6.5 Boiler and Steam Systems

EPA WaterSense

Overview

Boiler and steam systems are used in large building heating systems for heating water or to produce steam for industrial processes, cooking, or other operations. Hot water boilers are a subset of commercial and industrial boilers used to heat water. Steam boilers, which include water-tube and fire-tube systems, produce steam by boiling water. Low-pressure boilers are used most for commercial applications and heating water, while high-pressure boilers are more common for power generation and industrial processes.[27]

Hot Water Boilers

Hot water boilers are used to provide hot water for bathing, laundry, dishwashing, or similar operations. Unlike steam boilers, however, they do not produce steam. Instead, hot water boilers essentially act as commercial- or industrial-scale water heaters.[28]

Hot water boiler distribution systems can be open or closed. Open systems provide hot water to end uses, such as hand washing, bathing, and laundry. These can either be direct-supply systems or have loop piping, whereby the hot water is recirculated back to the hot water boiler. Open systems are typically found in food service or laundry operations. Recirculating systems are most commonly used in applications that need hot water instantaneously, such as hotels.

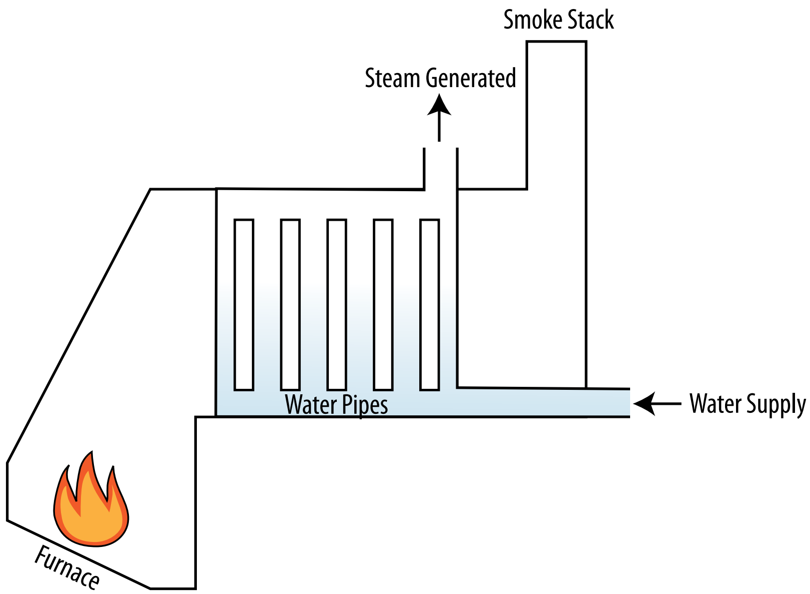
Closed systems are often used for heating buildings. Hot water is circulated in a closed loop for space heating, using either air heat-exchange or hydronic floor-heating systems. Water in closed-loop systems is typically treated to prevent corrosion and scaling. Additional water is needed only to make up for leaks and periodic additions.[29] Because water efficiency isn't a primary concern for hot water boiler systems, they are not discussed further in this section.

Water-Tube Boilers

Water-tube boilers (see Figure 6-5) are used for high-pressure boiler applications. In these systems, water circulates through tubes that are indirectly heated by fire. Exhaust gases remain inside the boiler shell and pass over tube surfaces to heat the water. The heated water then rises as steam to be used for cooking, as process steam, or for other operations. Water-tube boilers are lighter by design and thus able to withstand higher pressures. They are also capable of high efficiencies and generating saturated or superheated steam.

[27] East Bay Municipal Utility District (EBMUD). 2008. *WaterSmart Guidebook—A Water-Use Efficiency Plan Review Guide for New Businesses*. Pages THERM10-14. www.ebmud.com/for-customers/conservation-rebates-and-services/commercial/watersmart-guidebook.
[28] *Ibid.*
[29] *Ibid.*

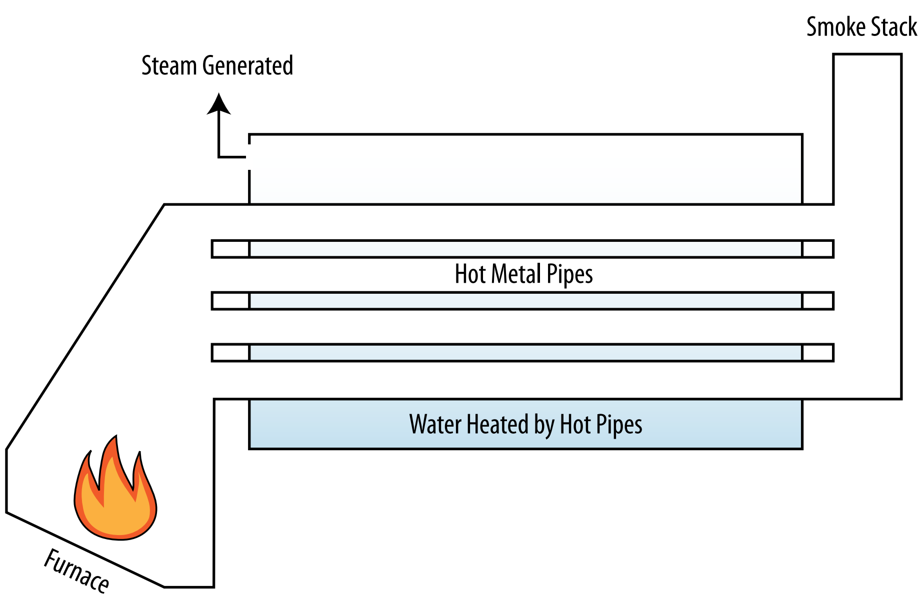
Figure 6-5. Water-Tube Steam Boiler Configuration



Fire-Tube Boilers

The most common type of steam boiler is the fire-tube boiler (see Figure 6-6).[30] In this type of system, a gas- or oil-fired heater directs heat onto a series of tubes that are immersed in water, which transfers heat to the water, generating steam.

Figure 6-6. Fire-Tube Steam Boiler Configuration



[30] *Ibid.*

In both types of steam boiler configurations, as the steam is distributed, its heat is transferred to the ambient environment and, as a result, it recondenses to water. This condensate is then either discharged to the sewer or captured and returned to the boiler for reuse. If the condensate is discharged to the sanitary sewer, most codes require it to be cooled to an acceptable temperature before discharging. The hot condensate is typically tempered with cool water to meet the temperature discharge requirements.

As the water is converted to steam, dissolved solids, such as calcium, magnesium, chloride, and silica, are left behind. With evaporation, the total dissolved solids (TDS) concentration increases. If the concentration gets too high, the TDS can cause scale to form within the system or can lead to corrosion. The concentration of TDS is controlled by removing (i.e., blowing down) a portion of the water that has a high concentration of TDS and replacing that water with make-up water, which has a lower concentration of TDS. Some boiler operators practice continuous blowdown by leaving the blowdown valve partially open, requiring a continuous feed of make-up water.

From a water-efficiency standpoint, installing and maintaining a condensate recovery system to capture and return condensate to the boiler for reuse is the most effective way to reduce water use. Recovering condensate:

- Reduces the amount of make-up water required.
- Eliminates or significantly reduces the need to add tempering water to cool condensate before discharge.
- Reduces the frequency of blowdown, as the condensate is highly pure and adds little to no additional TDS to the boiler water.

In addition, since the steam condensate is relatively hot, when it is added back to the boiler, it requires less energy to reheat to produce steam again.

Proper control of boiler blowdown water is also critical to ensure efficient boiler operation and minimize make-up water use. Insufficient blowdown can lead to scaling and corrosion, while excessive blowdown wastes water, energy, and chemicals. The optimum blowdown rate is influenced by several factors, including boiler type, operating pressure, water treatment, and quality of make-up water. Generally, blowdown rates range from 4 to 8 percent of the make-up water flow rate, although they can be as high as 10 percent if the make-up water is poor quality with high concentrations of solids.[31,32]

Blowdown is typically assessed and controlled by measuring the conductivity of the boiler make-up water compared to that in the boiler blowdown water. Conductivity provides an indication of the overall TDS concentration in the boiler. The blowdown percentage can be calculated as indicated in Equation 6-6. The boiler water quality is

[31] U.S. Energy Department (DOE), Energy Efficiency & Renewable Energy (EERE). January 2012. *Minimize Boiler Blowdown*. www1.eere.energy.gov/industry/bestpractices/pdfs/steam9_blowdown.pdf.

[32] DOE, EERE. January 2012. *Return Condensate to Boiler*. www1.eere.energy.gov/manufacturing/tech_deployment/pdfs/steam8_boiler.pdf.

often expressed in terms of cycles of concentration, which is the inverse of the blow-down percentage.[33]

Equation 6-6. Boiler or Steam System Blowdown Percentage (percent)

= Conductivity of Make-Up Water ÷ Conductivity of Blowdown

Where:

- Conductivity of Make-Up Water (milligrams per liter of TDS)
- Conductivity of Blowdown (milligrams per liter of TDS)

Controlling the blowdown percentage and maximizing the cycles of concentration will reduce make-up water use; however, this can only be done within the constraints of the make-up and boiler water chemistry. As the TDS concentration in the blow-down water increases, scaling and corrosion problems can occur, unless carefully controlled.

The amount of make-up water required is a key driver of the overall water use of the boiler. Make-up water quantity is dictated by the amount of water that is lost from the system, particularly steam condensate that is discharged and not returned to the boiler, and the amount of blow down, as illustrated in Equation 6-7.

Equation 6-7. Boiler or Steam System Make-Up Water (gallons)

= Condensate Loss + Blowdown

Where:

- Condensate Loss (gallons)
- Blowdown (gallons)

By recovering steam condensate and carefully controlling the amount and frequency of blowdown, boiler water and energy use can be significantly reduced.

Operation, Maintenance, and User Education

There are a number of ways to improve water efficiency of boiler and steam systems by changing operation, maintenance, and user education techniques. Best management practices include: maintaining boilers, steam lines, and steam traps; choosing a water treatment vendor that focuses on water efficiency; reading meters and water chemistry reports to closely monitor water use; minimizing blowdown; and improving make-up water quality to increase cycles of concentration.

[33] North Carolina Department of Environment and Natural Resources, et al. May 2009. *Water Efficiency Manual for Commercial, Industrial and Institutional Facilities*. Pages 49-52. savewaternc.org/bushome.php.

Maintaining Boilers, Steam Lines, and Steam Traps

When maintaining boilers, steam lines, and steam traps, consider the following:

- Regularly check steam and hot water lines for leaks and make repairs promptly.
- Regularly clean and inspect boiler water and fire tubes.
- Develop and implement an annual boiler tune-up program.
- Provide proper insulation on piping and the central storage tank to conserve heat.
- Implement a steam trap inspection program for boiler systems with condensate recovery. When steam traps exceed condensate temperature, this inspection can reveal whether the trap is leaking condensation. Monitor temperature using an infrared temperature device.[34] Repair leaking traps as soon as possible.[35]

Choosing a Water Treatment Vendor

When choosing a water treatment vendor, select one that focuses on water efficiency. Request an estimate of the quantities and costs of treatment chemicals, volumes of make-up and blowdown water expected per year. Choose a vendor that can minimize water use, chemical use, and cost, while maintaining appropriate water chemistry for efficient scale and corrosion control.

Reading Meters and Water Chemistry Reports

When reading meters and water chemistry reports, consider the following:

- If available, have operations and maintenance personnel read the make-up and condensate return flow meters regularly to quickly identify leaks or other problems.
- Ensure the water treatment vendor produces a report every time he or she evaluates the water chemistry in the boiler. When these reports are received, read them to ensure that monitoring characteristics, such as conductivity and cycles of concentration, are within the target range. By paying proper attention to the water chemistry reports, problems within the system can be identified quickly.

Minimizing Blowdown

To minimize blowdown, consider the following:

- Calculate and understand the boiler's cycles of concentration. Check the ratio of conductivity of blowdown water to the make-up water. Use a handheld conductivity meter if the boiler is not equipped with permanent conductivity meters. This ratio should match the target cycles of concentration.

[34] *Ibid*.

[35] DOE, EERE, Federal Energy Management Program. July 1999. *Steam Trap Performance Assessment: Advanced technologies for evaluating the performance of steam traps*. www1.eere.energy.gov/femp/pdfs/FTA_SteamTrap.pdf.

- Work with the water treatment vendor to prevent scaling and corrosion and optimize cycles of concentration.

Improving Make-up Water Quality

To improve make-up water quality, consider the following:

- Consider pre-treating boiler make-up water to remove impurities, which can increase the cycles of concentration the boiler can achieve. Water softeners, reverse osmosis systems, or demineralization are potential pre-treatment technology options. Refer to *Section 7.2: Water Purification* for more information.
- When increasing cycles of concentration, ensure that discharged water meets allowable water quality standards.

Retrofit Options

To improve the efficiency of an existing boiler and steam system, consider retrofitting the system by recovering steam condensate and installing meters and control systems to monitor water use.

Recovering Steam Condensate

When recovering steam condensate, consider the following:

- Install and maintain a condensate recovery system to return condensate to the boiler for reuse.
- Where condensate cannot be returned to the boiler and must be discharged to the sanitary sewer, employ an expansion tank to temper hot condensate rather than adding water to cool it.

Installing Meters and Control Systems

When installing meters and control systems, consider the following:

- Install an automatic blowdown control system, particularly on boilers that are more than 200 horsepower, to control the amount and frequency of blowdown rather than relying on continuous blowdown.[36] Control systems with a conductivity controller will initiate blowdown only when the TDS concentrations in the boiler have built up to a certain concentration.
- If not already present, install flow meters on the make-up water line and the condensate return line to monitor the amount of make-up water added to the boiler. Refer to the previous "Operation, Maintenance, and User Education" section for recommendations on how to use the meter once it is installed.

[36] EBMUD, *op. cit*.

- Install automated chemical feed systems to monitor conductivity, control blowdown, and add chemicals based on make-up water flow. These systems minimize water and chemical use while protecting against scale buildup and corrosion.

Replacement Options

Because replacing a boiler involves significant capital costs, first implement efficient operations and maintenance procedures and perform any retrofits available to optimize the current boiler's management scheme. After exhausting all efficient management practices, consider the costs and benefits of boiler replacement.

Boiler replacement options will vary depending upon the size of the facility and existing equipment. Conduct an energy audit to help reduce heating loads; ensure the boiler system is appropriately sized; and identify whether it is possible to reduce the boiler size. When looking to replace an existing boiler, consider installing a small summer boiler, distributed system, or heat-capture system for reheating or dehumidification requirements. Also, consider alternative technologies such as heat pumps.

Savings Potential

Significant water savings can be achieved by improving the boiler system management scheme. A key mechanism to reduce water use is to maximize the cycles of concentration. Installing an automatic blowdown control system is one way to minimize blowdown and maximize cycles of concentration. Switching to an automatic control system can reduce a boiler's energy use by 2 to 5 percent and reduce blowdown by as much as 20 percent.

Additional Resources

American Society of Mechanical Engineers. 1994. *Consensus Operating Practices for Control of Feedwater/Boiler Water Chemistry in Modern Industrial Boilers*.

Council of Industrial Boiler Owners (CIBO). November 1997. *CIBO Energy Efficiency Handbook*. www.cibo.org/pubs/steamhandbook.pdf.

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