

BOILER

DEFINITION

A boiler or Steam generator is, usually, a closed vessel made of steel. Its function is to transfer to heat produce by the combustion of fuel (solid, liquid gaseous) to water, and ultimately to generate steam.

USAGES OF BOILER IN INDUSTRIES

The steam generated is employed for the following purposes:

- i) For generating power in steam engines or steam turbines.
- ii) In the textile industries for sizing and bleaching etc. and many other industries like; Sugar mills, Chemical industries.
- iii) For heating the buildings in cold weather and for producing hot water for hot water supply.

FUNCTION / WORKING

The primary function/Working of a boiler is to produce steam at a given pressure and temperature. To accomplish this, the boiler serves as a furnace where air is mixed with fuel in a controlled combustion process to release large quantities of heat. The pressure-tight construction of a boiler provides a means to absorb the heat from the combustion and transfer

this heat to raise water to a temperature such that the steam produced is of sufficient temperature and quality (moisture content) for steam loads.

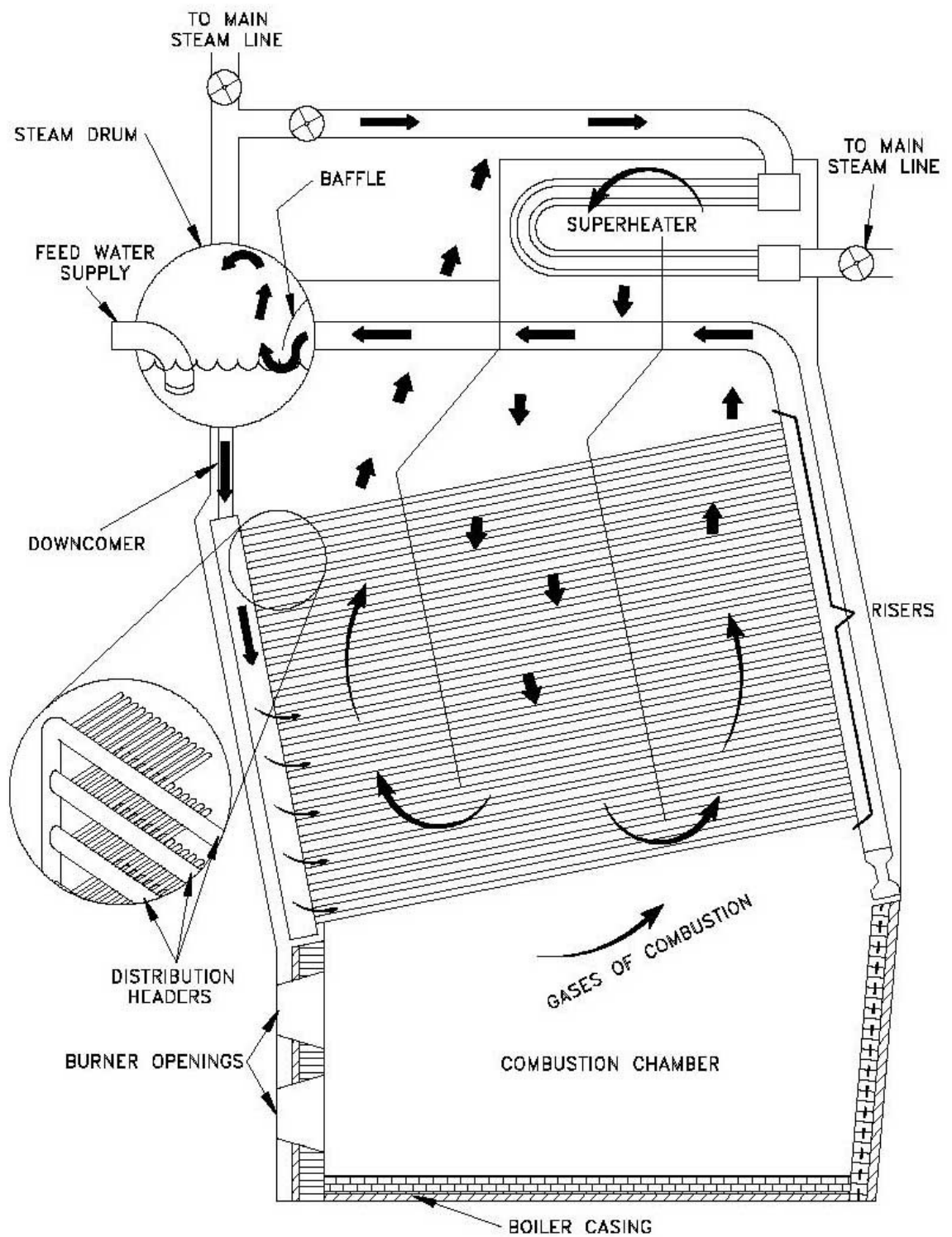
OPERATION

The boiler has an enclosed space where the fuel combustion takes place, usually referred to as the furnace or combustion chamber. Air is supplied to combine with the fuel, resulting in combustion. The water in the risers or circulating tubes absorbs the heat of combustion. The density difference between hot and cold water is the driving force to circulate the water back to the steam drum. Eventually the water will absorb sufficient heat to produce steam.

Steam leaves the steam drum via a baffle, which causes any water droplets being carried by the steam to drop out and drain back to the steam drum. If superheated steam is required, the steam may then travel through a super heater. The hot combustion gasses from the furnace will heat the steam through the super heater's thin tube walls. The steam then goes to the steam supplies System and the various steam loads.

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Some boilers have economizers to improve cycle efficiency by preheating inlet feed water to the boiler. The economizer uses heat from the boiler exhaust gasses to raise the temperature of the inlet feed water.



TYPICAL FUEL BOILER

FUEL BOILER COMPONENTS

STEAM DRUM

The steam drum separates the steam from the heated water. The water droplets fall to the bottom of the tank to be cycled again, and the steam leaves the drum and enters the steam system. Feed water enters at the bottom of the drum to start the heating cycle.

DOWNCOMERS

Down comers are the pipes in which the water from the steam drum travels in order to reach the bottom of the boiler where the water can enter the distribution headers.

DISTRIBUTION HEADERS

The distribution headers are large pipe headers that carry the water from the down comers to the risers.

RISERS

The piping or tubes that form the combustion chamber enclosure are called risers. Water and steam run through these to be heated. The term risers refer to the fact that the water flow direction is from the bottom to the top of the boiler. From the risers, the water and steam enter the steam drum and the cycle starts again.

COMBUSTION CHAMBER

Located at the bottom of a boiler, the combustion chamber is where the air and fuel mix and burn. It is lined with the risers.

CLASSIFICATION OF BOILERS

There are many classifications of steam boiler

01) ACCORDING TO THE CONTENTS IN THE TUBE

The steam boilers according to the contents in the tube may be classified as

- a) Fire Tube or Smoke Tube Boiler
- b) Water Tube Boiler

a) Fire Tube or Smoke Tube Boiler

In Fire tube and smoke tube boiler the flames and hot gases (exhaust gases), produce by the combustion of fuel, pass through the tubes (called multi tubes), which are surrounded, by water. The heat is conducted through the walls of the tubes from the hot gasses to surrounding water.

b) Water Tube Boiler

In Water Tube steam Boiler the water is contain inside the tube which are surrounded by flame and hot gasses from outside

2) ACCORDING TO THE POSITION OF FURNACE (HEATING SURFACE)

The steam boiler according to the furnaces are classified as

- a) Internally fired Boilers
- b) Externally Boilers

a) Internally fired Boiler

In internally fired steam Boilers the furnace is located inside the Boiler shell. Most of the fired tube steam boilers are internally fired Boiler.

b) Externally Boiler

In Externally fired steam boiler, the furnace is arranged underneath in a brick-work setting. Water tube steam boilers are always externally fired.

3) ACCORDING TO THE AXIS OF THE SHELL

The steam boilers, according to the axis boiler shell, may be classified as

- a) Vertical Boilers
- b) Horizontal Boilers

a) Vertical Boiler

In vertical steam boiler, the axis of the shell is vertical. Simple vertical boiler and Cochran boiler are vertical boilers.

b) Horizontal Boiler

In Horizontal steam boiler, the axis of the shell is horizontal. Lancashire boiler, Locomotive boiler, and Babcock and Wilcox boiler are horizontal boilers.

4) ACCORDING TO THE NUMBER OF TUBE

The steam boilers, according to the Number of Tubes, may be classified as

- a) Single Tube Boilers
- b) Multi tubular Boilers

a) Single Tube Boiler

In Single tube steam Boilers, there is an only one-fire tube or water tubes. Simple vertical boiler and Cornish boiler is Single Tube Boiler.

b) Multi Tubular Boiler

In Multitubular steam boilers, there are two or more fire tubes or water tubes. Lancashire boiler, Locomotive boiler, Cochran boiler, Babcock and Wilcox boiler are Multitubular boilers.

In forced circulation steam boilers, there is forced circulation of water by a centrifugal pump driven by some external power. Use of forced circulation is made in high-pressure boilers such as La-Mont boiler, Benson boiler, Loeffler boiler and velcon boiler.

06) ACCORDING TO THE USES

The steam boilers, according to their use, may be classified as:

- a) Stationary Boilers
- b) Mobile Boilers

a) Stationary Boilers

The stationary steam boilers are used in power plants, and in industrial process work. These are called stationary because they do not move from one place to another.

b) Mobile Boilers

The Mobile steam boiler is those, which move from one place to another. These boilers are locomotive and marine boiler.

07) ACCORDING TO THE SOURCE OF HEAT

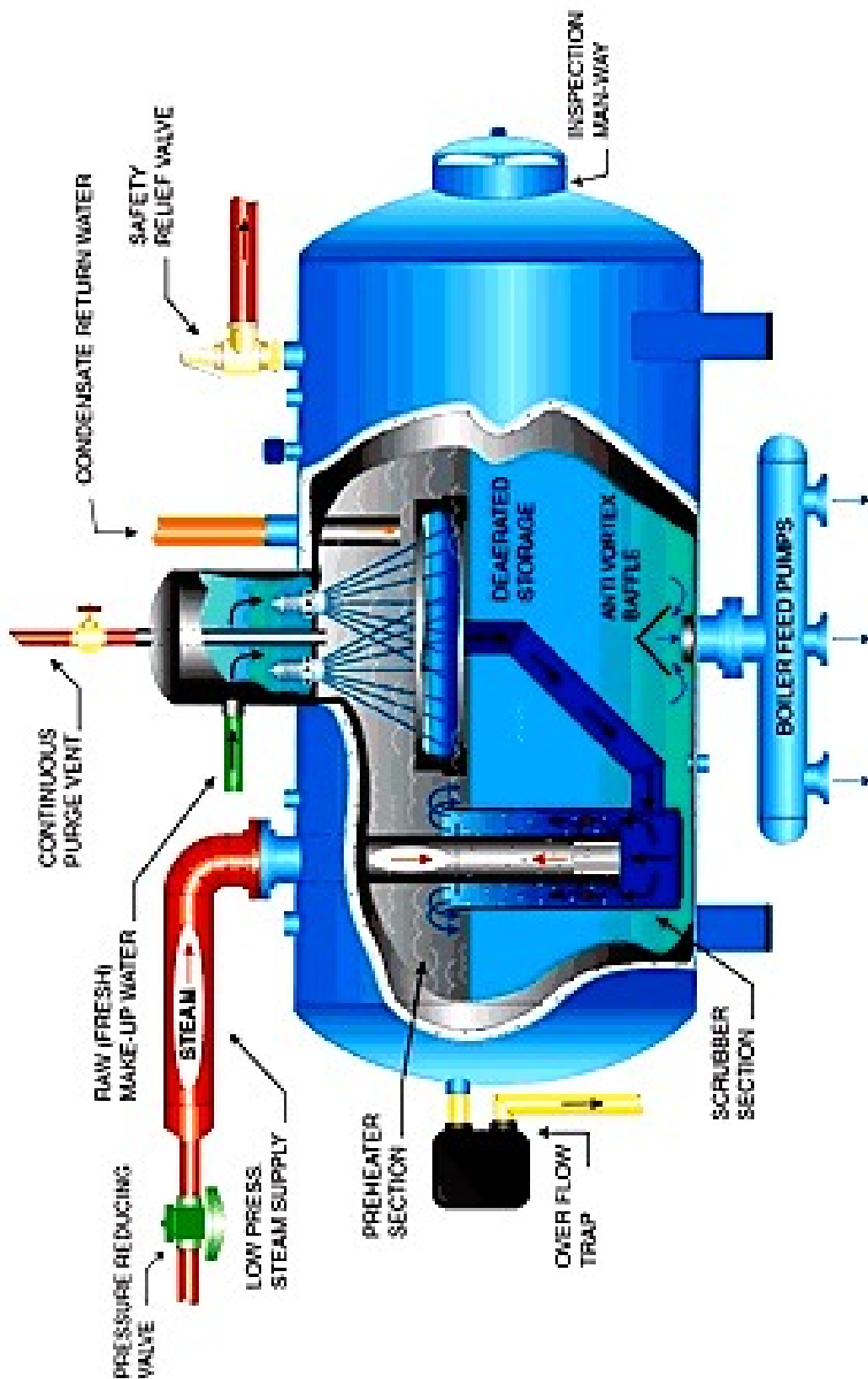
TYPES OF BOILER

- 1) WATER TUBE BOILER
- 2) FIRE TUBE BOILER

WATER TUBE BOILER

A **water-tube boiler** is a type of boiler in which water circulates in tubes which are heated externally by the fire. Water-tube boilers are used for high-pressure boilers. Fuel is burned inside the furnace, creating hot gas which heats up water in the steam-generating tubes. In smaller boilers, additional generating tubes are separate in the furnace, while larger utility boilers rely on the water filled tubes that make up the walls of the furnace to generate steam. The heated water then rises into the steam drum. Here, saturated steam is drawn off the top of the drum. In some services, the steam will reenter the furnace in through a superheater in order to become superheated. Superheated steam is used in driving turbines. Since water droplets can severely damage turbine blades, steam is superheated to 730°F (390°C) or higher in order to ensure that there is no water entrained in the steam. Cool water at the bottom of the steam drum returns to the feed water drum via large-bore 'down comer tubes', where it helps pre-heat the feed water supply. To increase the economy of the boiler, the exhaust gasses are also used to pre-heat the air blown into the furnace and warm the feed water supply. Such water-tube boilers in thermal power station are also called *steam generating units*.

The older fire-tube boiler design—in which the water surrounds the heat source and the gases from combustion pass through tubes through the water space—is a much weaker structure and is rarely used for pressures above 350 psi (2.4 MPa). A significant advantage of the water tube boiler is that there is less chance of a catastrophic failure: here is not a large volume of water in the boiler nor are there large mechanical elements subject to failure.



WATER-TUBE BOILER

CLASSES OF WATER-TUBE BOILER

- **D-TYPE BOILER**

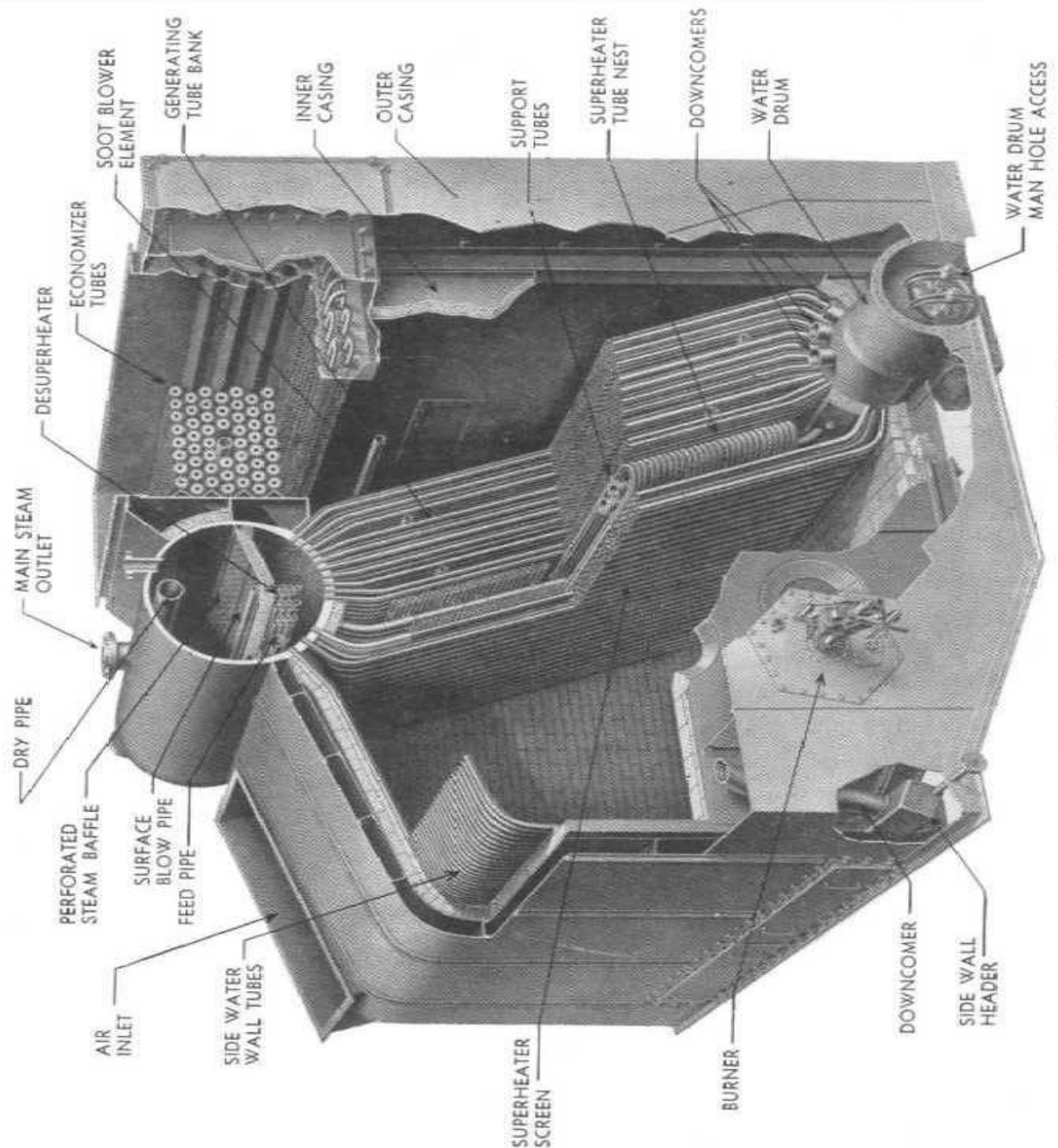
This is the most common type of small-medium sized boilers, similar to the one shown in the schematic diagram. It is used in both stationary and marine applications. It consists of a large steam drum vertically connected to a smaller water drum (a.k.a. mud drum) via multiple steam-generating tubes. These are surrounded by walls made up of larger water filled tubes, which make up the furnace.

STEAM DRUM

The steam drum is a cylinder located at the top of the boiler. It runs lengthwise from the front to the back of the boiler. The steam drum provides a space for the saturated steam generated in the tubes and for the separation of moisture from the steam. (Remember, saturated steam is steam that has not been heated above the temperature of the water from which it was generated). The steam drum also serves as a storage space for boiler water, which is distributed from the steam drum to the down comer tubes. During normal operation, the steam drum is kept about half full of water. The steam drum either contains or is connected to many of the important controls and fittings required for the operation of the boiler.

At the bottom right side of the boiler you will find the water drum, and on the bottom left side is the sidewall header. Notice the header is smaller than the water drum. Most boilers have more than one header. They are identified by their location. For example, a header at the back

of the boiler is called a rear wall header. A header on a screen wall is called a screen wall header.



D TYPE BOILER

• BABCOCK & WILCOX BOILER

The three boilers are “water tube” boilers based on a design of two Americans, George Herman Babcock and Stephen Wilcox, patented in 1867. It became the most successful water tube boiler with over four million n.h.p. installed world wide by 1904. The three at Twyford represent the classic Babcock and Wilcox boiler of the period 1900-14. Our 1916 boiler is now the oldest one of its type which is steam able.

Looking at the boiler, the steam drum A at the top is supported by straps from steel columns set in walls lined with refractory bricks. The water tubes, from which the boiler gets its name, are mounted between two sets of headers.

The rear set B nearly touches the boiler floor and are fed by large tubes from the bottom of the drum.

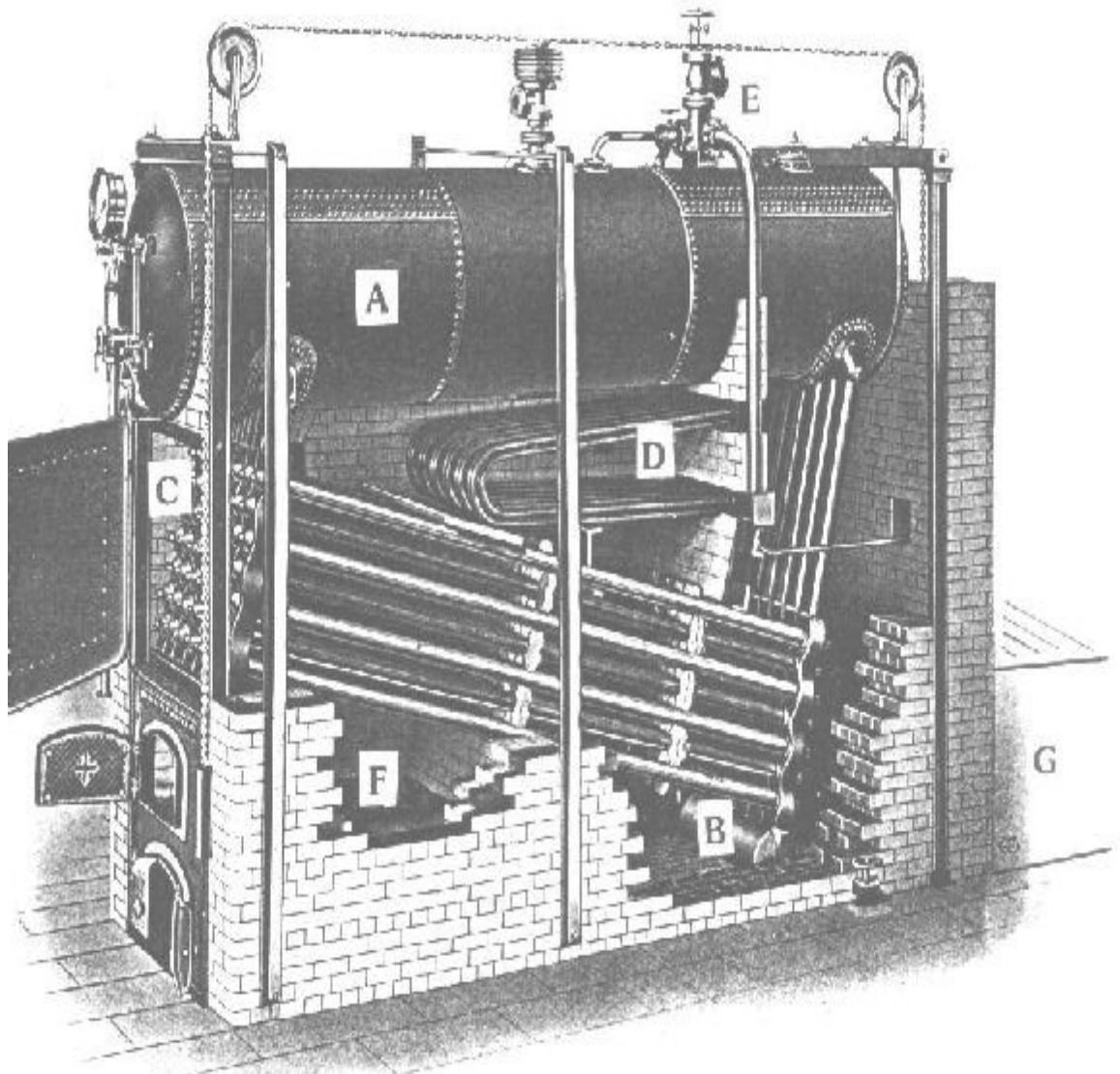
The front set C connect with the front of the drum by a short manifold so that the group of sixty 4 inch diameter tubes slopes up towards the front over the fire grate F. This layout promotes good water circulation by thermo-syphon action. You can see the front headers on the unrestored boilers; “saturated” steam is taken direct from the top of the steam drum via a stop valve at the rear of the drum.

Steam for the engine, however, is “superheated” by being collected through two tubes high in the steam space and fed through twenty U-shaped tubes D below the drum where the steam picks up extra heat energy from the flue gases before passing to the main stop valve E.

The front of the steam drum has a pressure gauge and two gauge glasses to monitor the water level. The original working pressure was 160 p.s.i. but we now operate at 100 p.s.i. (7 bar or 0.7 MPa).

The water level is maintained by one or more of the engine driven feed pump, auxiliary steam feed pumps or an electric pump. The boiler feed water comes from condensed steam in the hot well, Since steaming recommenced we have introduced an additional water storage tank beside the chimney, which is used to hold treated boiler water whilst the boiler is in use or in a dry storage condition. Steam grate blowers keep the boiler airways free of ash and induced air is forced up through the grate. Any solids deposited in the water tubes during steaming tend to collect at the bottom of the “downcomers”, the headers at the rear of the tube stack.

Here, there is a special drain called the “blowdown” which, when operated during steaming, dumps water and deposited sludge in the blowdown pit outside. Steam plus hot water at 175 °C is violent and dangerous. Control of the furnace is by a damper, a sliding trapdoor, in the passage from the boiler to the chimney G. The damper is counterbalanced and operated by a large weight hanging to the right of the fire doors. The operating chain passes over guide pulleys at the top of the boiler frame.



Babcock & Wilcox Land Boiler, Fitted With Superheater

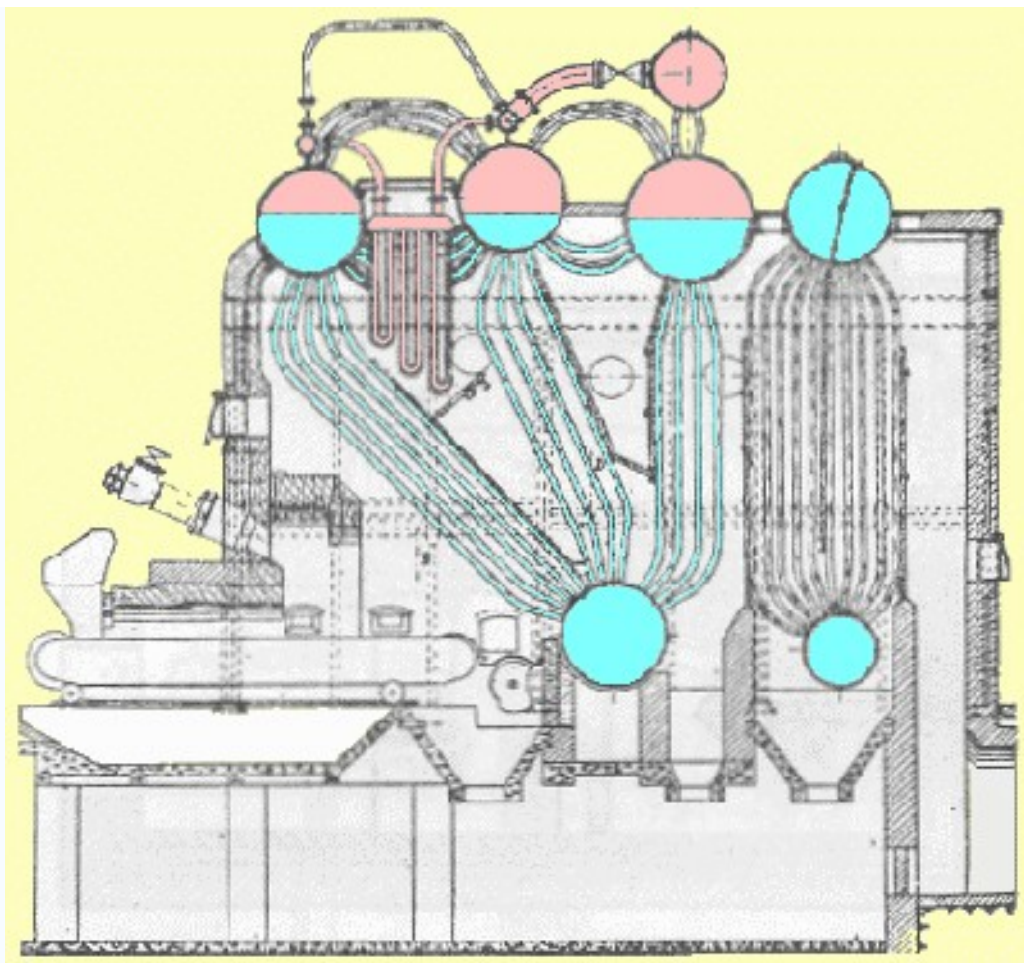
- A** **STEAM DRUM**
- B** **REAR SET**
- C** **FRONT SET**
- D** **U-shaped tubes**
- F** **FIRE GRATE**
- G** **CHIMNEY**

- **STIRLING BOILER**

This kind of boiler has never, as far as I know, been used on ships.

A water tube boiler in which two, or more, upper drums and one lower drum are connected by highly inclined banks of water tubes curved so as to enter the drums radially, the upper drums being also connected by horizontal steam and water tubes.

This is a four-drum Stirling boiler with a superheater and economizer, with a chain-grate setting designed to burn coal.



STIRLING BOILER

• **THORNYCROFT BOILER**

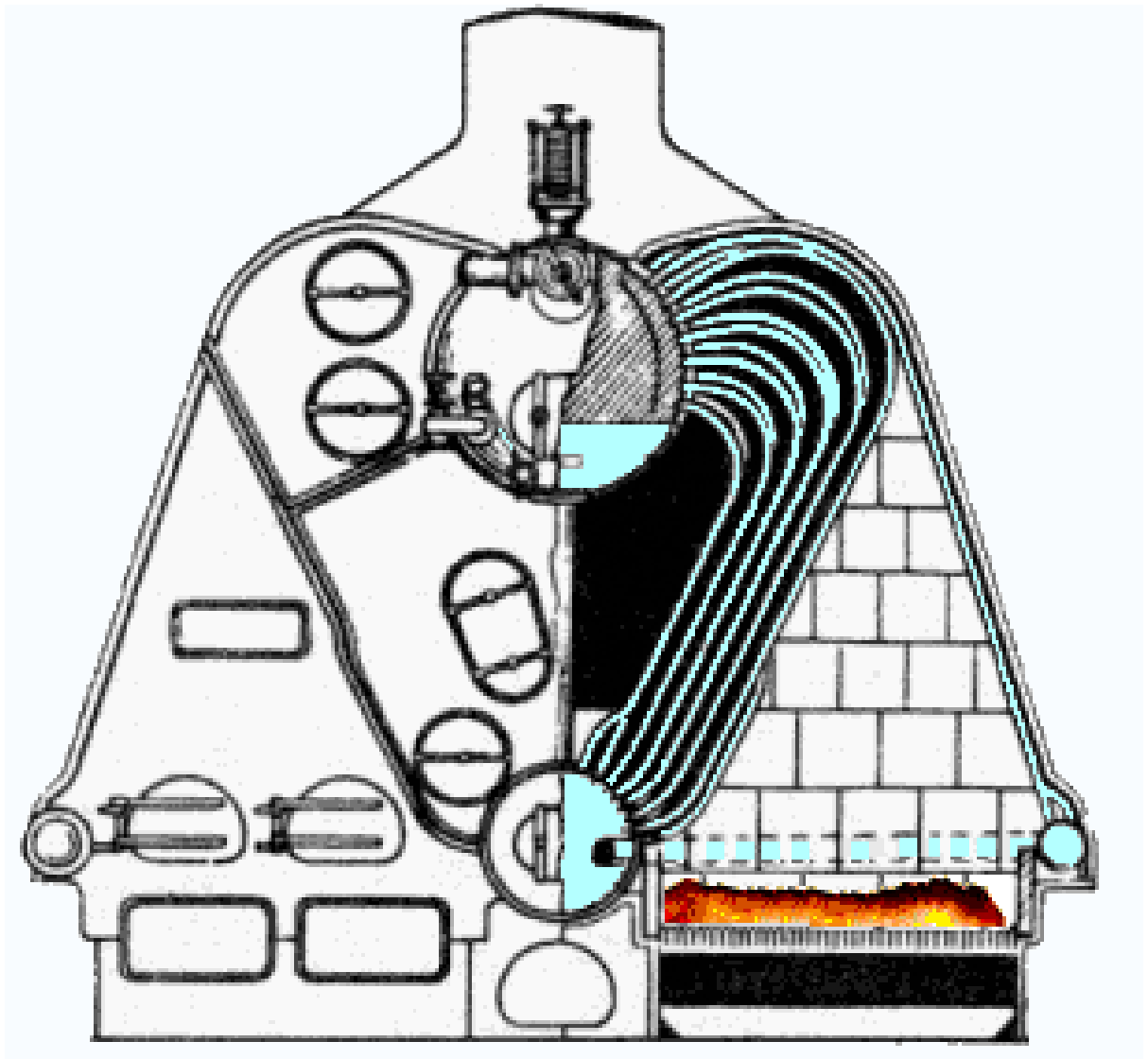
The Thornycroft boiler has an upper steam drum and a lower water drum connected together by banks of tubes. The tubes are very curved and all of them discharge into the steam drum above the water level. In later models some of the tubes discharge below the level. A down comer between the steam drum and the water drum is located behind the boiler.

The flue gas pass through the banks of tubes and violent circulation arise in the tubes and the evaporated steam conveys water to the steam drum. This water heavy circulation keeps the tubes free from deposits.

These boilers have an upward narrowing shape and call for -- especially if they are placed side by side -- a larger space than other square-shaped boilers.

This boiler has two lower drums. Huge downcomers are installed between the steam drum and the water drums.

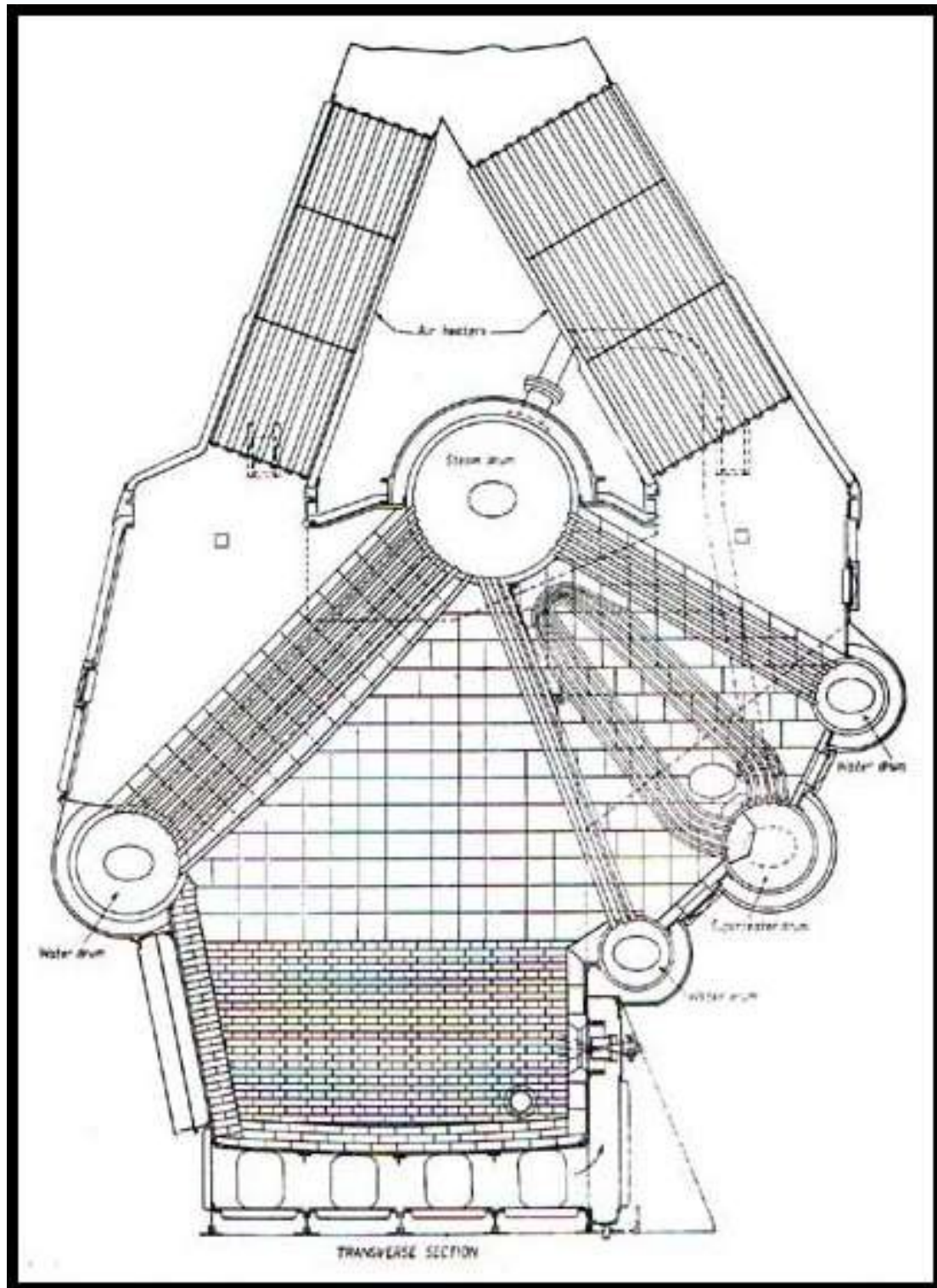
Thornycroft water tube boiler with two water drums. Notice that the fire in the furnace doesn't heats the downcomers



THORNYCROFT BOILER

- **YARROW BOILER**

This type has three drums in a delta formation connected by water tubes and is generally fuel oil-fired. Due to its three drums, the Yarrow boiler has a greater water capacity. Hence, this type is usually used in older marine boiler applications. Its compact size made it attractive for use in transportable power generation units during World War II. In order to make it transportable, the boiler and its auxiliary equipment (fuel oil heating, pumping units, fans etc.), turbines, and condensers were mounted on wagons to be transported by rail.

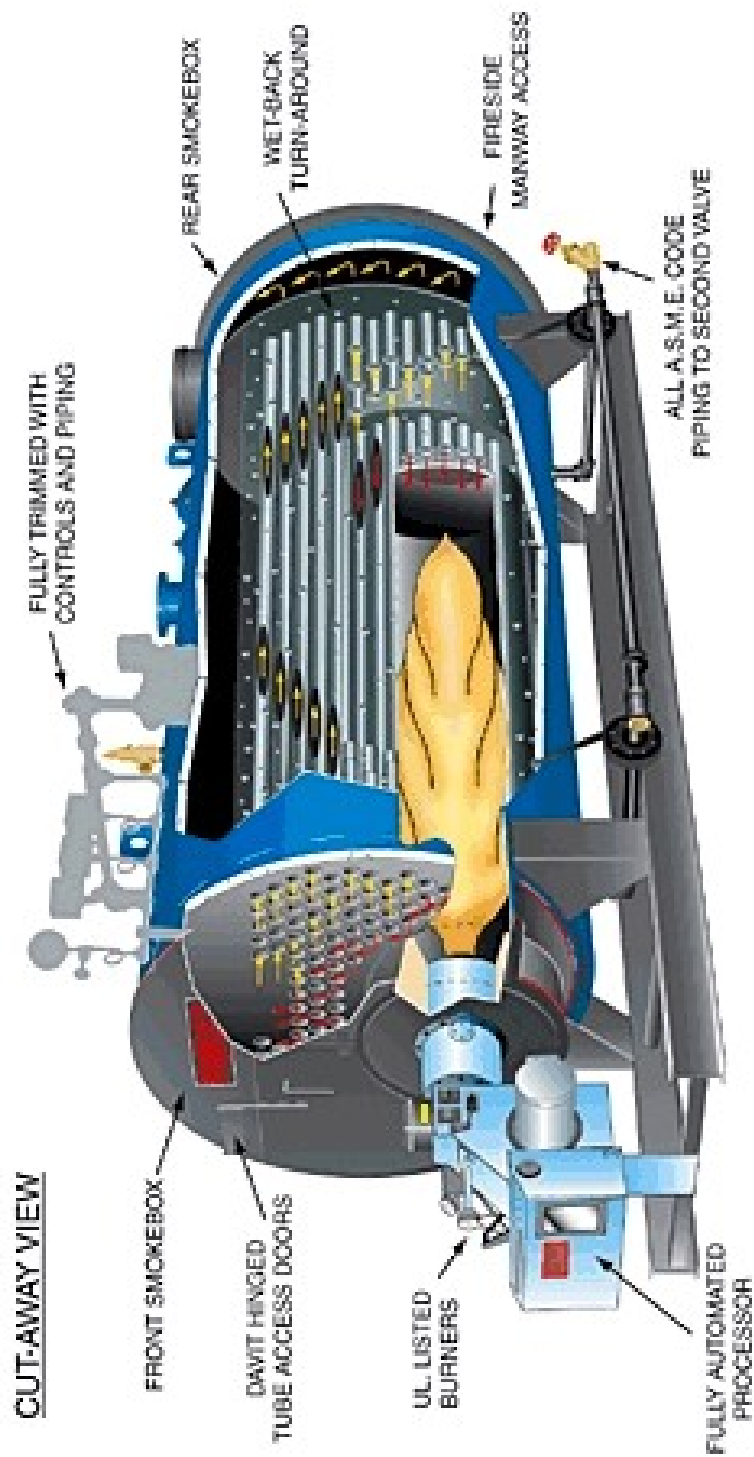


Yarrow boiler

FIRE-TUBE BOILER

A **fire-tube boiler** is a type of boiler in which hot gases from the fire pass through one or more tubes within the boiler. It is one of the two major types of boilers, the other being the water-tube boiler. A fire tube boiler can be either horizontal or vertical. A fire-tube boiler is sometimes called a "smoke-tube" boiler.

This type of boiler was used on virtually all steam locomotives in the horizontal "locomotive" form. It is also typical of early marine applications and small vessels, such as the small riverboat used in the movie The African Queen. It also has extensive use in the stationary engineering field, typically for low pressure steam use such as heating a building.



FIRE TUBE BOILER

In the locomotive type boiler, fuel is burnt in a firebox to produce hot combustion gases. The firebox is surrounded by a cooling jacket of water connected to the long, cylindrical boiler tube. The hot gases are directed along a series of *fire tubes*, or *flues*, that penetrate the boiler and heat the water thereby generating saturated steam. The steam rises to the highest point of the boiler, the *steam dome*, where it is collected. The dome is the site of the *regulator* that controls the exit of steam from the boiler.

In the locomotive boiler, the saturated steam is nearly always passed into a superheated, back through the larger flues at the top of the boiler, to dry the steam and heat it to *superheated steam*. The superheated steam is directed to the cylinders or a turbine to produce mechanical work. Exhaust gases are fed out through a chimney, and may be used to pre-heat the feed water to increase the efficiency of the boiler.

Draught for fire tube boilers, particularly in marine applications, is usually provided by a tall smokestack. In all steam locomotives, since Stephenson's Rocket, additional draught was supplied by directing exhaust steam from the cylinders into the smokestack through a blast pipe, to provide a piratical vacuum. Modern industrial boilers use fans to provide forced draughting of the boiler.

Another major advance in the Rocket was large numbers of small diameter fire tubes instead of a single large flue (a *multi-tubular boiler*). This greatly increased the surface area for heat transfer, allowing steam to be produced at a much higher rate. Without this, steam locomotives could never have developed effectively as powerful prime movers.

SAFETY CONSIDERATIONS

Because the fire-tube boiler itself is the pressure vessel, it requires a number of safety features to prevent mechanical failure. Boiler explosion, which is a type of BLEVE (Boiling Liquid Expanding Vapor Explosion), can be devastating.

- Safety valves release steam before a dangerous pressure can be built up
- Fusible plugs over the firebox melt at a temperature lower than that of the firebox, therefore melting and dousing the fire in water should it overheat.
- **Stays**, or ties, physically link the firebox and boiler casing, preventing them warping

The fire-tube type boiler that was used in the Stanley Steamer automobile had several hundred tubes which were weaker than the outer shell of the boiler, making an explosion virtually impossible as the tubes would fail and leak long before the boiler exploded. In nearly 100 years since the Stanley's were first produced, no Stanley boiler has ever exploded.

CLASSES OF FIRE-TUBE BOILER

- **Cornish boiler** has a single large flue containing the fire
- **Lancashire boiler** has two large flues containing the fires
- **Locomotive boiler** has a double-walled firebox and a large number of small flue-tubes. Larger flue-tubes carry the super heater elements, where present. Forced draught is provided in the locomotive boiler by injecting exhausted steam back into the exhaust via a blast pipe.

LOCOMOTIVE BOILER

A **locomotive** (from Latin **loc** - 'from a place', ablative of 'locus' = 'place' + Medieval Latin **motives** = 'causing motion') is a railway vehicle that provides the motive power for a train, and has no payload capacity of its own; its sole purpose is to move the train along the tracks. In contrast, many trains feature self-propelled payload-carrying vehicles; these are not normally considered locomotives, and may be referred to as multiple units or railcars; the use of these self-propelled vehicles is increasingly common for passenger trains, but very rare for freight (see however Cargo Sprinter). Vehicles which provide the motive power to haul an unpowered train, but are not generally considered locomotives because they have payload space or are rarely detached from their trains, are known as power cars.

Traditionally, locomotives haul (pull) their trains. Increasingly common these days in local passenger service is push-pull operation, where a locomotive pulls the train in one direction and pushes it in the other, and is therefore optionally controlled from a control cab at the opposite end of the train. This is especially true of "High Speed Rail lines", such as Germany's ICE and France's TGV trains



LOCOMOTIVE BOILER

ADVANTAGES

There are many reasons why the motive power for trains has been traditionally isolated in a locomotive, rather than in self-propelled vehicles.^[4] These include:

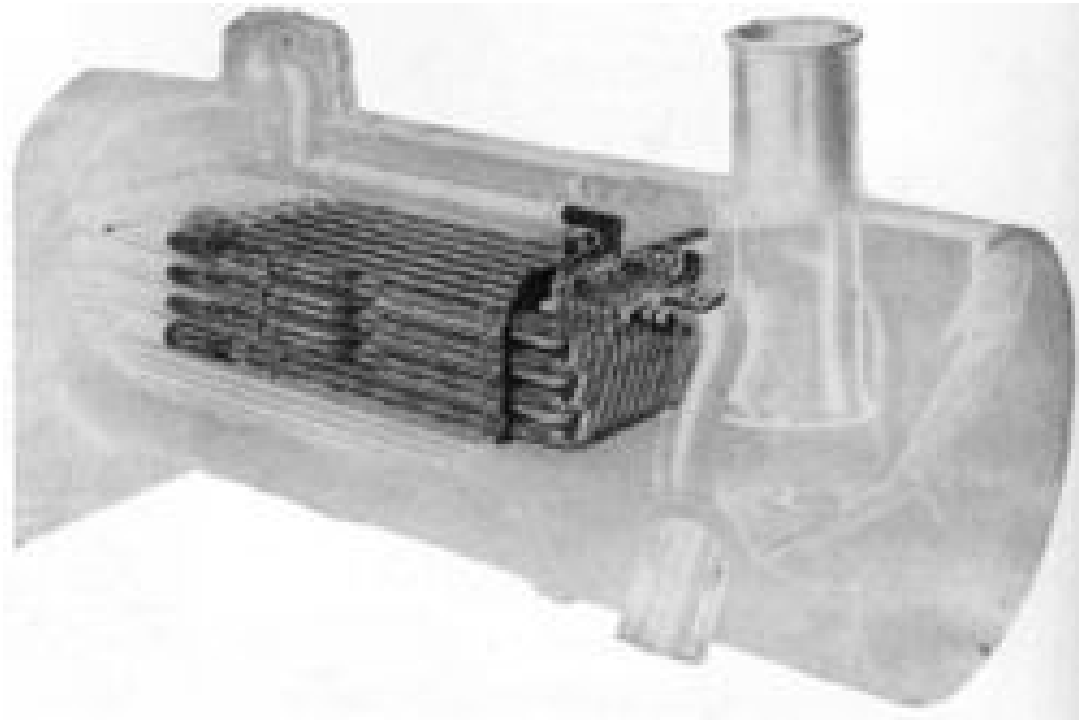
- Ease of maintenance - it is easier to maintain one locomotive than many self-propelled cars.
- Safety - it is often safer to locate the train's power systems away from passengers. This was particularly the case for steam locomotives, but still has some relevance for other power sources.
- Easy replacement of motive power - should the locomotive break down, it is easy to replace it with a new one. Failure of the motive power unit does not require taking the whole train out of service.
- Maximum utilization of power cars - idle trains do not waste expensive motive power resources. Separate locomotives mean that the costly motive power assets can be moved around as needed.
- Flexibility - large locomotives can be substituted for small locomotives where the gradients of the route become steeper and more power is needed.
- Obsolescence cycles - separating the motive power from the payload-hauling cars means that either can be replaced without affecting the other. At some times, locomotives have become obsolete when their cars are not, or vice versa.

DISADVANTAGES

There are several disadvantages of locomotives compared to multiple unit (MU) trains.

- Energy efficiency - Multiple units are more energy efficient than locomotive-hauled trains and more nimble, especially on grades, as much more of the entire train's weight (sometimes all of it) is placed on power-driven wheels, rather than suffer the dead weight of unpowered coaches;
- No need to turn locomotive - Multiple units have cabs at each end, so that the train may be reversed without having to uncouple/re-couple and move the locomotive, which results in quicker turnaround times, reduced crewing costs, and enhancing safety;
- Reliability – Due to Multiple Unit trains having multiple engines the failure of one engine does not prevent the train from continuing its journey. A locomotive drawn train typically only has one power unit meaning the failure of this causes the train to be disabled (although some locomotive hauled trains may contain more than one power unit and be able to continue at reduced speed after the failure of one)
- Safety – Multiple units normally have completely independent braking systems on all cars meaning the failure of the brakes on one car does not prevent the brakes throughout the train from operating safely.

SUPERHEATED STEAM BOILER



A superheated boiler on a steam locomotive.

Most boilers heat water until it boils, and then the steam is used at saturation temperature (i.e., saturated steam). Superheated steam boilers boil the water and then further heat the steam in a super heater. This provides steam at much higher temperature, and can decrease the overall thermal efficiency of the steam plant due to the fact that the higher steam temperature requires a higher flue gas exhaust temperature. However, there are advantages to

superheated steam. For example, useful heat can be extracted from the steam without causing condensation, which could damage piping and turbine blades.

Superheated steam presents unique safety concerns, however, if there is a leak in the steam piping, steam at such high pressure/temperature can cause serious, instantaneous harm to anyone entering its flow. Since the escaping steam will initially be completely superheated vapor, it is not easy to see the leak, although the intense heat and sound from such a leak clearly indicates its presence.

HYDRONIC BOILERS

Hydronic boilers are used in generating heat typically for residential uses. They are the typical power plant for central heating systems fitted to houses in northern Europe (where they are commonly combined with domestic water heating), as opposed to the forced-air furnaces or wood burning stoves more common in North America. The hydronic boiler operates by way of heating water/fluid to a preset temperature (or sometimes in the case of single pipe systems, until it boils and turns to steam) and circulating that fluid throughout the home typically by way of radiators, baseboard heaters or through the floors. The fluid can be heated by any means....gas, wood, fuel oil, etc, but in built-up areas where piped gas is available, natural gas is currently the most economical and therefore the usual choice. The fluid is in an enclosed system and circulated throughout by means of a motorized pump. Most new systems are fitted with condensing boilers for greater efficiency.

Hydronic systems are being used more and more in new construction in North America for several reasons. Among the reasons are:

- They are more efficient and more economical than forced-air systems (although initial installation can be more expensive, because of the cost of the copper and aluminum).
- The baseboard copper pipes and aluminum fins take up less room and use less metal than the bulky steel ductwork required for forced-air systems.

- They provide more even, less fluctuating temperatures than forced-air systems. The copper baseboard pipes hold and release heat over a longer period of time than air does, so the furnace does not have to switch off and on as much. (Copper heats mostly through conduction and radiation, whereas forced-air heats mostly through forced convection. Air has much lower thermal conductivity and higher specific heat than copper; however, convection results in faster heat loss of air compared to copper. See also thermal mass.)
- They do not dry out the interior air as much.
- They do not introduce any dust, allergens, mold, or (in the case of a faulty heat exchanger) combustion byproducts into the living space.

Forced-air heating does have some advantages, however. See forced-air heating.

NATURAL CIRCULATION BOILER

Systems in these units, the fluid flow are induced by the difference in the specific weight of the water-steam mixture in the evaporator tubes where the water is boiled. The driving force for flowing through the evaporator section is equal to the product of difference in the average specific weights and the height of the evaporator tubes. This driving force is balanced by the frictional pressure drop in the supply and evaporator tubes as the result of the two-phase flow of water and steam. “Down comer” tubes located in the cooler part of the boiler, to the bottom or “mud” drum. From the mud drum, the water flows back to the steam drum through the evaporator or “riser” tubes. In the steam drum, the steam and water are separated and the steam is washed and dried before it is sent to the super heater. The lower drum is commonly called as mud drum because any water impurities naturally gravitate to this drum.



NATURAL CIRCULATION BOILER

FORCED CIRCULATION BOILER

In a force-circulation boiler, the fluid is pumped through the evaporator section of the boiler. This permits operation of the power cycle at very high pressures, even above the critical pressure. High-pressure operation theoretically improves the efficiency of the basic steam cycle. The forced circulation system eliminates the need for boiler height, it is lighter in weight, it used smaller tubes and Drums or no drums at all, and the lower total water content in the boiler reduces the danger of a steam explosion. In addition to the problems associated with the main circulation pump and potentially higher operating pressures, some of these systems also require extremely pure water-orders of magnitude purer than that required for natural circulation systems.

There are many different kinds of forced-circulation boilers, depending upon the circulation paths in the evaporator.



FORCED CIRCULATION BOILER

BENSON BOILER

The most widely used forced circulation boiler system is Benson Boiler.

In the Benson Boiler, the water is pumped to about 35 MPa (5000 psi) in the main feed pump. This compressed Water is then piped to the economizer section, through the evaporator tubes, through a transition section, and finally through a convection superheater, where it is exhausted to the turbine at a pressure of around 24MPa (35000 psi). This supercritical boiler system requires extremely pure water. The impurity concentration must be no higher than a few pars per billion because any impurity in the water will normally be deposited in the boiler tubing. The Ramsin boiler is essentially identical to the Benson boiler except that the evaporating section is composed of inclined T-bundle coils arranged in a spiral array.

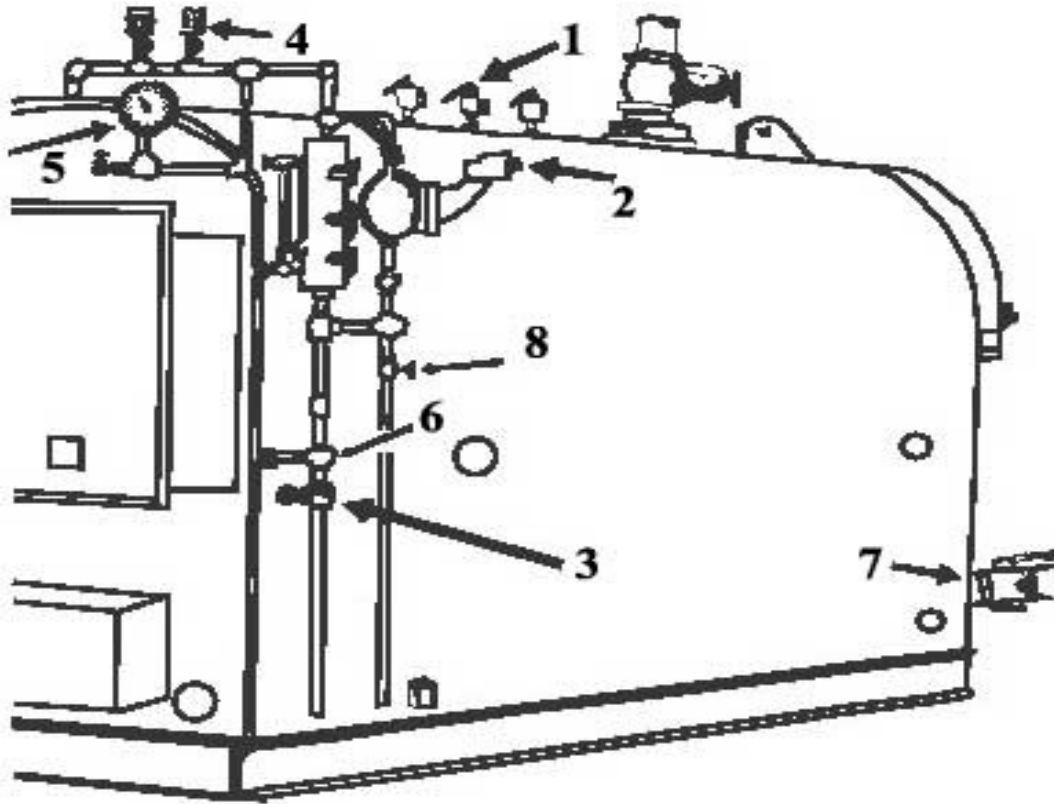
LAMONT BOILER

The Laymont boiler closely resembles the natural-circulation boilers because it has a steam drum. Since the water-steam mixture is separated in this drum, the system must operate at a pressure below the critical Pressure the velox boiler is an interesting unit because it combines the steam or Rankine power cycle with the gas turbine or Brayton power cycle. This system is very different from the so-called combined-cycle systems that are becoming increasingly popular. In these latter systems, the gas turbine discharge is called as the source of hot combustion air compressed 200 to 300 KPA (29 to 44 psi) in an air compressor that is driven by the gas turbine. The air is then heated and passed through the steam generator before it is discharged to the gas turbine. This unit produces steam at 1.4 to 8 MPa (200 to 1200 psi). It has a relatively high overall thermal efficiency but the steam-generator casing is essentially a pressure vessel, which significantly increases the capital cost of the system.

As mentioned earlier, some of the forced-circulation system requires ultra-pure water but the Loeffler and the Schmidt-Hartman boilers can operator while using feed water with relatively high impurity levels. Both these units must operator at pressure below the critical pressure. In Loeffler boiler, the water is evaporated by part of the superheated steam and the resulting saturated steam is pumped through the super heater section. In the Schmidt-Hartman boiler, condensing steam in a higher-pressure, closed natural-circulation, secondary system, boils the water.

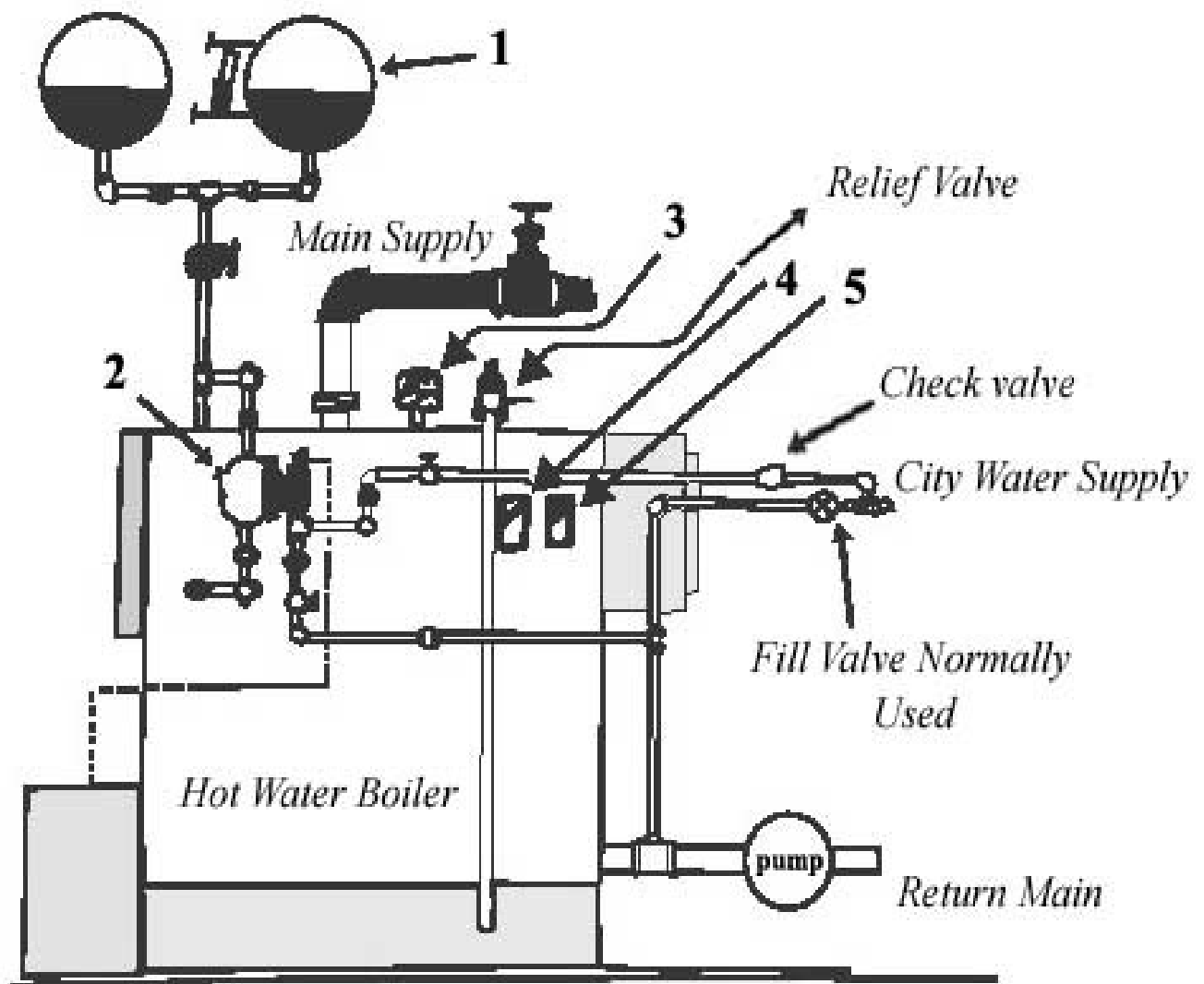
The steam boilers may also be classified according to the source of heat supplied for producing steam. These sources may be the combustion of solid, Liquid or gaseous fuel, hot waste gases as by-

products of other chemical processes, electrical energy or nuclear energy, et BOILER TERMINOLOGY



Steam Boiler

- 1) Safety Valve
- 1) Low Water Cut Off
- 2) Water column blow-down valve
- 3) Pressuretrols (one is high-limit safety)
- 4) Steam pressure-gauge
- 5) Water column clean-out (cross tee)
- 6) Bottom blow-off and drain valve
- 7) Low-water cutoff/blow-off valve



HOT WATER BOILER

- 1) Expansion tank
- 2) Low-water cutoff
- 3) Combination temperature/pressure gauge or altitude/temperature gauge

Boiler water level

The first duty when taking over a boiler-room shift is to make certain the pipe, fittings and valves between the water glass and boiler are free and open by blowing down the water column and water glass and noting the promptness of the return of water to the glass.

The most important rule

The most important rule for the safe operation of boilers is to maintain the proper water-level at all times, and as constant a level as conditions will permit. If water is not visible in the water glass, shut the boiler off immediately until a safe water-level has been determined.

Low water and feed water controls

The low-water cutoff is the most important electrical/mechanical device on your boiler for maintaining a safe water-level. If a low-water condition develops, it could very well result in an overheating and explosion of your boiler. The low-water cutoff should be tested at least weekly.

Low-water cutoff, evaporation test (steam boiler)

While the boiler is in operation, shut off the feed water pump and monitor the boiler water

level. The low-water cutoff should shut down the burner before the water level goes out of sight low; if the burner does not shut off, restart the feed water pump before the water level goes out of sight low and immediately troubleshoot the low-water cutoff to determine the cause of failure. The boiler must be under constant attendance by a properly licensed engineer at all times during this test.

Low-water cutoff, slow drain test (steam boiler)

While the boiler is in operation, shut off the feed water pump and slowly open the bottom blow valve to drain the water from the boiler. The low-water cutoff should shut down the burner before the water level goes out of sight low; if the burner does not shut off, restart the feed water pump before the water level goes out of sight low and immediately troubleshoot the low-water cutoff to determine the cause of failure. The boiler must be under constant attendance by a properly licensed engineer at all times during this test.

Firing

Aside from the standpoint of economy, maintain the fire as uniformly as possible to avoid an excessive rate of combustion, undesirable variations in temperature and possible explosions. The destructive force in a boiler explosion is

Caused by the instant release of energy stored in the water as heat.

Water gauges

Keep all connections and valves clear. Test by blowing down the water glass and water column regularly. Gauge cocks or tri-cocks should also be blown regularly.

Safety valves

The safety valve is the most important valve on the boiler. Safety valves prevent dangerous over pressurization of the boiler. Safety valves are installed in case there is failure of pressure controls or other devices designed to control the firing rate. All safety valves should be kept free of debris by testing the safety valve regularly. This should be done when the steam pressure is at approximately 75 percent of the safety valve set pressure. Safety and safety-relief valves on low-pressure boilers should be tested at least quarterly, this is in accordance with the National Board Inspection Code.

Blow-down valves

The concentration of solids in the boiler should be measured and the boiler blown-down at such intervals as necessary to maintain established limits. Blow-down valves are placed at the lowest point of the boiler for the purpose of blowing sediment or scale from the boiler. They should be

maintained in good working order and are to be opened and closed carefully when used.

Starting fires in a boiler

Before starting fires in a cold boiler or restarting a fire that may have been accidentally extinguished, the entire fireside of the boiler must be thoroughly ventilated (purged) with the dampers open to remove unburned gases before attempting to relight the fire. Attempting to start a fire in a boiler with unburned gases is the most common cause of boiler furnace explosions.

Boiler-room requirement

A current proper engineer's license and log shall be posted in the boiler room. It is the responsibility of the owner and the engineer to make sure the boiler is inspected annually.

Hot-water systems

These systems are equipped with expansion tanks for the expansion and contraction of the water as the temperature varies

Firing cycle, power burners

The burner will start when the aqua stat or pressuretrol calls for heat. The breeching Damper will open and the draft fan will purge the combustion chamber. The main gas or oil valve will be energized when the pilot or ignition is proved.

Repairs

Any excessive overheating or burning, and any major repairs, must be reported to your boiler inspector.

c. CONSTRUCTION METHODS FOR JOINING & CLEANING BOILER

METHODS OF JOINING BOILER ELEMENTS

Welding, forge welding and riveting are use for joining boiler element. **Welding** is the predominant method of joining boiler pressure parts **Forge welding** of joints is limited by the power boiler code to an ultimate strength of 35,000 lb per sq in with steel plates manufactured in accordance with SA-285 grades A& B steel. But **riveting** on numerous existing boilers will continue pressure Vessel code, power boilers section I for detailed requirements on old riveted boiler joints.

WELDING

Welding is a localized coalescence (fusing together) or consolidation of metal where joining is produced by heating to fusion temperatures, with or without the application of pressure, and with or without the use of a filler metal. The filler metal (when used) has a melting point of approximately that of the pieces (base metal) joined together.

The weld is that portion which has been melted during welding. And the welded joint is the union of two or more members produced by the welding process.

METHOD OF WELDING

The most common method of welding pressure parts is by fusion (melting) of the metal, the heat being supplied in one of several different ways. In fusion welding, no pressure is applied between the pieces being welded. Arc welding, gas welding, and Thermit welding are classified as fusion welding, but arc welding is the most common.

ARC WELDING

Arc welding is a localized progressive melting and flowing together of adjacent edges of the base metal parts, caused by heat produced by an electric arc between a metal electrode, or rod and the base metal. Both metals are melted. On cooling they solidify, thus joining the two pieces with continuous material.

FORGE WELDING

Forge welding is a welding process of heating two or more pieces metal and then hammering them together. Its use is ancient, doubtlessly being the first method devised for the joining of metals. It was first applied to wrought iron and steel, but is now used to join a host of similar and dissimilar metals. However, with the invention of electrical and gas welding methods during the Industrial Revolution, forge welding has been largely replaced.

Forge welding between similar materials is caused by solid-state diffusion. This results in a weld that only consists of the materials without any fillers or bridging materials.

Forge welding between dissimilar materials is caused by the formation of a lower melting temperature eutectic between the materials. For this reasons many dissimilar metals welded together with superior properties of the weld.

The welding temperature is above the forging temperature, and not so very far away from the melting point of the metal. It is typically 50–90% of the melting temperature. Steel welds at a lower temperature than iron. The metal may take on a glossy, or wet, appearance at the welding temperature. Care must be taken to avoid burning the metal, which is overheating to the point that it gives off, sparks from rapid oxidation.

One of the most famous applications of forge welding is in the production of Japanese katana blades. During the process a billet of steel is repeatedly drawn out, folded back and welded

upon itself. Another lesser-known application was the manufacture of shotgun barrels. Metal wire was spooled onto a mandrel, and then forged into a barrel that was thin, uniform, and strong. Often such objects are acid etched to expose the underlying pattern of metal which is unique to each item and adds to their aesthetic appeal.

RIVET

A rivet is a semi-permanent mechanical fastener. Before it is installed it consists of a smooth cylindrical shaft with a head on one end. The end opposite the head is simply called the buck-tail. On installation the rivet is placed in a pre-drilled hole. Then it is "upset" (i.e. deformed) so the shaft fills the hole and the tail expands to about 1.5 times the original shaft diameter and holds the rivet in place. To distinguish between the two ends of the rivet, the original head is called the factory head and the deformed end is called the buck-tail.

There are several methods for upsetting the rivet. Rivets that are small enough and soft enough are often "bucked". In this process the installer places a rivet gun against the factory head and holds a bucking bar against the tail or a hard working surface. The bucking bar is a specially shaped solid block of metal. The rivet gun provides a series of high-impulse forces that upset the rivet in place. Rivets that are large or hard may be more easily installed by squeezing instead. In this process a tool in contact with each end of the rivet clinches to deform the rivet.

Because there is effectively a head on each end of an installed rivet it can support tension loads (loads parallel to the axis of the shaft); however, it is much more capable of supporting

shear loads (loads perpendicular to the axis of the shaft). Bolts and screws are better suited for tension applications.

Three aluminum blind rivets: 1/8", 3/32", and 1/16". The shaft pulls out leaving only a rivet —everything below the flange.



Blind rivets are tubular and are supplied with a mandrel through the center. The rivet assembly is inserted into a hole drilled through the parts to be joined and a specially designed tool used to draw the mandrel into the rivet. This expands the blind end of the rivet and the mandrel snaps. This gives the rivets their common name of pop rivet (See blind rivet). Blind rivets are often avoided for critical structural joints because they generally have less load carrying capability than solid rivets. Furthermore, because of the mandrel they are more prone to failure from corrosion and vibration.

THREADED CONNECTIONS ALLOWED AT HIGH PRESSURE SIDE

When and turning point came in steam /water so there will be pressure is increased so that we use like a elbow, bends etc which is threaded type connection to join tube. The code states that through connection larger than 3 in pipe size shall not be used when the maximum allowable pressure exceeds 100 psi. But this 3 in pipe size restriction does not apply to (1) plug closures poses. The number of threads that must be engaged and the minimum plates. The number of threads that must be engaged and the minimum plate thickness required.

BOILER MOUNTINGS AND ACCESSORIES

Boiler Mountings

1. Water level Indicator
2. Pressure Gauge.
3. Safety Vales,
4. Lever Safety Valves.
5. Dead Weight Safety Valves.
6. High teem and low water safely valve.
7. Spring Loaded Safety Valves.
8. Steam stops Valve.

9. Blow off cock.
10. Feed Check Valves.
11. Fusible Plug

Boiler Accessories

1. Feed Pump,
2. Super heater
3. Economizer.

BOILER MOUNTINGS

These are the fittings, which are mounted on the boiler for its proper and safe functioning. Through there are many types of boiler mountings, yet the following are important from the subject point of view.

1. Water level indicator. .
2. Pressure gauge.
3. Safety valves.
4. Stop valve.
5. Blow of cock.
6. Feed check value.
7. Fusible plug.

WATER LEVEL INDICATOR

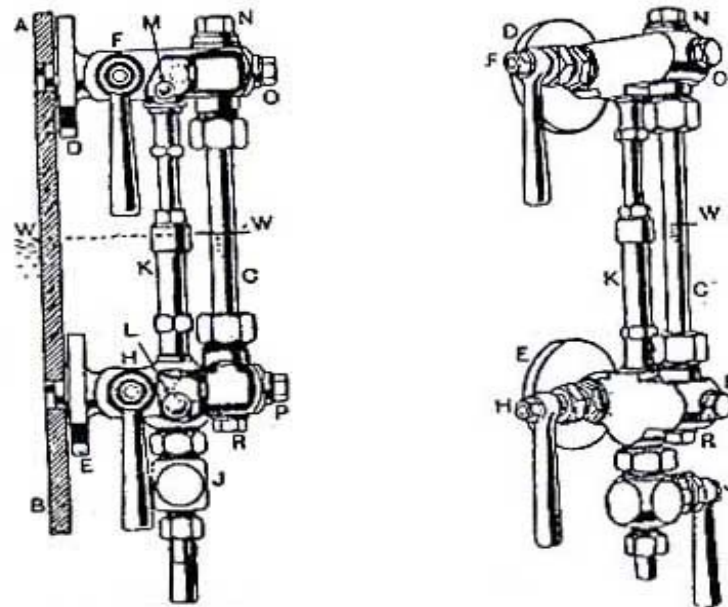
An Early form of water level indicator, now rarely used, consists of a float inside the boiler attached to a thin brass rod, which passes vertically through a gland in the boiler shell. The upper end of this rod is attached to a chain, which passes over a pulley from which it is led to the front of the boiler where it passes over another pulley from which it hangs; the hanging part of the chain carries a balance weight and, at its lower level in the boiler. A serious defect of the float gauge is the friction of the rod in the gland, which may cause erroneous indication of the water level

Try cocks, generally three in number, placed at different levels on the front end of the boiler are sometimes used to determine approximately the water level.

The most satisfactory water-level indicator, and the one now almost exclusively used, is the glass tube water gauge, by means of which the exact level of the water in the boiler is constantly shown.

A good form of glass tube water gauge, although not of the simplest construction. AB is the front end plate of the boiler and W is the water level, C is a strong glass tube whose ends pass through stuffing boxes in hollow

gunmetal castings having flanges D and E for bolting to the boiler. F and H are cocks, which control the passages between the boiler and the glass tube.



WATER LEVEL INDICATOR

AB	<i>Front End Plate Of the Boiler</i>
C	<i>Strong Glass Tube</i>
D	<i>Flanges</i>
E	<i>Bolting</i>
F & H	<i>Cocks</i>
J	<i>Third Cock (Blow Through Cock)</i>
K	<i>Hollow Column</i>
L & M	<i>Balls</i>
N.O.P & R	<i>Screwed Plug</i>

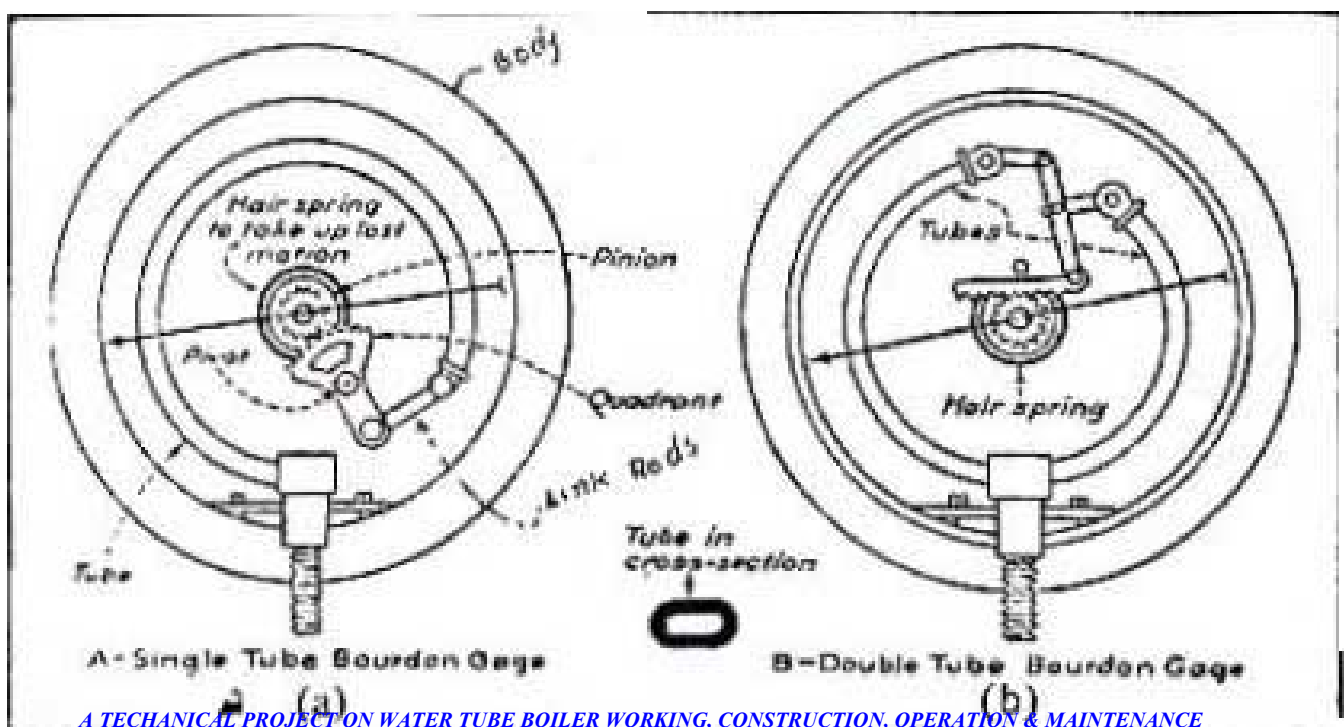
When these passages are open the handles of the cocks F and H are vertical as shown. The water then stands in the glass at the same level as in the boiler. A third cock J, called a blow-through cock, and is ordinary closed, its handle being then vertical as shown.

The complication of the gauge illustrated over the simpler forms of the glass water gauge is due to the arrangement for automatically shutting off the steam and water supply to the glass to should the latter, from any cause, get broken. The hollow column K. balls L and M are in the positions shown when the gauge is in normal working conditions connect the upper and lower castings. Should the glass tube get broken the rush of water in the bottom passage carries the ball L into the positions shown by the dotted circle and shut off the water. At the same time the steam rushing through the upper passage aided by the water rushing upwards through the column K drives the ball M into the position shown by the dotted circle and shuts off the steam. The attendant may then approach the gauge with perfect safety and shut the cocks F and H then proceed to renew the glass tube. Screwed plugs N.O.P and R are convenient for constructional purposes and also give access to the various passages for the purpose of clearing out, when necessary, any sediment, which may have lodged in them. The passage may however be kept quite clear by frequent blowing through. In blowing through the cock J is opened and, first F is closed and H opened, then H is closed and F opened.

STEAM PRESSURE GAUGE

Steam pressure gauge indicates pressure of steam boiler. Figure shows the construction of gauges the pressure gauge in the fig. Is a single tube bourdon gauge with dial removed to show interior mechanism? The bent bourdon tube of oval cross-section is closed at one end and connected at the other to boiler pressure. Closed end of tube is attached by links and pins to a toothed quadrant, which in turn meshes with a small pinion on the central spindle. When pressure is applied to interior of oval tube, it

When pressure is applied to interior of oval tub, it tends to assume a circular cross-section, but before the tube can do so it must straighten out. This tendency to straighten moves the free end, turning the spindle by the links and gearing, and causing the needle to move and register the pressure on a graduated dial.



Types of steam pressure gauges.



The double-tube bourdon gauge is more rigid than the single tube. It is more suitable for locomotive and portable boilers. In diaphragm gauge, a corrugated flexible metal diaphragm is clamped tightly with a small pinion on the central pointer spindle.

Recording gauges have a mechanism similar to that of tube and diaphragm gauges described, but a revolving chart operated by clockwork takes the place of the stationary dial, and a pen which traces a record on the chart is attached to end of pointer.

SAFETY VALVE

A safety valve is used to protect boilers against excessive pressure, by automatically discharging steam when the pressure rises above a definite point, at which the valve is set to open. Each boiler shall have at least one safety valve, and if it has more 500sq. ft. of water heating surface it shall have two or more.

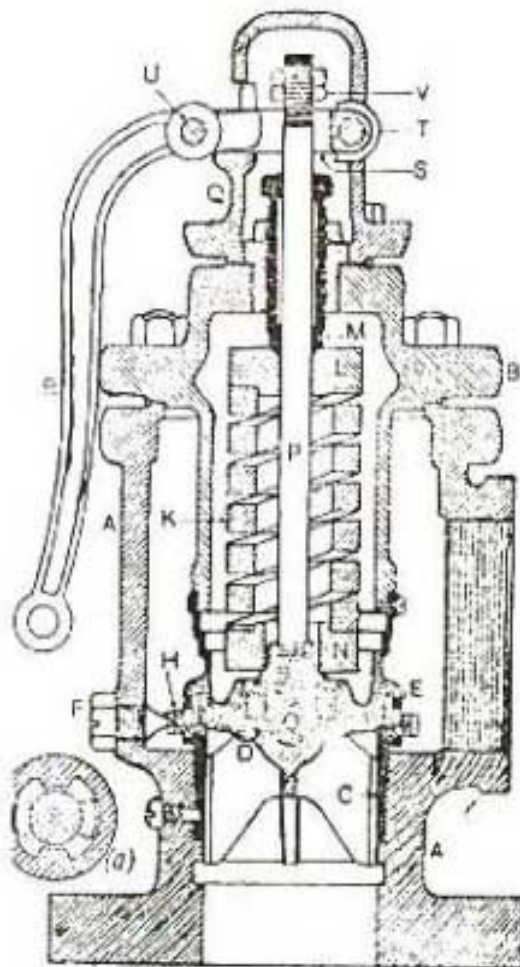
The safety valve should be bolted directly to the steam drum, without pipe, bends or valves. It should be large enough to discharge the maximum amount of steam that the boiler is capable of generating, without building up the discharge pressure more than 6% above the maximum allowable working pressure. If the discharge pipe from the safety valve is used, it should be properly dripped and should have an open end. Each valve should have its own discharge pipe. There are three principle types of safety valves, direct loaded, lever and weight and direct spring loaded.

Spring Loaded Safety Valve

Spring-loaded safety valve, which is more commonly used on boiler, is explained here in detail. The figure shows detail construction of pop safety valve. A is the body and B the cover. C is the seating and D the valve the bearing surface between them being inclined at 45

degrees. The area preventing the escaping steam by the lip E of the valve increases the lift the action of the lip can be adjusted without opening up the valve, as follows.

Remove the set-screw F, pass a pointed rod through aperture and using it as a ratchet work the notched screwed ring H round, thus raising or lowering it, and decreasing or increasing amount of steam diverted from the lip through the lateral openings in the prolongation of the setting which directs the steams on the lip.



- | | |
|---|------------------------|
| A | Body |
| B | Cover |
| C | Seating |
| D | Valve bearing surface |
| E | Lip For Escaping Steam |
| F | Set Screw |
| H | Notched Screwed Ring |
| K | Spring |
| L | Washers |
| M | Adjusting Screw |
| N | Spherical Bearing |
| O | Lugs |
| P | Lifting Screwed |
| Q | Cap |
| R | Lever |
| S | Lever |
| T | Pin |
| U | Pin |
| V | Nut |

Safety Valve

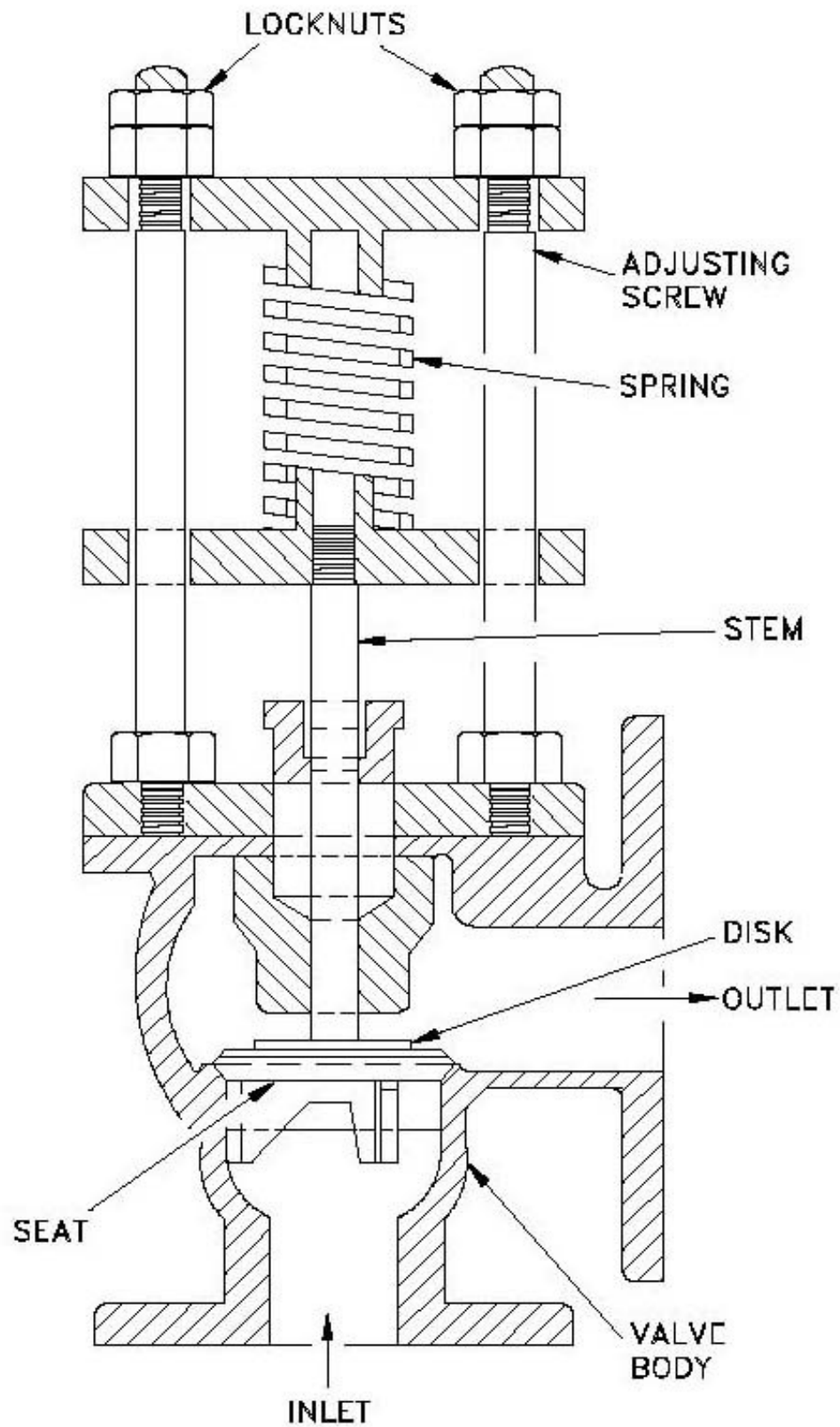
The ring H is screwed upwards if the pressure is not sufficiently relieved, and downwards if it is relieved too much. After adjusting the ring H replace the setscrew F so that the point catches in one of the notches of the ring. The spring K presses on washers L and N of which L has a spherical bearing on the adjusting screw M while N has spherical bearing on the piece O that presses on the valve. The lifting stem P is screwed into the piece O and locked with a

rivet passing transversely through both. The piece O has lugs on it which lie in recesses in the valve as shown at (a). This arrangement enables the valves to be rotated on its seat by turning the stem P after removing the cap Q.

The valves may be lifted from its seat by means of the lever R and forked lever S. The lever S is jointed to the cap Q by the pin T and to the lever R by the pin U. turning the lever R outwards causes the lever S to press upwards on the nut V which is lock on the lifting stem P.

It will be seen that the spring K is completely protected from contact with the escaping steam.

By locking the pin T with a special nut or with the pad lock the load on the wall cannot be tampered with.



Safety Valve

This is a device attached to the steam chest for preventing Explosions due to excessive internal pressure of steam. A steam boiler is usually, provided with two safety valves. These are directly placed on the boiler. In brief the functions of a safety valve are to blow off the steam when the pressure of steam inside the boiler exceeds the working pressure. The following are the four types of safety valves.

1. Lever safety valve,
2. Dead weight safety valve,
3. High steam and low water safety valve, and
4. Spring loaded safety valve

It may be noted that the first three types of the safety valves are usually employed with stationary boilers. But the fourth type is mainly used for locomotive and marine boiler.

LEVER SAFETY VALVE

A lever safety valve used on steam boilers is shown in Fig.13.3. It serves the purpose of maintaining contact safe pressure inside the steam boiler. If the pressure inside the boiler exceeds the designed limit, the valve lifts from its seat and blows off the steam pressure automatically.

A lever safety valve consists of a valve body with a flange fixed to the steam generator. The bronze valve gear is hinged to the body and the valve and is also made of bronze valve gear.

is screwed to the body and the valve and seat of same material rusting is considerably reduced. The strut transmits the thrust on the valve.

The guide keeps the lever in a vertical plane. The load is properly adjusted at the other end of the lever.

When the pressure of steamer exceeds the safe limit, the upward thrust of steam raises the valve from its seat. This allows the steam to escape till the pressure falls back to its original position.

DEAD WEIGHT SAFETY VALVE

A dead weight safety valve, used for stationary boilers is shown in Fig.13.4 the valve is made of gunmetal, and rests on its gunmetal seat. It is fixed to the top of a steel pipe. This pipe is bolted to the mounting block, riveted to the top of the shell. Both the valve and the pipe are covered by a case which contains weights these weights keep the valve on its seat under normal working pressure. The case hangs freely over the valve to which it is secured by means of a nut.

When the pressure of steam exceeds the normal pressure the valve as well as the case (a long with the weights) are lifted up from its seat this enables the steam to escape through the discharge pipe this enables steam outside the boiler house

The lift of also valve is controlled by atuts. The head of the stud's projects into the interior of the casing. The control of parity of the dead weight forty valves is considerably below the valve which enaure the load langue vertically,

The dead weight valve has the advantage that is cannot be reading ared because any added weight must be equal to the total indivial pressure of steam on the valve. The only disadvantage of the heavy load which these valves carry.

HIGH STEAM LOW WATER SAFETY VALVES

These valves are placed at the top of Cornish and Lancashire Boilers only. It is a combination of two valves. One of which is the lover safety valve which bellows off steam when the working persevere of team exceeds. The second valve operates by blowing off the steam when the water level becomes too law.

A best known combination of high steam low water safety valve is shown in Fig. 13.5 it consists of a main valve known as lever safety valve) and rests on its seat. In the center of the main valve, a seat for a hemispherical valve is formed for low water operation. This valve is loaded directly by. The dead weights attached to the valve by a long rod, there is a lever J.K. that has its fulerum at A. The lever has a weight E suspended at the end K. When it is Boiler Mountings and Accessories.

Fully immereel in water, it is balanced by a weigh F at the other end J of the lever.

When the water level falls, the weight E. out of water and the weight will not be sufficient to balance weight E. Therefore weight E down. There are tow projections on the lever to the loft of the fulcrum, which comes in contact with a collar attached to the rod. When weight E comes down, the hemispherical valves is lofted up a drain pipe is provided to carry water, which is deposited in the valve casing.

STEAM STOP VALVE.

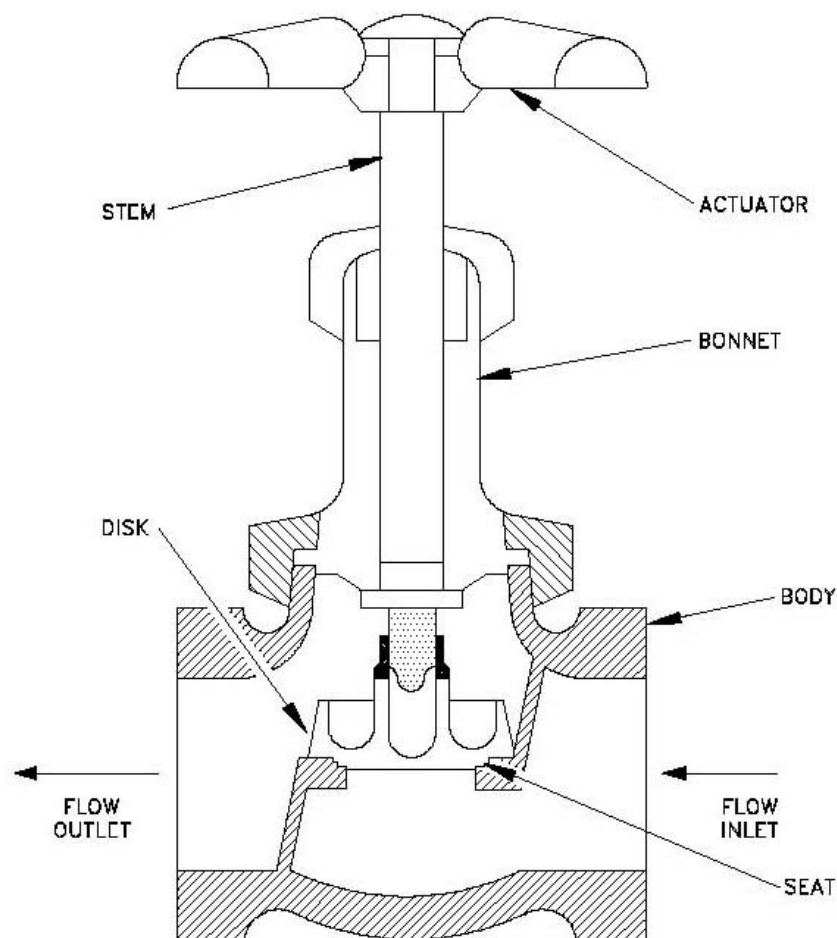
It is the largest valve on the steam boiler. It is usually fitted to the highest part of the shall by means of a flange ac shown in Fig. 13.7 the principal function of a stop valve is:

1. To control the flow of steam from the boiler to the main steam pipe.
2. To shut off the steam completely when required.

The body of the stop valve is made of cast iron and cast steel the valve, valve seat and the nut through which the valve spindle works, are made of brass or gun metal,

The spindle passes through a gland and stuffing box. The spindle is rotted by means of a hand wheel; the upper portion of the spindle is sewed and made to pass thought a nut in a cross head carried by two pillars. The pillars are screwed in the cover of the body as shown in the figure. The boiler pressure acts under the valve, so that the valve must be closed a gains the pressure, the valve is generally, fastened to the spindle which lift it up.

A non-return valve is, sometimes, fitted near the stop valve to prevent the accidental admission of steam from other boilers. This happens, when a numbers of boilers are connected to the same pipe and when one is empty and under repairs.



Stop Check Valve

Blow-off valves

Periodically it is necessary to empty the boiler in order that it may be cleaned and inspected internally. It is also a common practice periodically to discharge a

portion of the water from the bottom of the boiler in order that any sediment, which may have been deposited at bottom, may be lowest part of the boiler. This valve is either fitted directly to the boiler shell or to a short branch or to an elbow pipe of cast steel as shown at W in the illustration of a Lancashire boiler.

(10)

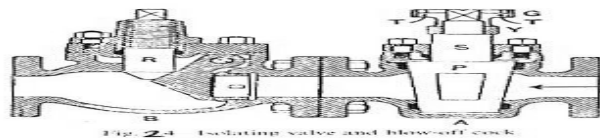


Fig. 2.4 Isolating valve and blow-off cock



Fig. 2.5

When several boilers are arranged to discharge into the same waste pipe, the blow-off valve of each boiler should have connected to it an isolating valve, which will prevent water which is being discharge from one boiler being blown, into another which may be open for inspection, the blow-off valve of which has been inadvertently left open.

A blow off cock a and an isolating valve B. the cock and isolating valve is shown closed. The plug P of the cock is conical and fits into the body or casting

which is packed with asbestos packing in grooves round the top and bottom of the plug as shown. There are also grooves connecting those at the top and bottom, which are like wise packed. The asbestos packing is rammed in tight and the plug bears on the packing. Cocks packed in this way keep tight better under high pressure and are more easily operated than stuffing box in the cover. The plug is held down by a yoke Y and to stud bolts, not shown, one behind and the other in front of the shank S. The yoke Y has formed on it a guard G on the inside of which is two vertical slots T through which pass projections on the box spanner used for operating the cock. The use of this guard is to prevent the spanner being removed while the cock is open.

The isolating valve B is off hinged non-return type and opens outwards, the amount of opening being regulated by the screwed stop R.

When the blow-off cock is not associated with an isolating valve and when the cock is only partially open, the flow of gritty water scores the plug and the asbestos packing becomes injured with the result that the cock afterwards leaks. With an isolating valve, however, the cock may be opened full while the isolating valve is closed and the latter is then allowed to open to any desired extent. Again in closing, the isolating valve is first shut and then the blow-off cock is closed. The scoring action of the gritty water on the partially open

isolating valve is not a serious matter because it is not so important that this valve should be absolutely watertight.

PRINICIPAL

The principal functions of a blow off cock are:

1. To empty the boiler whenever required.
2. To discharge the mud, scale or sediments which are accumulated at the bottom of the boiler?

It is fitted to the bottom of a boiler drum and consists of a conical plug fitted to the body or casing the casing the caring is packed, with asbestos packing, in grooves the top and bottom of the plug the asbestos packing is made tight and plug bears on the packing it may be noted that the cocks packed in this way keep the grip better under high pressure and early operated than unpacked.

The shank of plug passes through a gland and stuffing box the cover the plug is hold down and not shown in the figure the yoke it there are two

FEED CHECK VALVE

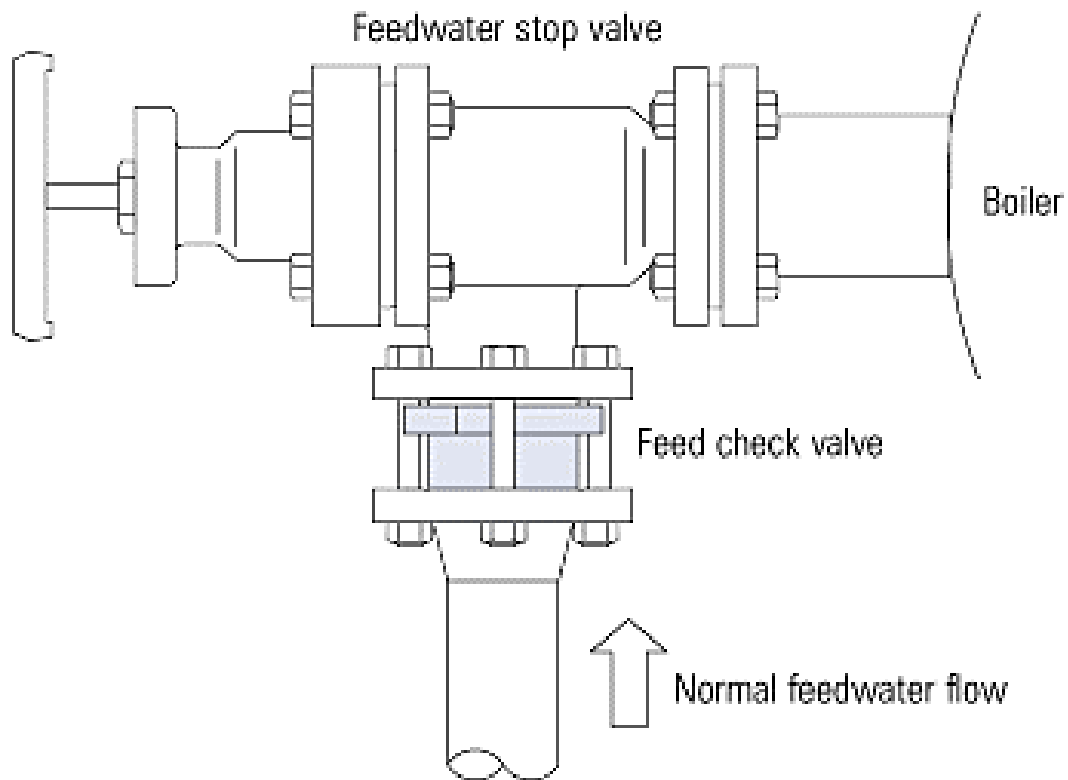
At the boiler end of the delivery pipe from the feed-water pump a non-return valve must be placed as the boiler as possible. This non return valve or check valve is usually provided with an arrangement for regulating by hand the extent

of its opening because it is important that the water level in the boiler should be maintained as nearly as possible constant.

A good design of feed check valve in fig .C the lift of the check valve is controlled by an extension of the spindle of the screw down valve V above it. It is most important that the check valve should be kept in perfect condition. To ensure this it may, in the design illustration, be

To ensure this it may, in the design illustrated, be examined and cleaned or reground when the boiler is under steam by closing the valve V, shutting off the feed water, and then uncoupling the elbow E which contains the check valve and its seat. Before doing this, however, sufficient water is fed into the boiler to keep it going while the check valve is disconnected.

The flanged A is bolted to the end of the boiler shell at a point from which an internal perforated pipe leads the feed water and distributes it near the working level of the water in the boiler.



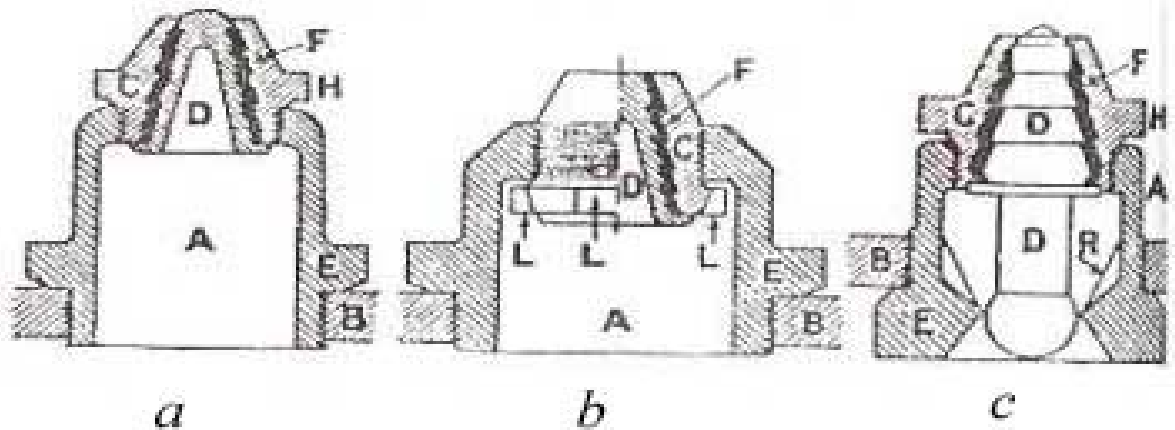
FEED CHECK VALVE

FUSSIBLE PLUGS

Fusible plug are used to provide protection against low water and consequent damage to boiler. These are used on fire-tube boilers. Some water tube boilers are also equipped with the fusible plugs.

The crown of furnace or combustion chamber should be fitted with a plug held in position by a fusible metal or alloy. This plug under normal conditions is covered with the water in the boiler, which keeps the temperature of the fusible metal below its melting point. But should the water in the boiler fall below the

“low water” level the fusible metal is melted by the heat of furnace, the plug drops out and steam rushes into the furnace or combustion chamber crown is in danger of being overheated.



Illustrate two forms of fusible plug patented by the National Boiler Insurance Co, Manchester. A is a hollow gunmetal plug screwed into the first D is a third hollowed gunmetal plug separated from C by an annulus of fusible metal F. The inner surface of C and the outer surface of D are groove as shown, so that when the fusible metal is poured in the plugs C and D are locked together. H is a hexagonal flange on C for fixing or removing C.

The spaces between the lugs L serve to receive the prongs of a special key or

Spanner when it is required to screw or unscrew the plug C.

The renew the fusible plug only the part C need be taken out. In the design C may be removed and replaced by operating from the inside of the furnace, but in the design C can only be operated from the inside of the boiler.

It will be observed that the fusible metal is protected from the fire by the flange on the lower and of D. Also, in the design there is contract at the top between C and D so that the fusible metal is completely enclosed.

Fig. C shows one of the using of fusible plug patented by the V uncial Boiler Insurance Co, Manchester. The inner plug D in this design is made of copper and has a prolongation with a spherical end, which practically closes the entrance, at the fireside, to the cavity beneath the plug. When the alloy is fused the plug D is not blown right out into the fire but after dropping a certain distance is held suspended, while at the same time a free way is provided for the escaping steam. This is affected by means of the flange on the plug D and the ribs R on the interior of A. The hanging plug is then visible to the stoker when he is firing and warning is therefore given even, when the fire has just been lighted, before sufficient water has been fed into the boiler to cover the furnace crown, in which case the crown might become over heated before any system was provided.

The fusible metal is subjected to deterioration due to exposure to heat and it should be renewed at intervals of say, two years.

BOILER ACCESSORIES

These are the devices, which are used as integral parts of a boiler, and help in running efficiently though there are many types of boiler accessories yet the following are important from the subject point of view.

FEED PUMP

We know that water in a boiler, is continuously converted into steam, which is used by the engine thus we need a feed pump to deliver water to the boiler. A feed pump may be of centrifugal type or reciprocating type, But a double acting reciprocating pump is commonly used as a feed pump these days.

The pressure of steam inside a boiler is high. So the pressure of feed water has to be increased proportionately before it is made to enter the boiler. Generally, the pressure of feed water is 20 % more than in the boiler.

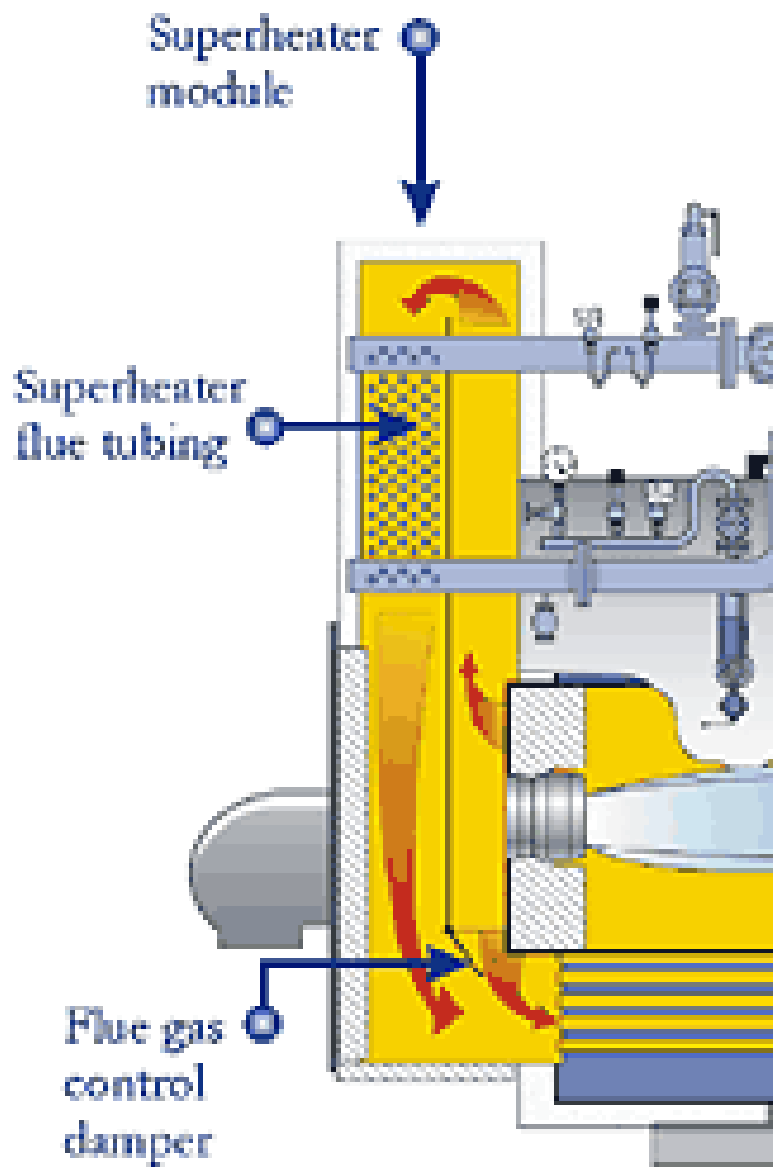


Feed Pump

SUPER HEATER

A superheater is a device in a steam boiler that heats the steam generated by the boiler again, increasing its thermal energy and decreasing the likelihood that it will condense inside the boiler. Super heaters increase the efficiency of the steam boiler, and were widely adopted. Steam, which has been superheated, is logically known as superheated steam; non-superheated steam is called saturated steam or wet steam. Super heaters were applied to steam locomotives in quantity from the early 20th century, to most steam vehicles, and to stationary steam engines including power stations.

In locomotive use, by far the most common form of superheater is the fire-tube type. This takes the saturated steam supplied in the dry pipe into a superheater header mounted against the tube sheet in the smoke box. The steam is then passed through a number of superheater elements—long pipes that are placed inside special, widened fire tubes, called flues. Hot combustion gases from the locomotive's fire pass through these flues just like they do the fire tubes, and as well as heating the water they also heat the steam inside the superheater elements they flow over. The superheater element doubles back on itself so that the heated steam can return; most do this twice at the fire end and once at the smoke box end, so that the steam travels a distance of four times the header's length while being heated. The superheated steam, at the end of its journey through the elements, passes into a separate compartment of the superheater header and then to the cylinders as normal.



ECONOMIZER

Economizers are mechanical devices intended to reduce energy consumption, or to perform another useful function like preheating a fluid. The term economizer is used for other purposes as well. Boiler, power plant, and heating, ventilating, and air-conditioning (HVAC) uses are discussed in this article.

Boilers

In boilers, economizers are heat exchange devices that heat fluids, usually water, up to but not normally beyond the boiling point of that fluid. Economizers are so named because they can make use of the enthalpy in fluid streams that are hot, but not hot enough to be used in a boiler, thereby recovering more useful enthalpy and improving the boiler's efficiency. They are a device fitted to a boiler which saves energy by using the exhaust gases from the boiler to preheat the cold water used to fill it (the feed water).

Power plants

Modern-day boilers, such as those in coal-fired power stations), are still fitted with economizers which are descendants of Green's original design. In this context they are often referred to as feed water heaters and heat the condensate from turbines before it is pumped to the boilers.

Economizers are commonly used as part of a HRSG in a combined cycle power plant. In a HRSG, water passes through an economizer, then a boiler and then a superheater. The economizer also prevents flooding of the boiler with liquid water that is too cold to be boiled given the flow rates and design of the boiler.

A common application of economizers in steam power plants is to capture the waste heat from boiler stack gases (flue gas) and transfer it to the boiler feed water. This raises the temperature of the boiler feed water thus lowering the needed energy input, in turn reducing the firing rates to accomplish the rated boiler output. Economizers lower stack temperatures, which may cause condensation of acidic combustion gases and serious equipment corrosion damage if care is not taken in their design and material selection.



MAINTENANCE, INSPECTION AND REPAIR

PURPOSE OF INTERNAL INSPECTION

To check on the structural soundness of the pressure-containing parts, and to note any condition that can affect its strength to confine the pressure. Wear, deterioration, corrosion, scale, oil, cracks, grooving, thinning and other such weakening conditions require inspection. Most boilers develop their own areas of trouble spots, depending on uses, operating conditions and maintenance practices. Check exposed metal surfaces inside the boiler for effectiveness of water treatment and scale solvent also for oil or other substances that enter with feed water. Oil or scale on heating surfaces weakness the metal, causing bagging or rupture. Corrosion areas next to a seam are more serious than in a solid plate away from seams. Thinning on a joint is dangerous because the strength of a joint is less than that of a solid sheet.

Check for evidence of grooving and cracks along longitudinal seams of shells and drums. Carefully look for internal grooving in fillets of unstayed heads. Inspect stays and stay bolts for even tension, fastened ends for cracks where stays or stay bolts are punched or drilled for rivets or bolts. Manholes and other openings are subject to corrosion thinning and cracks. See that openings to water column connections, dry pipes, and syms are free of obstructions such as mud and scale.

Ligaments between tube holes in heads (of all type boilers) often crack then leak and weaken the boiler. Also, on both water and fire tube boilers the beading and flaring on tube ends need checking for erosion and corrosion, cracks and thinning. Welded nozzle and other such openings require inspections for weld washout, cracks and evidence of deterioration of the joints.

Carefully inspect the plate and tube surfaces that are exposed to the fire. Look for places that might become deformed by bulging or blistering during operation. Solids in the waterside of lower generating tubes cause blisters when sludge settles in tubes and water cannot carry away heat.

The Boiler must be taken out of service until the defective part or parts have been properly repaired. Blistered tubs usually must be cut out and replaced with new.

Lap-joint boilers are apt to crack where plates lap in a longitudinal or straight seam. If there is evidence of leakage or trouble at this point, remove the rivets and examine the plate carefully if cracks exist in the seam. Cracks in shell plates are usually dangerous, expect fir cracks that run from the edge of the plate into the rivet holes of girth seams. Usually, a limited number of such fire cracks are not very serious.

Test stay bolts by tapping one end of each bolt with a hammer. For best results hold a hammer or heavy tool at the opposite end while tapping. A broken bolt is indicated by a hollow sound.

Tubes in boilers deteriorate faster at the ends toward the fire tapping the outer surface with a light hammer shows if there is serious posed to the products of combustion. Lack of water-cooling is the cause.

Tubes subject to strong draft often thin from erosion caused by impingement of fuel land ash particles. Soot blowers, improperly used, will also thin the tubes. A leaky tube spraying hot

water on nearly sooty tubes will corrode them seriously from an acid condition. Short tubes or nipples joining drums or headers lodge fuel and ash, and then cause corrosion if moisture is present. First clean, then thoroughly examine all such places.

Baffles in water boilers often move out of place. Then combustion gas, short-circuiting through baffles, raises the temperature o positions of the boiler, accusing trouble. Heat localization from improper or detective burners or operation causing a blowpipe effect must be corrected to prevent overheating.

INSPECTION OF EXTERNAL FITTING BOILERS

Safety valves are the most important attachments on a boiler.

These should be no rust, scale or foreign matter in casings to hinder free operation. The best way to test the setting and freedom of sys is by piping the valve with pressure. If this cannot be done, test by try levers. Inspects the discharge pipe to make sure it is secure. Operations have been killed because a valve discharging into the boiler room fills the space with steam in a few seconds. The opening in the discharge line must not be plugged.

Pressure gages have to be removed to test by comparing with a standard test gage. Blow out the pipe leading to the pressure gage. Make sure water column connections are free by removing plugs, or the tees. Examine the condition of the water column and gage glass attachments.

Examine the supports of the boiler structure. Make sure that ash and soot won't bind the structure to produce excessive strains from expansion under operating conditions. Look also for evidence of corrosion from soot on structural supports. Check the blow down valves to

see that they work freely and are packed and that external piping and fittings are not corroded or damaged.

RULES FOR REPAIRING CRACKS ON BOILERS

Two conditioned are covered:

1. Unstated Areas.

Cracks in unstated shells, drums or headers of boilers or pressure vessels may be repaired by welding, provided the cracks do not extend between rivet holes in a longitudinal riveted seam within 8 in., measured from the nearest calking edge. The total length of any one such crack shall not exceed 8 in. Cracks of greater length may be welded, provided the complete repair is radiographer and stress relived.

Cracks of any length in unstated furnaces may be welded, provided the welds are thermally stress-relived. Welds applied from both sides of the plate shall be used wherever possible. Welds applied from one side only shall be subject to the approval of the authorized from one side only shall be subject to the approval of the authorized inspector. Field repair of cracks at the knuckle or the turn of the flange of the furnace opening is prohibited unless approved by the enforcement authority.

2. Stayed Areas.

Fusion welding but multiple may repair cracks of any length in stayed areas or star cracks radiating from rivet or stayed holes shall not be welded.

LAP CRACK

Lap cracks are fatigue-type cracks in the longitudinal joints of lap-seam riveted boilers. They develop because a lap seam is not part of a true cylinder. Thus a bending action is created. The crack progresses until the plate cannot hold the force created by internal pressure, resulting in an explosion.

FIRE CRACKS

Cracks caused by radiant heat usually around circumferential riveted seams of thick plates. They are caused by the comparatively greater difference in expansion on the boilerplate between the waterside and fireside surfaces. Look for lower seam exposed to radiant heat. Welding as long as they are not of the star crack type can repair fire cracks. But first check with a commissioned boiler inspector.

STEAM SYSTEM BASICS

PRINCIPAL

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,

component separation, and is a source of water for many process reactions.

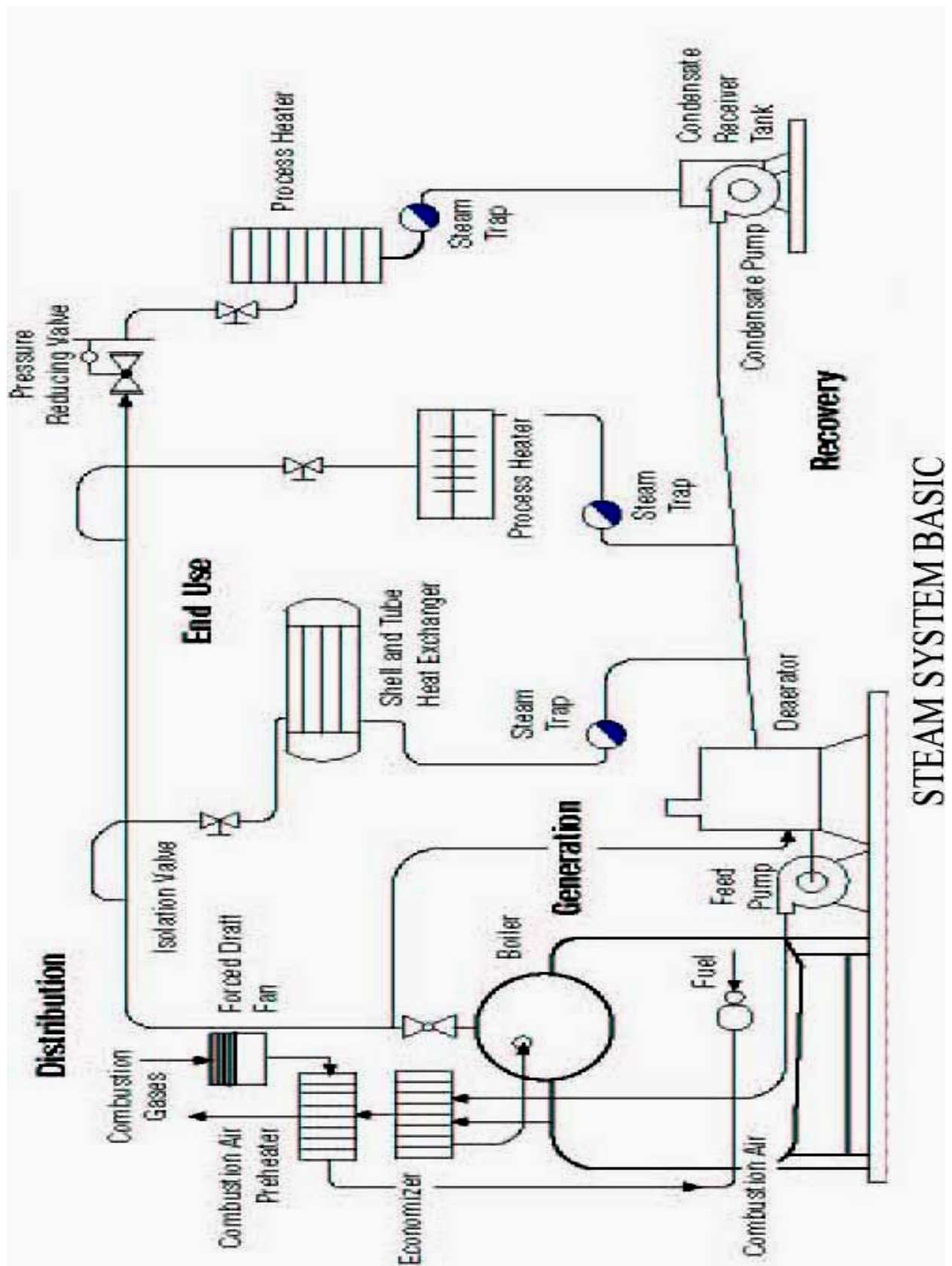
Steam has many performance advantages that make it an indispensable means of delivering energy. These advantages include low toxicity, ease of transportability, high efficiency, high heat capacity, and low cost with respect to the other alternatives. Steam holds a significant amount of energy on a unit mass basis (between 1,000 and 1,250 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. For example, in 1994, industry used about 5,676 trillion Btus of steam energy, which represents about 34 percent of the total energy used in industrial applications for product output¹.

Steam use in the Industries of the Future² is especially significant. For example, in 1994, the pulp and paper industry used approximately 2,197 trillion Btu of energy to generate steam,

accounting for about 83 percent of the total energy used by this industry. The chemicals industry used approximately 1,855 trillion Btu of energy to generate steam, which represents about 57 percent of the total energy used in this industry. The petroleum refining industry used about 1,373 trillion Btus of energy to generate steam, which accounts for about 42 percent of this industry's total energy use.



STEAM SYSTEM OPERATION

This Sourcebook uses 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

The generation part of a steam system uses a boiler to add energy to a feed water 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, feed water system, and exhaust gases venting system. These systems are related, since problems or changes in one generally affect the performance of the others.

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 feed water pressure to above boiler pressure and inject it into the boiler to complete the cycle.

PROPERTIES OF STEAM

Sensible heat

Heat which results in an increase in temperature of a body without changing its state is known as sensible heat.

The amount of sensible heat is found by applying the formula,
Sensible heat = Weight * specific heat * temperature difference

Example: How much sensible heat per Kg is required to bring the temperature of water to 89 degree C from a temperature of 25 degree C? (sp. ht of water = 1)

Solution: Sensible heat = $W * sp. ht. * \Delta t$
 $1 * 1 * (89 - 25)$
 $= 64 \text{ chu absorbed by each Kg of water.}$

Latent Heat

The latent heat of evaporation is the quantity of heat absorbed by 1 Kg of steam during evaporation, and its value will vary with the pressure.

A column in steam tables gives the values of hfg for all pressures. It will be noticed that as the pressure increases, hfg decreases.

Consider 1 Kg of wet steam containing W_s Kgf of actual dry steam and W_w Kgf of water in suspension. Now, during evaporation of this 1 Kgf of Wet steam, only W_s kgf were evaporated, the remainder consisting of W_w Kgf of water; hence only W_s kgf has absorbed the latent heat. Thus

Latent heat absorbed = $W_s \text{ hfg} = x \text{ hfg}$
as $x = W_s$ for 1 kgf of steam

Hence, the latent heat of 1 Kgf of water steam is the latent pressure, multiplied by its dryness fraction.

Saturated steam

Steam which is in physical contact with the boiling water from which it has been generated is termed saturated steam, its temperature is the same as the boiling water and this is referred to as the saturation temperature (t_{sat}). The boiling water is referred to as saturated liquid because it is at the saturation temperature corresponding to that particular pressure (p_{sat}) under which evaporation takes place. If the vapour produced is pure steam, it is called dry saturated steam.

If the steam contains water (usually very fine particles held in suspension in the form of a mist) it is called Wet saturated steam.

Dryness fraction

The dryness fraction of Wet steam is the ratio of the weight of actual dry steam to the weight of the wet steam containing it.

Let x = Dryness fraction

W_s = Weight of dry steam contained in steam considered

W_w = Weight of water in suspension in steam considered

Then $x = W_s / (W_s + W_w)$

No steam can be perfectly dry whilst it is in contact with the water from which it is being formed.

Example:

One Kg of Wet steam contains 0.16 Kgf of moisture in
calculate the dryness fraction.

Solution:

Weight of dry steam = $1 - 0.16 = 0.84$ kgf

Dryness fraction = $0.84 / (0.84 + 0.16) = 0.84$

Super heated steam

In order to increase the temperature of steam above its saturation temperature, the steam must be taken away from direct contact with the water from which it was generated and heated externally, usually as it passes through superheater element by high temperature flue gases. If the steam is still wet as it enters the superheaters, the particles of water must first be evaporated to produce dry steam before the temperature is increased. Steam whose temperature is higher than its saturation temperature (which depends upon its pressure) is termed superheated steam and the difference in temperature between the superheated steam and its saturation temperature is referred to as the degree of superheat.

Formation of steam

Imagine 1 Kg of water at a temperature of 0 degree C, to be heated in a container; let the water be heated under a constant pressure. The temperature will increase as the heat is applied until the boiling point is reached. The temperature of the boiling point depends on the pressure; at the atmospheric pressure the temperature at the boiling point is 100 degree C but the temperature increases with pressure. The amount of heat absorbed by the water is being heated from freezing point to boiling is known as the enthalpy of water.

If the heating of this Kg of water is continued after the boiling point is reached, it will be noticed that there is no further increase of temperature as the pressure is maintained at the same constant amount. The heat absorbed is now being utilized in converting the water to steam and is known as latent heat. As long as there is still some water left unevaporated in the container, the steam formed will be wet steam. If the heating of this Kg of water continues, after a time the whole of the water will have been converted into wet steam. If the heating of this wet steam is further continued the particles of water suspended in it commence to evaporate and the wet steam will become drier.

