BOILER DESIGN AND OPERATION

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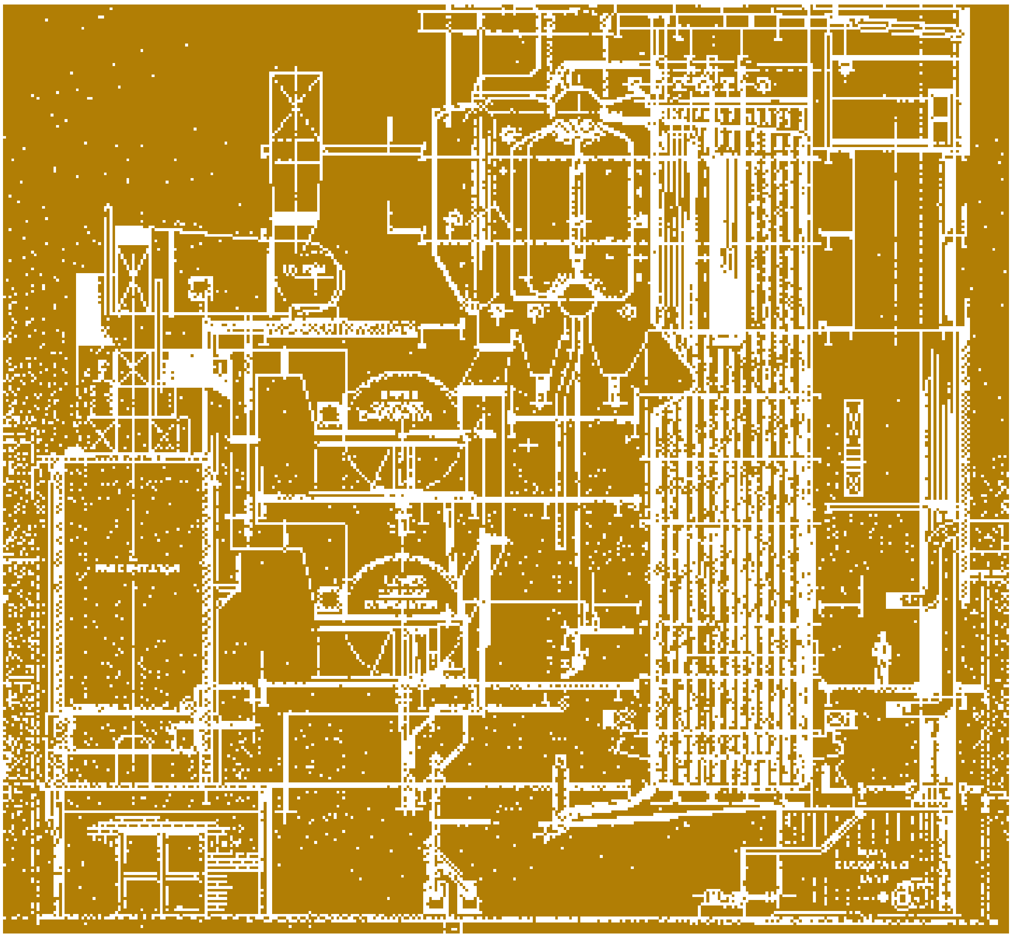

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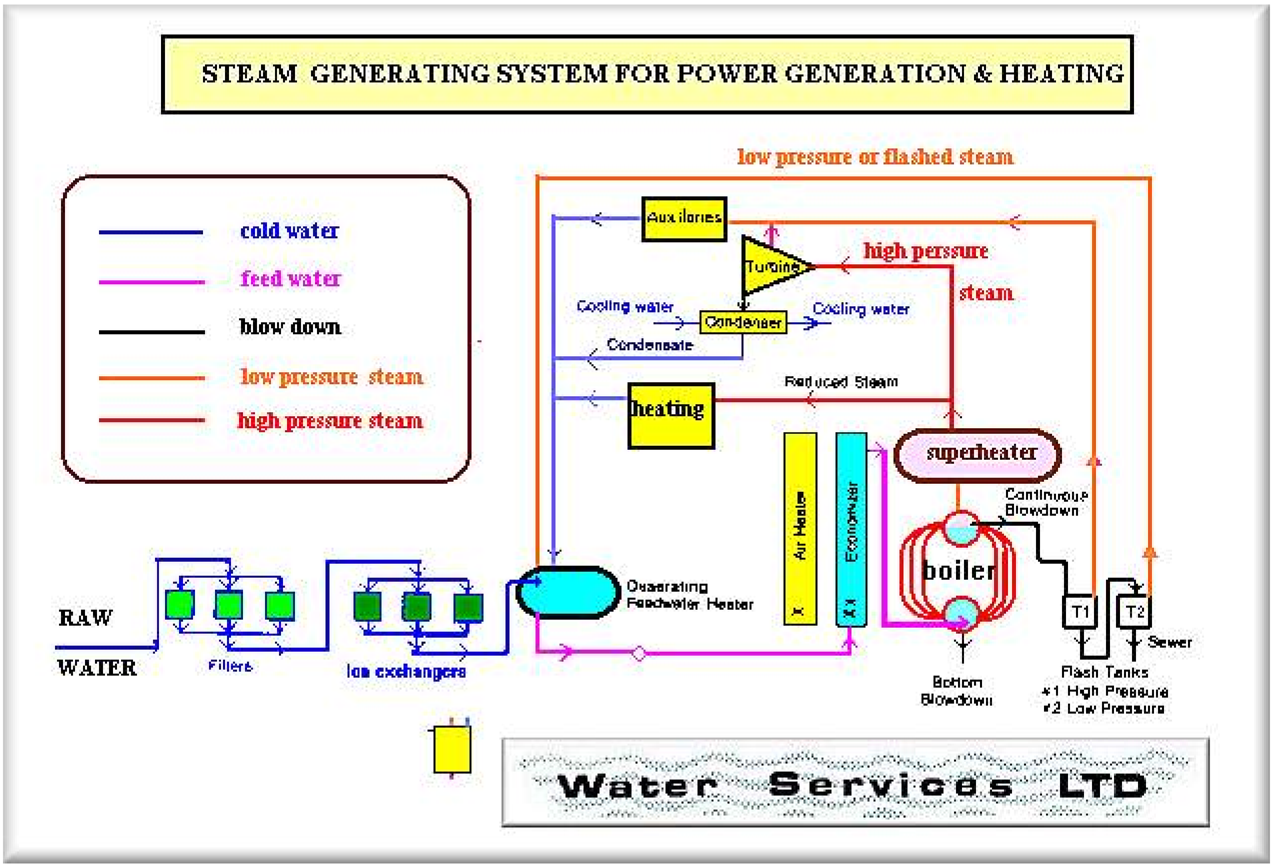
Boiler design and operation

Since James Watt's first observations on the power of steam over 150 years ago, it has become the major power source of the industrial world. Today, steam is the best energy transfer medium for many processes, including heating, plant process steam, power generation and utility operations.

Modern boilers range in size from small, residential units to the large steam generating systems used by public utilities. While the variety of steam generating systems in use today is broad, they all share the same principle of heat transfer and steam generation. In addition, all share the need for some degree of water purity. Contaminants commonly found in natural waters reduce operating efficiency of boilers and other plant equipment, leading to increased maintenance costs and reduced production capacity.

This training program is designed to familiarize you with water related problems which affect steam generating systems and steps you can take to minimize their occurrence in your plant.

Steam generating systems include three distinct sections: the preboiler, boiler and afterboiler.

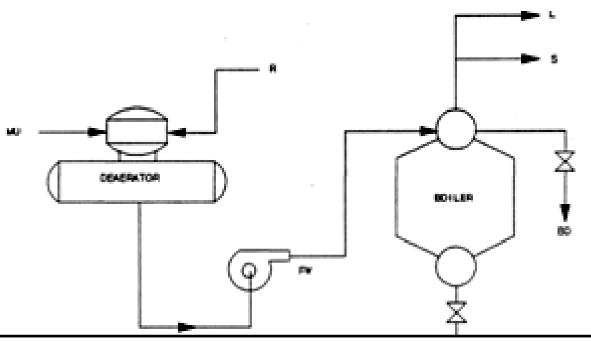


The preboiler phase

The preboiler phase employs various mechanical and chemical methods to remove impurities from raw water entering the system. This is pre-treatment.

The type of pre-treatment used depends on the requirements of the steam generating system and the quality of the water entering the system.

For example, low pressure boilers can generally tolerate some degree of impurities, while high pressure boilers used to drive turbines require



MU= Makeup	FW-Feedwater
BD=Blowdown	R=Returned Condensate
L=Losses	S=Steam

water that is virtually free of all impurities.

Feedwater is provided in two ways: make-up water and condensate.

Make-up is raw water used to *"make-up"* for water losses in the plant. Make-up water enters from the plant's water source and passes through pre-treatment equipment to remove impurities before it enters the boiler.

Condensate, on the other hand, is water which is recycled from the boiler. After steam has been used in the plant, it cools and turns back to water called condensate. Condensate is collected and passed through condensate return lines back to the feedwater system. In this way, the water can be recycled over and over again.

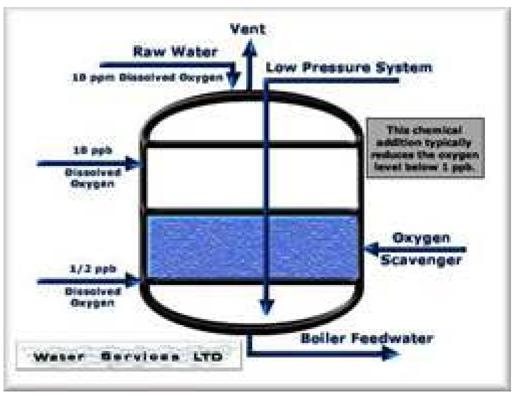
In addition to saving water, there are two other benefits to recycling condensate:

- Since condensate is hotter than make up water, the amount of heat required to generate steam is reduced resulting in fuel savings.
- Secondly, as condensate is generally high in purity, the amount of make-up requiring pre-treatment is also reduced.

The preboiler section may also include equipment to recover heat energy from hot combustion gases. These gases contain a considerable amount of heat energy which can be used to heat the feedwater.

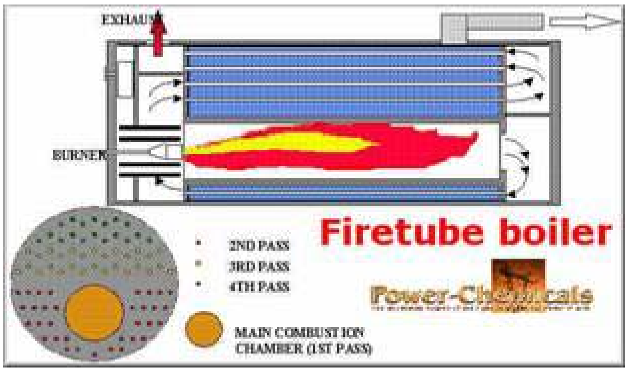
Waste gases escaping up the stack cause the greatest loss of heat in a steam generating system. The heat is recovered in an economizer, a heat exchanger placed between the boiler and stack. The recovered heat is used to raise the temperature of feedwater before it enters the boiler. Using waste combustion gas to raise the temperature of feedwater increases boiler efficiency and reduces fuel consumption.

Some plants employ deaerating feedwater heaters. In addition to heating the feedwater, deaerating heaters remove oxygen and other dissolved gases from the water.



The boiler phase

The boiler section, where the steam is produced includes a containing vessel along with heat transfer surfaces.



Industrial boilers are generally classified as either fire tube of water tube. This refers to the design of the boiler.

In a fire tube boiler, combustion takes place within a cylindrical furnace located within the boiler and combustion gases pass through tubes surrounded by water.

The combustion gases leave the furnace through the rear of the boiler, then reverse direction and pass through the boiler tubes several times, increasing the amount of heat transfer.

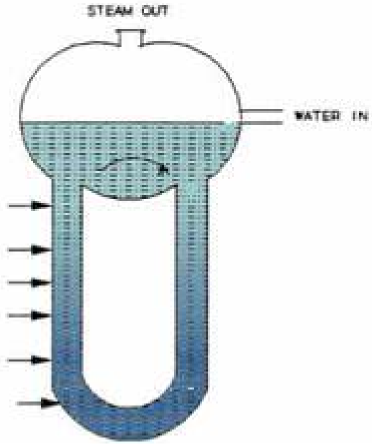
To maintain high gas velocity throughout the tubes, the number and diameters of tubes in each succeeding pass are reduced.

In water tube boilers, water is converted to steam inside the tubes, while hot gases pass over and around the outside of the tubes. Water tube boilers can operate at higher pressures than fire tube boilers.

The flow of steam and water within a water tube boiler is called circulation.

This circulation is critical in preventing tubes from overheating. When tubes overheat, metal softens, weakens and may eventually rupture.

In a simple water tube circuit, bubbles of steam form in the heated tubes or *"risers"*.



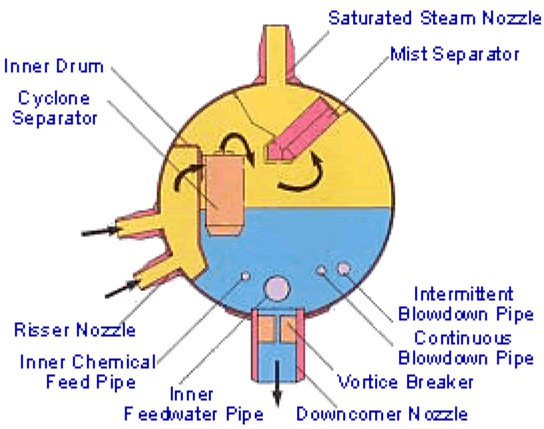
The resulting steam and water mixture is lighter than cooler water on the unheated side of the boiler, and rises to a steam drum at the top of the boiler. Here the bubbles rise to the surface and steam is released.

The water then flows from the drum down through the cooler rubes, or *"downcomers"*, completing and repeating the cycle.

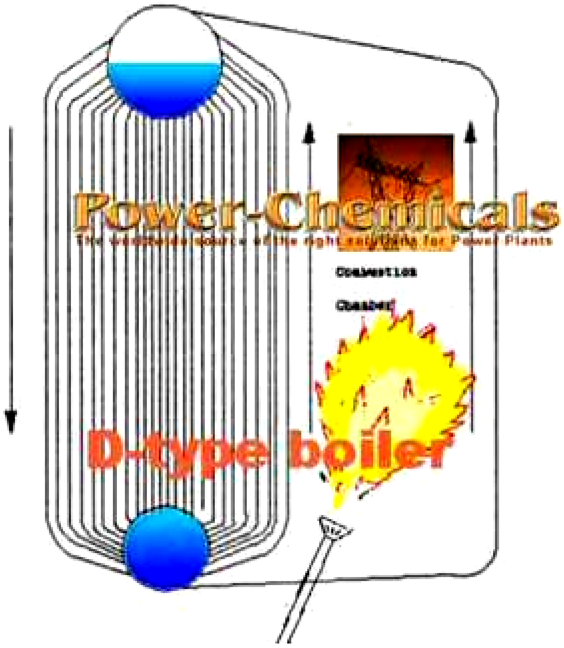
Because the steamdrum is so important in the efficient operation of the boiler, we'll go a bit more into detail about this subject.

The main purpose of the steam drum is the separation of steam from water. This is accomplished by providing sufficient volume and low enough velocity to allow the steam to escape.

This separation of steam and water is assisted by steam separators within the drum. These are mechanical devices, such as baffles installed in the space above the water level to rapidly change the direction of steam flow.

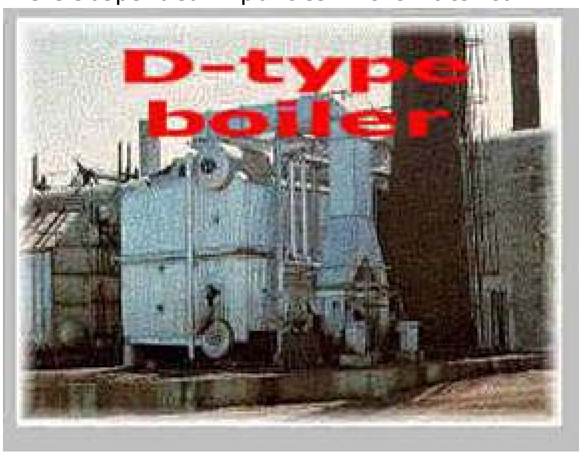


Some steam drums contain more intricate devices



called cyclone separators, which swirl the steam in a circular motion. Water droplets being carried by the steam are trapped in steam separators and drain back into the water. This prevents water from leaving the steam. The term *"carry-over"* refers to any contaminant that leaves the steam drum along with the steam.

In addition water tube boilers usually include one or more *"bottom drums"* or *"mud-drums"* where suspended impurities in the water can

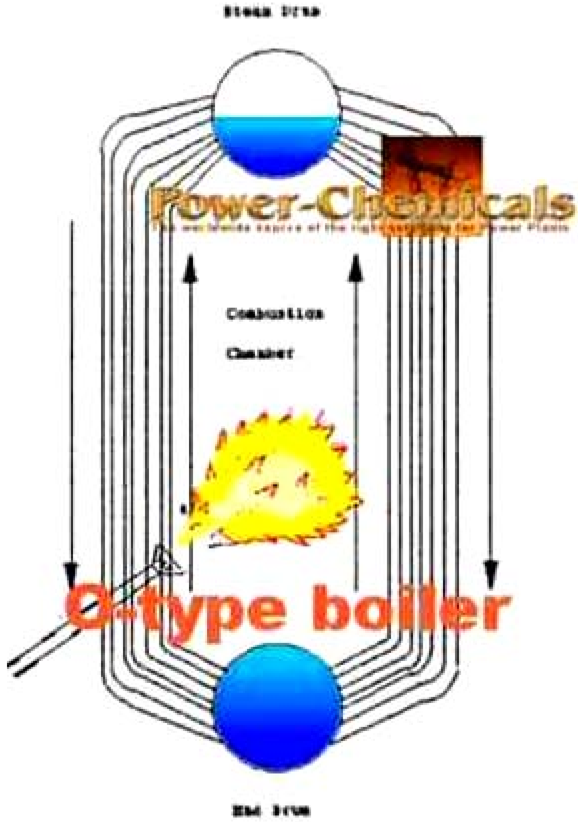


settle out.

The continuous or intermittent removal of small amounts of water and impurities from these drums is called blow-down.

Water tube boilers are classified according to their design. In a *"D"* type boiler, the steam drum is placed directly above the mud drum. The furnace and boiler are placed off to one side.

The *"O"* type boiler also utilizes two drums, with the burner position in the center of the boiler.

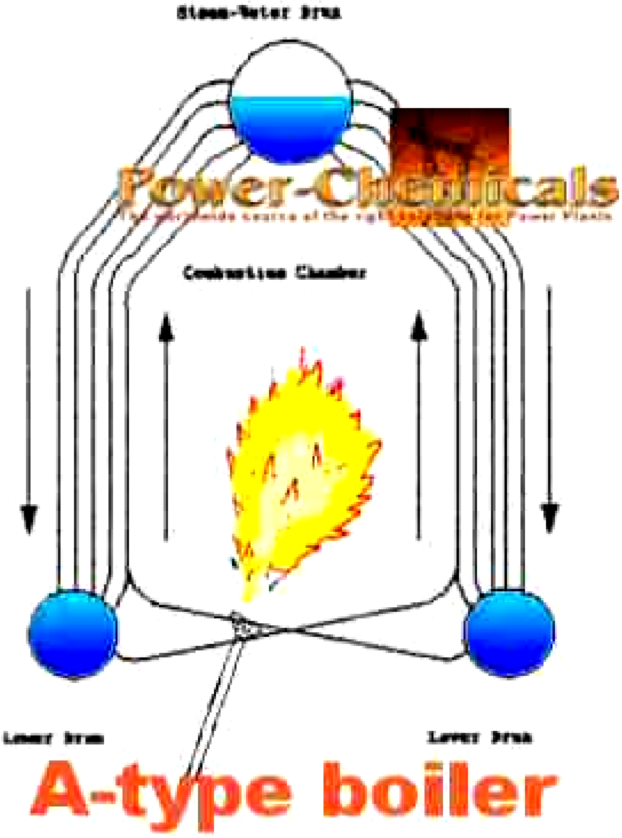


The *"A"* type boiler has two small mud drums with a larger single steam drum. Regardless of design, all

water tube boilers rely on circulation to allow steam to rise and pass on to the afterboiler section where it is carried to the plant and used as a source of energy.

In some boiler water systems, steam may pass through a superheater raising steam temperature in order to generate more energy. This works as follows:

Heating water at any given pressure will cause the water to boil and steam to be released. A change in



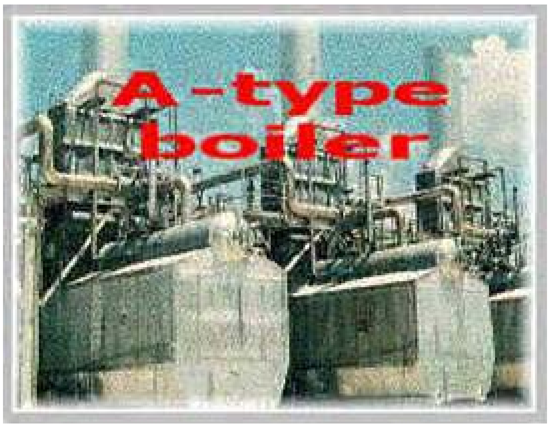
pressure results in a change to the boiling point of water.

For example, at atmospheric pressure, water boils at 100 degrees Celsius. At a pressure of 10 Bar, water boils at other temperatures. Steam tables list the boiling point of water at various pressures (see the enclosed table).

Regardless of the boiling point, when water boils, the water and steam have the same temperature. This is called the saturation temperature.

As long as the water and steam remain in contact, the temperature will remain at the saturation temperature. The boiler is only capable of producing saturated steam.

To raise the temperature of steam and increase energy production, without increasing pressure, steam must be heated out of contact with water. This is done in a superheater.



The afterboiler phase

Saturated steam leaving the drums of large industrial and utility boilers is commonly directed through superheaters. Superheater tubes have steam on one side and hot combustion gases on the other.

Temperatures here are higher than in boiler tubes. The superheated steam can then be used to drive turbines which function to drive some other rotating piece of equipment.

The largest turbines are used to drive generators and produce electric power.

Once steam is used in the plant, it is condensed and returned to the feedwater system. Condensate re-enters the preboiler, having made one complete pass through the steam generating system.

In a system with a properly maintained chemical treatment programme, condensate is high in purity. As mentioned earlier, this reduces the amount of water which must be pretreated before it enters the boiler.

In addition, because condensate has a high heat value, less energy is required to heat the feedwater.

The more condensate your plant can return to the boiler, the lower your make-up and fuel requirements will be. This results in increased energy efficiency of your boiler.

We have now handled the components of an industrial steam generating system. The system consists of three sections.

- The preboiler section removes impurities from incoming make up water and raises the temperature of the feedwater before it enters the boiler.

The boiler heats the water to boiling and separates steam.

- The afterboiler phase superheats the steam to a temperature above boiling and carries it to the plant where it is put to work.

If not lost in the system through process consumption or leaks, steam condenses and is recycled in the feedwater.

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