# Steam Generation and Distribution

There are three principal forms of energy used in industrial processes: electricity, direct-fired heat, and steam. Electricity is used in many different ways, including mechanical drive, heating, and electrochemical reactions. Direct-fired energy directly transfers the heat of fuel combustion to a process. Steam provides process heating, pressure control, mechanical drive, and component separation, and, is a source of water for many process reactions.

Steam has many performance advantages that make it an indispensable means of delivering energy. These advantages include low toxicity, ease of transportability, high efficiency, high heat capacity, and low cost with respect to the other alternatives. Steam holds a significant amount of energy on a unit mass basis (between 1,000 and 1,250 British thermal units per pound [Btu/lb]) that can be extracted as mechanical work through a turbine or as heat for process use. Since most of the heat content of steam is stored as latent heat, large quantities of heat can be transferred efficiently at a constant temperature, which is a useful attribute in many process heating applications.

Steam is also used in many direct contact applications. For example, steam is used as a source of hydrogen in steam methane reforming, which is an important process for many chemical and petroleum refining applications. Steam is also used to control the pressures and temperatures of many chemical processes. Other significant applications of steam are to strip contaminants from a process fluid, to facilitate the fractionation of hydrocarbon components, and to dry all types of paper products.

The many advantages that are available from steam are reflected in the significant amount of energy that industry uses to generate it.

### Steam System Operation

There are four categories to discuss steam system components and ways to enhance steam system performance: generation, distribution, end use, and recovery. These four areas follow the path of steam as it leaves the boiler and returns via the condensate return system.

## Generation

Steam is generated in a boiler or a heat recovery steam generator by transferring the heat of combustion gases to water. When water absorbs enough heat, it changes phase from liquid to steam. In some boilers, a superheater further increases the energy content of the steam. Under pressure, the steam then flows from the boiler or steam generator and into the distribution system.

## Distribution

The distribution system carries steam from the boiler or generator to the points of end use. Many distribution systems have several take-off lines that operate at different pressures. These distribution lines are separated by various types of isolation valves, pressure-regulating valves, and, sometimes, backpressure turbines. A properly performing distribution system delivers sufficient quantities of high quality steam at the right pressures and temperatures to the end uses. Effective distribution system performance requires proper steam pressure balance, good condensate drainage, adequate insulation, and effective pressure regulation.

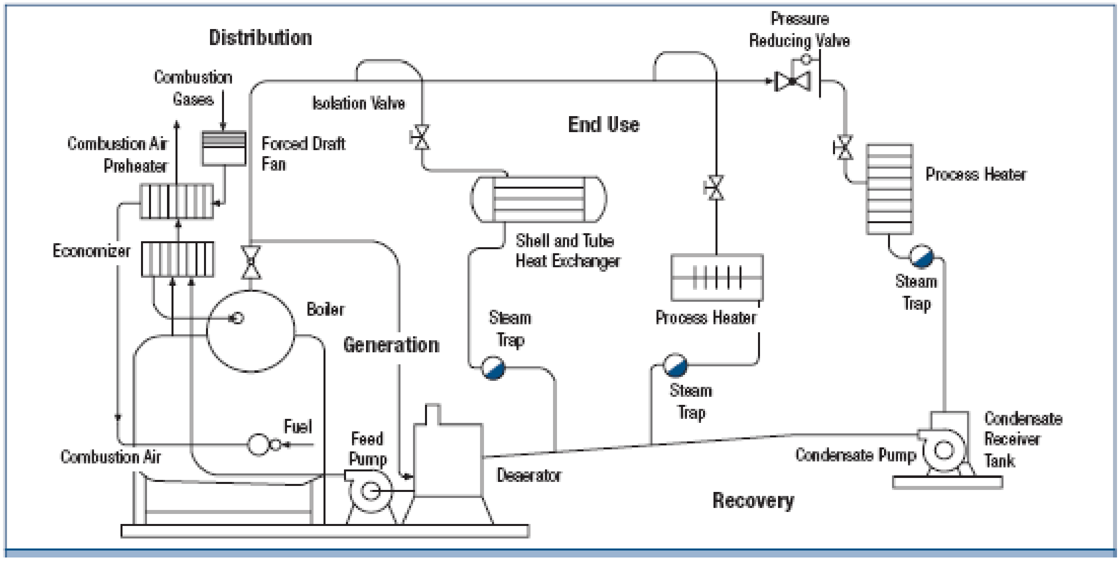
### End Use

There are many different end uses of steam. Examples of steam's diverse uses include process heating, mechanical drive, moderation of chemical reactions, and fractionation of hydrocarbon components. Common steam system end-use equipment includes heat exchangers, turbines, fractionating towers, strippers, and chemical reaction vessels.

In a heat exchanger, the steam transfers its latent heat to a process fluid. The steam is held in the heat exchanger by a steam trap until it condenses, at which point the trap passes the condensate into the condensate return system. In a turbine, the steam transforms its energy to mechanical work to drive rotating machinery such as pumps, compressors, or electric generators. In fractionating towers, steam facilitates the separation of various components of a process fluid. In stripping applications, the steam pulls contaminants out of a process fluid. Steam is also used as a source of water for certain chemical reactions. In steam methane reforming, steam is a source of hydrogen.

## Recovery

The condensate return system sends the condensate back to the boiler. The condensate is returned to a collection tank. Sometimes the makeup water and chemicals are added here while other times this is done in the deaerator. From the collection tank the condensate is pumped to the deaerator, which strips oxygen and non-condensable gases. The boiler feed pumps increase the feedwater pressure to above boiler pressure and inject it into the boiler to complete the cycle. Figure 1 provides a general schematic description of the four principal areas of a steam system. The following sections discuss the components in these areas in greater detail.




## Generation

The generation part of a steam system uses a boiler to add energy to a feedwater supply to generate steam. The energy is released from the combustion of fossil fuels or from process waste heat. The boiler provides a heat transfer surface (generally a set of tubes) between the combustion products and the water. The most important parts of the generating system include the boiler, the fuel supply, combustion air system, feedwater system, and exhaust gases venting system. These systems are related, since problems or changes inone generally affect the performance of the others.

## Boilers

There are two basic types of boilers: firetube and watertube. The fundamental difference between these boiler types is which side of the boiler tubes contains the combustion gases or the boiler water/steam.

## Firetube boilers

In firetube boilers, the combustion gases pass inside boiler tubes, and heat is transferred to water on the shell side. Scotch marine boilers are the most common type of industrial firetube boiler. The Scotch marine boiler is an industry workhorse due to low initial cost, and advantages in efficiency and durability. Scotch marine boilers are typically cylindrical shells with horizontal tubes configured such that the exhaust gases pass through these tubes, transferring energy to boiler water on the shell side.

Scotch marine boilers contain relatively large amounts of water, which enables them to respond to load changes with relatively little change in pressure. However, since the boiler typically holds a large water mass, it requires more time to initiate steaming and more time to accommodate changes in steam pressure. Also, Scotch marine boilers generate steam on the shell side, which has a large surface area, limiting the amount of pressure they can generate. In general, Scotch marine boilers are not used where pressures above 300 psig are required. Today, the biggest firetube boilers are over 1,500 boiler horsepower (about 50,000 lbs/hr).

Firetube boilers are often characterized by their number of passes, referring to the number of times the combustion (or flue) gases flow the length of the pressure vessel as they transfer heat to the water. Each pass sends the flue gases through the tubes in the opposite direction. To make another pass, the gases turn 180 degrees and pass back through the shell. The turnaround zones can be either dryback or water-back. In dryback designs, the turnaround area is refractorylined. In water-back designs, this turnaround zone is water-cooled, eliminating the need for the refractory lining.

## Watertube boilers

In watertube boilers, boiler water passes through the tubes while the exhaust gases remain in the shell side, passing over the tube surfaces. Since tubes can typically withstand higher internal pressure than the large chamber shell in a firetube, watertube boilers are used where high steam pressures (3,000 pounds per square inch [psi], sometimes higher) are required. Watertube boilers are also capable of high efficiencies and can generate saturated or superheated steam. In fact, the ability of watertube boilers to generate superheated steam makes these boilers particularly attractive in applications that require dry, high-pressure, high-energy steam, including steam turbine power generation. The performance characteristics of watertube boilers make them highly favorable in process industries, including chemical manufacturing, pulp and paper manufacturing, and refining. Although firetube boilers account for the majority of boiler sales in terms of units, water-tube boilers account for the majority of boiler capacity.

## Waste Heat Recovery Boiler (WHRB)

These boilers may be either firetube or watertube design and use heat that would otherwise be discarded to generate steam. Typical sources of heat for WHRBs include exhaust gases or high temperature products from an external manufacturing process in refineries and chemical manufacturing facilities, or combustion of a waste fuel in the boiler furnace.

## Heat Recovery Steam Generators (HRSGs)

HRSGs transfer energy from the exhaust of a gas turbine to an unfired or supplementary fired heat-recovery steam generator to produce steam. Exhaust gases leave the gas turbine at temperatures of 1000°F (538°C) or higher and can represent more than 75% of the total fuel energy input. This energy can be recovered by passing the gases through a heat exchanger (steam generator) to produce hot water or steam for process needs. If the amount of steam needed by the process exceeds the amount produced by simple heat recovery, then supplementary fuel can be burned in the ducting between the gas turbine and the HRSG.

## Superheaters

Superheaters add energy to steam, resulting in a steam temperature that exceeds the saturation temperature at a specific pressure. Superheaters can be convective or radiant. Radiative superheaters rely on the energy transferred directly from the combustion flame to increase the energy level of the steam, while convective superheaters rely on the transfer of additional energy from the flue gases to the steam.

## Economizers

In many boilers, the flue gases still have useful amounts of energy even after they have passed through the boiler. In many of these applications, economizers provide effective methods of increasing boiler efficiency by transferring the heat of the flue gases to incoming feedwater. There are two principal types of economizers: noncondensing and condensing.

Noncondensing economizers are usually air-towater heat exchangers. Since these economizers are not designed to handle flue gas condensation, noncondensing economizers must be operated at temperatures that are reasonably above the dew points of the flue gas components. The dew point of the flue gases depends largely on the amount of water in the gas, which, in turn, is related to the amount of hydrogen in the fuel.

For example, to avoid condensation in the exhaust gases produced by burning natural gas, the exhaust gas temperature should typically be kept above 250°F. Condensing economizers are designed to allow condensation of the exhaust gas components. Due to latent heat recovery, these economizers typically extract more energy than do noncondensing economizers. Often, special materials are required.

## Combustion air preheaters

Combustion air preheaters are similar to economizers in that they transfer energy from the flue gases back into the system. In these devices, however, the energy is transferred to the incoming combustion air. The efficiency benefit is roughly 1% for every 40°F increase in the combustion air temperature.

## Boiler Insulation

The walls and combustion regions of boilers are typically lined with insulating materials to reduce energy loss and to prevent leakage. There are several types of boiler insulating materials, including brick, refractory, insulation and lagging. The selection and design of boiler insulating materials depends largely on the age and design of the boiler. Since the insulating lining is exposed to high temperatures and is subject to degradation, it should be periodically inspected and repaired when necessary.

## Boiler Control System

Boiler control systems are designed to protect the boiler and to ensure proper boiler operation. These systems include the combustion control system, flame safeguard, water level control, and fuel control.

### Combustion control system

The combustion control system regulates the fuel air mixture to achieve safe and efficient combustion and maintains steam system pressure. Control systems have varying levels of sophistication. Simple systems use a fixed linkage between the fuel-regulating valve and the combustion air damper. This is called single point positioning. A change in steam pressure makes a proportional change in the combustion air and fuel. Advanced systems rely on signals from transmitters to determine independent fuel valve and air damper positions. This is called a full monitoring system.

### Burner flame safeguard system

A flame safeguard system is an arrangement of flame detection systems, interlocks, and relays which will sense the presence of a proper flame in a furnace and cause fuel to be shut off if a hazardous condition develops. Modern combustion systems are closely interlocked with flame safeguard systems and also pressure-limit switches, low-water level cutoffs, and other safety controls that will stop the energy input to a boiler when an unsafe condition develops. The flame safeguard system senses the presence of a good flame or proper combustion and programs the operation of a burner system so that motors, blowers, ignition, and fuel valves are energized only when they are needed and then in proper sequence.

### Safety shutoff valve

Safety shutoff valves isolate the fuel supply to the boiler in response to certain conditions such as low or high gas pressure or satisfied load demand. The type of safety shutoff valves and the settings are often determined by code or insurance requirements.

### Water level control

The boiler water level control system ensures a safe water level in the boiler. Typically, the control system provides a signal to the feedwater control valve to regulate the feed rate. Simple water level control systems that only sense water level are single element systems. More complex systems incorporate additional data such as steam flow rate (dual element system) and feedwater flow (triple element system) and will provide better water level control during abrupt load changes.

### Safety valve

The safety valve is the most important valve on the boiler and keeps the boiler from exceeding its maximum allowable working pressure (MAWP).

### Steam pressure control

Steam pressure controls regulate the combustion equipment to maintain a constant pressure in the steam header. As the pressure rises above or falls below the pressure setting, the control adjusts the burner firing rate to bring the pressure back to the setpoint.

### Nonreturn valve

The nonreturn valve is a combination shutoff and check valve that allows steam out of the boiler, but prevents backflow from the steam header in the event the boiler pressure drops below that of the header. The valve is opened only when the pressure inside the boiler rises slightly above the steam header pressure.

### Steam flow meter

Steam flow meters are helpful in evaluating the performance of the system and can provide useful data in assessing boiler performance, calculating boiler efficiency, and tracking the amount of steam required by the system. In some systems, steam flow meters provide a measurement signal for the boiler control system. Additionally, steam flow meters can be useful in benchmarking efforts. There are three basic types of steam flowmeters: differential pressure (DP), vortex, and Coriolis.

Differential pressure flowmeters rely on the change in pressure as steam flows by an element such as a nozzle, orifice, or venturi. This pressure difference provides an indication of flow velocity, which, in turn, can be used to determine the flow rate.

Vortex flowmeters rely on the principal that flow past an element creates vortices that have frequencies that correspond to the flow velocity.

Coriolis flowmeters rely on tubes placed in the steam flow path that twist according to the velocity of the flow.

## Boiler Feedwater System

The boiler feedwater system supplies water to the boiler. Sources of feedwater include returning condensate and makeup water. Feedwater is typically stored in a collecting tank to ensure that a steady supply of heated water is available to the boiler.

### Feedwater flow control valve

A modulating feedwater flow control valve moves up or down in response to the water level transmitter(s). On smaller firetube boilers, it is not uncommon for the feedwater valve to operate in a closed or open position, depending on the water level transmitter signal.

### Softener

Softeners remove hardness minerals, such as calcium, magnesium, and iron, from a water supply. The presence of hardness in boiler water leads to many problems, including scale buildup and foaming, which reduce boiler efficiency and can cause tube failure. Softeners reduce this problem through an ion exchange process. As the hard water passes through a chamber filled with resin, an exchange occurs that removes hardness minerals from the water. The sodium that replaces the hardness minerals has a higher solubility in water and generally will not form scale.

### Pretreatment equipment

Pretreatment equipment improves the quality of the incoming water so that it may be used in the boiler without excessive scaling or foaming, which can reduce boiler efficiency and cause tube failure. Pretreatment equipment includes, but is not limited to, clarifiers, filters, softeners, dealkalizers, decarbonators, reverse osmosis (RO) units, and demineralizers.

### Deaerator, deaerating heater, and atmospheric deaerator

The presence of oxygen in the boiler system can be a significant problem due to its corrosivity at high temperatures. Deaerators and deaerating heaters use heat, typically steam, to reduce the oxygen content in water. Deaerators and deaerating heaters are typically pressurized tanks that raise the water temperature to the point of saturation. They also break the incoming water into either fine droplets or thin sheets to facilitate the removal of oxygen and other non-condensable gases. Depending on the design, the feedwater oxygen content can be reduced to levels ranging from 7 to 40 parts per billion (ppb).

Atmospheric deaerators are typically found in smaller, lower-pressure boiler systems. They operate at atmospheric pressure, so the maximum operating temperature is 212°F. Most will operate at temperatures lower than this. Atmospheric deaerators cannot achieve the same level of oxygen removal as deaerators and deaerating heaters, typically providing water with oxygen levels of 0.5 to 1 parts per million (ppm). In applications that require lower oxygen levels than achievable with a deaerator, deaerating heater, or open feedwater heater, a chemical agent, known as an oxygen scavenger, can be used to remove more oxygen. In most systems, an oxygen scavenger is part of the system's water treatment program.

### Feedwater pump

Feedwater pumps transfer water from the deaerator to the boiler. Feedwater pumps are driven by electric motors or by steam turbines. In a modulating feedwater system, the feedwater pumps run constantly as opposed to an on/off operation in relatively small boilers.

### Collecting/Storage tank

The return of condensate is often erratic due to changing steam requirements by the end uses. The condensate is usually returned to a condensate receiver or directly to the deaerator if the system does not have a receiver. Pretreated water may also be stored in a tank prior to use. This provides the boiler system with additional water capacity in case the pretreatment equipment malfunctions. The condensate and pretreated water, or makeup, are transferred from the storage tanks to the deaerator prior to being sent to the boiler.

## Boiler Combustion Air System

The combustion air system supplies the oxygen necessary for the combustion reaction. To provide enough air for the amount of fuel used in industrial boilers, fans are typically required. Dampers, inlet valves, or variable speed drives typically control the amount of air allowed into the boiler.

## Forced draft fan

A forced draft fan is located at the inlet of a boiler and pushes ambient air into the burner region, ensuring that adequate air is delivered to the combustion process. These fans either pull air directly from the boiler room or connect to a duct system that allows outside air to be drawn into the boiler.

## Induced draft fan

Induced draft fans are located on the outlet gas side of the boiler and pull flue gases out. The induced draft fan creates a slightly negative furnace pressure that is controlled by outlet dampers on the boiler. In some systems where a bag house, mechanical collector, or precipitator is involved, special considerations should be given in sizing and selection of this fan.

## Damper

Dampers control the amount of air allowed into and out of a combustion chamber. Dampers, in combination with fuel regulating devices, are positioned by the combustion control system to achieve certain fuel-to-air ratios. Dampers on the boiler outlet are used to regulate the negative furnace draft.

## Boiler Fuel System

There are many different types of fuels used in boilers, requiring several different types of fuel handling systems. Fossil fuels such as coal, oil, and gas are most commonly used. Waste fuels are used in many industries, particularly the forest products, petroleum refining, and chemical manufacturing industries where there is an available supply of waste products such as bark, wood chips, black liquor, and refinery gas.

## Fuel regulating valve

In gaseous and liquid fuels, regulating valves control the fuel delivered to the boiler. In many systems, these valves can be quickly shut in response to an operating problem.

## Fuel

The fuel types that are commonly used in boilers include natural gas, coal, propane, fuel oils, and waste fuels (for example, black liquor, bark, and refinery gas). Fuel type significantly affects boiler operation, including efficiency, emissions, and operating cost. Coal accounts for about 14% of the boiler capacity. Fuel oils account for about 21%. Other fuels, which include waste fuels, account for about 29% of the boiler capacity.

## Fuel flow meter

Fuel meters measure the amount of fuel delivered to a boiler. Fuel meters provide essential data in determining boiler efficiency. Since fuel flow meters measure volume or mass of fuel, it is important to know the energy content of the fuel when determining boiler efficiency.

## Burner

Burners combine the fuel and air to initiate combustion. There are many different types of burners due to the many different types of fuels. Additionally, burners have different performance characteristics and control requirements. Some burners are on/off while others allow precise setting of the fuel:air mixture over a range of conditions. Some burners can fire different types of fuel, allowing boiler operation to continue despite the loss of one fuel supply.

## Boiler Blowdown System

The boiler blowdown system includes the valves and the controls for the continuous blowdown and bottom blowdown services. Continuous blowdown removes a specific amount of boiler water (often measured in terms of percentage of feedwater flow) in order to maintain a desired level of total dissolved solids in the boiler. Setting the flow for the continuous blowdown is typically done in conjunction with the water treatment program. Some continuous blowdown systems rely on the input of sensors that detect the level of dissolved solids in the boiler water. The bottom blowdown is performed to remove particulates and sludge from the bottom of the boiler. Bottom blowdowns are periodic and are typically performed a certain number of times per shift or according to a set schedule. In some systems, bottom blowdowns are controlled by an automatic timer. Bottom blowdown should never be permitted unless it is recommended by the boiler manufacturer. This is because in higher pressure boilers, especially those above 700 pounds per square inch gauge (psig), bottom blowdown may cause water starvation in some portions of the boiler circuit.

## Boiler blowdown heat exchangers and flash tank

The continuous blowdown water has the same temperature and pressure as the boiler water. Before this high energy water is discharged into the environment, it is often sent to a heat exchanger and flash tank. Flash tanks permit the recovery of low-pressure flash steam, which can be used in deaeration or process heating. They also permit the use of a smaller heat exchanger than would be required without the flash tank. Blowdown heat exchangers are most often used to preheat boiler makeup water.

## Distribution

The distribution system transports steam from the boiler to the various end uses. Although distribution systems may appear to be passive, in reality, these systems regulate the delivery of steam and respond to changing temperature and pressure requirements. Consequently, proper performance of the distribution system requires careful design practices and effective maintenance.

The piping should be properly sized, supported, insulated, and configured with adequate flexibility. Pressure-regulating devices such as pressure reducing valves and backpressure turbines should be configured to provide proper steam balance among the different steam headers. Additionally, the distribution system should be configured to allow adequate condensate drainage, which requires adequate drip leg capacity and proper steam trap selection. Steam distribution systems can be broken down into three different categories: buried pipe, above-around, and building sections, and selection of distribution components (piping, insulation, etc.) can vary depending on the category.

## Piping

Steam piping transports steam from the boiler to the end-use services. Important characteristics of well-designed steam system piping are that it is adequately sized, configured, and supported. Installation of larger pipe diameters may be more expensive, but can create less pressure drop for a given flow rate. Additionally, larger pipe diameters help to reduce the noise associated with steam flow. As such, consideration should be given to the type of environment in which the steam piping will be located when selecting the pipe diameter. Important configuration issues are flexibility and drainage. With respect to flexibility, piping (especially at equipment connections), needs to accommodate thermal reactions during system start-ups and shutdowns. Additionally, piping should be equipped with a sufficient number of appropriately sized drip legs to promote effective condensate drainage. Additionally, the piping should be pitched properly to promote the drainage of condensate to these drip lines. Typically, these drainage points experience two very different operating conditions, normal operation and start-up; both load conditions should be considered in the initial design.

## Insulation

Thermal insulation provides important safety, energy savings, and performance benefits. In terms of safety, insulation reduces the outer surface temperature of the steam piping, which lessens the risk of burns. A well-insulated system also reduces heat loss to ambient workspaces, which can make the work environment more comfortable. Consequently, the energy saving benefits include reduced energy losses from the steam system and reduced burden on the cooling systems that remove heat from workspaces. In addition to its safety and energy benefits, insulation increases the amount of steam energy available for end uses by decreasing the amount of heat lost from the distribution system. Important insulation properties include thermal conductivity, strength, abrasion resistance, workability, and resistance to water absorption. Thermal conductivity is the measure of heat transfer per unit thickness. Thermal conductivity of insulation varies with temperature; consequently, it is important to know the right temperature range when selecting insulation. Strength is the measure of the insulation’s ability to maintain its integrity under mechanical loads. Abrasion resistance is the ability to withstand shearing forces.

Workability is a measure of the ease with which the insulation is installed. Water absorption refers to the tendency of the insulation to hold moisture. Insulation blankets (fiberglass and fabric) are commonly used on steam distribution components (valves, expansion joints, turbines, etc.) to enable easy removal and replacement for maintenance tasks.

Some common insulating materials used in steam systems include calcium silicate, mineral fiber, fiberglass, perlite, and cellular glass.

## Valves

In steam systems, the principal functions of valves are to isolate equipment or system branches, to regulate steam flow, and to prevent overpressurization. The principal types of valves used in steam systems include gate, globe, swing check, pressure reducing, and pressure relief valves. Gate, globe, and swing check valves typically isolate steam from a system branch or a component. Pressure reducing valves (PRV) typically maintain certain downstream steam pressure conditions by controlling the amount of steam that is passed. These reducing valves are often controlled by transmitters that monitor downstream conditions. Pressure relief valves release steam to prevent overpressurization of a system header or equipment.

### Steam Separators
In some steam systems, wet steam is generated. This wet steam contains water droplets that can reduce the effectiveness of the steam system. Water droplets erode turbine blades and passages, and pressure reducing valves, thus reducing efficiency and life. Furthermore, liquid water can significantly reduce heat transfer rates in heat exchange components, as well as result in water hammer.

Removing water droplets before they each end-use equipment is necessary. Steam separators remove water droplets, generally relying on controlled centrifugal flow. This action forces the entrained moisture to the outer wall where it is removed from the separator. The means of moisture removal could be a steam trap or a drain. Some manufacturers include the trap as an integral part of the unit. Additional accessories include water gauge connections, thermometer connections, and vent connections. Steam separators can be installed in either a horizontal or vertical line. They are capable of removing 99% of particulate entrainment 10 microns and larger over a wide range of flows.

### Steam Accumulators
A steam accumulator is a large insulated pressure vessel, partially filled with hot water (saturated liquid). When steam supply exceeds demand, the excess high-pressure steam is charged into the accumulator through special charging nozzles.  The steam is condensed, giving up its latent heat, to raise the pressure, temperature, and heat content of the water body. When the steam demand exceeds the supply, the pressure in the accumulator drops and the additional required steam flashes from the water, taking back the heat previously stored. A simple system of control valves and check valves regulates the charging and discharging. The excess steam is charged quietly and smoothly, and when steam is needed, it is available with the speed of a control valve operation. There is also an accumulator design that stores hot water for use as boiler feedwater.

### Steam Traps
Steam traps are essential for proper distribution system performance. During system start-ups, traps allow air and large quantities of condensate to escape. During system operation, the traps allow collected condensate to pass into the condensate return system, while minimizing the accompanying loss of steam. There are three primary types of traps: thermostatic, mechanical, and thermodynamic.

### Common Performance Improvement Opportunities
Several steam system improvement opportunities are common to many industrial facilities. These opportunities can be categorized according to the part of the system in which they are implemented.

### End-Use Improvement Opportunities
There are many ways to optimize steam use depending on the process and the equipment. In some cases, equipment can be installed to make the process more efficient; for example, multiple-stage dryers are often more efficient than single-stage dryers. However, in general, optimizing the efficiency of steam-supplied end uses requires a case-by-case assessment.

Some improvement opportunities are available to many different systems.

1. Inspect and Repair Steam Traps
2. Insulate Steam Distribution and Condensate Return Lines
3. Use Feedwater Economizers for Waste Heat Recovery
4. Improve Your Boiler's Combustion Efficiency
5. Tip Sheet Number Skipped
6. Tip Sheet Number Skipped
7. Clean Boiler Waterside Heat Transfer Surfaces
8. Return Condensate to the Boiler
9. Minimize Boiler Blowdown
10. Recover Heat from Boiler Blowdown
11. Use Vapor Recompression to Recover Low-Pressure Waste Steam
12. Flash High-Pressure Condensate to Regenerate Low-Pressure Steam
13. Use a Vent Condenser to Recover Flash Steam Energy
14. Use Low-Grade Waste Steam to Power Absorption Chillers
15. Benchmark the Fuel Costs of Steam Generation
16. Minimize Boiler Short Cycling Losses

17. Install Removable Insulation on Valves and Fittings
18. Deaerators in Industrial Steam Systems
19. Cover Heated, Open Vessels
20. Replace Pressure-Reducing Valves with Backpressure Turbogenerators
21. Consider Steam Turbine Drives for Rotating Equipment
22. Consider Installing High-Pressure Boilers with Backpressure Turbine-Generators
23. Install an Automatic Blowdown Control System
24. Upgrade Boilers with Energy-Efficient Burners
25. Consider Installing Turbulators on Two- and Three-Pass Firetube Boilers

Reference:

www1.eere.energy.gov/industry/bestpractices/pdfs/steamsourcebook.pdf