

Appendix A. Steam

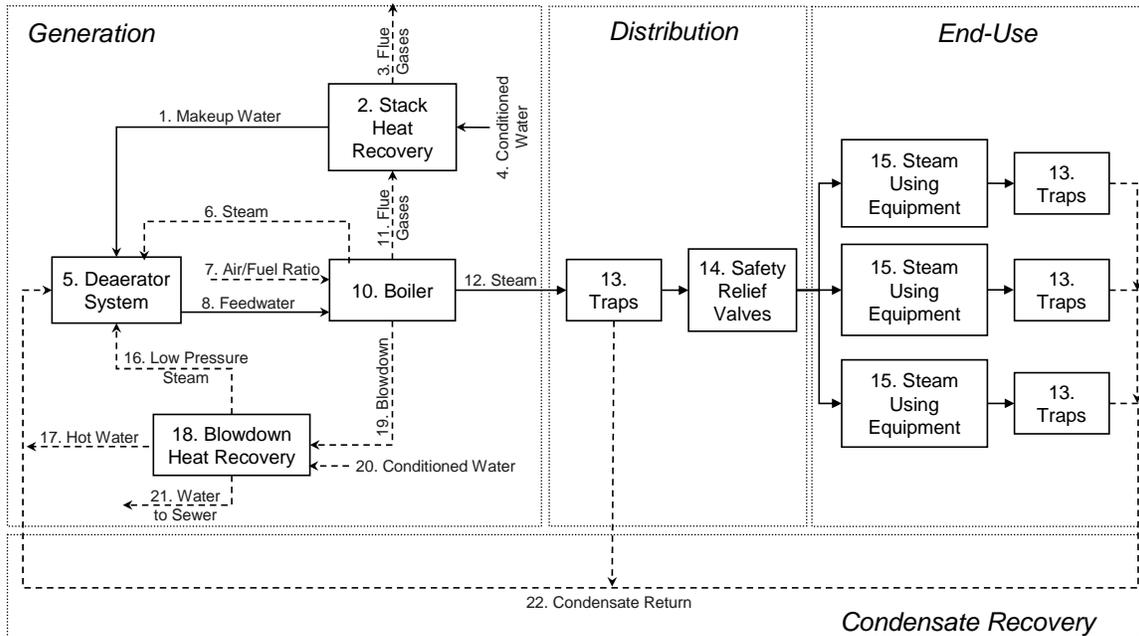


Figure A.1 – Steam system layout

Steam has a long, proud history, powering, among other things, the beginning of the Industrial Revolution. Steam’s high capacity to store energy in the form of heat and move a controlled amount of it easily and efficiently throughout a manufacturing facility has, to this day, made it a popular choice for a wide variety of industrial uses. In fact, over 45% of all fuel burned by U.S. manufacturers is used to generate steam. In the food processing industry, steam is used for processes like cooking, drying, and sterilizing. A general description of a steam system follows.

STEAM SYSTEM OVERVIEW (REFER TO FIGURE A.1 ABOVE)

A steam system can be divided into four distinctive areas:

- generation
- distribution
- end-use
- condensate recovery

Generation

Boiler

Feedwater (8) is transformed into vapor or steam (12) in the boiler (10). Most packaged boilers are classified as either water-tube or fire-tube. In a water-tube boiler, water flows inside a series of tubes that are externally heated by combustion gases. A fire-tube boiler is oppositely configured—water flows outside a series of tubes, which are heated

internally by combustion gases. In the boiler, a mixture of air (7) and a chosen base fuel (9) such as natural gas, fuel oil, coal, etc., supports combustion.

A boiler's air/fuel ratio is optimal when the amount of air mixed with the fuel is neither too little nor too much. If the air/fuel mixture does not have enough air (i.e., oxygen), incomplete combustion occurs. On the other hand, if the air/fuel mixture has too much air, the combustion becomes inefficient and stack temperature rises. This reduces the efficiency of the boiler because energy that could have been used to heat the water in the boiler is used instead to heat the excess air.

Since it is impossible to supply the precise volume of air needed for combustion, it is generally recommended that a small amount of excess air should be available to the boiler to ensure that complete combustion takes place.

Burner Management

Safety is a priority in boiler operation. The burner management system ensures the safety of the boiler and burner, monitoring such items as the flame, fuel pressures, temperatures, water level, etc. In addition, these systems are often designed to do other repeatable functions for the operator, including start-up and shut-down sequences.

Combustion Control

The separate purposes of the combustion control system and the burner management system can be a source of confusion. As stated, burner management is a safety system that monitors the burner; combustion control is the process of continuously regulating the flow of air and fuel to meet the demand for steam. The combustion control system is common to all steam generators, and the following control methods are used:

- single-point positioning
- parallel positioning
- metering
- steam flow/air flow

A single-point positioning combustion control system is the simplest type available. Interpreting a drop in boiler head pressure as a demand for steam, it increases the supply of air and fuel through a single mechanical device. Single-point positioning is the least costly system and, with characterizing fuels, provides an acceptable mixture of fuel and air.

Parallel positioning also responds to a drop in boiler steam pressure, but it controls the air and fuel supply separately. Unlike single-point positioning, this method allows for adjustments to the air/fuel mixture. However, since the relationship between the air and fuel is constant, the method cannot be fully optimized to match the ideal air/fuel ratio.

A metering system measures the fuel and air and properly mixes them for the combustion process. The most efficient method of control, it can even tie together the responses of multiple controllers, thus allowing one boiler to respond to a supply failure in another unit. It also prevents one boiler from getting too far ahead on the air/fuel ratio when a

change in demand is experienced. These systems are normally used in plants that want to achieve the highest possible combustion efficiency.

A steam-flow/air-flow combustion control system is used when fuel cannot be metered and when the fuel energy content changes, such as with wood or coal. This system measures the steam output and airflow and mixes the fuel and air to achieve a high combustion efficiency.

An oxygen trim system can be added as an additional loop to any of the above systems. This loop measures the amount of oxygen in the flue gases (11) leaving the boiler and produces a signal that is compared to a predetermined set point. The system then adjusts the air supply to maintain the optimal air/fuel ratio for that particular boiler load. According to Nebraska Boiler Company, more oxygen is generally appropriate at very low loads (10% or more) but only 2-3% at full load.³⁰

Blowdown

Solids, either suspended or dissolved, are always present in water. High levels of total dissolved solids (TDS), which eventually become sludge and settle in the bottom of a boiler, can both lower the boiler's heat transfer capabilities and cause significant damage to the unit. High levels of TDS also lead to foaming and carryover of liquid water into the steam supply. This reduces the efficiency of the system and can lead to water hammer, which may damage pipes, control valves, steam traps, and end-use equipment.

Solids are removed from the boiler by a process known as blowdown (19). There are two types of blowdown: bottom and surface.

Bottom blowdown is a manual process to remove the dissolved solids that have accumulated on the bottom of the boiler. The procedure is performed at regular intervals according to the type of boiler and steam and water usage.

Surface blowdown, also known as top blowdown, removes solids that are floating on or near the surface of the water in the boiler. Boilers have a metered opening just below the water's surface; high pressure inside the boiler forces or blows hot water (and the TDS) through this opening. There are three types of surface blowdown: intermittent, continuous, and automatic.

Intermittent blowdown is performed manually at intervals determined by the operator. The interval should be based on the amount of TDS in the boiler water, which can be very difficult to determine. Intermittent blowdown is recommended for boilers with low concentrations of TDS and/or with very minimal use of makeup water (1).

Continuous blowdown is normally done on boilers that have water with high concentrations of TDS. As the name implies, a small amount of water is continuously blown from the boiler to keep dissolved solids at acceptable levels.

³⁰ Nebraska Boiler, www.neboiler.com.

All blowdown procedures remove hot water and, therefore, energy from the steam system. This causes a decrease in total energy efficiency. Removing more water than is necessary to control TDS wastes energy and also money if water treatment chemicals are unnecessarily removed. In order to reduce these wastes and improve steam reliability, an automated blowdown system can be installed to optimize the interval and quantity of blowdowns. The automated system consists of controls, an automated valve, any necessary piping, and equipment that indicates TDS levels based on some measurement, such as the conductivity or relative density of the water.

The quantity of TDS in the water and/or the amount of makeup water used determines whether the blowdown should be intermittent, continuous, or automated.

Blowdown Heat Recovery

To further reduce the energy lost due to required blowdown, some type of blowdown heat recovery (18) process can be used. This will generally include two methods of recovery: heat exchanger and flash steam generation.

To recover the heat content of the water, a heat exchanger must be used. The water itself, which cannot be recirculated because of its high TDS content, is sent to the sewer (21). The conditioned water (20) is heated by the heat exchanger and sent to the deaerator system (5) to be part of the feedwater (8) supplied to the boiler.

Because the pressure inside a boiler is high, the water near its surface is at a temperature well above the point at which water would evaporate at normal atmospheric pressures. When this water is removed from the boiler, it experiences a tremendous drop in pressure, which immediately converts some of the water into steam in a process known as “flashing.” This is dangerous if not handled correctly, but it also presents a second opportunity for energy recovery from surface blowdown. If this water is released into what is called a flash system, the heat/energy is captured in the form of low-pressure steam (16). This steam is free of TDS and can be returned to the deaerator system or used in a low-pressure steam end-use application.

Deaerator System

Feedwater is provided to the boiler from the deaerator system. Water enters the system from different sources including makeup water, hot water (17) from blowdown heat recovery, and condensate return (22). Before the water enters the boiler, all dissolved gases are removed to minimize corrosion. This process requires energy that is usually supplied by injecting some of the steam (6) produced by the boiler and/or low-pressure steam flashed from blowdown heat recovery.

Deaerators can use an atmospheric tank or a pressurized tank. One advantage of a pressurized tank is that condensate can be returned at a higher pressure and temperature, which reduces the amount of energy needed at the boiler to generate steam. The higher temperature also reduces the amount of dissolved gases in the water.

When a pressurized tank is used, deaeration takes place in two stages: the first stage is a spray assembly; the second stage will use either an atomizer or trays. Atomizer or spray-

type deaerators use a high-velocity steam jet to remove gases. Tray-type deaerators use agitation created by spilling the water over several stacked plates usually arranged in a staggered pattern.

Stack Heat Recovery

Steam absorbs most but not all of the heat generated during combustion. Over 20% of it is normally exhausted from the boiler through the stack. (As discussed earlier, more heat is exhausted as the quantity of excess air is increased). A stack heat recovery (2) device can capture much of this energy, which is frequently used to heat water or air. There are three types of heat exchangers commonly used for stack heat recovery:

- economizer (pre-heating makeup water)
- air pre-heater (heating boiler combustion air)
- condensing-type economizer (heating process water)

An economizer is used to pre-heat makeup water that is needed because of system losses from blowdown and condensation. There are three different ways to position an economizer: in series prior to the deaerator (as shown in Figure A.1 above); in series between the deaerator and the boiler; or in parallel with the deaerator providing constant flow between the two.

An air pre-heater raises the temperature of the boiler combustion air so that less energy from the boiler is needed to heat the air. Both an air pre-heater and an economizer will reduce stack temperature; however, it is important that stack temperature remains hot (commonly above 300°F) to avoid condensation of gases that could produce acids that might damage the stack.

The use of condensing-type economizers is restricted to facilities that use high volumes of hot water for processes such as sterilization and equipment cleanup. Because of the volume of water that is heated, stack temperature will be dramatically reduced, causing condensation. This condensate is corrosive and could destroy standard stack materials. Therefore, special materials and a bypass are used in conjunction with a condensing-type economizer. The bypass is necessary to protect the special materials from damages caused by high stack temperatures.

Stack heat recovery systems can improve boiler efficiency as much as 15%.

Clean Heat Transfer Surfaces

It is normal for heat transfer surfaces to become fouled over time. Inside of a boiler, both the fire and water sides can be affected by the accumulation of dirt. The accumulation acts as an insulator, thus reducing heat transfer and wasting energy. In a fouled boiler, the wasted heat increases stack temperature. Heat exchangers like economizers can accumulate dirt, which also impacts efficiency.

Distribution

The distribution system is responsible for carrying the steam from the boiler to the end-use equipment in the plant. The distribution system must be properly designed to account for condensate drainage, system pressure, and flow control.

Support

All steam supply and condensate return pipes should be properly supported, guided, and anchored, allowing for expansion of the pipes due to temperature changes. A structure that is too tight can deform pipes and cause leaks.

Steam Traps

As steam moves throughout the system, it changes temperature, causing some condensation. Condensate may produce pipe hammering and can damage equipment by producing rust. Air can also cause condensate to form.

Steam traps (13) are automatic valves that separate air and condensate from the steam. A leaky trap wastes energy by allowing steam to enter the condensate return or by not expelling the condensate from the steam line, which reduces the efficiency of the system. Traps are classified into three main groups—mechanical, thermostatic, and thermodynamic—and there are several different types of traps in each group.

Because the traps function in different ways, sizing, positioning, and installation procedures vary, so attention must be paid to manufacturers' instructions. For example, some traps must be installed with the outlet pointing upward.

Safety Relief Valves

Safety relief valves (14) are placed on steam systems to protect components from damage caused from excessive pressure build-up in steam using equipment (15). These valves are often placed near the end-use equipment that it protects. For proper installation of pipes and relief valves, ASME B31.1—Power Piping code should be followed.

Insulation

As the temperature of the steam in the distribution system drops, it wastes energy. While some temperature drop is unavoidable, effectively insulating vessels, steam lines, valves, and even condensate return lines can help to reduce energy losses.

Condensate Recovery

The condensate recovery system is responsible for capturing the condensate present in the steam system and returning it to the deaerator system. The water quality of condensate is high enough for reuse in the boiler. Because its temperature is relatively high compared to cold makeup water, it requires much less energy to be reconverted into steam. In addition, it does not contain high TDS levels and does not require additional chemical treatment. As much condensate as is practical should be returned to the deaerator system. It can be recovered from processes, drips, or the steam lines (tracers) used to keep

product from solidifying or freezing. Although drips and tracers generate relatively small amounts of condensate, they should not be neglected.

More information about the basics of steam systems is widely available. Refer to the list of resources at the end of this chapter.

ENERGY SAVINGS OPPORTUNITIES AND RELATED BEST PRACTICES

Since over 45% of all fuel burned by U.S. manufacturers is used to generate steam, proper management of this system is an important part of an effective EM system. The following paragraphs describe various factors that present opportunities for energy savings; where available, the accepted best practices associated with each factor are also given.

Supply

Correct Sizing of Boilers and Operating at High-Efficiency Firing Rates

Boilers differ in efficiencies due to model differences, type differences, etc. Food processors should identify the efficiency of their boilers and determine at what firing rates the efficiency peaks. Once this is known, the equipment can be set up for optimal use. Automatic controls can be installed to monitor the temperature and pressure of the system and control it accordingly.

The size of the boiler should be carefully considered. Oftentimes, companies purchase units that are capable of producing much more steam than the company needs. Short cycling occurs when oversized boilers quickly meet the demand for steam. The equipment becomes idle for a relatively long period of time, which leads to decreased energy efficiency. Operating boilers at very low rates also reduces efficiency, since some losses are fixed independent of the amount of steam produced.

Consider an example from Tip Sheet #16 of the U.S. Department of Energy (DOE), “Improving Steam System Performance: A Sourcebook for Industry.” In this example, a large boiler with a cycle efficiency of 72.7% (E_1) is substituted with a smaller boiler with 78.8% (E_2) cycle efficiency. The fraction of fuel saved can, therefore, be calculated as follows:

$$\text{Fraction Fuel Savings} = \left(1 - \frac{E_1}{E_2}\right) \times 100 = \left(1 - \frac{72.7}{78.8}\right) \times 100 = 7.7\%$$

As seen above, savings from operating a boiler at its best efficiency can be extremely valuable.

DOE's Industrial Technologies Program offers free software programs that allow users to assess current steam systems and potential energy saving improvements. These are available at the DOE Best Practices webpage.³¹

Air/Fuel Ratio

Inexpensive equipment is available that can determine the amount of excess air in combustion by measuring the contents of flue gases. DOE recommends such an investment for boiler systems with annual fuel costs above \$50,000. Equipment that measures oxygen is more precise than carbon dioxide measuring devices. Information from the combustion analysis equipment is used to calibrate the settings on the air and fuel supply systems.

Periodic testing and adjustments to the burner are recommended to increase boiler efficiency. Contact the burner manufacturer for safety procedures and instructions before doing adjustments, and always adhere to applicable codes. Common practice is to test and adjust at two points only, a high- and low-firing rate, but this usually results in inefficient combustion at intermediate rates. The best practice is to adjust the burner at several different points along the air/fuel ratio curve.

In modern boilers, excess air should be set to approximately 10% (2.2% oxygen). This will vary from boiler to boiler and from application to application; always consult the boiler manual. Reducing excess air reduces stack temperature, as explained earlier. A widely used rule of thumb for estimating energy savings is that for every 40°F reduction in stack temperature there will be a corresponding increase in boiler efficiency of 1%.

Turbulators

In a fire-tube boiler, combustion gases usually pass back and forth multiple times. Since the water has more opportunity to absorb the combustion heat before it's exhausted, the overall efficiency of the boiler is increased. However, this also creates a problem. The turbulence of the exhaust gases becomes less intense on the later passes, allowing layers to form with the coolest layers to the outside nearest the tubes' surfaces. As a result, heat transfer is less efficient.

A device known as a turbulator can be used in multi-pass fire-tube boilers to increase the efficiency of heat transfer between the combustion gases and the surfaces of the tubes. Turbulators are available in different designs, including small baffles, twisted metallic strips, or steel coils that are inserted in the tubes. Heat transfer is enhanced when these devices reintroduce turbulence to the flow of the gases, breaking up the laminar boundary layer of gas near the tubes' surfaces. Turbulators are normally installed on the last pass where the gas flow is most laminar.

Turbulators are not yet widely accepted in the marketplace, but DOE has issued a bulletin that recommends that they be considered for two- and three-pass fire-tube boilers. Because turbulators can increase the heat absorption from combustion gases and thereby

³¹ U.S. DOE ITP Best Practices, <http://www.oit.doe.gov/bestpractices/>.

lower stack temperatures, DOE touts them as “a substitute for a more costly economizer or air-preheater. They are simple, easy to install and low cost.” DOE documents the case of a manufacturing facility that installed turbulators into their fire-tube boilers and reduced stack temperature by 140°F, improving boiler efficiency by 3.25% and reducing fuel costs by 4%.³²

Boiler Room Ventilation

As previously stated in a description of air-fuel ratio, air is a basic element in combustion. Improper ventilation in the boiler room may lead to oxygen starvation in the burner, which results in incomplete fuel combustion. The commonly accepted process for calculating the amount of air required for boiler room ventilation is:

- determine the maximum burner CFM (flow rate) requirement for each boiler
- add all boilers’ CFM requirements
- total required CFM X 1.1 = required CFM for the boiler room ventilation

This process does not take into consideration any other co-located applications (e.g., air compressors) that could add to the required amount of intake air. Always consult local codes that may supersede this recommendation.

Note that sufficient air is frequently provided through open doorways. However, during inclement weather, personnel frequently close these openings in order to maintain a workable room temperature. This can starve the boiler, upsetting the air/fuel ratio and dramatically reducing efficiency. Improper ventilation is usually noticeable in doorways where fast airstreams enter the room from adjacent areas. This airflow is caused by a negative pressure buildup when more air is exhausted through the stack than is brought into the boiler room.

Proper room ventilation affects energy usage by ensuring sufficient oxygen is available for complete fuel combustion. When the air supply is insufficient, combustion is incomplete or burners must run longer at higher firing rates to provide the needed steam.

Preheating Boiler Intake Air

All air that is used in the boiler is raised to combustion temperature. This requires energy that could otherwise be used to heat the water in the boiler. For this reason, it is a best practice to preheat the combustion air by absorbing heat that is otherwise wasted. This is commonly done through an air-to-air heat exchanger on the exhaust stack, or simply by collecting air from a warmer location, such as the air close to the ceiling. However, special attention must be taken to the capacity of the burner fan and to readjusting the air/fuel ratio. Warmer air is less dense and therefore carries less oxygen per volume. Thus, as air temperature increases, the fan will have to blow more air to the burner to keep the necessary oxygen.

³² “Consider Installing Turbulators on Two- and Three-Pass Firetube Boilers,” U.S. Department Of Energy, Steam Tip Sheet #25, April 2004.

Preheating boiler intake air is usually economically feasible for large water-tube boilers because some changes to the burner fan may be necessary. On smaller boilers, the cost of these component changes usually extends the payback period beyond acceptable limits.

A common rule of thumb is that every 40°F increase in air intake temperature yields approximately 1% in boiler efficiency improvement.

Burner Fan Motors

Installing premium efficiency motors and variable frequency drives (VFD) on burner fan motors may significantly reduce energy consumed by the boiler. Refer to the motors appendix of this document for more details.

Burner Management

Because the burner management system is so important to boiler room safety, a thorough audit of all boiler safety devices should be performed at least once a year. Furthermore, this system should be independent and not be used for other purposes such as combustion control.

Steam Pressure

Reducing steam pressure can reduce energy usage, maintenance costs, and labor costs. At low pressures, there is a decrease in leakage and losses due to transportation resistance. In addition, the steam is also at a lower temperature, thus there is a direct savings of energy. The reduction in steam leakage due to a reduced flow rate and pressure saves energy and makeup water costs. Makeup water costs can be significant because of water treatment expenses.

Decreasing steam pressure (and therefore temperature) also reduces heat transfer losses during steam distribution. If the change means that an operator needn't be present in the boiler room at all times or if a lesser-ranked worker can be substituted, there may be labor cost savings as well. Valves and pipes are less stressed at lower pressures, which can result in reduced maintenance costs.

Pressure should be reduced to the minimum allowed by the boiler and plant equipment. Remember to consider line losses when finding the minimum allowable pressure for the system. For safety reasons, it is important to refer to the boiler manufacturer's documentation before adjusting the minimum boiler pressure.

Deaerators

The deaerator supplies water to the boiler as feedwater. Feedwater temperature is important because raising feedwater temperature 6°C results in a savings in boiler fuel of approximately 1%. A tray-type deaerator is the most energy-efficient deaeration system and should be used whenever possible.

Whenever there has been a significant change to the steam system, like the addition of end-use equipment, increased condensate return, or heat recovery energy conservation measures, it is important to re-examine deaerator steam requirements.

Installation of continuous dissolved oxygen monitoring devices will help to identify operating practices that result in poor oxygen removal.

Minimizing Blowdown

As much condensate as possible should be recovered to reduce the volume of makeup water needed. Amount and frequency of blowdowns is dependent on the quantity and condition of the boiler makeup water. The blowdown rate normally should not be over 1-3% of the steam output.

Because bottom blowdown is performed manually, this type of procedure can only be improved by observing the content of the water drained. If the water drained does not contain impurities, the procedure can be done less often, until an optimal frequency is found for the plant. Heat recovery is not feasible on bottom blowdown systems.

The correct time interval between intermittent blowdowns should be determined using the aforementioned process for minimizing bottom blowdown.

The blowdown should be performed in such a way that the TDS level is kept to its maximum allowable value. Wulfinghoff's Energy Efficiency Manual provides an equation for approximating the amount of blowdown as follows:

$$\text{Blowdown rate} = \text{Makeup rate} \times \frac{\text{TDS of Feedwater}}{\text{TDS in Boiler} - \text{TDS of Feedwater}}$$

Automatic blowdown should be used whenever feasible to save energy on reducing blowdowns and also for better heat recovery.

Heat Recovery from Blowdown

Heat recovery is more efficient with continuous and automatic blowdown systems. If the correct equipment is used, up to 78% of the heat can be recovered. Heat can be recovered from the water and the flash steam.

To recover the heat content of the water, a heat exchanger must be used since TDS is present. Water heated on the heat exchanger can be sent to the deaerator tank to become part of the makeup water. For collecting the steam portion, the blowdown must be dumped in a flash tank where a portion of the water is flashed to steam. The flashed steam may be directly taken to the deaerator tank since it is free of TDS.

The Industrial Assessment Center program has shown energy savings of approximately \$3,800/year on a 400-hp fire-tube boiler with automatic blowdown system for heat recovery.

Heat Recovery From Stack Flue Gases

When possible, heat from the stack should be recovered. An economizer can efficiently recover wasted stack heat and transfer it to boiler makeup water. As mentioned before, an increase of water temperature of 6°C results in a savings in boiler fuel of approximately

1%. For air pre-heaters, an increase of air temperature of 40°F results in an increase of boiler efficiency of 1%.

Condensing economizers require more changes and cost more but can provide about 10-15% increase in boiler efficiency.

Clean Heat Transfer Surfaces

Heat transfer surfaces should be cleaned periodically. Cleaning intervals depend on individual systems based on the boiler type and amount of makeup water used. Boiler water sampling can detect fouling on the water side. It is recommended that surfaces be cleaned at least once a year. Correct blowdown and water treatment will aid in keeping the water side surface clean. Insufficient blowdown will increase the amount of dirt in the steam system.

Monitor Fuel Usage and Document Price

Documentation is a critical component of improving energy efficiency. Factors to document include type of fuel, cost, amount used, operating steam pressure, and feedwater temperatures. Auxiliary systems (pumps, fans, etc.) can also be included for calculating the base price, which is normally based on 1,000 pounds of steam.

The following suggestions will make the documentation process easier and more efficient:

- Keep track of and document information related to the quantity and cost of fuel as well as quantity of steam (if possible).
- Keep a log of air/fuel ratio tests and adjustments to the burner.
- Build a pressure and load schedule; this is important when trying to set up the system to maximize boilers' efficiency.

The following equation can be used to find the cost of 1,000 pounds of steam based on the cost of fuel:

$$\text{Steam Cost} = \frac{A}{B} \times 1,000 \times 1,006 \times \frac{100}{E}$$

Where:

A = cost of fuel per therm

B = conversion constant, Btu per therm (100,000 for natural gas)

E = boiler efficiency

Information does not serve any purpose if not used. Examine the data on air/fuel ratio tests and adjustments to the burner, looking for ways that best practices can be applied to improve the system. The log can also be used to find problems in the system by tracking data that indicate the system is behaving unpredictably. Look for the likely causes of such data.

Distribution

Proper Use of Steam Traps

As with any device, traps fail with time. Periodic testing must be performed to find malfunctioning traps. Traps that are not serving their purposes can waste energy, negatively impact production, and damage equipment by allowing condensate or air to enter the product or by decreasing the temperature of the steam.

Testing of traps can be done in the following manner: ultrasonic testing, listening to audible trap sounds, checking condensate vents, opening test valves, visually checking using a sight glass, and measuring temperature differences.

Drip leg and steam trap stations should be installed at low points in the piping system, wherever pipes change direction, and at locations just upstream of valves that are normally closed.

It is estimated by DOE that systems not inspected during a three-to-five-year period will show about 15-30% of traps failed. A 1/8-inch trap on a 150 psig steam line can waste approximately \$3,000/yr.³³

Insulation

DOE's Industrial Technologies Program offers free software on choosing proper insulation material and thickness. The software is called 3E Plus and is available at the Best Practices webpage.³⁴ A 100-foot section of inefficiently insulated or bare steam pipe can lose as much as 480 MBtu/year³⁵.

Insulation should not be limited to steam pipes. Joints, valves, tanks, and condensate lines should also be insulated, as they are also sources of heat loss.

Fix Steam Leaks

Needless to say, steam leaks are a waste of money. More importantly, high-pressure steam leaks can be very dangerous. Leakage is most common at joints, valves, fittings, or where a sealant is present. If water treatment is not good, corrosion can cause pipes to leak as well.

Leaks can often be detected visually or by the sound. In some cases, larger leaks are not immediately repaired simply because the operator thinks that the leak is not a leak but a normal part of the operation. In most cases, steam should not be visible in a plant, as it should be discharged in a return system.

Infrared scanners and ultrasonic equipment can help detect smaller leaks.

³³ "Inspect and Repair Steam Traps," U.S. Department of Energy, Steam Tip Sheet #1, June 1999. Example uses \$4.50 per thousand pounds of steam.

³⁴ U.S. DOE ITP Best Practices, <http://www.oit.doe.gov/bestpractices/>.

³⁵ For uninsulated 2" pipe operating at 365°F or 150 psig steam pressure. Source, Plant Support and Evaluations, Inc.

Approximately \$100/yr can be saved in energy alone by fixing a very small leak with steam pressure of about 120 psig. There are usually additional savings because fixing the leak reduces the amount of makeup water that must be added to the boiler and reduces the pressure drop (and temperature drop) in the system.

Return of Condensate

Annual savings for properly returning condensate to the boiler can greatly decrease the usage of fuel. DOE estimates that up to about 18% of fuel used to heat makeup water can be saved with this action. In most cases, condensate should be returned at the highest pressure possible. If a low-pressure steam use is available at the facility, condensate can also be flashed to steam. In all cases, it is beneficial to return condensate to the boiler even if it is at atmospheric pressure so that some heat and the water can be reused.

Make sure that the condensate return piping is correctly sized. It is normal for some flash steam, which has a larger volume than water, to be present on the return system. Condensate pipes should be sized to accommodate a water-vapor mixture.

Safety

Be proactive about safety matters. Don't wait for accidents to happen before you make changes to enhance the safety features of your system. Install a reliable burner management system. Furthermore, follow codes and regulations regarding boilers, pressure vessels, and piping.

Be aware that in most cases your boiler inspector will not check your piping system unless it is close to the boiler. This does not mean that he considers the piping correct and safe. A good starting point for safety information is code B31.1 provided by the American Society of Mechanical Engineers (ASME).

RESOURCES

Printed Material

ASME B31.1, Power Piping.

Moran, M.J. and Shapiro, H.N., Fundamentals of Engineering Thermodynamics, John Wiley & Sons, 4th ed., 1999.

Mull, T.E., Practical Guide to Energy Management for Facilities Engineers and Managers, ASME, NY, 2001.

Singh, R.P. and Heldman, D.R., Introduction to Food Engineering, Academic Press, 3rd ed., 2001.

Wulfinghoff, D.R., Energy Efficiency Manual, Energy Institute, MD, 1999.

DOE maintains an extensive listing of publications and articles that provide information on steam, related best practices, and standards. They are listed in categories and can be found at the following webpages:

Total Steam System: <http://www.oit.doe.gov/bestpractices/steam/totalsteam.shtml>

Generation: <http://www.oit.doe.gov/bestpractices/steam/generation.shtml>

Distribution: <http://www.oit.doe.gov/bestpractices/steam/distribution.shtml>

End use: <http://www.oit.doe.gov/bestpractices/steam/enduse.shtml>

Recovery: <http://www.oit.doe.gov/bestpractices/steam/recovery.shtml>

On-Line Tools

U.S. Department of Energy

Best Practices: www.oit.doe.gov/bestpractices

Steam tools and publications: <http://www.oit.doe.gov/bestpractices/steam/tools.shtml>

- Fact Sheets
- BestPractices Steam Reports
- Technical Briefs
- Industry Successes
- Steam Tips
- Case Studies
- Financial Tools
- Technical Tools
- Training
- Library
- Software
- Energy Service Companies/Assistance Centers

Software Tools: www.oit.doe.gov/bestpractices/software_tools.shtml

- Process Heating Assessment and Survey Tool (PHAST)
- Steam System Scoping Tool
- Steam System Assessment Tool (SSAT)
- 3E Plus – Insulation Thickness Computer Program

Energy Efficiency and Renewable Energy – Industrial Technologies Program

Energy Information Bridge: www.osti.gov/bridge

Energy Matters: www.oit.doe.gov/bestpractices/energymatters/energy_matters.shtml

Spirax Sarco Learning Center:

www.spiraxsarco.com/learn/default.asp?redirect=html/3_13_01.htm

Steaming Ahead: www.steamingahead.org

Organizations

Association of Energy Engineers: www.aeecenter.org

Boiler Efficiency Institute: www.boilerinstitute.com

Council of Industrial Boiler Owners (CIBO): www.cibo.org

Gas Research Institute: www.gri.org

Iowa State University Industrial Assessment Center (IAC): (515) 294-3080 or
www.me.iastate.edu/iac

United Kingdom Energy Efficiency: www.etsu.com