Steam Boilers

A boiler is a steam generating unit. It is a closed metallic vessel contains partly water. By heating water above the atmospheric pressure, steam could be generated at the desired pressure and temperature. To heat the water, fuels like coal, diesel oil, gas etc may be used.

The function of a boiler is to evaporate water into steam at constant pressure and to supply the required type of steam.

Applications

The steam boilers are used
(i) To drive steam turbines, marines, Locomotives etc.
(ii) In industries viz textile, paper, sugar, tyre, chemical, breweries etc., as processing agent.
(iii) In connection with mines, cranes etc.

Classification

BASIS	TYPES OF BASIS
According to relative positions of water and hot gas carrying tubes. According to location of furnace. According to use. According to direction of the principal axis of the shell According to required height of circulation. According to pressure of steam produced. According to the method of water circulation.	Water tube boilers and Fire tube boilers (smoke tube boilers) Externally fired boilers and Internally fired boilers. Stationary boilers, Portable boilers, Locomotive boilers and Marine boilers. Horizontal axis boilers, Vertical axis boilers and Inclined axis boilers. High-head boilers and Low head boilers. Low pressure boilers and High pressure boilers. Natural circulation boilers and Forced circulation boilers.

Fire Tube Boilers Principle

Here the hot flue gases pass through one or more tubes which are surrounded by water as shown

Water Tube Boilers Principle

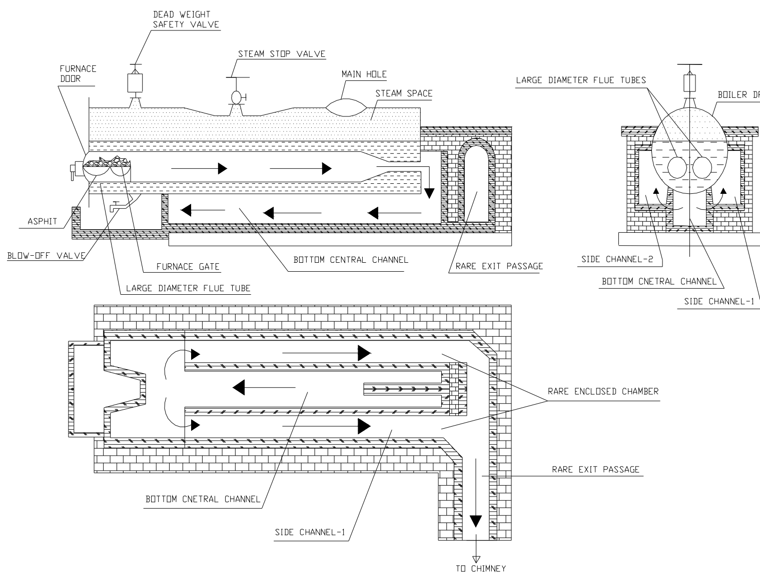
Here the water circulates through the tubes and the hot flue gases surround them externally as shown. The tubes are slightly inclined to produce a syphonic flow of water.

Comparison of Water Tube and Are Tube Boilers

Water Tube Boilers	Fire Tube Boilers
Generation of steam is quicker. Suitable for large power Plants and ships. Suitable for any type of fuel Pure water is necessary Bursting of water tube is less serious High initial cost and not so reliable.	Generation of steam is slow. Suitable for low power Plants and locomotives. Only coal is suitable as fuel. Pure water is not necessary Bursting of fire tube is disastrous Low initial cost and has greater reliability.

Lancashire Boiler

The two views of a Lancashire Boiler. It is a stationary, internally fired, horizontal, natural circulation and low pressure Fire tube boiler.



Construction

The boiler consists of a horizontal cylindrical shell W of length about 4 to 5 times its diameter, placed on brickwork as shown in the figure Two conical fire tubes F of diameter about 0.4 times of that of the boiler shell are fitted inside the shell which extend over the entire length of shell Grates G are provided in each of the fire tubes at the front end of the shell. Ash pit lies beneath the grate. One bottom flue BF and two side flues SF - I and SF - 2 are formed by the brick setting. Both the fire tubes lay below the water level as shown. The space above the water level is the steam space SS. A low fire brick bridge B is provided at the end of the grate. It prevents the entry of unburned fuel and ash particles into the fire tubes. Also it helps in deflecting the hot gases upward to provide better heat transfer. The boiler is mounted with essential mountings and accessories Fusible plug E, stop valve V, safety valve S, blow-off cock C, pressure gauge P, water gauge 1, Antipriming pipe A etc. as shown in the figure. The super heater is placed at the end of the fire tubes. The economizer is placed at the end of the side flues. (not shown in

e) A chimney Flue CF is used to provide the draught.

Working

Pump the water into the boiler shell through the economizer with the help of a non-return feed valve till the fire tubes submerge in it. The fuel is charged through the fire holes on to the grate and burnt. The hot gases travel upto the back end of the fire tubes transferring about 83% of the total heat to the water. Then they travel in the downward direction through the bottom flue to the front of the boiler transferring about 9.5% of total heat, where they are divided into two streams and travel through the side flues transferring the remaining 7.5% of the total heat before reaching the chimney. The path of hot gases are shown by arrows in the figure. The flow of gases controlled by dampers, which regulates the rate of combustion as well as steam generation. The mud and sediments formed in the shell removed using the blow-off cock.

The steam is accumulated in the steam space above the water level, is passed over an antipriming pipe A, to flow through a super heater K. The hot gases before entering the bottom. flue passed over the super heater. The superheated steam is finally drawn through steam stop valve V

Advantages of Lancashire Boiler

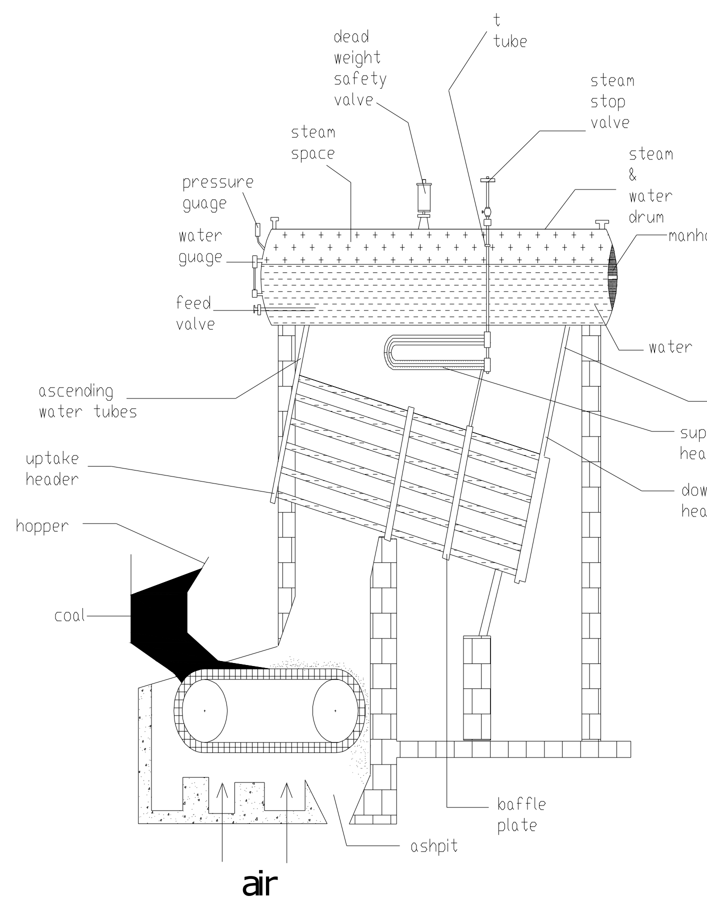
(1) It is economical, easy to operate, clean and inspect.
(2) Low maintenance cost.
(3) Load fluctuations can be easily met due to large water storage.
(4) Overall efficiency is as high as 80 to 85% due to super heater and economizer.

Disadvantages

(1) Steam generation is slow (9000kg/hr)
(2) Occupies more space (about $40m^2$ for 5000kg/hr capacity)
(3) Maintenance of brick work is tedious.
(4) The grate area is limited to the small diameter of the fire tubes.
(5) Low pressure Boiler (upto 20 bar only)

Babcock and Wilcox Boiler

Babcock and wilcox boiler. It is a stationary horizontal, externally fired, natural circulation, inclined straight tube and high pressure water tube boiler.



Construction
The boiler consists of four main parts.

(1) A horizontal, steam and water steel drum.
(2) A series of inclined (15^0 to the horizontal) straight water tubes with header boxes connected at right angles to them.
(3) A grate
(4) A superheater

The steam and water steel drum SWD is suspended from iron girders (not shown in the figure) resting on iron columns IC for easy expansion and contraction of the shell. The water tubes WT are connected to the drum by short tubes, with the uptake header (riser) UH on the lefthand side of the figure and by longer tubes to the downtake header DH on the right hand side. The tubes which are in multiple rows are fitted to the headers. The headers are provided with hand holes with caps CP for periodical inspection and cleaning. The furnace F is arranged below the riser. Coal is fed to the grate G through the fire hole H. Two fire brick baffles B1 and B2 are arranged across the water tubes. These deflect the hot gases thrice before escaping through the chimney. A superheater SH is placed between the drum and the tubes to superheat the steam. The boiler is surrounded on all four sides by firebrick walls. A mudbox M to precipitate the sediments and dirt in water. Doors D and manhole MH for inspection and cleaning the unit are provided. The blow-off cock BC is fitted to the mud box. The damper is operated with pulley-chain arrangement. A steam pipe SP which is surrounded by an antipriming pipe AP is connected to the superheater. Other mountings i.e., pressure gange P, water gange WG, safety valve S, stopvalve V and fusible plug FP are fitted as shown in the figure.

Working

The steel drum is filled with water about half of its capacity leaving the rest of it for steam space. the coal is charged onto the grate and burnt. The hot gases move up and down between the baffles in a beneficial path as shown in the figure. They transfer heat to the water in the tubes and the steam in the super-heater in the Zones (1), (2) and (3). Finally, the hot gases exit through the chimney. The draught is regulated by a damper. The portion of water tubes nearer to the furnace are heated to a higher temperature and therefore the density of water decreases and rises into the uptake header and the short tubes along with wet steam. They enter into the steel drum where the steam separates from the water and collects in the steam space. At the same time the water at the back end which is at a lesser temperature enters into water tubes through the long tube and the downtake header. Hence natural circulation of water (convective current) is established. The steam collected in the steam space is led to the superheater, through the steam pipe which is surrounded by an antipriming pipe. The superheated steam is tapped through the steam stop valve.

Specifications, Applications and Advantages

Babcock and Wilcox boilers of normal capacity raises steam between 10 to 20 bar at a steam rate of 20000kg/hr. High capacity boilers produce steam at about 40 bar with a steam rate upto 40000kg/hr. These are used in thermal power stations and marine engines. The boiler may expand and contract freely. The defective tubes can be replaced easily. The draught loss is comparatively minimum. In order to generate the steam at higher rate with effective heating, bent tubes are arranged in Zigzag manner. They are in sinuous form when viewed in the direction of the tubes.

Advantages of superheating

(1) It has a comparatively greater volume and contains more heat units per Kg at any given pressure. Hence, it can be made to do more work more efficiently.

(2) Useful for steam engines and steam turbines as the boiler tubes are subjected to fewer stresses. Also due to saving in the fuel and capital cost of the plant.

Water Turbines

Water/Hydraulic turbine is a prime mover. It converts hydro power into mechanical energy and further into hydro-electric power. It is a modification over water wheels of earlier days.

Principle

Generally it consists of a wheel called runner or rotor. A number of specially designed buckets or blades or vanes are fixed around the periphery of the runner. It is made to rotate either by a single or double or multiple jets of water or by flow of water. If a generator is coupled to this runner, then electrical energy generates. A good source of water for hydro-electric power plants are natural lakes or reservoirs at higher elevation. Artificial sources are dams across rivers.

Classification

Basis	Types
Action of water Name of the originator Direction of flow of water in the runner Head and Quantity of source of water. Disposition of runner shaft. Specific speed (n_s)	Impulse turbines, Reaction turbines Pelton wheel, Francis turbine, Kaplan turbine etc. Tangential flow turbine Radial flow turbine (a) Inward flow (b) Outward flow(c) Axial flow turbine Mixed flow turbine High head turbine Medium head turbine Low head turbine Vertical shaft and Horizontal shaft $8.5 < n_s < 30$ (Pelton wheel) $50 < n_s < 350$ (Francis turbine) $2\ 50 < n_s < 850$ (Kaplan turbine)

Principle of Impulse Turbine
The rotor of the turbine is made to rotate with the help of a single jet or multiple jets of water impinging on a series of specially designed buckets fitted around its periphery. Here the entire hydro energy is converted in to kinetic energy by passing the water through a pipe called Penstock and then through a converging nozzle to form high velocity free jet (s) of water. Generally it is used in high head plants. But it may also be used with lower heads, provided if the discharge is small. Example: Pelton wheel, Turgo turbine, Girard turbine, Banki turbine etc.

Principle of Reaction Turbine
It operates with its runner submerged in water. Here only a part of water brought from the source is converted into kinetic energy and the rest remains as pressure head. Water from penstock is made to flow to the runner at high pressure through stay vanes and guide vanes. Then pressure decreases and reaction pressure exists. As a result the runner rotates. After doing the work, the water is discharged to the tail race through a draft tube Example: Francis turbine, Kaplan turbine, Deriaz turbine, Bulb (Tubular) turbine, Propeller turbine, Jonval turbine, Thomson turbine, Fourneyron turbine etc.

Difference between Impulse and Reaction Turbines

Impulse Turbine	Reaction Turbine
The entire hydro energy is converted into Kinetic Energy The water jet(s) strikes a few buckets at a time with kinetic energy. The pressure of the flowing water which is equivalent to the atmospheric pressure remains constant throughout. There will be free access of air between the buckets and the runner. The runner need not run full. It is possible to regulate the flow without loss Draught tube is not necessary losses, if discharge is low	Only a part of it is converted into kinetic energy and the rest remains as pressure head. The water is guided by the guide blades to flow over the blades with pressure energy. The pressure of the flowing water decreases after gliding over the blades. The runner should always run full and submerged in water. It is not possible to regulate the flow without loss. Draught tube is necessary No losses even discharge is low.

Advantages of Pelton Wheel (Impulse Turbines)

(1) Simple in, construction and easy maintenance.

(2) To derive more power, multiple jets (2 to 6) pelton wheel may be used.

Disadvantage of Pelton Wheel (Impulse Turbine)
A lot of head loss occurs when the river discharge is low.

Pelton Wheel (Free jet Turbine)

Construction and Working

Fig shows a single jet pelton wheel. It is a high head, tangential flow, horizontal shaft, impulse turbine. It requires comparatively less quantity of water. Here specially designed buckets are evenly spaced and fitted around the periphery of the runner. The runner is supported on a horizontal shaft and is housed in a casing. A nozzle is fitted at the end of the penstock. It is provided with a spear rod. A hand wheel is fitted to the spear rod so as to reciprocate it to get a desired size jet of water. The water is conveyed to the turbine through penstock and the nozzle to form a free jet of water. The nozzle is kept very close to the bucket to minimise the losses due to the windage. Also the jet is so adjusted that it is tangential to the pitch circle of the runner. The jet of water at high velocity impinges the bucket(s). It may be noted that only a few buckets will be struck by the jet at a time. As a result the runner rotates, supplying power to the shaft. After performing work on the buckets the water discharges freely in to the tail race. A brake nozzle is used to slowdown the speed of the runner quickly to rest, with the help of a direct water jet over the back of the buckets. In order to derive more power, bigger size runners with multiple nozzles are used. The number of nozzles are depending on the specific speed. Two nozzles with a horizontal shaft and four or six nozzles with a vertical shaft are the popular designs.

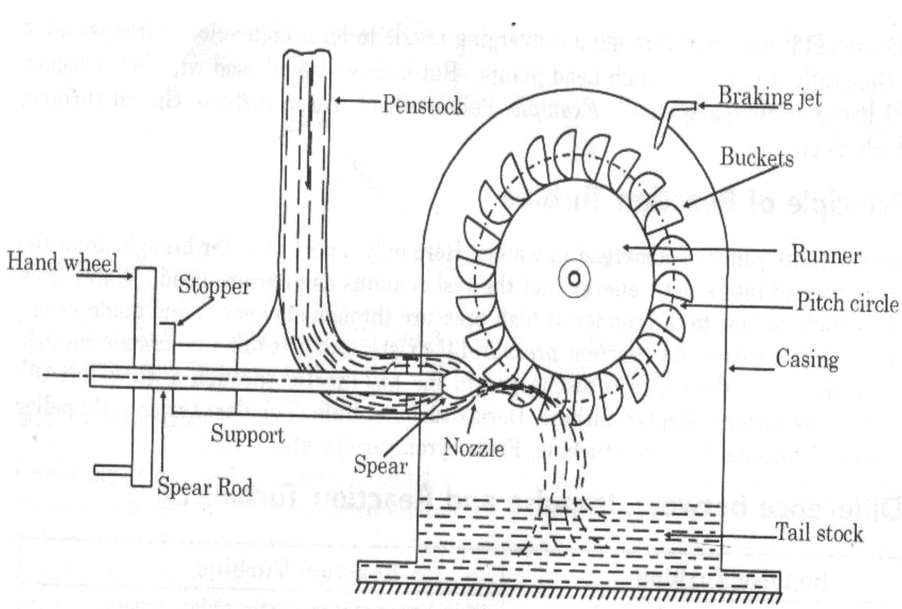


Fig 6.1 *Single Jet Pelton Wheel*

Francis Turbine

It is a mixed flow reaction turbine. It requires medium quantity of water. There are two main types (i) Closed type and (ii) Open flume type. In general, closed type with a vertical shaft is using as medium head turbine.

Construction

Fig shows two views of a Francis turbine. Here a numbe of guide vanes are fixed around the circumference of the runner. It is surrounded by a pair of upper and lower stay rings having stay vanes in between them. Each guide vane is made to rotate about its pivot centre with the help of individual link and lever.

The runner is supported by a regulating shaft. The guide vanes operate similar to engine valves, allowing only required quantity of water. The runner is enclosed in a spiral casing or scroll casing. The exit end of the runner is connected to the small end of the draft tube. The big end of draft tube is submerged deep in the tail race. Hence the entire water passage right from the head race up to tail race is totally enclosed.

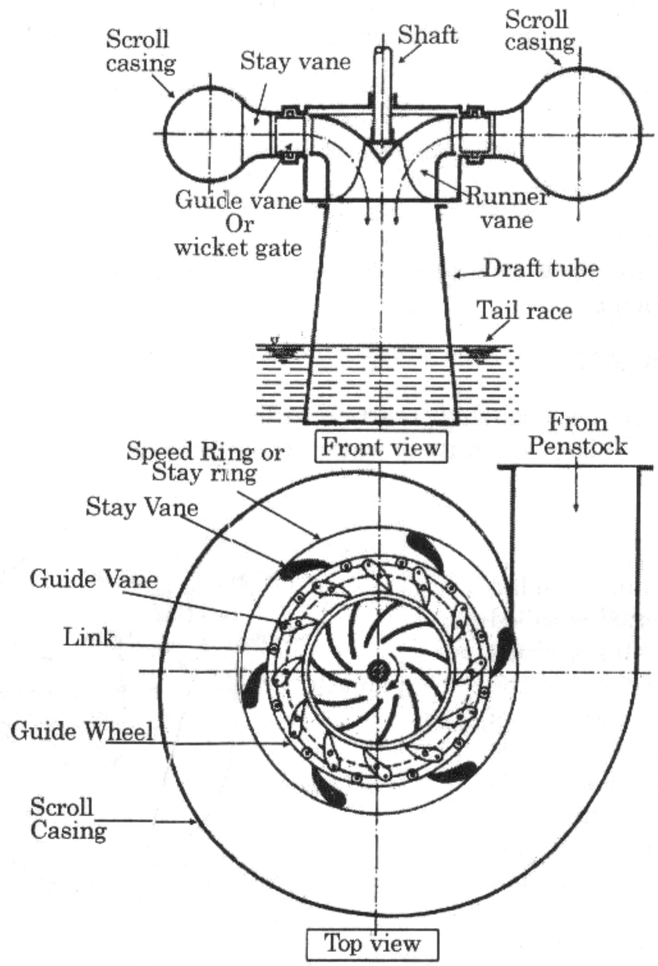


Fig 6.2 *Two Views of Francis Turbine*

Working

Water from the penstock is brought down to the turbine at high pressure through a spiral casing. It enters Into stay rings. The stay vanes pass the water smoothly and radially to the guide vanes. The runner thus surrounds completely with water. During the process, the pressure decreases. 'Thus a difference of pressure between the guide vanes and the runner exists which drives the runner. The movement of runner is affected by both pressure and kinetic energy of water. After doing work the water is discharged to the tail race axially from the centre of the turbine through a draft tube.

Advantage

No head loss occurs even at low discharge of water.

Disadvantages

(i) Eddy losses are inevitable.

(ii) Since the spiral casing is grounded, the runner is not easily accessible. Hence dismantling is difficult.

Kaplan Turbine

It is an axial flow, low head, vertical shaft reaction turbine. The water flows parallel to the axis of the shaft. It requires large quantity of water. It operates in an entirely closed conduit from inlet to tail race.

Construction

Fig 6.3 shows two views of a Kaplan turbine. Here the runner is called T boss or hub. It resembles a ships propeller. It is the extension of the Runner Vane Race vertical shaft. Here a number of guide vanes are enclosed in a guide wheel. The runner is enclosed in a spiral casing or scroll casing. The runner vanes are fixed around the circumference of the boss. The exit end of the turbine is connected to the small end of the draft tube. The big end of the draft tube is opened to the tail race.

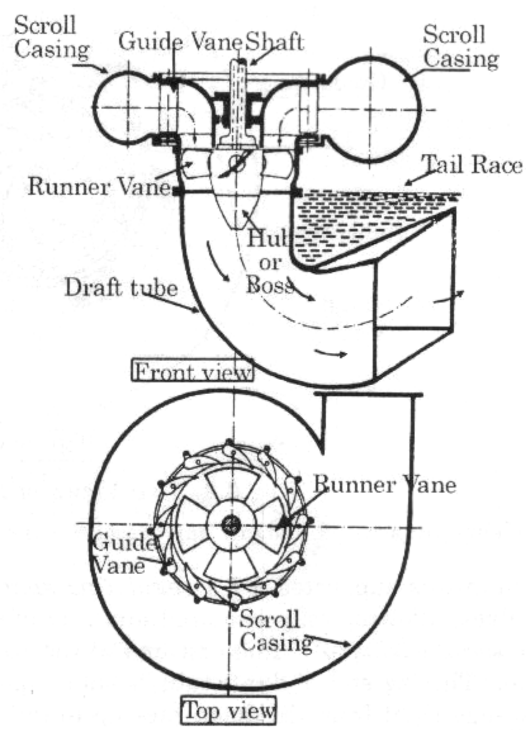


Fig 6.3 *Two Views of Kaplan Turbine*

Working

Water from the penstock is brought down to the turbine through a spiral casing. Water flows through the turbine passing from the guide vanes after taking a 900 turn in the axial direction. The guide vanes pass water on to the runner vanes smoothly. As a result the boss rotates. The specially designed vanes facilitate smooth flow of water to the tail race through a draft tube, while runner is in motion.

Advantages
Simple in construction and requires less space.
Eddy losses are almost eliminated.

Disadvantage
Cavitation is likely to occur due to high velocity flow of water.

Differences between Francis and Kaplan Turbines

Francis Turbine	Kaplan Turbine
It is a mixed flow turbine. . Medium head turbine, requires medium quantity of water of water. Number of guide vanes are around 16 to 24 The runner is supported by a regulating shaft. Guide vanes are assembled with the help of links and levers to act as valves. Requires large space. Eddy losses are inevitable Cavitation do not occurs Draft tube is of simple elbow type.	It is an axial flow turbine Low head turbine, requires large quantity Number of guide vanes are around 3 to 8. The runner (Boss) is the extension of the vertical shaft. Guide vanes are made adjustable for smooth flow of water. They are so designed and fixed around the hub. Requires less space due to sloped vanes It is almost eliminated. Cavitation is likely to occur Draft tube is of circular to rectangular type.