Brewers Association
Steam Boilers

Prepared by the Brewers Association
Engineering Technical Subcommittee

DOCUMENT PURPOSE AND SCOPE

The purpose of this document is to provide an overview and some considerations regarding the purchase and installation of a steam boiler for your brewery. This document does not provide specific equipment recommendations, but instead is intended to create awareness regarding many of the major considerations a potential brewery owner should be aware of when choosing steam as the heating medium for their brewery.

Steam boilers are a complex subject and there are many things an owner/operator needs to know when it comes to the selection, installation, operation, and maintenance of a steam boiler for your brewery. If you do not have experience with calculating heat requirements, it is best to consult with local, certified contractors who have experience in this area. They can recommend the appropriate equipment to suit your current and future needs and are familiar with the local ordinances governing the installation and operation of steam boilers.

Brewery Steam Boiler Topics Covered Include:

- Boiler Types and Equipment considerations
- Best Practices for Operation and Maintenance
- Terminology

SAFETY PREFACE

Steam boilers can be inherently dangerous if they are not equipped with the appropriate safety devices, inspected regularly, and operated according to the manufacturer's recommendations by trained personnel. To quote a boiler industry expert, "when working only a few feet away from a piece of equipment with more expansive energy than dynamite, you need to ask yourself: Do I have enough training to operate this equipment safely?" Further information about boiler safety and operator training can be found here in this issue of the MBAA Technical Quarterly:

Steam Boilers in the Craft Brewing Industry and The Need for Proper Training

Boiler vs. Water Heater

The lines between boilers and water heaters are blurred. While some water heaters are referred to as boilers, the term "water heater" typically refers to a device that heats water at less than water's boiling point. Generally, the term "boiler" refers to a device that produces saturated water with the use of heat and pressure. In this paper, the term "boiler" refers to "saturated water boilers". Saturated water boilers that are engineered such to allow a space for the vapor (steam) to collect and be drawn off, are called "steam boilers".

TYPES OF STEAM BOILERS

As the name suggests, these boilers are designed to generate steam. Steam is generally the preferred heating method for the wort side of the brewing process. The use of steam creates an easily controlled and efficient transfer of heat. Saturated steam at a particular pressure has a known temperature. By controlling the pressure of the steam, the amount and temperature of heat transfer can be consistently controlled. A pressure boiler is used to transfer heat from a flame or electric heat source to water and ultimately produce steam. There have been many boiler designs over the years but modern pressure boilers can be broken down into two basic designs: pressure tank boilers and pressure tube boilers. Pressure tank boilers are generally referred to as “fire tube” boilers and have water/steam contained within a pressure tank. Pressure tube boilers are generally referred to as “water tube” boilers and have water/steam contained within many pressure tubes. With modifications, both fire tube and water tube boilers can produce pressurized high temperature water instead of steam. Some companies make both steam and water boilers while other companies just focus on steam.

Steam Generator Terminology

Steam Generator is a term that is sometimes used to describe a boiler type with low water usage compared to steam output. Typical construction is a spiral coil of water tube, arranged as a single, or monotube, coil. Saturated water boilers of any design can generate steam. When choosing a boiler, focus on one that meets your heating and total cost of ownership needs and not on the terminology used.

1. **Fire Tube Boilers,** also known as Scotch Marine boilers, consist of a pressure tank with many tubes inside through which hot flue gas flows, heating the surrounding water to the point of producing steam. Modern fire tube boilers have multiple passes through the pressure tank before the flue gas exits the boiler. Fire tube boilers are suitable for low pressure and for high pressure below 300 psig. Electric steam boilers have a pressure tank and therefore share characteristics with fire tube boilers. Instead of tubes with hot flue gas they have electric heating elements.
2. **Water Tube Boilers** consist of many pressure tubes that travel through the combustion chamber, heating the water inside the tubes to the point of producing steam. Water tube boilers are typically constructed with a lower and upper header with many tubes between the two headers. Water is always in the lower header and steam is always in the upper header. Water tube boilers are suitable for low and high pressure needs as well but can achieve pressures significantly higher than fire tube boilers. Because of their lower water volume, as compared to fire tube boilers, water tube boilers produce steam much faster from a cold start and they are physically smaller in size for the same steam output. A variation on the theme of a water tube boiler is a sectional cast iron boiler. These are for low pressure applications and are ideal for spaces with limited access because they are assembled on site. Another variation of a water tube boiler is a coil tube boiler which has one tube formed into a continuous coil in the combustion chamber and water is pumped through the coil. The pump speed is increased or decreased depending on steam demand. While this style boiler can be used for low pressures, it is ideal for high pressure with some units reaching 3,000 psig making it perfect for the power generation industry.

There are many boiler manufacturers. Some exclusively manufacture one style of boiler and some manufacture both fire tube and water tube boilers. There are many design differences and features within the two basic types of boilers that can improve the reliability and efficiency. Care should be taken when evaluating each boiler style and additional features of each manufacturer to determine which is best suited for your application including a cost benefit analysis of the features and designs. For more information on how different boilers work, see videos of firetube vs. watertube boilers.

Saturated Water and Steam

Saturated water is water at a temperature that will not increase with additional heat input. It is fully "saturated" with heat and no more heat can be added. Water at sea level can get no hotter than 212º Fahrenheit, which is also referred to as "boiling point". At this point, temperature can only be increase by heating in a pressure vessel. Water and steam in the pressure vessel are saturated so knowing the pressure allows the temperature to be calculated. (e.g. - 30 psi = 274F) See references for an online calculator.

Saturated steam is an invisible vapor at the surface of saturated water and is at the same temperature as the heated water from which it was generated. The reason that you can see steam that escapes from a boiler is because the water molecules immediately begin to bind together (condense) which makes steam visible. This is referred to as "wet steam". The temperature of saturated steam can be increased with no pressure increase, if exposed to a secondary heat source and this is called "superheated steam". Unlike saturated steam, superheated steam is a poor thermal conductor and is not suitable for brewery heating applications.

3. Other Boiler Specifications

a. Low vs. High Pressure: The heating requirements for most small-scale breweries can be satisfied with a low-pressure steam boiler. Some of the benefits of low-pressure steam include lower fuel consumption, reduced regulatory oversight, reduced stack emissions, reduced water treatment chemical consumption, etc. If you can achieve the required heat transfer using low pressure steam, then you can avoid the cost and regulatory burdens of high-pressure boilers. High pressure steam does have some advantages when it comes to piping size and temperature consistency. All boilers cycle on and off to maintain a pressure range. With low pressure boilers, your end process will feel this swing in temperature as the pressure changes during the cycle. High pressure steam is too hot for the wort side of the brewing process so pressure reducing valves must be installed to reduce the pressure and thereby the temperature. These valves act as a buffer between the boiler and the end process; allowing a consistent pressure to be supplied to brewing vessels.

b. **Steam Boiler Output**: Steam boiler output is measured in Boiler Horsepower (BHP); 1,000 British Thermal Units per hour (MBH); Pounds of Steam per hour (lbs/hr), kilograms of steam per hour (kg/hr) or Kilowatts per hour (kWh). (1 BHP = 33.4714 MBH = 34.5 lbs/hr = 15.7 kg/hr = 9.8095 kWh).

c. **Fuel Source**: Natural gas is by far the most common fuel source for both fire tube and water tube boilers, but this is not the only option. In parts of the country where fuel oil is common, this can be used as the fuel source. Propane is also an option where natural gas or fuel oil is not available. Boilers can be fitted to accept both gas and fuel oil and can be switched between them depending on price. Electric boilers are a viable option for most brewery sizes with boiler outputs at several hundred horsepower. These boilers have pressure tanks like gas fed fire tube boilers so most operations will be similar; e.g. slow cold start. Even though they are more efficient, the operating fuel costs will likely be higher with electric boilers because natural gas, in most parts of the country, is significantly less per kW than electricity.

Electricity is priced per kilowatt (kW) and natural gas is priced per thousand cubic feet (MCF). There are links to conversion resources at the end of this paper that will assist with converting input and output BTUs to kW and natural gas MCF to kW for an apples-to-apples fuel cost comparison. If your local electricity is from renewable sources, electric boilers have environmental benefits. Electric boilers consume significant amperage, so the cost of electrical system upgrades is a major factor.

d. **Efficiency:** Since electric boilers do not require vent stacks, they are very efficient; with outputs between 95% and 99%. Natural gas boilers are typically between 80% and 85% efficient which means that 15% - 20% of the heat goes up the stack. Many gas boiler manufactures offer a condensing economizer on the vent stack and other methods to wring out every BTU from the flue vent gas. Fire tube boilers can increase the number of times the tubes pass through the pressure tank, transferring more heat with every pass. Water tube boilers have tubes with curves which exposes the tubes multiple times to the heat source. Many manufacturers offer Low NOx (Nitrogen oxides) burners that can significantly reduce the greenhouse gas emissions from their boilers.

EQUIPMENT CONSIDERATIONS

1. **Sizing the Boiler**: Sizing the boiler is based on the heat transfer needs of your mash tun, kettle, hot liquor tank, CIP tank, etc. There are on-line resources which can assist with these calculations. One such resource is at this link; Sizing a Boiler for a Brewery. The MBAA has a resource; Practical Handbook for the Specialty Brewer: Brewing, Engineering, and Plant Operations, Volume 3. Also, a qualified boiler vendor can easily compute this requirement based on the number of vessels and will propose a suitably sized boiler to satisfy your heating requirements. Unless you are routinely doing these calculations, it is best to let a boiler professional do the final calculations to ensure you do not end up purchasing a boiler that is too small to meet the demand. If you are purchasing new equipment, your equipment vendor will be able to supply the required boiler output needs. An additional factor to be considered in sizing your boiler is other steam requirements, i.e., facility environmental heating, kitchen, hot water, etc. Here again a boiler professional can be most helpful to ensure the entire steam demand for your facility (process and non-process) is taken into consideration when sizing the boiler.

2. **Boiler Location:** A steam boiler is usually located in a separate space, depending on local ordinance. Personal safety is the main reason for locating the steam boiler away from the primary production space. As noted at the beginning of this document, boilers have tremendous expansive potential which can be detrimental to the health and well-being of your personnel as well as the physical structure of the facility; should the boiler breach. Because boilers are often located away from the main production spaces, a boiler can fall into a state of neglect, creating a recipe for disaster if regular maintenance is ignored. In addition, the remote nature of boilers can put operators at risk when venturing into less inhabited areas of the building. For smaller operations such as nano breweries, brewpubs, and small breweries, locating the steam boiler outside of the facility may be optimal.

   There are other factors regarding the location of the steam boiler in addition to the safety consideration noted above. Some of the steam demand may be used to heat process water. For example, locating the hot liquor tank adjacent to the steam boiler can not only reduce the length of steam piping, but also provides an opportunity to optimize the layout of the process vessels in the production area.

   Sufficient space should be allowed for the steam boiler during the design and layout of the facility. In addition to the space required for the boiler itself, space will be required for water treatment equipment and a boiler feedwater tank and associated pumps. In some cases, the boiler feedwater tank may be located on the same skid as the boiler thus minimizing the space requirement. And finally, operation and maintenance of the boiler require it to be accessible on all sides. Allowing sufficient space for these functions is an important consideration in locating the steam boiler.

3. **Boiler Selection:** Choosing a steam boiler is best done with the assistance of a qualified vendor unless you have an engineer on staff. As discussed above this vendor can ensure the boiler is appropriately sized for the demand and has an integral control system that will properly regulate the boiler. With limited exceptions the boiler feedwater will need to be treated prior to use in the boiler to prevent internal corrosion of the boiler and associated steam piping. Be sure to follow water quality requirements published by the boiler manufacturer. An analysis of the local water is routinely available from your local water authority. It should be checked at least quarterly to ensure there have not been any major changes requiring a change to the treatment of the boiler feedwater. This is especially true in areas where the municipal water is sourced differently (municipal wells, groundwater, aquifers, lakes, etc.) at different times of the year. Local boiler vendors will be familiar with these water conditions and can recommend to appropriate treatment to prevent damage to the boiler and the steam system.

4. **Steam System:** Once you have decided what boiler you are going to purchase, the next step is to retain a licensed mechanical contractor to design and install your steam system. Generally speaking, companies selling boilers have personnel on staff that can design and install your steam system, or they subcontract this work. There are multiple factors which need to be considered in the design and installation of your steam system, including but not limited to the following:

    - Safety relief valves
    - Piping: Choosing correctly sized steam piping and allowance for steam pipe expansion
    - Steam piping insulation
    - Steam traps
    - Condensate return system

Figure 1. Left: Steam supply line at top of image with condensate system and steam traps depicted in the lower right-hand side; **Figure 2.** Right: an example of a condensate return system.

Types of Steam There are four principal types of steam, two of which are relevant to brewing.

1. Plant Steam: needs water treatment to prevent corrosion and is not usually food safe. This type of steam is commonly used for steam jackets; however, some facilities are using this steam for food and beverage processes unknowingly.
2. Culinary Steam: contains FDA approved chemicals added to water and is safe for direct contact with food/beverage (Ex. keg sterilization).
3. Clean Steam: Suitable for stainless steel contact with no added chemicals.
4. Pure Steam: Suitable for stainless steel contact, mineral-free using de-ionized feedwater, bacteria and virus-free, sterile. This type of steam may be used in pharma and computer chip manufacturing.

For more information, read Different Steam Classifications

BOILER BEST PRACTICES

1. **Steam Boiler Safety Equipment:** Steam boilers are equipped with safety devices to protect the equipment and the equipment operators. The following safety devices are indicated in Figure 3:
    1. Fuel (natural gas in this case) control valve (regulates the flow of fuel to the burner assembly)
    2. Burner control unit with a flame detector (shuts off the fuel supply is it does not detect a flame)
    3. Sight glass & water level sensing unit (shuts the boiler down when there is not any water)
    4. Safety relief valve (prevents the boiler and steam system in the event of excess pressure buildup)

Steam boilers should never be operated if any of these devices are defective and/or not operating properly.

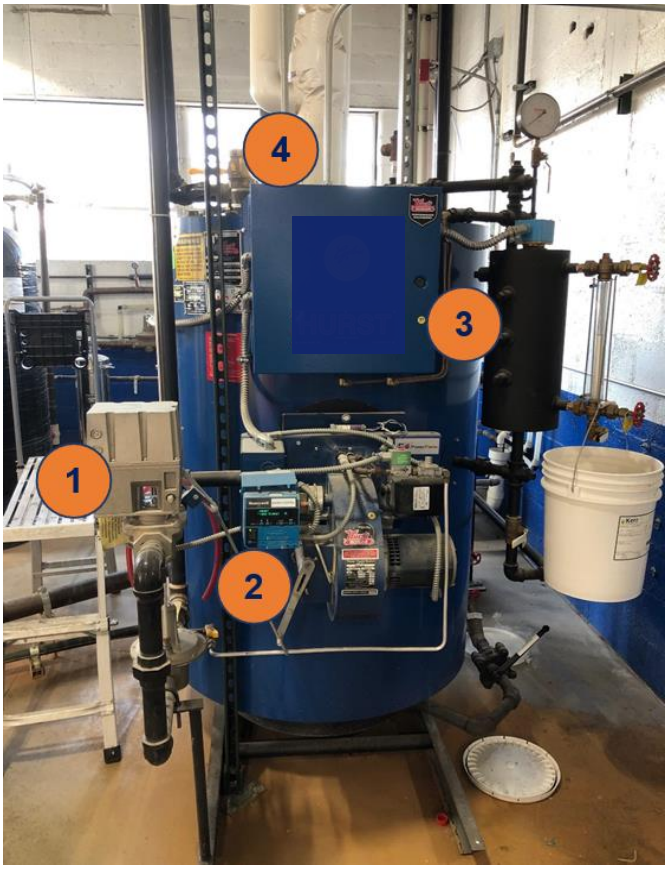

Figure 3: Typical safety equipment installed on a steam boiler, irrespective of size.

2. **Operation and Maintenance:** In smaller breweries operating on a single shift, the boiler will generally be started ahead of brewing to ensure an adequate supply of hot liquor is available to support brewing operations. Larger breweries producing multiple brews per day will generally have the boiler operating continuously.

    a. Steam boilers should only be operated by trained personnel. It is critical to follow established startup and shutdown procedures to prevent damage to the boiler and steam system. Periodic blowdowns are required to keep the boiler clear of sediments which can impede heat transfer. The frequency of blowdowns will depend on the hours of operation. The boiler manufacturer will have a recommended frequency for blowdowns.
    b. Maintenance of the boiler is critical, should not be postponed and should only be performed by trained personnel. None of the boiler piping, controls, safety equipment should be modified by anyone other than trained personnel.
    c. It is a good practice of have a boiler log an example of which is shown below. Local ordinances may require the log. The boiler room log lists boiler operation data that can be used to increase boiler safety and efficiency as well as identifying potential malfunction (example on right).

BOILER ROOM LOG

Month	Sunday	Monday	Tuesday	Wednesday	Thursday
BOILER OPERATION DATA					
Boiler on Line					
Pressure (psi)					
Stack Temp					
Condensate Return Temp					
Feedwater Heater Temp					
Fuel Oil Tank Temp					
Fuel Oil Pump Suction Pressure					
Fuel Oil Pump Discharge Pressure					
Fuel Oil Temp at Burner					
Outside Temp					
BOILER OPERATOR DUTIES					
Blowdown					
Gauge Glass					
Water Column					
Low Water Cutoff					
Test Flame Scanner					
Safety Valve Test*					
*Tested once a month when boiler is coming off the line					
Fuel Oil Accessories					
Change Over Strainer & Clean					
Clean Fuel Oil Burner					
Fuel Oil Gauge Readings					
Start of Shift					
End of Shift					
Gal. Consumed					
Operator's Initials					
Special Instructions:					

3. **Inspections:** Steam boilers should be inspected during startup and shutdown for obvious leaks. It will be safer and more efficient to conduct repairs before the boiler has reached its operating temperature and pressure. The boiler should be periodically checked during operation for any obvious issues so these can be addressed during the next shutdown. Periodic boiler inspections may be required by local and state laws. For smaller breweries without licensed & trained boiler operators, these inspections are generally performed by a local boiler company. The cost of these inspections can vary, and it may be possible to include these in the purchase agreement.

BOILER TERMINOLOGY

1. **Blowdown**: Periodic venting of water from the boiler. This water contains the most concentrated precursors of potential sludge build-up. This significantly reduces the potential of build-up in the boiler which can negatively impact boiler efficiency.
2. **Boiler Horsepower (BHP)**: One boiler horsepower is equal to the thermal energy rate required to evaporate 34.5 lbs. of fresh water at 212 °F in one hour.
3. **Boiler water treatment**: Removal or chemical mediation of boiler feedwater impurities to avoid scale, corrosion, or foaming.
4. **British Thermal Unit (BTU):** The amount of heat required to raise the temperature of one pound of water by one-degree Fahrenheit.
5. **Flame detector:** a safety device on gas boiler which shuts off gas to the boiler if it fails to sense a flame at the burner tip in the firebox.
6. **Fire tube boiler:** A boiler where the primary heating surfaces are tubes with hot gas flowing inside of a pressure tank.
7. **High pressure steam boiler**: A steam boiler that operates at a steam pressure greater than 15psi.
8. **Kilograms of steam:** The amount of steam produced from 1 kilogram or 1 liter of water.
9. **Low pressure steam boiler**: A steam boiler that operates at a steam pressure of less than 15psi.

10. **MBH**: One thousand British Thermal Units per hour.
11. **Pounds of steam**: The amount of steam produced from one pound or 15.3378 fluid ounces of water.
12. **Safety relief valve:** An automatic valve used to release excess pressure within the boiler.
13. **Saturated steam:** Saturated steam, also referred to as “dry steam”, is steam that is in direct contact with and at the same temperature as the heated water from which it was generated.
14. **Sight glass:** A glass tube which provides a visual indication of the water level in the boiler.
15. **Steam trap:** A device used to discharge condensates and non-condensable gases with a negligible consumption or loss of live steam. Most steam traps are nothing more than automatic valves; they open, close, or modulate automatically. Steam traps must perform these important functions:
    - Discharge condensate as soon as it is formed
    - Have a negligible steam consumption (i.e. being energy efficient)
    - Have the capability of discharging air and other non-condensable gases
16. **Superheated steam:** Is saturated steam where additional heat is applied to raise the temperature. Superheated steam is used for its kinetic energy as opposed to its thermal energy. It is a poor thermal conductor but heating delays condensation making it ideal power for a turbine electric generator.
17. **Water tube boiler:** A boiler whose primary heating surface is composed of many small tubes filled with water.
18. **Firebox:** The area in the boiler where fuel is burned. Etymology is from the box where wood or coal was burned in 19th century steam engines and locomotives. It is also referred to as a combustion chamber or furnace.
19. **Boiler turndown:** The ratio between the boiler's maximum and minimum output. A 50 hp boiler with a turndown ratio of 5:1 continues to operate at 20% power or 10 hp before cycling off. Fuel is wasted when a boiler cycles on and off so a higher turndown ratio reduces cycling and saves energy.
20. **High fire/Low fire:** is one form of burner control common to steam boilers. High fire is the maximum burner output and is used at start-up and at high steam demand. Low fire produces lower heat and fuel usage during lower steam demand reducing wear and tear on the boiler. Boiler controls automatically switch between high fire and low fire depending on the demand.

ADDITIONAL REFERENCES

- MBAA Practical Handbook for the Specialty Brewer: Brewing Engineering and Plant Operations
- Different Types of Boilers
- Various States of Water

Online Conversion Tools

- Convert Energy Form (e.g. BHP >> MBH; BHP >> kW/hr)
- Natural Gas Conversion to Kilowatts
- Helpful Conversion Factors
- Calculate Saturation Temperature