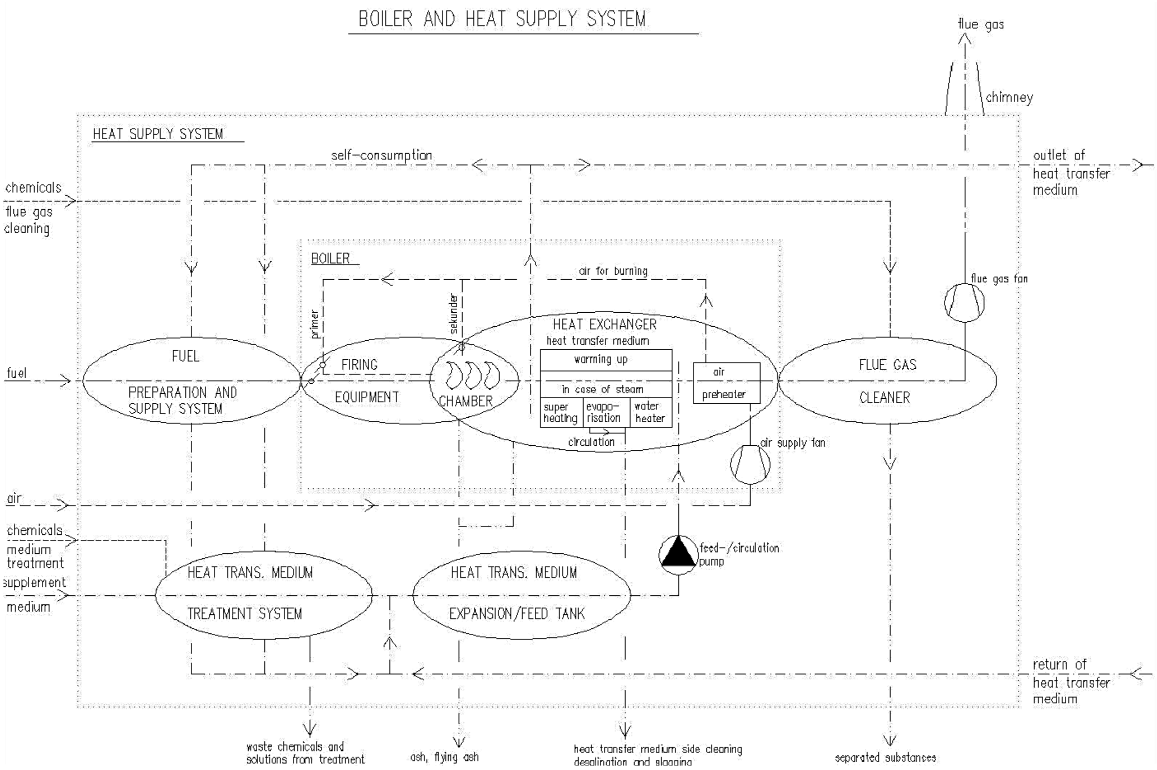
Elements of boiler and heat supply system



Enclosed Figure shows elements and its connections of the boiler and heat supply system. Inner dotted line shows that scope generally treated as boiler and outer dotted line includes total heat supply system.

Functional parts of boilers

Firing equipment

Main function is to perform combustion process:
Tasks:

- Fuel preparation for reaction and feeding into the fire chamber
- Fuel quantity control according to power demand
- Feeding of combustion air into the fire chamber and mixing it to fuel. Sometimes it is divided into primary and secondary air.
- Control of air quantity in order to keep excess air factor at optimal value
- Starting combustion, ignition
- Keeping up continuous reaction in order to avoid fluctuation
- Perform as total and complete combustion as it possible
- Low level pollutant emission
- Safe and automatic operation

Firing or combustion chamber

Fire chamber is that room where combustion process runs. It is functional part of firing equipment. Filing equipment without combustion chamber is called **burner**. It is important that burner has to fit to combustion chamber in order to perform above mentioned tasks. Combustion chamber is generally surrounded by heat exchanger part.

Heat-exchanger part

Task of heat exchanger part to take heat from flue gas heated up by chemical reaction and transform it to heat transfer medium. Heat can be transferred by means of radiation or convection. At the combustion chamber heat is transferred mainly by radiation, so this part is called **radiation heating surface** part. At further sections, where flue-gas temperature is lower heat transfer happens mainly by convection, so these heating surfaces are called **connective ones**. In case there is not phase change at heat transfer medium side at all the parts only heating up of the medium happens. In case of steam generators heating surfaces can be divided into **water heater (economizer), evaporation surface and superheater** sections. Heat from flue gas also can be used for heating up combustion air. This heating surface is called **air preheater**.

Auxiliary equipment

Fuel supply system

Task so this system is to prepare fuel for reaction and for feeding into the combustion chamber. Furthermore fuel has to be available when it is needed, so storage or utility connection is also included in this system. In case preparation needs heat it is generally supplied from the boiler, which is called **self consumption**.

Flue-gas cleaning system

For fulfilling environmental protection rules at a lot of cases flue gas cleaning system is necessary to apply, in order to remove harmful components from flue gas. There are several physical and chemical processes which are used depending on harmful components needs to be removed.

Flue-gas removal fan

Its task is to deliver flue gas and giving enough pressure for flue gas side hydraulic resistance. Intensive heat transfer can be gained only with turbulent heat transfer at a certain velocity level, which is caused higher pressure drop. Furthermore flue gas cleaning system also increases flue gas-side resistance.

Heat transfer medium system

Circulation or feed pump

This pump feeds heat transfer medium into the boiler or keeping up circulation flow in it.

Expansion- /feeding tank

A certain quantity of heat transfer medium has to be available all the time in order to keep up ability of absorption of generated heat by combustion. Otherwise heating surfaces could be overheated and destroyed.
In case of water or thermo-oil systems medium is expanded because of temperature increase. In this case expansion is absorbed by this tank as well, so it is called expansion tank.

Heat transfer medium preparation system

The heat transfer medium is necessary to prepare. Generally it means some kind of filtering. In case of water some softening or desalination process has to be performed.

Boiler design

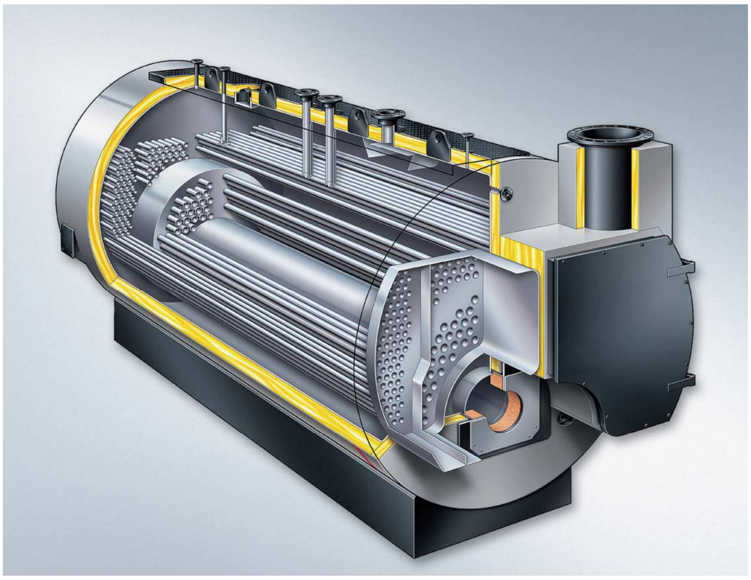
Steam generation is the process of turning water into steam by application of heat. Essentially, a boiler is a container into which water can be fed and, by the application of heat, evaporated continuously into steam. A steam generator is a complex combination of heat exchangers: **economizer, evaporator, superheater, reheater, and air preheater**. The term boiler is often used to mean the whole steam generator in the literature. Boilers are designed to transmit heat from an external combustion source (usually fuel combustion) to a fluid contained within the boiler itself. The selection of heat generating equipment is based on the following prime requisites:

1. Quantity of steam or hot water required
2. Pressure, temperature, or steam quality required
3. Anticipation of future needs
4. Location and purpose of the installation
5. Load characteristics

Fire tube steam boilers

The name firetube derives from the fact that in boilers of this type all or most of the work is done by heat transfer from hot combustion products flowing inside tubes to the water surrounding them. Combustion takes place in a cylindrical furnace within the shell. Space above the water level serves for steam separation and storage. Firetube boilers are produced in sizes up to about 30 tons per hour. They are restricted to 20 bar steam pressure. The firetube boiler serves its chief use where steam demands are relatively small. It is not used with turbine applications, as it is not well suited for the installation of superheaters. The firetube boiler is limited in physical size and design adaptability. It has the advantage, however, of large water storage capacity and the ability to dampen the effect of wide and sudden swings, fluctuations in steam demand. Because of its large water volume,

the tune required to arrive at operating pressure from a cold start is considerably longer than for a watertube boiler.
Its ability to handle overfiring is limited and dependent upon boiler type. With increased output, the gas temperature rises rapidly.
The installed cost of a firetube boiler is relatively low and considerably less than that of a corresponding drum type watertube boiler.
It can be seen that high pressures and large diameters would lead extremely thick shell plates. Hence, there is a rather definite economical limit on pressure and capacity that can be reached with firetube boilers.



Design

The firetube boiler is designed around its furnace and tube passes. Many arrangements have been developed. Tubes have been placed in horizontal, inclined, and vertical positions, with one or more passes. The boiler is designated as through-tube or return-tube according to the direction of hot gas flow. It may have an internal furnace, or it may be externally fired. The internal furnace may be a straight flue type located within the cylindrical sheet and surrounded by waterwalls, or it may be a firebox type with the furnace substantially surrounded by a water-cooled heating surface except at the bottom.

Construction

The shell of the firetube boiler may be cylindrical or oval. The waterline is usually established at a point not less than 50 mm above the top of the upper row of tubes, or crown sheet. The space above the waterline is called the **steam space**. The tubes are expanded (rolled or pressure expanded) or welded into the **tube sheet**. The tubes may be in vertical banks, or they may be staggered. Tubes are usually 50 to 100 mm in diameter, as dictated by draft loss and type of fuel. Often there is a diameter decrease.
The boiler may have one, two or occasionally as many as four passes. A **pass** being a group of tubes through which the combustion products flow essentially in the same direction. Smoke boxes (also known as hoods or chambers) collect the combustion gases for rerouting through a second pass or for discharge through the stack or breeching.

2-pass design:

These boilers tend to be simplest in design. A variety of arrangements are employed to extract most of the heat from the combustion gas during the relatively short travel time between the burner and stack. Designers have to give attention to the number and arrangement of the second-pass tubes. While waterside inspection and cleaning are easier when tubes are lined up vertically and horizontally, a staggered layout tends to give a more circuitous flow of water around these tubes, promoting increased heat transfer.

3-pass design:

The 3-pass design firetube boiler offers a popular approach. It adds another boiler length to the travel of the hot gas.

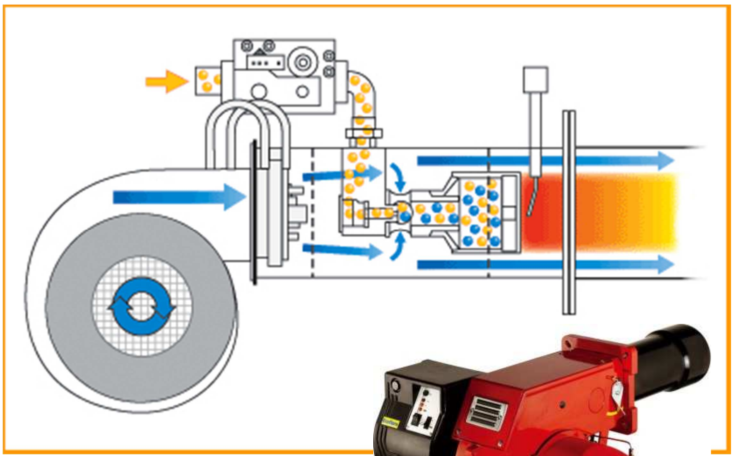
Burners for fire tube boilers

The burner is the principal device for the firing of fuel.

Low-And High-Pressure Gas Burners.

The important thing in all gas-burning devices is a correct air-and-gas mixture at the burner tip. Low-pressure burners, using gas at a pressure less than 15 kPa (2 psi), are usually of the multi-jet type, in which gas from a manifold is supplied to a number of small single jets, or circular rows of small jets, centered in or discharging around the inner circumference of circular air openings in a block of some heat-resisting material. The whole is encased in a rectangular cast-iron box, built into the boiler setting and having louver doors front to regulate the air supply. Draft may be natural, induced, or forced.

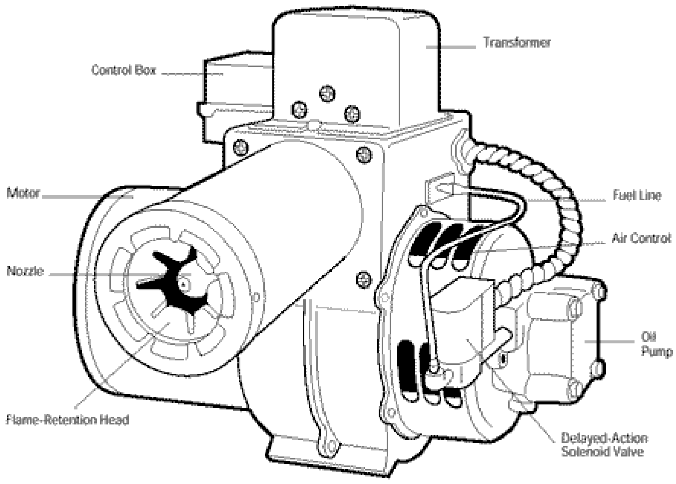
In a high-pressure gas mixer, the energy of the gas jet draws air into the mixing chamber and delivers a correctly proportioned mixture to the burner.hen the regulating valve is opened, gas flows through a small nozzle into a venturi tube (a tube with a contracted section). Entrainment of air with high-velocity gas in the narrow venture section draws air in through large openings in the end. The gas-air mixture is piped to a burner. The gas-burner tip may be in a variety of forms. In a sealed-in tip type, the proper gas-air mixture is piped to the burner, and no additional air is drawn in around the burner tip. Size of the air openings in the venture tube end is increased or decreased by turning a revolving shutter, which can be locked in any desired position. Excess air levels in natural gas burner is in the order of 5%.



Oil Firing Burners

The primary function of burner is to atomize fuel to millions of small droplets so that the surface area of the fuel is increased enabling intimate contact with oxygen in air. The finer the fuel droplets are atomized, more readily will the particles come in contact with the oxygen in the air and burn.

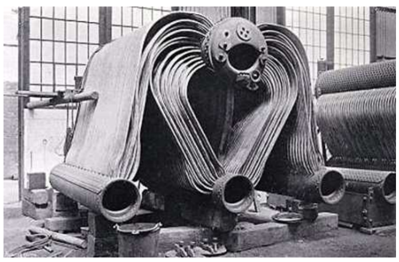
Burners for fuel oil can be classified on the basis of the technique to prepare the fuel for burning i.e. atomization. Atomization is carried out in nozzle or by primary pressurized air or steam or by rotating disc. Completion of combustion is ensured by secondary air. Oil preheat to reduce its viscosity for fine atomization can be necessary.



Watertube boilers

The firetube boilers become limited as capacity and pressure requirements increase. Larger shell diameters require thicker plates to withstand the pressure and temperature stresses. Temperature differentials in the boiler create high stresses of indeterminate magnitude. These stresses, combined with the effects of precipitates and other deposits, have caused many boiler explosions. Because of its smaller component sizes and ability to accommodate expansion, the steel watertube boiler is much more suitable for large capacities and high pressures through the inherent safety of its design.

The watertube boiler is composed of drums and tubes, the tubes always being external to the drums and serving to interconnect them. The **drum** is used for storage of water and steam separation. As they are not required to contain any tubular heating surface, they can be much smaller in diameter than a firetube boiler shell and can therefore be built to resist higher pressures. The tubes contain the entire heating surface. The drum boiler has **natural water circulation** or **controlled (forced) circulation** designs. Watertube boilers maybe of the **straight-tube** or **bent-tube** type (early developments). The various bent-tube boilers, with higher pressure and temperature characteristics, have gradually replaced the straight-tube boiler for high duty service and now monopolized the power generation industry. The first cost of a small watertube boiler is higher than that of an equivalent firetube boiler. Higher efficiency will eventually offset this higher first cost, however. In utility plant practice, the high first cost of superheaters and economizers is recaptured rapidly.

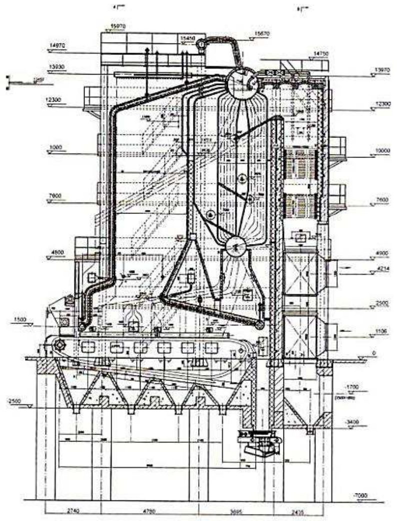


bent-tube type boiler

Boiler circulation

To remove heat from the boiler surfaces, it is necessary that adequate and positive water and steam circulation be provided (in a predetermined

direction) throughout the boiler circuits. The flow of water, steam, or other fluid within the boiler is called **circulation**.
Circulation in evaporator depends on type of circulation used to generate steam. Nearly all industrial steam watertube boilers depend on natural circulation in evaporator. A few high-pressure steam boilers and most hot water boilers depend on positive (forced) circulation, which is induced by pumps. High pressure and supercritical boilers for power plants have once-through design (zero circulation) of evaporator. The only function of water flow in an evaporator system is to insure that sufficient water is fed to each tube receiving heat to keep its surface thoroughly wetted to ensure good cooling.
Proper circulation is a necessity. The rate of steam release is directly related to the circulation rate of the water. Sluggish or stagnant circulation permits large bubbles to form, resulting in blistered or burned-out tubes.



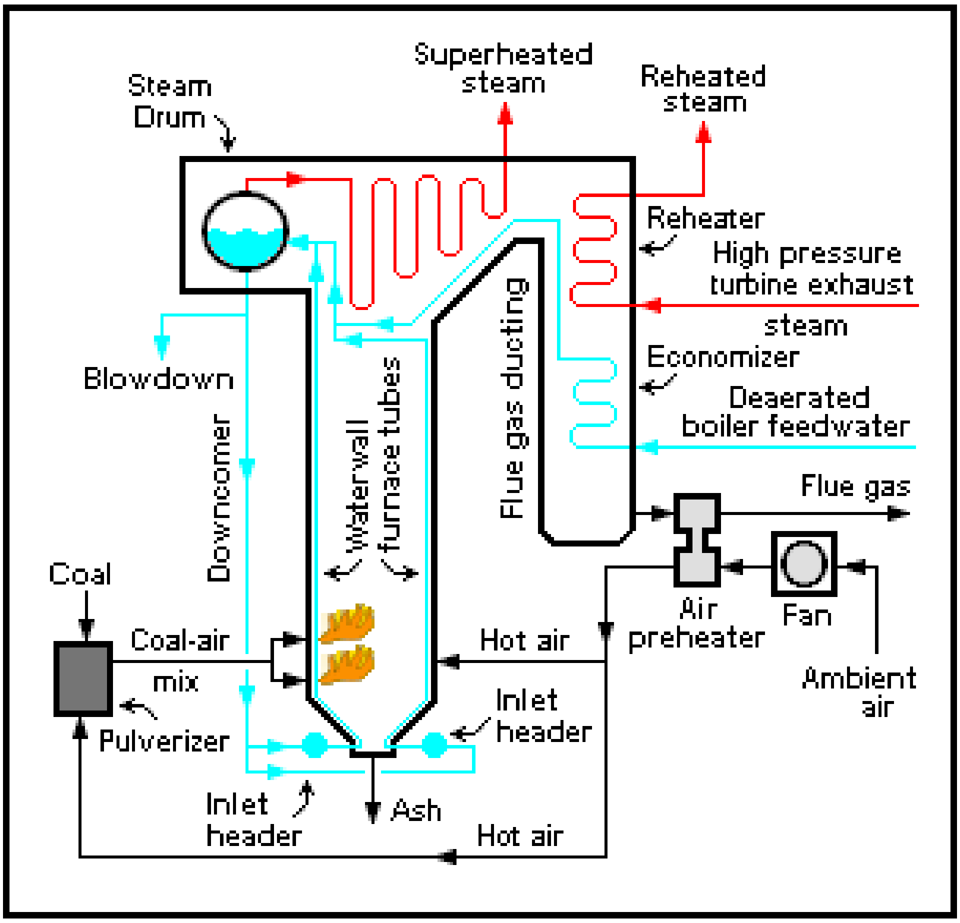
straight-tube type boiler

Natural circulation
Water can circulate through vertical evaporator circuits solely because of the difference in level and density between the steam-water mixture on the generating tubes outlet and water in the inlet headers. Natural circulation is the movement of the circulating fluid in conformance with available heat flow rate.

Circulation ratio
It would be highly desirable for a boiler to evaporate all the water circulating through the generating tubes. If this happened however the amount of solids deposited on the tubes would be greater than could be tolerated. It is customary, therefore to circulate from 3 to 20 times more water than is evaporated. This mixture of steam and water washes the precipitates from the tubes. The ratio by weight of the water fed to the steam-generating tubes to the steam actually generated is called the **circulation ratio**. In a drum boiler, the circulation ratio can be from 3:1 up to 20:1. The typical circulating rate is 5:1. In a once-through boiler the circulation ratio is 1:1.

Once-through boilers
In contrast to natural circulation and forced circulation designs - in which more water is circulated than steam is generated and a drum or drums serve as a collecting and steam-releasing point - the once-through design consists, in theory, of a single tube (no drum) into which goes feedwater and out of which comes saturated or superheated steam. In actual units, of course, the theoretical single circuit becomes a number of parallel circuits. At pressures subcritical, a once-through unit may have a separator to deliver saturated steam to the superheater and to return collected moisture to the feed pump suction. The once-through cycle is, of course, ideally suited for pressures above the critical point where water turns to steam without actually boiling. The once-through boiler requires **demineralized feed water** to avoid deposition of minerals in evaporator tubes.

Recent development of steam generators for power plants
The advent of the water-cooled furnace walls, called **water-walls**, eventually led to the integration of furnace, economizer, boiler, superheater, reheater and air preheater into the modern steam generator with higher steam temperatures and pressures contribute to improved boiler efficiency.
Superheaters and reheateres are heat-absorbing surfaces which raise the temperature of steam above its saturation point. There are many reasons for doing this. First, there is a basic thermodynamic gain in efficiency. Second advantage is that superheating dries the steam before it enters the turbine.
The use of a large number of steam feedwater heaters (up to seven or eight) means a smaller economizer, and the high pressure means a smaller boiler surface because the latent heat of vaporization decreases rapidly with pressure. Thus a modern high-pressure steam generator requires more superheating and reheating surface and less boiler surface than old units.
Water at 230 to 260 °C from the plant high-pressure feedwater heater enters the economizer and leaves close saturated or as a saturated two-phase mixture of low steam content. It then enters the steam drum at midpoint. Water from the steam drum flows through insulated downcomers, which are situated outside the furnace, to a header. The header connects to the water tubes that line the furnace walls and act as risers. The water in the tubes receives heat from the combustion gases and boils further. The density differential between the water in the downcomer and that in the water tubes helps circulation. Steam is separated from the bubbling water in the drum and goes to the superheater and the high-pressure section of the turbine. The exhaust from that turbine returns to the reheater, after which it goes to the low-pressure section of the turbine.



Steam Drum
Superheated steam
Reheated steam
Reheater
High pressure turbine exhaust steam
Economizer
Deaerated boiler feedwater
Flue gas
Blowdown
Downcomer
Waterwall furnace tubes
Flue gas ducting
Air preheater
Fan
Ambient air
Coal
Coal-air mix
Pulverizer
Hot air
Inlet header
Inlet header
Ash
Hot air