Steam Turbines and Boilers

Under construction

Learning resources based on authentic materials

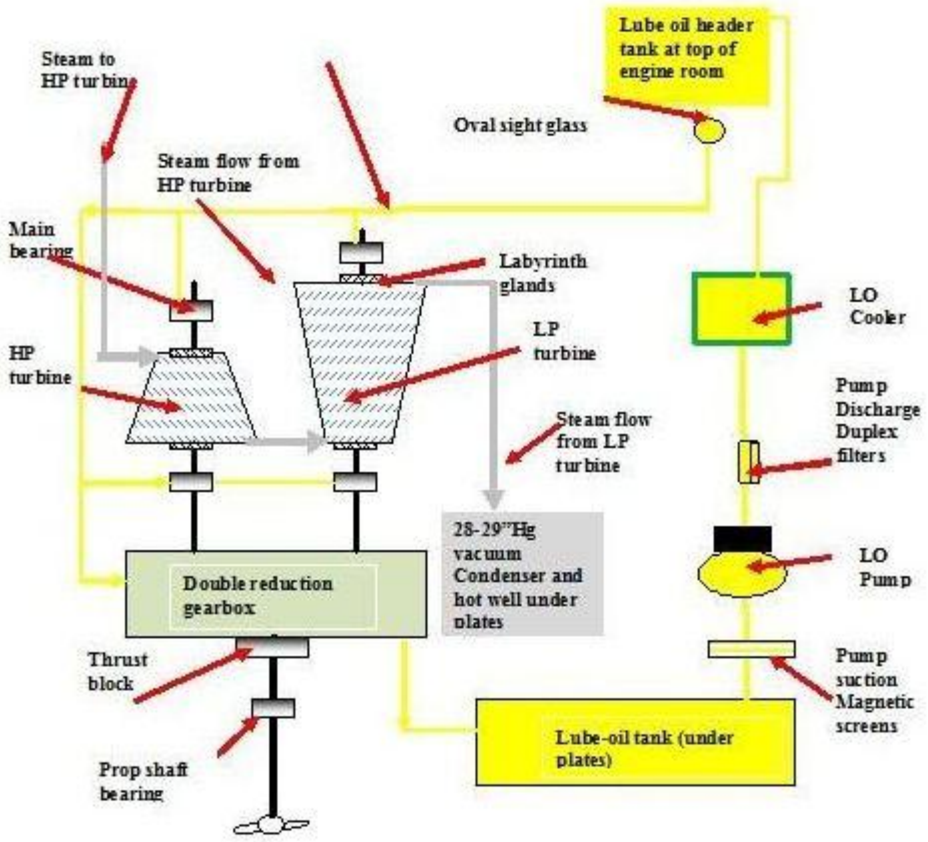
- **Steam Turbines for Marine Propulsion**

- http://www.brighthubengineering.com/marine-engines-machinery/55877-steam-turbines-for-marine-propulsion/
- http://www.machineryspaces.com/boiler.html
- Video: https://www.youtube.com/watch?v=qqe43wSDfiw

- Marine steam turbine engines have largely been replaced by the more economical marine two stroke diesel engine, mainly for commercial reasons as the diesel engine is much more economical. Notwithstanding this there are still a few about, running like clockwork- their one big selling point along with reliability, little maintenance, and high speed- pushing large cruisers and battleships along at forty knots, but they are very thirsty. Let's find out how steam turbines work in the context of marine turbine engines.

The Cross Compound Double Reduction Turbine

- For marine applications, the cross compound double reduction steam turbine was a popular choice because it was more compact, taking up less space in the ships engine-room. It also had the advantage of a built-in astern turbine giving easier astern movement, with up to 50% astern output power as that of the ahead turbine.
- This was a big advantage when the first oil super tankers were built – they took half a mile to stop from full ahead!
- In operation, the steam is supplied from the ship's boiler as high pressure, high temperature superheated steam and passes into the high pressure turbine, (HP) expanding through the blades and exiting into the low pressure turbine through a large bore insulated pipe.



CROSS COMPOUND DOUBLE REDUCTION MARINE STEAM TURBINE

- From here the low pressure steam passes through LP turbine blades, exiting from these and then being drawn by vacuum from the last few stages into main condenser.
- The high pressure and low pressure turbines are really separate turbines having their own drive shafts, which are coupled to a double reduction gearbox that decreases their revolutions from several thousand to about 100 RPM, the normal operating propeller shaft speed.
- The high pressure turbine rotor also has several rows of blades that are used as an astern turbine, which enables the ship to maneuver when arriving or departing ports. Also the astern turbine can be used in an emergency to avoid collision at sea, and although I have had to emergency stop and put astern a large marine main diesel engine, I have thankfully never had to carry this operation out on any steamships that I served on as marine engineer, as they were all tankers, so I cannot comment on its viability.

- Both the high pressure and low pressure steam turbines have glands at each end which stop the steam from escaping into the engine-room from the high pressure stage and which stop the loss of condenser vacuum through the low pressure stage. These glands are known as labyrinth type and, as the name suggests, are made up of a series of three rings and are supplied with two different pressures, which effectively seals both turbines shafts and end covers, with the supplied steam exiting to the gland cooler.

- A common lube oil system is used to lubricate the various components and keep them cool by pumping the oil through a cooler. The oil is drawn from the drain tank a through a set of magnetic strainers by the lube oil pump into a set of duplex filters, then onto the main lube oil cooler before supplying oil under pressure to the turbine white metal bearings, gearbox, gearbox sprays, and thrust block. There is also a secondary back-up lube oil pump driven by the turbine shaft supplying oil to gearbox and thrust.
- An overhead tank, usually positioned at the top of the engine-room, is also supplied by the pump through a bleed off orifice. From the tank there is a vertical overflow pipe incorporating a circular glass window, usually illuminated from behind, from which the oil can be observed flowing back down into the system.

- The reason for the header tank is in the event of a black-out or loss of a lube-oil pump, the header tank has the capacity to keep the turbine bearings supplied with oil until the turbine stops rotating, with the auxiliaries being supplied by the secondary pump. It is usual to have a lube oil purifier or centrifuge located within the system to remove any ingress of water or impurities from the oil.
- There is also another lube oil system known as gravity feed whereby the lubrication of all the components is by the overhead tank; this system is shown in the sketch.

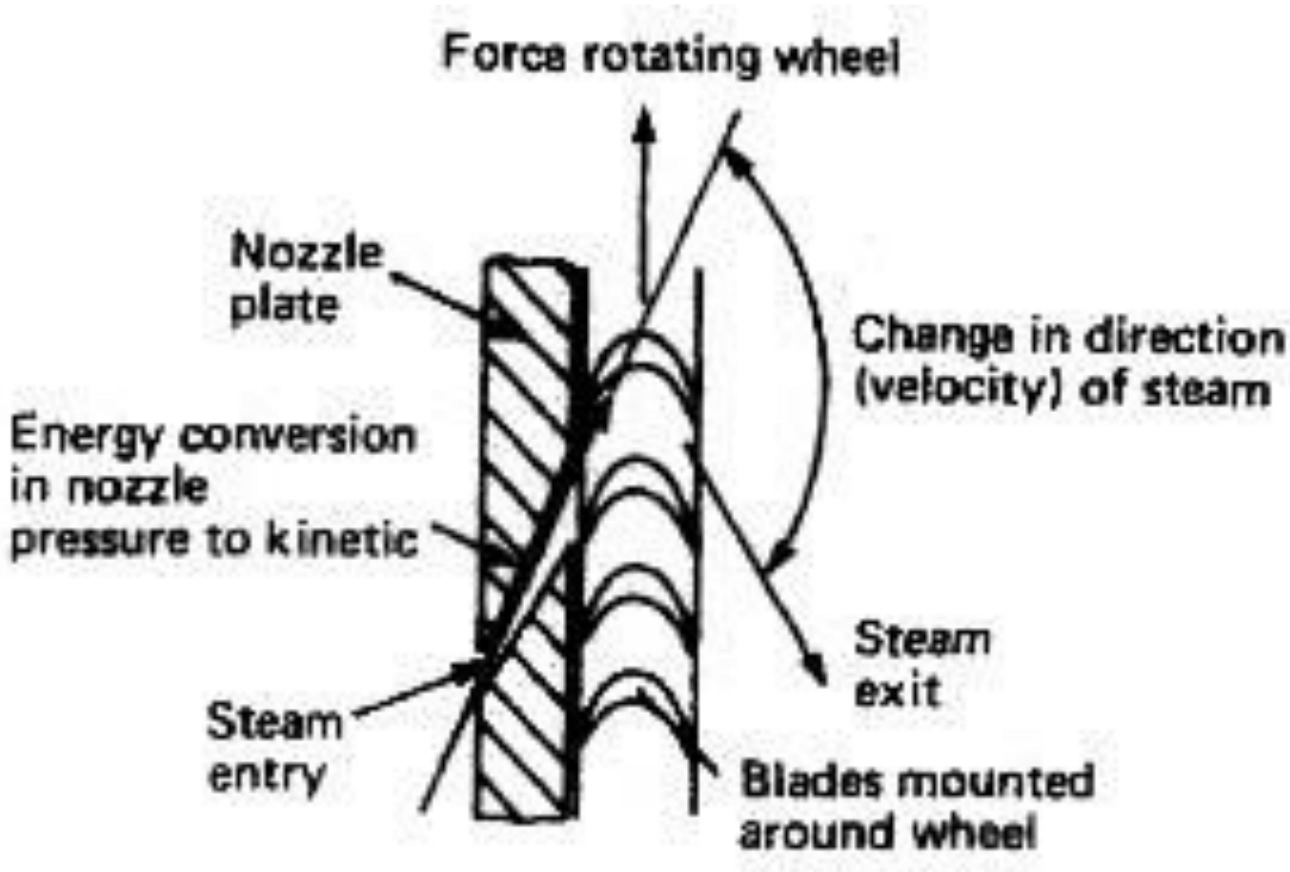
- **<u>Warming Through</u>**
- After the turbines and steam supply/exhaust have being idle in port, about two hours before standby, the turning gear should be withdrawn and the steam supply and exhaust system slowly warmed through. This is carried out firstly by raising a full vacuum about 28-29" Hg, and once this has been achieved, the ahead steam valve should be *slowly* opened a few notches rotating the shaft a few revs only, holding for one minute before shutting again, the astern turbine also being operated similarly. This should be continued to ensure all the pipe-work, turbine covers and rotors, expansion plates and condensate returns to boilers are all well warmed through and expanded up to working temperature.
- Remember any water in the system will damage the turbines so only superheated steam should be used, and operate the steam drains and check the steam traps if applicable
- A typical steam turbine layout in a ship's engine room is shown below.

Steam turbines and gearing - operating principle

- http://www.machineryspaces.com/steam-turbines.html

- The steam turbine has until recently been the first choice for very large power marine propulsion units. Its advantages of little or no vibration, low weight, minimal space requirements and low maintenance costs are considerable.
- Furthermore a turbine can be provided for any power rating likely to be required for marine propulsion. However, the higher specific fuel consumption when compared with a diesel engine offsets these advantages, although refinements such as reheat have narrowed the gap.

Fig: Energy conversion in a steam turbine



- The steam turbine is a device for obtaining mechanical work from the energy stored in steam. Steam enters the turbine with a high energy content and leaves after giving up most of it. The high-pressure steam from the boiler is expanded in nozzles to create a high-velocity jet of steam. The nozzle acts to convert heat energy in the steam into kinetic energy. This jet is directed into blades mounted on the periphery of a wheel or disc (Figure above).

- The steam does not 'blow the wheel around'. The shaping of the blades causes a change in direction and hence velocity of the steam jet. Now a change in velocity for a given mass flow of steam will produce a force which acts to turn the turbine wheel, i.e. mass flow of steam (kg/s) x change in velocity (m/s) = force (kgm/s2).

  This is the operating principle of all steam turbines, although the arrangements may vary considerably. The steam from the first set of blades then passes to another set of nozzles and then blades and so on along the rotor shaft until it is finally exhausted. Each set comprising nozzle and blades is called a stage.

Steam Turbines Warming Through

- The turbines are to be warmed through gradually following a stay in port or other occasion when they have been shut down. The bulkhead, stop, and manoeuvring valves are to remain shut. Warming through is to commence, not less than 12 hours prior to the estimated time of departure. The Deck Officer of the watch, or Duty Deck Officer is to be contacted and permission to turn the turbines/propeller requested.

  Once the Deck Officer has confirmed that this can safely be carried out then and only then can the turbines be turned.

  Lubricating oil circulation is to be started, and low vacuum created. Rotation can then commence after which the gland steam can be opened gradually. On no account is gland steam to be admitted with the turbine rotors stationary. The temperatures are to be raised to the manufacturers recommendations. Once this has been achieved the turning gear can be disengaged.

  It is the responsibility of the Chief Engineer Officer to ensure that disengagement of the turning gear is physically sighted. No reliance is to be placed on any remote indicating devices. A request is then to be made to the Officer of the watch on the bridge for permission to turn the engine on live steam.

Normal Operation

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The main engine is to be operated within the limits of power, maximum evaporative capacity and pressure of the boilers, and the revolutions per min set out in the commissioning letter issued when the vessel entered Company service.

Only if subsequent specific instructions have been issued by the Company, are the original commissioning letter parameters to be countermanded.

- **Stand By Manoeuvring**

  The Officer of the watch on the Bridge must give the Engine Department at least one hours notice before Stand By for manoeuvring. Regardless of the time of day or type of vessel i.e. unmanned engine room or conventional watchkeeping, the Chief Engineer Officer, and the Engineer Officer of the watch or Duty Engineer Officer are to be informed.

  Reduction in speed from full speed to the recognised manoeuvring speed is to be as gradual as possible and in accordance with the manufacturer's instructions. The operating parameters are to be maintained avoiding sudden variations of boiler loading etc.

Cooling Down

- When the main turbines are stopped and "Finished with Engines" has been rung, the nozzle control, manoeuvring, guardian, bulkhead and stop valves are to be shut and verified as shut. As soon as the above mentioned valves are verified as shut, permission is to be sought from the Officer of the watch on the Bridge to turn the turbines/propeller.

  Once permission is granted, then the turning gear is to be engaged and the turbines rotated with the lubricating oil supply maintained, low vacuum, and gland steam on, over a minimum period of 4 hours.

- **Maintaining Temperatures during Short Stays in Port**

  If the ETD is six hours or less then the following procedure is to be adhered to. Following "Finished with Engines" permission is to be sought to turn the turbines/propeller on live steam. With the lubricating oil supply maintained, low vacuum, and gland steam on the turbines are to be turned on ahead steam for approximately 2 propeller revolutions every five minutes, using astern steam as appropriate for checking ahead rotation only.

- **Control Systems Maintenance**

  Testing and maintenance of any turbine control system alongside a berth is strictly forbidden under live steam conditions. The main steam stop, guardian and bulkhead stop valves are to be shut prior to maintenance work being carried out.

  In the case where a simulated test would be unsatisfactory and operation with live steam has to be carried out, then the vessel is to be suitably anchored or stopped at sea, before maintenance or testing is carried out. Running Hours for Turbines and Boilers should be recorded in the "Turbine and Boilers Running Hours" and returned to the Managing Office on a monthly basi

Turbine protection

- A turbine protection system is provided with all installations to prevent damage resulting from an internal turbine fault or the malfunction of some associated equipment. Arrangements are made in the system to shut the turbine down using an emergency stop and solenoid valve. Operation of this device cuts off the hydraulic oil supply to the manoeuvring valve and thus shuts off steam to the turbine. This main trip relay is operated by a number of main fault conditions which are;

  1. Low lubricating oil pressure.
  2. Overspeed.
  3. Low condenser vacuum.
  4. Emergency stop.
  5. High condensate level in condenser.
  6. High or low boiler water level.

  Other fault conditions which must be monitored and form part of a total protection system are:

  1. HP and LP rotor eccentricity or vibration.
  2. HP and LP turbine differential expansion, i.e. rotor with respect to casing.
  3. HP and LP thrust bearing weardown.
  4. Main thrust bearing weardown.
  5. Turning gear engaged (this would prevent starting of the turbine).

  Such 'turbovisory' systems, as they may be called, operate in two ways. If a tendency towards a dangerous condition is detected a first stage alarm is given. This will enable corrective action to be taken and the turbine is not shut down. If corrective action is not rapid, is unsuccessful, or a main fault condition quickly arises, the second stage alarm is given and the main trip relay is operated to stop the turbine.

Steam turbines gearing arrangement

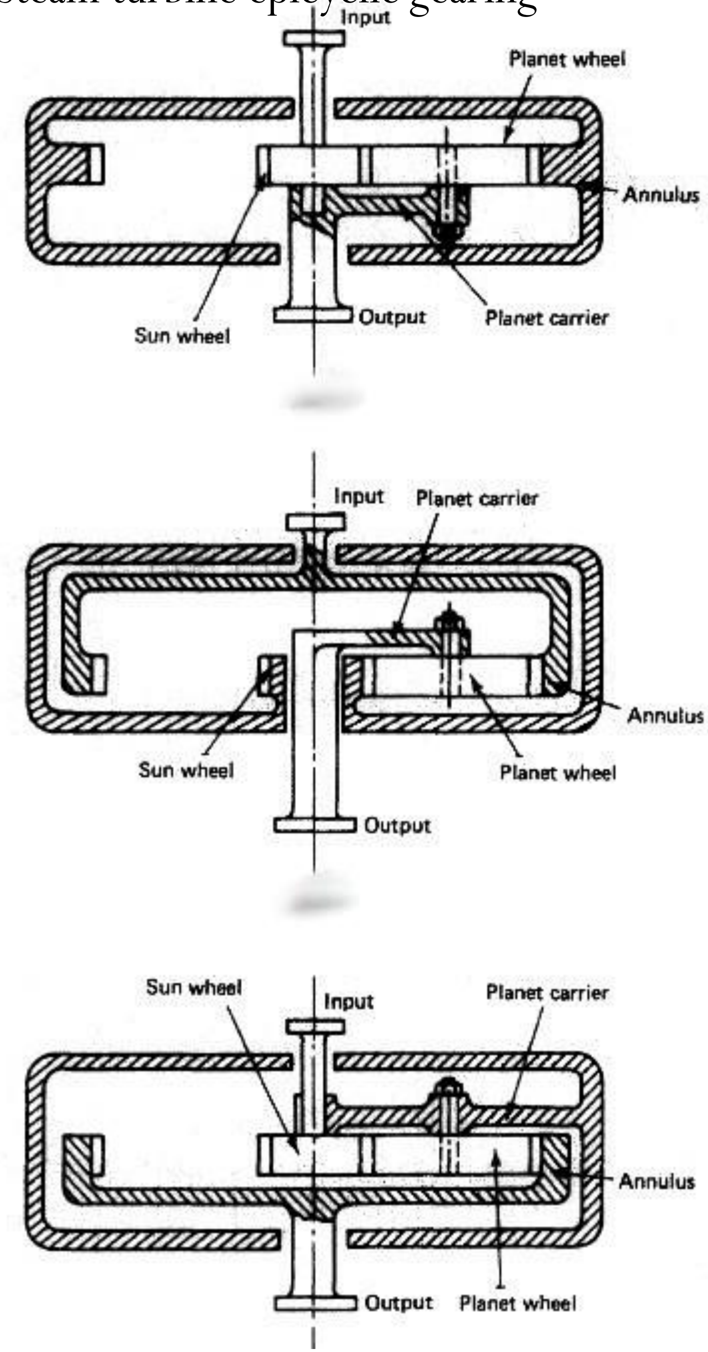
- **Turbine gearing**

  Steam turbines operate at speeds up to 6000rev/min. Medium-speed diesel engines operate up to about 750rev/min. The best propeller speed for efficient operation is in the region of 80 to 100 rev/min. The turbine or engine shaft speed is reduced to that of the propeller by the use of a system of gearing. Helical gears have been used for many years and remain a part of most systems of gearing. Epicyclic gears with their compact, lightweight, construction are being increasingly used in marine transmissions.

Epicyclic gearing

- This is a system of gears where one or more wheels travel around the outside or inside of another wheel whose axis is fixed. The different arrangements are known as planetary gear, solar gear and star gear
- The wheel on the principal axis is called the sun wheel. The wheel whose centre revolves around the principal axis is the planet wheel. An internal-teeth gear which meshes with the planet wheel is called the annulus.

Fig: Steam turbine epicyclic gearing



- The different arrangements of fixed arms and sizing of the sun and planet wheels provide a variety of different reduction ratios. Steam turbine gearing may be double or triple reduction and will be a combination from input to output of star and planetary modes in conjunction with helical gearing (Figure below).

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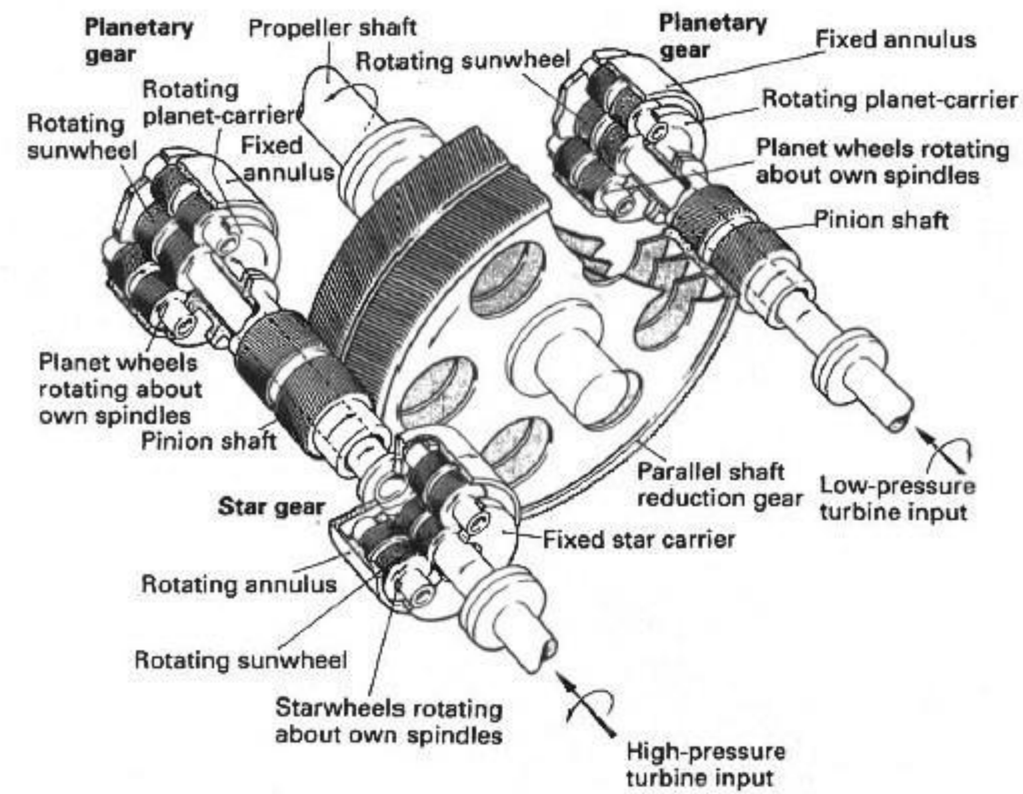
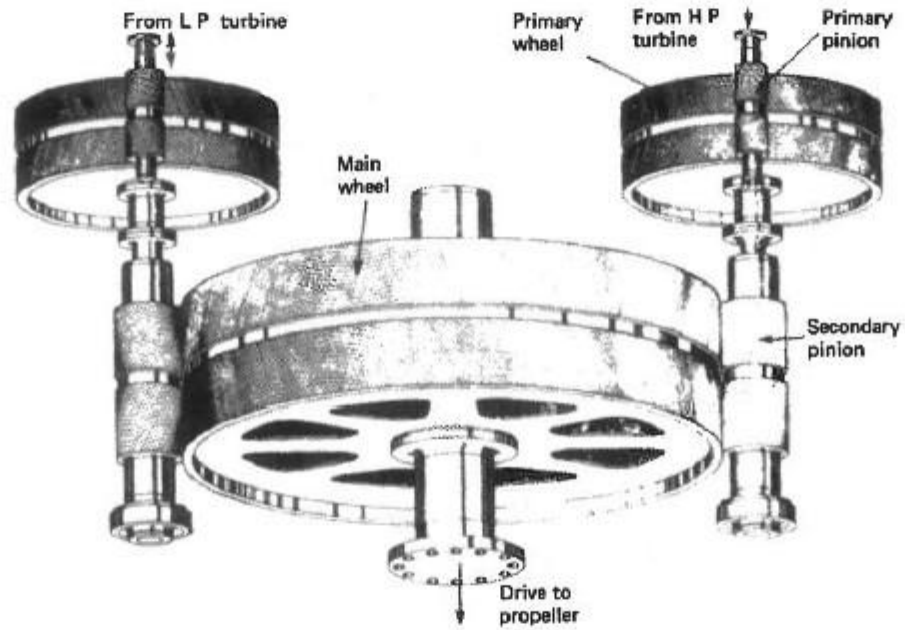
Fig: Turbine reduction gear



Helical gearing

- Single or double reduction systems may be used, although double reduction is more usual. With single reduction the turbine drives a pinion with a small number of teeth and this pinion drives the main wheel which is directly coupled to the propeller shaft. With double reduction the turbine drives a primary pinion which drives a primary wheel. The primary wheel drives, on the same shaft, a secondary pinion which drives the main wheel. The main wheel is directly coupled to the propeller shaft. A double reduction gearing system is shown in Figure below.

Fig: Turbine double reduction system



- All modern marine gearing is of the double helical type. Helical means that the teeth form part of a helix on the periphery of the pinion or gear wheel. This means that at any time several teeth are in contact and thus the spread and transfer of load is much smoother. Double helical refers to the use of two wheels or pinions on each shaft with the teeth cut in opposite directions. This is because a single set of meshing helical teeth would produce a sideways force, moving the gears out of alignment. The double set in effect balances out this sideways force. The gearing system shown in Figure is double helical.

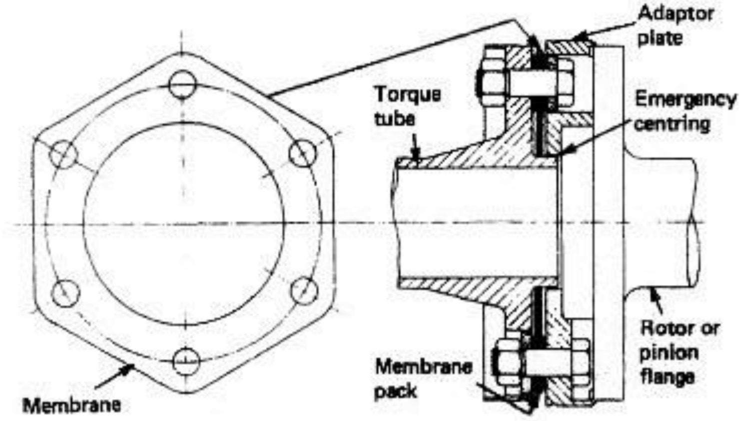
  Lubrication of the meshing teeth is from the turbine lubricating oil supply. Sprayers are used to project oil at the meshing points both above and below and are arranged along the length of the gear wheel.

- **Flexible coupling**

A flexible coupling is always fitted between the turbine rotor and the gearbox pinion. It permits slight rotor and pinion misalignment as well as allowing for axial movement of the rotor due to expansion. Various designs of flexible coupling are in use using teeth, flexible discs, membranes, etc.

The membrane-type flexible coupling shown in Figure above is made up of a torque tube, membranes and adaptor plates. The torque tube fits between the turbine rotor and the gearbox pinion. The adaptor plates are spigoted and dowelled onto the turbine and pinion flanges and the membrane plates are bolted between the torque tube and the adaptor plates. The flexing of the membrane plates enables axial and transverse movement to take place. The torque tube enters the adaptor plate with a clearance which will provide an emergency centring should the membranes fail. The bolts in their clearance holes would provide the continuing drive until the shaft could be stopped.

Fig: Turbine flexible coupling



Turning gear

The turning gear on a turbine installation is a reversible electric motor driving a gearwheel which meshes into the high-pressure turbine primary pinion. It is used for gearwheel and turbine rotation during maintenance or when warming-through prior to manoeuvring.

Part II.

Marine Boilers

Boilers

- Boiler arrangement for general cargo ships - how it works ?
- http://www.machineryspaces.com/boiler.html

- A boiler in one form or another will be found on every type of ship. Where the main machinery is steam powered, one or more large watertube boilers will be fitted to produce steam at very high temperatures and pressures. On a diesel main machinery vessel, a smaller (usually firetube type) boiler will be fitted to provide steam for the various ship services. Even within the two basic design types, watertube and firetube, a variety of designs and variations exist.

  A boiler is used to heat feed water in order to produce steam. The energy released by the burning fuel in the boiler furnace is stored (as temperature and pressure) in the steam produced. All boilers have a furnace or combustion chamber where fuel is burnt to release its energy. Air is supplied to the boiler furnace to enable combustion of the fuel to take place. A large surface area between the combustion chamber and the water enables the energy of combustion, in the form of heat, to be transferred to the water.

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- Boiler arrangement for general cargo ships - how it works ?

Formation of marine boiler

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A drum must be provided where steam and water can separate. There must also be a variety of fittings and controls to ensure that fuel oil, air and feedwater supplies are matched to the demand for steam. Finally there must be a number of fittings or mountings which ensure the safe operation of the boiler.

In the steam generation process the feedwater enters the boiler where it is heated and becomes steam. The feedwater circulates from the steam drum to the water drum and is heated in the process. Some of the feedwater passes through tubes surrounding the furnace, i.e. waterwall and floor tubes, where it is heated and returned to the steam drum. Large-bore downcomer tubes are used to circulate feedwater between the drums. The downcomer tubes pass outside of the furnace and join the steam and water drums.

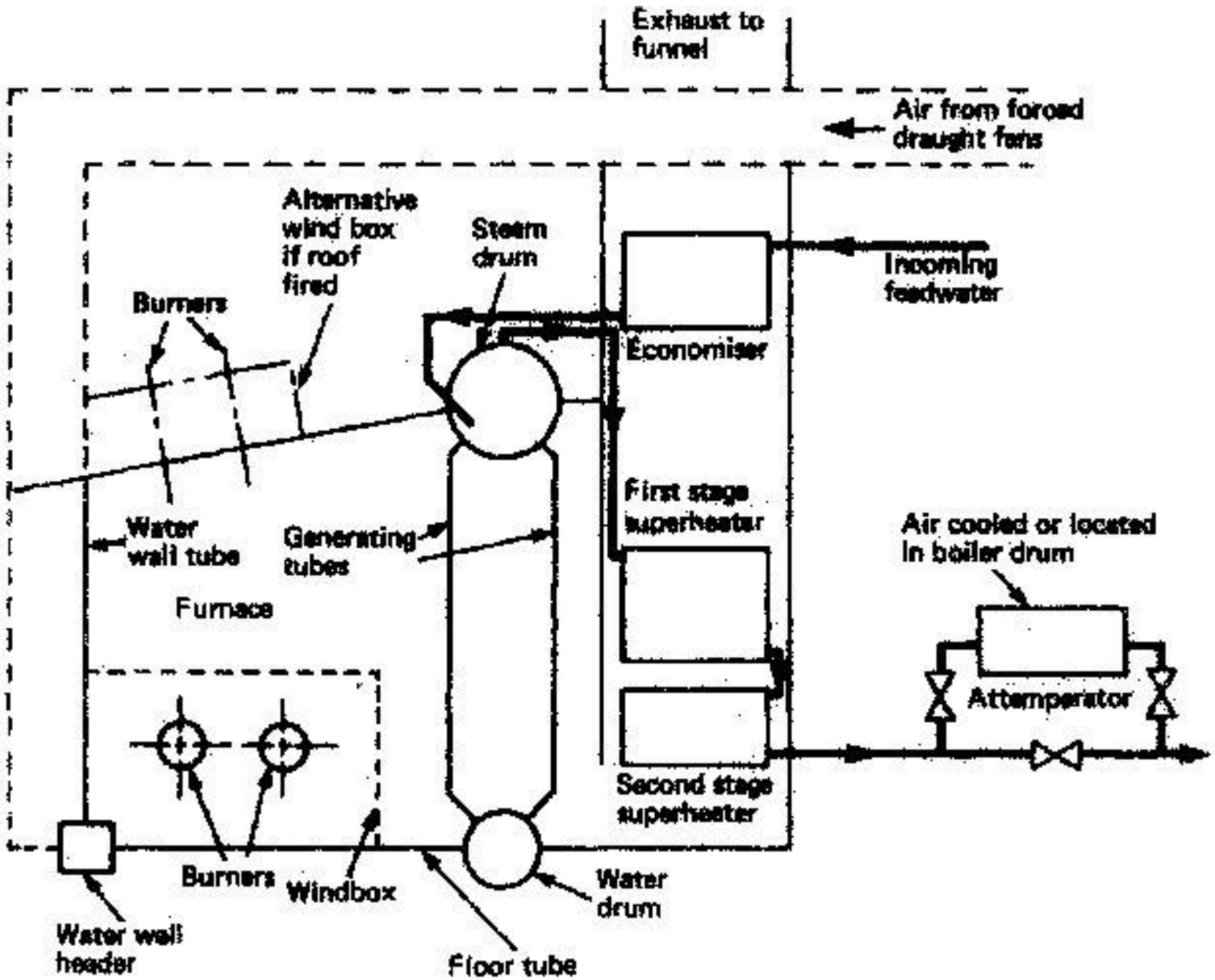


Fig: General cargo ship boiler arrangement

- The steam is produced in a steam drum and may be drawn off for use from here. It is known as 'wet' or saturated steam in this condition because it will contain small quantities of water, Alternatively the steam may pass to a superheater which is located within the boiler. Here steam is further heated and 'dried', i.e. all traces of water are converted into steam. This superheated steam then leaves the boiler for use in the system. The temperature of superheated steam will be above that of the steam in the drum. An 'attemperator', i.e. a steam cooler, may be fitted in the system to control the superheated steam temperature.

  The hot gases produced in the furnace are used to heat the feedwater to produce steam and also to superheat the steam from the boiler drum. The gases then pass over an economiser through which the feedwater passes before it enters the boiler. The exhaust gases may also pass over an air heater which warms the combustion air before it enters the furnace. In this way a large proportion of the heat energy from the hot gases is used before they are exhausted from the funnel. The arrangement is shown in Figure

- Two basically different types of boiler exist, namely the watertube and the firetube. In the watertube the feedwater is passed through the tubes and the hot gases pass over them. In the firetube boiler the hot gases pass through the tubes and the feedwater surrounds them.

Fire tube boilers

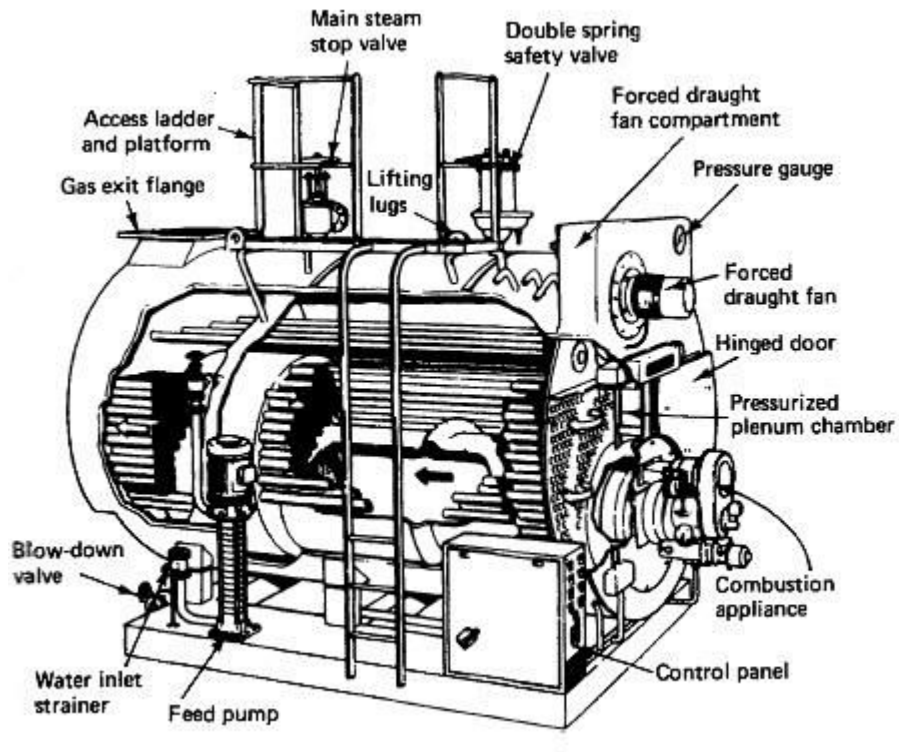
- **Requirement of firetube boiler for low-pressure steam production**

  A boiler is used to heat feed water in order to produce steam. The energy released by the burning fuel in the boiler furnace is stored (as temperature and pressure) in the steam produced.

  The firetube boiler is usually chosen for low-pressure steam production on vessels requiring steam for auxiliary purposes. Operation is simple and feedwater of medium quality may be employed. The name 'tank boiler is sometimes used for firetube boilers because of their large water capacity. The terms 'smoke tube' and 'donkey boiler are also in use.

- Most firetube boilers are now supplied as a completely packaged unit. This will include the oil burner, fuel pump, forced-draught fan, feed pumps and automatic controls for the system. The boiler will be fitted with all the appropriate boiler mountings.

Fig: Fire Tube Boiler arrangement



- A single-furnace three-pass design is shown in Figure above. The first pass is through the partly corrugated furnace and into the cylindrical wetback combustion chamber. The second pass is back over the furnace through small-bore smoke tubes and then the flow divides at the front central smoke box. The third pass is through outer smoke tubes to the gas exit at the back of the boiler.

  There is no combustion chamber refractory lining other than a lining to the combustion chamber access door and the primary and secondary quart. Fully automatic controls are provided and located in a control panel at the side of the boiler.

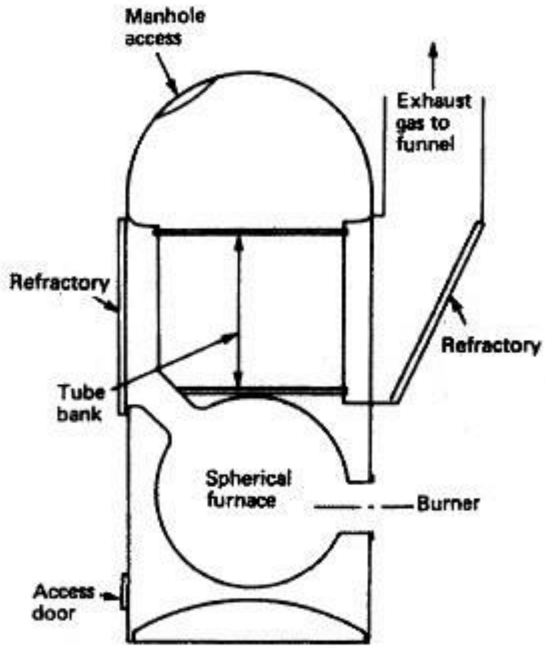


Figure 4.8 Cochran spheroid boiler

- **Cochran boilers**

  The modern vertical Cochran boiler has a fully spherical furnace and is known as the 'spheroid' . The furnace is surrounded by water and therefore requires no refractory lining. The hot gases make a single pass through the horizontal tube bank before passing away to exhaust. The use of small-bore tubes fitted with retarders ensures better heat transfer and cleaner tubes as a result of the turbulent gas flow.

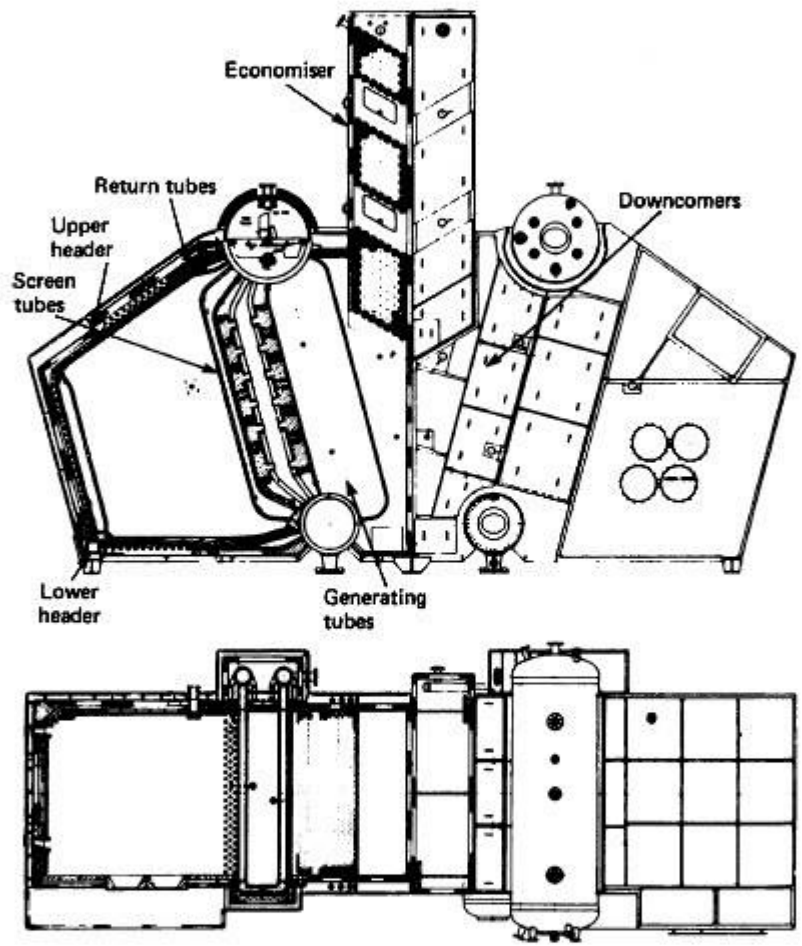
  Composite boilers

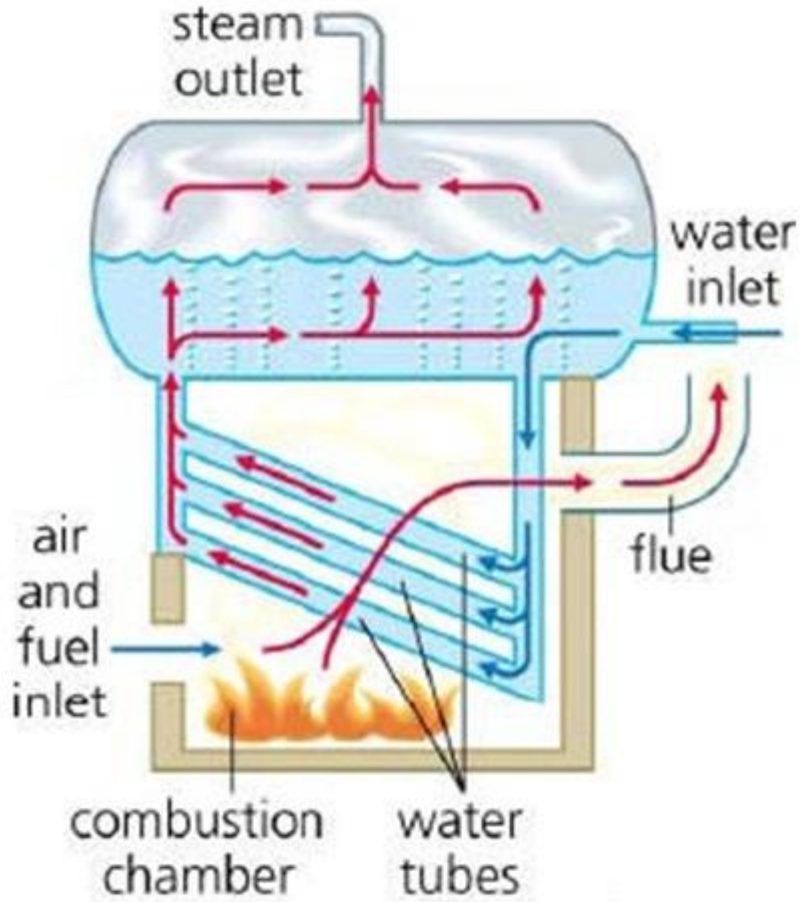
  A composite boiler arrangement permits steam generation either by oil firing when necessary or by using the engine exhaust gases when the ship is at sea. Composite boilers are based on firetube boiler designs. The Cochran boiler, for example, would have a section of the tube bank separately arranged for the engine exhaust gases to pass through and exit via their own exhaust duct.

Water tube boilers

- **Why Water Tube Boilers ?**
- http://www.brighthubengineering.com/marine-engines-machinery/43729-types-of-marine-boilers-watertube-boilers/

Water tube boiler functional requirement




steam
outlet
water
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air
and
fuel
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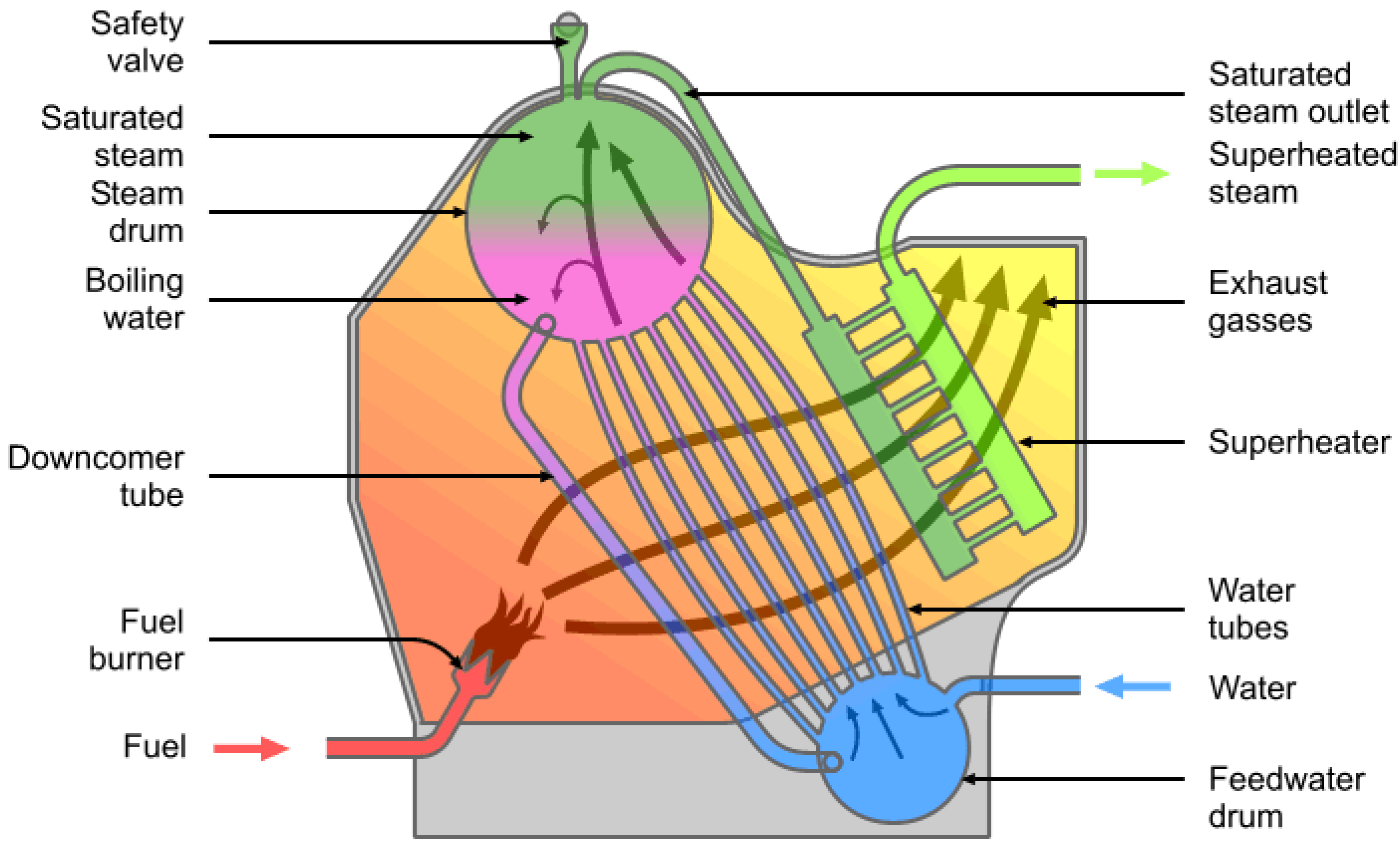
combustion
chamber
water
tubes


Safety valve
Saturated steam
Steam drum
Boiling water
Downcomer tube
Fuel burner
Fuel
Saturated steam outlet
Superheated steam
Exhaust gasses
Superheater
Water tubes
Water
Feedwater drum

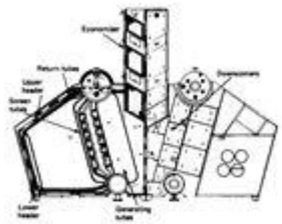
- A boiler is used to heat feed water in order to produce steam. The energy released by the burning fuel in the boiler furnace is stored (as temperature and pressure) in the steam produced.

  A double evaporation boiler uses two independent systems for steam generation and therefore avoids any contamination between the primary and secondary feedwater. The primary circuit is in effect a conventional watertube boiler which provides steam to the heating coils of a steam-to-steam generator, which is the secondary system. The complete boiler is enclosed in a pressurised casing.

- In contrast to its internal construction, which includes a small steam drum and small diameter tubes, the water tube boiler is used to generate steam having high pressure and temperature. These small internal parts produce high volume steam for high capacity applications.

- Water tube boilers are the most widely used boilers. These type has replaced many boilers, including the fire tube type, mainly because of the following reasons :
- The weight of the water tube boiler is much less than any type of boiler of equivalent size.
- Steam raising and steam generation process is much faster
- The design is custom made and flexible to include any kind of modifications
- It has very high efficiency than the rest of the boilers
- The design facilitates good natural circulation of the feed water

- The earlier versions of water tube boiler consisted of a single drum arrangement with headers connected using short, bent pipes with straight tubes. The hot gases used to pass over the tubes in only one go or a single pass.
- But with the advent of bent tube design, the boilers were fitted with two drums with a an integral furnace. The boilers are known as D shaped design or D shaped Boilers.



- The D type boiler has an arrangement of two drums at the side of the furnace and is surrounded by water tube walls . The steam drum is at the top and the water drum is located at the bottom of the whole system. The water wall tubes are connected either to the top and bottom headers or to the bottom header and the steam drum. The return tubes going to the steam drum are connected to the upper header.

Construction of a water tube boiler

- Both the drums are connected with large number of small diameter tubes which carry feed water. These small diameter tubes are known as generating tubes because they provide the main heat transfer surfaces for the production of steam. Water is circulated between both the drums with the help of externally fitted Large bore downcomers. Refractory material is used in the making of the furnace floor, burner wall and behind the water walls. The refractory material acts as an insulation, preventing heat from escaping. The superheater is located away from the furnace and in between the two boilers. The boiler is also provided with a double casing which allows the passage of combustion air to the air control register surrounding the burner.
- The D type boiler also has a two stage superheater - primary and secondary, located below the generating tubes. It also has an attemperator to control the temperature of steam. This basic D type boiler is also known as ESD (Emergency Shutdown Boiler).

- **The steam to steam generator working principle and operational procedure**

- **The steam to steam generator**

  A boiler is used to heat feed water in order to produce steam. The energy released by the burning fuel in the boiler furnace is stored (as temperature and pressure) in the steam produced.

  Steam-to-steam generators produce low-pressure saturated steam for domestic and other services. They are used in conjunction with watertube boilers to provide a secondary steam circuit which avoids any possible contamination of the primary-circuit feedwater. The arrangement may be horizontal or vertical with coils within the shell which heat the feedwater.
- The coils are supplied with high-pressure, hightemperature steam from the main boiler.

- **Raising Steam**

  Fuel Quality

  Boilers are usually fired using heavy fuel oil. If it is necessary because of insufficient steam for fuel heating, to use Diesel Oil or other lower viscosity fuel a single pressure jet burner with the smallest available tip is to be used. If this is not available, then the smallest steam atomising or steam assisted tip can be used, provided that the steam connections are blanked off. The boiler is to revert to firing on heavy fuel oil once appropriate steam heating pressure is reached.

  Purging

  Should the burner fail to ignite, or flame failure occur, then it is essential that the furnace is visually examined for unburned fuel and purged before any attempt is made to re-ignite the burner. If the boiler furnace or furnaces are fitted with automatic purging systems then these must be fully operational. If the furnace or furnaces are not fitted with automatic purging sequence systems or they are not operational then prior to burner ignition, and on each subsequent occasion prior to re-igniting the burner or burners the furnace spaces are to be purged using the forced draft fans to give a minimum of five full changes of furnace air.

- Manual Firing

  If manual firing has to be resorted to, then the procedure must be in accordance with the manufacturer's instructions and as agreed with the Technical Department of the relevant management office.

  Firing

  The procedure for firing must be in accordance with manufacturer's instructions. Heating should be gradual and uniform, starting with one burner using the smallest tip available. A period of six hours should normally be allowed for raising steam, but in cases where repairs to refractory, or parts subject to pressure, have been carried out the period should be extended to 24 hours with alternate registers used.

  Flow through Superheaters

  Steam flow through superheaters must be maintained at all times. In cases of emergency when steam is required at short notice the boiler manufacturer's instructions are to be adhered to.

  Venting

  Throughout the steam raising process, provision is to be made for venting all air from the boiler. This should be done solely by means of a designated air release cock or, if this is not fitted, by means of the steam pressure gauge cock. Under no circumstances are the steam connections of the water level gauge glasses to be used for venting purposes.

- Safety guideline for boiler operations in machinery spaces on board cargo ship

- **Working with marine boiler**

  Use of Boiler Gauge Glasses

  Boiler water is to be kept within the upper and lower limits at all times. If the water level disappears from either the top or the bottom of the glass and does not return immediately, then all burners are to be shut off until the water level has been restored in the gauge glass. Any such loss of water must be recorded in the Engine Log Book and reported to the Chief Engineer.

  Whenever the water level indicated is suspect it is essential that the remote water level indications are not used in place of the readings from the water level gauge glass. Low pressure water level gauge glasses are to be "blown down" by an approved method for the type of gauge glass at least once per watch or whenever the water level indication is suspect. High pressure water level gauge glasses are to be blown through only when necessary.

- Testing of Boiler Water Controls, Regulators, Alarms and Trips.

  All boiler controls, regulators, alarms and trips must be tested regularly in accordance with the applicable Planned Maintenance System and maker's recommendations. Each test is to be recorded with the signature of the Engineer Officer who conducted the test.

  Boiler level alarms or trip defects are to be rectified immediately. The boiler should not normally be operated with any such safeguards inoperative unless under the supervision of the Chief Engineer. In this circumstance the boiler must be continuously monitored.

  The appropriate Management office is to be advised of details of any defects, remedial measures taken, and confirmation of satisfactory re-tests which are also to be recorded in the Engine Room Log Book.

- <u>Boiler Water Tests and Treatment</u>

  Water in the boilers, steam/steam generators together with samples from their feed water systems is to be tested daily. Testing is to be carried out in accordance with procedures laid down by the suppliers of the water treatment systems. Completion of tests is to be recorded in Engine Room logbook and the full results entered on the appropriate forms and sent to the laboratory for evaluation. Test results indicating contamination or loss of chemical reserve are to be investigated immediately.

  Departures from normal operating conditions are to be recorded, and the relevant Management Office immediately advised.

- Storage and Handling of Boiler Chemicals

  Attention is drawn to the spontaneous combustion properties of certain oxygen scavenging materials such as hydrazine. Any material (e.g. cleaning material, rags, cotton waste, sawdust etc.) contaminated with chemicals of this type, must be washed or destroyed immediately, to avoid the risk of self ignition.

- <u>Blowing Down Boilers</u>

  Boilers are to be blown down at least once per week dependent upon the frequency required to control the level of dissolved solids contained in the boiler water. Ideally blowdown should be carried out under light load conditions with at least one tonne being blown down from each boiler, the actual quantity being recorded in the ER log book and the boiler water report forms.

  Blowing down is to be carried out irrespective of the salinity or chemical reserve readings. Use is also to be made of the surface blow down valve to remove scum from the boiler.

- Boiler Maintenance at Sea

  Should it become necessary to shut a boiler down for repairs or routine maintenance, and if this results in a reduction in speed or adversely affects operational requirements, the appropriate Management Office must be informed. Details concerning the reason for the shutdown and the likely delay should be advised. For main propulsion boilers, wherever possible, routine maintenance should be carried out during ballast rather than loaded passages.

- <u>Cleaning of Gas Side Surfaces</u>

  During cargo operations, in the interests of safety, and in particular to avoid the possible emission of sparks, the use of soot blowers or other devices for cleaning the gas side surfaces is prohibited.

- Safety Precautions during Boiler Operation, Maintenance and Cleaning

During the operation, cleaning and maintenance of boilers safe working practices are of paramount importance. Qualified personnel are to be familiar with correct operational procedures and manufacturers recommendations.

Where these operations involve personnel entering the gas or water spaces, the full safety precautions outlined in the Company Safety and Environmental Manual are to be adhered to. In particular, respirators, protective clothing, and low voltage lamps are to be used.

- Spark and Smoke Emission

  You should be aware that under various regulations applicable to the area your vessel is in, it may be an offence to emit dark smoke. The Master should therefore request appropriate detailed information from the local agent concerning the area emission regulations and pass the information to the Chief Engineer. Careful consideration should be given to the location and operational circumstance of the vessel before soot blowing. Permission should be sought from the bridge before soot blowing.

  Soot blowing or cleaning of turbochargers should not be carried out when gas freeing cargo tanks, when bunkering or transferring fuel or when working cargo alongside a terminal or during ship to ship transfer. In order to ensure that sparks are not generated from the funnel flame arrestors and screens they must be regularly checked and replaced when required. High back pressures can be generated if these devices become blocked. Flame screens must not be painted.

  Emissions of smoke, soot and exhaust gases such as COx, NOx and SOx (Carbon, nitrogen and sulphur) is minimised by controlled running, systematic maintenance and inspection routines of machinery, boilers and funnel. The emissions of exhaust gases contribute to pollution and environmental problems such as acidification and global warming. We aim to focus on control and reduction of the emission of these harmful gases. Reference is made to MARPOL Annex VI and of the Company's Safety and Environmental Procedures.

  Some of the ships are equipped with funnel filters to prevent large emissions from occurring. Special care shall be exercised during port stays and when starting main and auxiliary engines and lighting boilers.

- **General precautions**

A notice should be displayed at each boiler setting out operating instructions. Information provided by the manufacturers of the oil-burning equipment should be displayed in the boiler room.

To avoid the danger of a blowback when lighting boilers, the correct flashing up procedure should always be followed:

(i) there should be no loose oil on the furnace floor;

(ii) the oil should be at the correct temperature for the grade of oil being used; if not, the temperature of the oil must be regulated before lighting is attempted;

(iii) the furnace should be blown through with air to clear any oil vapour; (iv) the torch, specially provided for the purpose, should always be used for lighting a burner unless an adjacent burner in the same furnace is already lit; other means of ignition, such as introducing loose burning material into the furnace, should not be used. An explosion may result from attempts to relight a burner from the hot brickwork of the furnace;

(v) if all is in order, the operator should stand to one side, and the lighted torch inserted and fuel turned on. Care should be taken that there is not too much oil on the torch which could drip and possibly cause a fire;

(vi) if the oil does not light immediately, the fuel supply should be turned off and the furnace ventilated by allowing air to blow through for two or three minutes to clear any oil vapour before a second attempt to light is made. During this interval the burner should be removed and the atomizer and tip inspected to verify that they are in good order;

(vii) if there is a total flame failure while the burner is alight, the fuel supply should be turned off.

The avenues of escape from the boiler fronts and firing spaces should be kept clear.

Where required to be fitted, the gauge glass cover should always be in place when the glass is under pressure. If a gauge glass or cover needs to be replaced or repaired, the gauge should be shut off and drained before the cover is removed.