have soot blower systems that clean the fireside surfaces while the boiler is operating. Brushes and manual lances may also be used. Small boilers, including natural gas-fired boilers and those without soot blower systems, should be opened regularly for checking and cleaning.

Deposits (called scale) on the **waterside of the boiler tubes** can impair heat transfer. They can also reduce boiler efficiency, restrict water circulationand lead to serious mechanical and operating problems.

Scale causes the tubes' metal temperature to rise, which increases the flue gas temperature. In extreme cases, the tubes fail from overheating.

Tip: Remember, one millimeter of scale buildup can increase fuel consumption by 2%.

Rather than shutting down and draining the boilers to visually inspect the cleanliness of boiler waterside surfaces, waterside conditions can be estimated by testing the boiler water while the boiler is running. Certain water treatment chemicals can then be injected depending on the results. Boiler water is tested daily in small, low-pressure boiler plants and every hour in large, high-pressure plants. The water treatment and testing program is critical to ensuring the maximum efficiency and reliable operation of any boiler plant.

An upward trend in flue gas temperatures over weeks or months usually indicates that a deposit has built up on either the fireside or waterside of boiler heat-exchange surfaces. The boiler should be inspected promptly.

1.2 Keep unwanted air out

Effective control of excess combustion air also involves guarding against infiltration (ingress) of unwanted air into the boiler combustion cavity or the flue system. The air enters through cover leaks, observation ports, faulty gaskets and other openings.

1.3 Blowdown water - dollars down the drain

Even treated ("demineralized") boiler feedwater contains small amounts of dissolved mineral salts. Ongoing water evaporation in steam boilers and fresh boiler makeup water increases the concentration of these minerals and leads to scale formation. To prevent this, boiler water must be blown down periodically. Usually, the blowdown is excessive, "just to be sure." The blowdown water is heated, thus wasting heat, water and water treatment chemicals. As minimum preventive measures, test the boiler water periodically for the level of dissolved solids and adjust the blowdown rate.

When the blowdown is done once a day or once a shift, the content of dissolved solids immediately after blowdown is far below the acceptable maximum. If the blowdown can be done more often and with less water – or continuously – the total dissolved solids (TDS) content can be maintained closer to the desired maximum level of safety. The key is good control of TDS. Automatic blowdown control systems with continuous blowdown TDS measurements are available on the market. Water-heating boiler systems, obviously, do not incur the blowdown costs.

1.4 Maximize hot condensate return

A steam and condensate system must be properly designed to eliminate water hammer and reduce losses and maintenance. Losing hot condensate from a steam boiler system increases water consumption, water treatment chemicals and the thermal energy needed to heat the makeup water. Additional energy is lost in the form of flash steam. This develops when the process pressure, under which the condensate is returned, is released in the condensate return tank. Such losses can be minimized, for example, by submerging the condensate return inlet in the tank or installing a spray condenser fitted on top of the tank.

A **closed-loop system** that delivers steam condensate under pressure to be reboiled practically eliminates losses and needs less steam process equipment.

2. RECLAIMING BOILER SYSTEM HEAT LOSSES

2.1 Flue gas

Herein lies the best opportunity for heat recovery in the boilerhouse.

Tip: A 20˚C (36˚F) reduction in flue gas temperature will improve boiler efficiency by about one percent.

Even with well-adjusted burners providing the minimum flue gas temperatures while achieving complete fuel combustion, the exit temperatures of the flue gas may normally range from 175°C (350°F) to 260°C (500°F). Still, there is ample room to recover some of this heat that would otherwise "go up the stack."

Heat exchangers can be used for preheating boiler feedwater (called economizers) or combustion air (air heaters). Economizers typically increase the overall boiler efficiency by three to four percent.

Designers and operators of economizers must consider potential corrosion problems, particularly in fuels containing sulphur. Moisture containing corrosive sulphuric acid is likely to condense on any heat exchanger surfaces that fall below the acid dewpoint. This usually occurs near the inlet of the combustion air or feedwater to be heated.

Each boiler has its specific limit of low flue gas temperature, which should be determined individually if supplementary heat exchange is being considered. Since the flue gas temperatures are lower at lower loads, economizers often have some form of by-pass control that maintains the flue gas temperature above a preset minimum.

Condensing economizers improve the effectiveness of reclaiming flue gas heat. They cool the flue gas below the dew point. Thus they recover both sensible heat from the flue gas and latent heat from the moisture which condenses. Some moisture may be present in the fuel, but most of it is formed by combustion of the hydrogen component of the fuel. Since condensation (and the resulting danger of corrosion) is inevitable, the heat exchanger system must be made of materials that will not corrode. In direct-contact economizers, water is sprayed directly into the flue gas. The resulting hot water is collected and used after treatment to neutralize its corrosion potential. (This is an incidental advantage of direct-contact flue gas condensing: it removes particles and acid gases, such as SO2, from exhaust.) With condensing economizers, the overall boiler efficiencies can exceed 90 percent. (Heat pumps can complement a system for recovering flue gas heat, further increasing the reclaim efficiency.)

2.2 Blowdown heat recovery

Some ways to limit blowdown volume and heat loss were covered earlier. Heat exchangers can reclaim the sensible heat from the blowdown that goes into sewerage for heating boiler makeup water and the like.

2.3 BOILER USE AND SIZING

The use and sizing of a boiler system comes up for review when it needs to be replaced or extensively upgraded. Many boiler plants, particularly those used for space heating, face large seasonal or other variations in demand. The efficiency with which boilers convert fuel energy into steam or hot water drops off sharply at low load – when output falls below 40 percent of the maximum capacity rating. It therefore makes sense to select boiler sizes to match varying demand. A small boiler could be installed to operate at close-to-full load for periods of low demand; one or two larger boilers could handle peak loads.

In evaluating a boiler system’s use and sizing, consider current and future heating and process steam requirements. More opportunities for improving energy efficiency may be revealed while the process and process equipment are being reviewed.

3. COMBINED HEAT AND POWER GENERATION – COGENERATION

Old, inefficient boiler systems often need major, expensive upgrades. In such instances, where there are both electrical and heating demands or where electricity can be profitably sold, a case can be made for cogeneration – combined heat and power generation (CHP). CHP may need more fuel and considerably more capital above that needed to simply meet the heat requirement. But the bonus is the electric energy that CHP provides at high thermal efficiency. This means that the total energy, electrical and thermal, is supplied at lower cost. The high overall energy efficiency of CHP (up to 85 percent), CHP’s environmental benefits in reducing CO2 and Nox Emissions. A CHP unit typically consists of a prime mover, such as a gas turbine or piston engine, and a heat recovery steam generator, which is a type of boiler. The prime mover drives an electric generator and sometimes other equipment, such as air compressors. Its exhaust, via the steam generator, provides steam for heating or process use. CHP units are now available in sizes ranging from a few kilowatts to tens of megawatts of output.

4. OTHER CONSIDERATIONS

To optimize the performance and improve the energy efficiency of a boiler system, consider other factors. Some are a matter of regular maintenance and small-scale improvements; others are considered when a major upgrade is required.

4.1 Insulation

An audit of a boiler system may reveal that the insulation of the boiler and its piping system is inadequate, in need of repair or missing altogether.

4.2 Heating needs

Reducing the boiler's steam operating pressure to the minimum needed by the end user, or reducing the temperature of the fluid in the pipes in fluid heating systems, can dramatically affect the energy savings and the quantity of GHGs generated. These savings come from burning less fuel in the boiler or heater and lowering the amount of heat lost in the piping system.

To change the system's operating pressure or fluid temperature, verify that the boiler and end devices can run at the lower pressure (temperature). The potential environmental and dollar savings are worth investigating.

4.3 Distribution system losses

In steam systems, steam traps can fail (on average) up to 25 percent of the time. Steam leaking from pipe fittings, valves and traps can cause large energy losses. As well, water leaked from the system must be replaced, chemically treated and heated. This is a less apparent, but still expensive, consequence. Heating fluid systems also face this problem.

Ensure that the distributing pipework is the proper dimension. Oversized pipes increase capital, maintenance and insulation costs, and generate higher surface heat losses. Undersized pipes require higher pressure and extra pumping energy and have higher rates of leakage.

Redundant, obsolete pipework wastes energy: because it is kept at the same temperature as the rest of the system, the heat loss per length of pipe remains the same. The heat losses from extra piping add to the space heat load of the facility and thus to the ventilation and air-conditioning needs. Moreover, redundant pipework receives scant maintenance and attention, incurring further losses.

4.4 Improper de-aeration of boiler feedwater

Steam with as little as one percent by volume of air in it can reduce the efficiency of heat transfer by up to 50 percent. Pay attention to the de-aeration process as well as to the proper functioning of air vents.

4.5 Heat cascading

Plants with several heating needs may have an excellent opportunity to improve their overall energy efficiency with heat cascading. The heat exhausted from one part of the process can be used to heat another. While the high-grade heat supplied from fuel should be directed to the process needing the highest temperature, its exhaust heat should be used in lower temperature applications. The heat finally exhausted should be at the lowest temperature that can be economically achieved.

Reference:

http://oee.nrcan.gc.ca/publications/infosource/pub/cipec/2000-869_Boilers_and_Heat_E.pdf