

Steam Generator (Boiler)

ME 267

Fundamentals of Mechanical Engineering

Md. Mahbubul Islam

BUET, Dhaka

www.mislam.info/ocw.html**Steam Generator**

A steam generator or boiler is usually a closed vessel made of steel. Its function is to transfer the heat produced by the combustion of fuel to water and ultimately to generate steam.

Open vessels, generating steam at atmospheric pressure are not considered to be boiler

The steam produced may be supplied to

- Power Generation
- Heating
 - Space heating
 - Hot water supply
- Industrial Processes
 - Sugar mills
 - Chemical industries

Steam Generator (Boiler)

Classification of Boilers

- Relative position of hot gas and water
 - Fire tube boiler
 - Hot gasses pass through the tubes that are surrounded by water. Horizontal return tubular, vertical tubular, Lancashire, Cochran, Cornish, locomotive fire box, scotch marine etc.
 - Water tube boiler
 - The tubes contain water and the hot gases flow outside
 - Babcock and Wilcox, Stirling boiler, La-mont boiler, Benson boiler and Loeffler boiler

07/03/2011

ME 267

3

Steam Generator (Boiler)

Classification of Boilers...

- Method of firing
 - Internally fired boiler
 - Lancashire, Locomotive, and Scotch
 - Externally fired boiler
 - Babcock and Wilcox
- Pressure of steam
 - High pressure ($>80 \text{ kg/cm}^2$)
 - Babcock and Wilcox, Lamont etc
 - Low pressure ($<80 \text{ kg/cm}^2$)
 - Cochran, Cornish, Lancashire and Locomotive

07/03/2011

ME 267

4

Steam Generator (Boiler)

Classification of Boilers...

- According to the axis of shaft
 - Vertical tubular
 - Horizontal tubular
- Method of circulation of water
 - Natural circulation
 - Forced circulation
- Nature of service to be performed
 - Land boilers
 - Portable boiler
 - Mobile boilers

07/03/2011

ME 267

5

Steam Generator (Boiler)

Classification of Boilers...

- Method of circulation of water
 - Natural circulation
 - Forced circulation
- Heat source
 - Combustion of solid, liquid, or gas
 - Electrical or nuclear energy
 - Hot waste gases of other chemical reactions

07/03/2011

ME 267

6

Steam Generator (Boiler)

Fire Tube Boilers

A fire tube boiler is a type of boiler in which hot gases / flue gases (products of combustion) from a fire (heat source) pass through one or more tubes running through a sealed container of water. The heat energy from the gases passes through the sides of the tubes by thermal conduction, heating the water and ultimately creating steam. A fire-tube boiler is sometimes called a "smoke-tube boiler" or "shell boiler" or sometimes just "fire pipe".

Types of Fire Tube Boiler

- Cochran boiler,
- Lancashire boiler,
- Scotch marine boiler,
- Locomotive boiler etc.

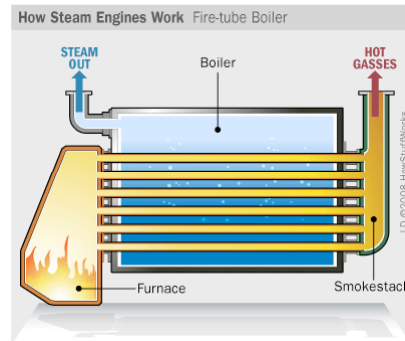


Fig.: Schematic Diagram of a fire Tube Boiler

07/03/2011

ME 267

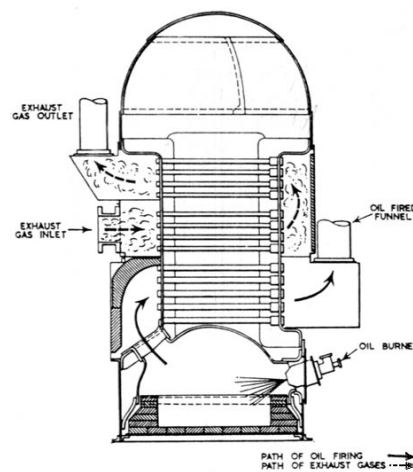
7

Steam Generator (Boiler)

Fire Tube Boiler

Cochran Boiler

- Vertical
- Multitubular
- Internally fired
- Natural circulation
- Favourable in small plants
- Coal or oil burnt



07/03/2011

ME 267

8

Steam Generator (Boiler)

Fire Tube Boiler

Cochran Boiler

- Consists of an external cylindrical shell and a fire box
- fuel is fed into the grate through the fuel door and lighted
- fuel is burnt on the grate and hot gases go to the combustion chamber through a short flue tube
- hot gases pass through fire tubes and heat the surrounding water and convert it into steam
- Since the steam is lighter, it goes up the steam space as crown of the boiler and the grate are both hemispherical in shape
- waste gases enter the smoke box and are released through the chimney
- During shut down , the boiler attendant can enter the boiler through the man hole

07/03/2011

ME 267

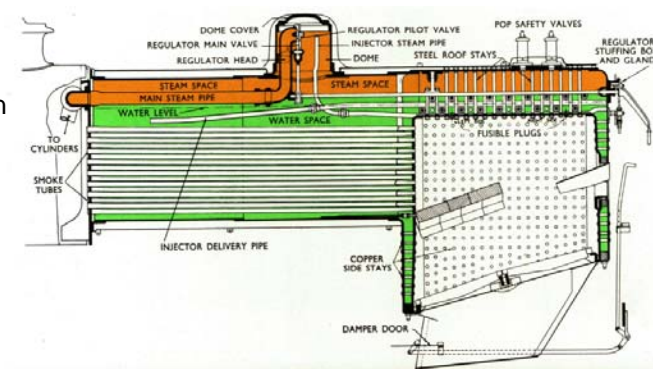
9

Steam Generator (Boiler)

Fire Tube Boiler

Locomotive Boiler

- Horizontal
- Multi-tubular
- Natural circulation
- Internally fired
- Fire tube
- Portable



07/03/2011

ME 267

10

Steam Generator (Boiler)

Fire Tube Boiler

Locomotive Boiler

- Mostly used for railways
- Designed to be capable of meeting sudden and fluctuating demands of steam
- Fuel is fed into the firebox through the fuel door
- Air enters through the damper and the slots in the grate plate
- The hot gases pass through large fire tubes and enter the smoke box
- Circulation of air and hot gases is improved by means of induced draft produced in the smoke box

07/03/2011

ME 267

11

Steam Generator (Boiler)

Water Tube Boiler

A water tube boiler is a type of boiler in which water circulates in tubes heated externally by the hot gases / flue gases. 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.

Types of water tube boiler

- Babcock & Wilcox boiler,
- Stirling boiler etc.

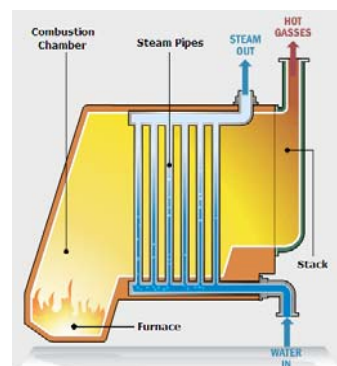


Fig.: Schematic Diagram of a Water Tube Boiler

07/03/2011

ME 267

12

Steam Generator (Boiler)

Water Tube Boiler

The drums are used for storage of water and steam. As they are not required to contain tubular heating surface, they can be much smaller in diameter than the fire tube shell and can, therefore, be built to resist high pressure

Generation of steam is quicker as water is subdivided into small volume.

The initial cost, operational cost and maintenance costs of water tube boiler is higher than that of an equivalent fire tube boiler

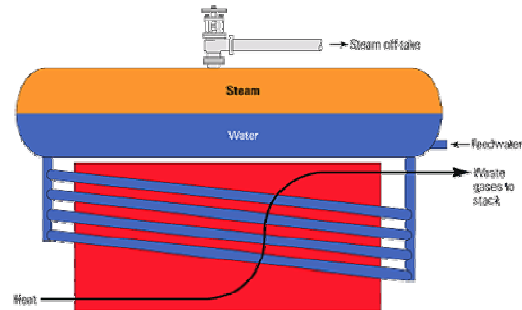


Fig.: Schematic Diagram of a Water Tube Boiler

07/03/2011

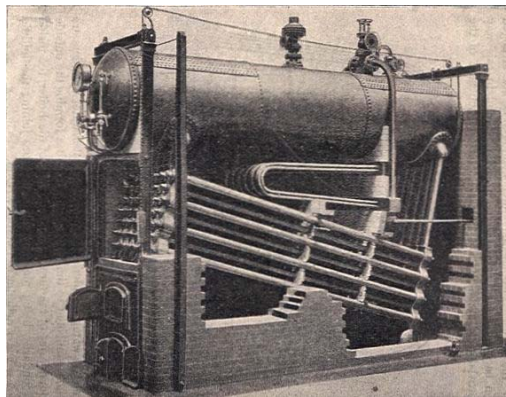
ME 267

13

Steam Generator (Boiler)

Water Tube Boiler

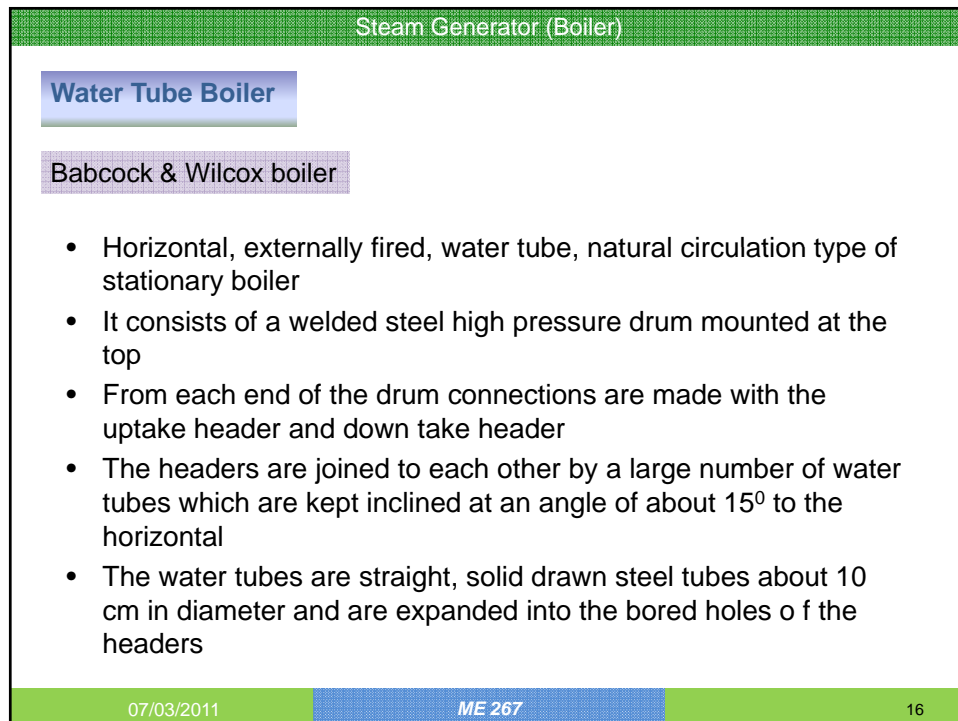
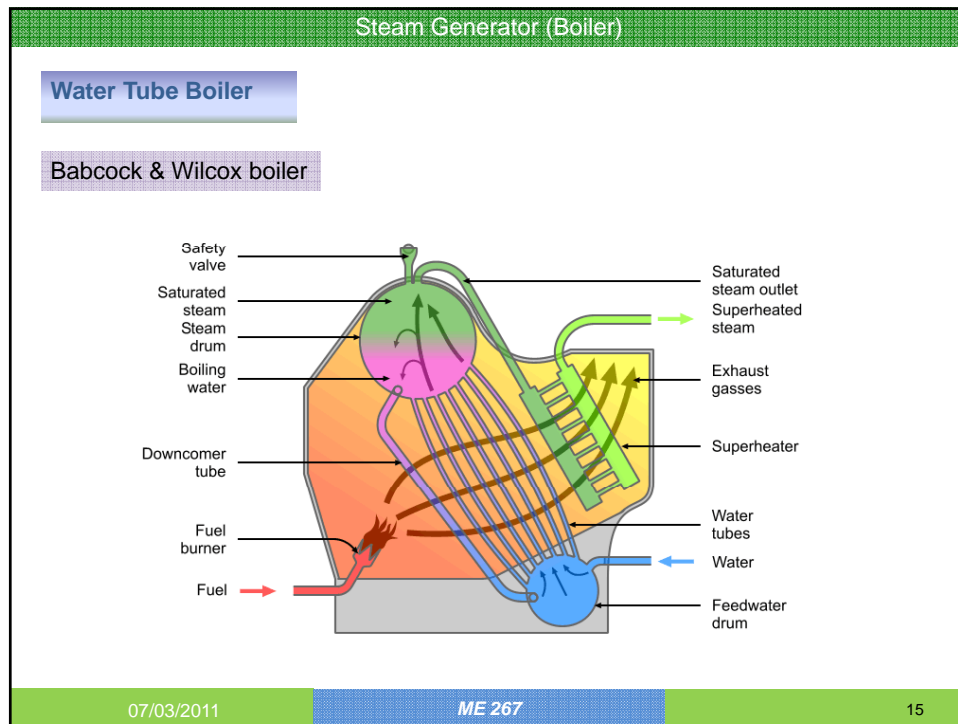
Babcock & Wilcox boiler



07/03/2011

ME 267

14



Steam Generator (Boiler)

Water Tube Boiler

Babcock & Wilcox boiler

- The heating surface of the unit, forms the outer surface of the tubes and half of the cylindrical surface of the water drum which is exposed to flue gases
- The furnace is arranged below the uptake header
- The coal is fed to the chain gate stoker through the fire door
- Baffles are provided across the water tubes to act as deflectors to the flue gases and to provide them with gas passes
- The circulation of water is maintained by convective currents

07/03/2011

ME 267

17

Steam Generator (Boiler)

Comparison between Water Tube and Fire Tube Boilers

Fire Tube Boiler	Water Tube Boiler
The hot gases from the furnace pass through the tubes which are surrounded by water in the shell	The water circulates inside the tubes which are surrounded by hot gases from the furnace
It cannot handle high pressure	It is a high pressure boiler
The rate of generation of steam is relatively low	The rate of generation of steam is high
Overall efficiency is up to 75%	Overall efficiency is up to 90%
It is not preferable for fluctuating loads for a longer time period	It is preferred for widely fluctuating loads
The operating cost is less	The operating cost is high
The bursting chances are less but bursting produces greater risk to the damage of the property	The bursting chances are higher but bursting doesn't produce any destruction to the whole boiler
It is generally used for supplying steam on a small scale and is not suitable for large power plants	It is used for large power plants

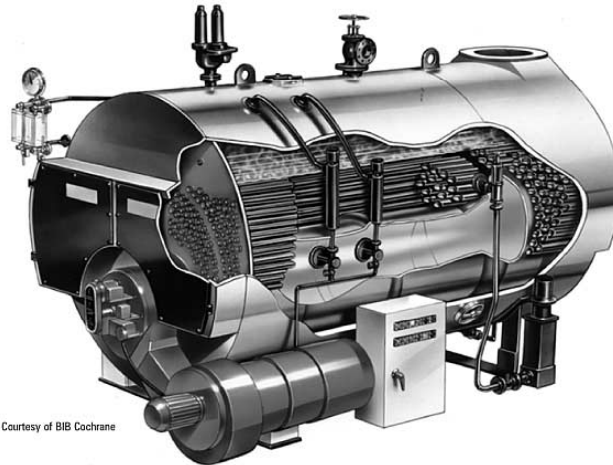
07/03/2011

ME 267

18

Steam Generator (Boiler)

Modern Package boiler



Courtesy of BIR Cochrane

07/03/2011

ME 267

19

Steam Generator (Boiler)

Boiler Mountings

Mountings are required for proper and safe functioning of the boiler which are generally mounted over the boiler shell.

- Water Level Indicator
- Pressure gauge
- Safety valves
- Steam stop valve
- Blow off cock
- Fusible plug
- Feed Check valve

07/03/2011

ME 267

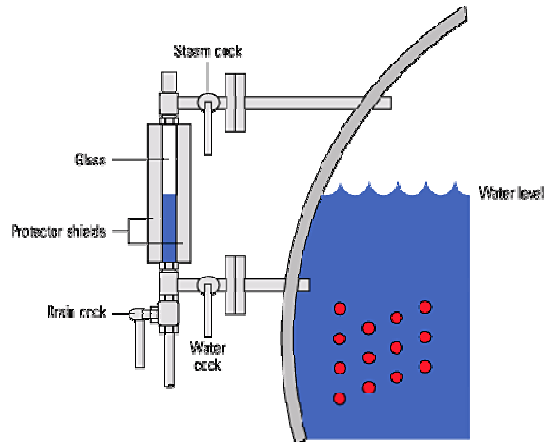
20

Steam Generator (Boiler)

Boiler Mountings

Water Level Indicator

- The water level indicator is needed to ascertain the water level of a boiler.
- Two water level indicators should be fitted for each boiler in such a place that the water level can be constantly seen.



07/03/2011

ME 267

21

Steam Generator (Boiler)

Pressure Gage

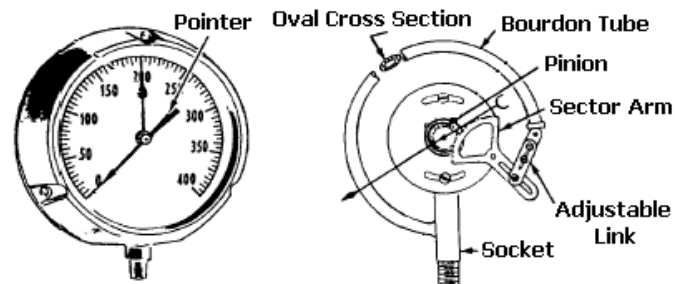


Fig.: A Bourdon Tube Pressure Gage

- A pressure gauge is an instrument by means of which the pressure exerted inside a vessel can be measured.
- There are two types of pressure gauges, one is *Bourdon tube pressure gauge* and the other is *diaphragm type gauge*.

07/03/2011

ME 267

22

Steam Generator (Boiler)

Safety Valve

- The safety valve (pressure relief valve) is used in a boiler to relieve the pressure of steam when it is above the working pressure.
- Its function is to discharge a portion of the steam from the boiler automatically when the steam pressure exceeds the normal limit. It is mounted on the top of the shell.
- As per boiler regulation two safety valves are required to be fitted in each boiler.

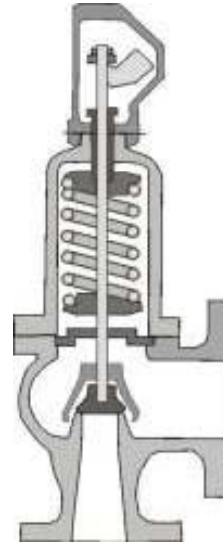


Fig.: A Spring Loaded Safety Valve

07/03/2011

ME 267

23

Steam Generator (Boiler)

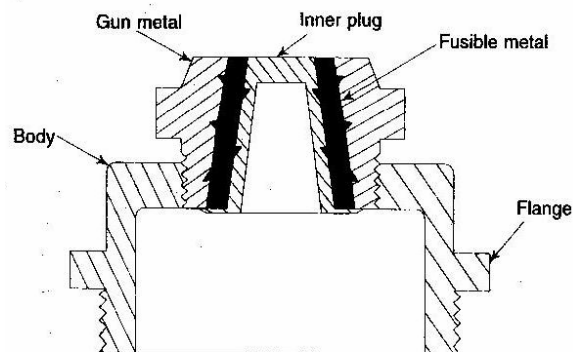
Fusible Plug

Fig.: A Fusible Plug

The function is to extinguish the fire in the event of water level in the boiler shell falling below a certain specified limit

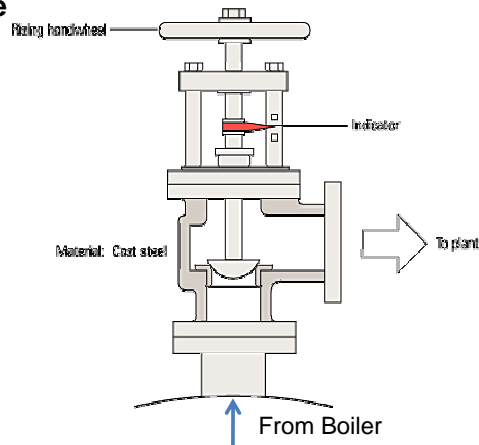
07/03/2011

ME 267

24

Steam Generator (Boiler)

Steam Stop Valve



- The function of the stop valve or junction valve is to regulate the flow of steam from the boiler to the main steam pipe.
- To shut off the steam completely when required.

07/03/2011

ME 267

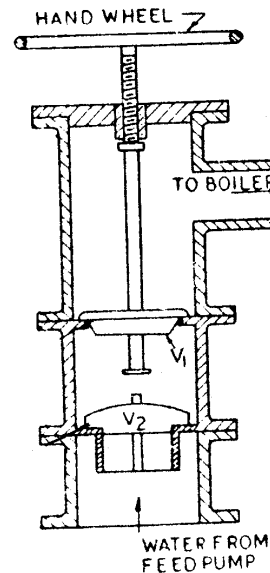
25

Steam Generator (Boiler)

Feed check valve

The feed check valve is used to control the supply of water to the boiler and to prevent the escaping of water from the boiler when the pump pressure is less or the pump is stopped.

It is fitted over the shell slightly below the normal water level of the boiler.



07/03/2011

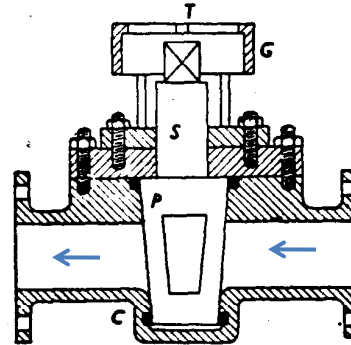
ME 267

26

Steam Generator (Boiler)

Blow-off cock

- The blow-off cock has two main functions:
 - It may empty the boiler when necessary for cleaning, inspection and repair.
 - It may discharge a portion of water when the boiler is in operation to blow out mud, scale or sediments periodically.
- It is fitted at the lowest part of the boiler either directly with the boiler shell or to a pipe connected with the boiler.



07/03/2011

ME 267

27

Steam Generator (Boiler)

Boiler Accessories

Accessories are used for efficient running of the boiler

- Superheater
- Economiser
- Air preheater

07/03/2011

ME 267

28

Steam Generator (Boiler)

Economizer

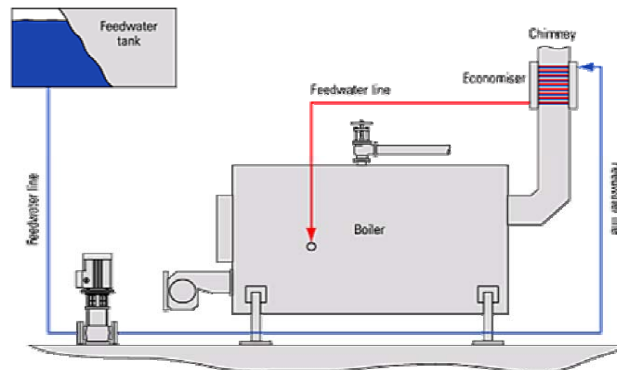


Fig.: An Economizer

- Use to recover some heat being carrying by exhaust flue gases.
- Heat recovered is utilized in raising the temperature of the feed water.
- Feed water at raised temperature is supplied to the boiler, thus less heat is required for conversion into steam.
- Prevents thermal shock.

07/03/2011

ME 267

29

Steam Generator (Boiler)

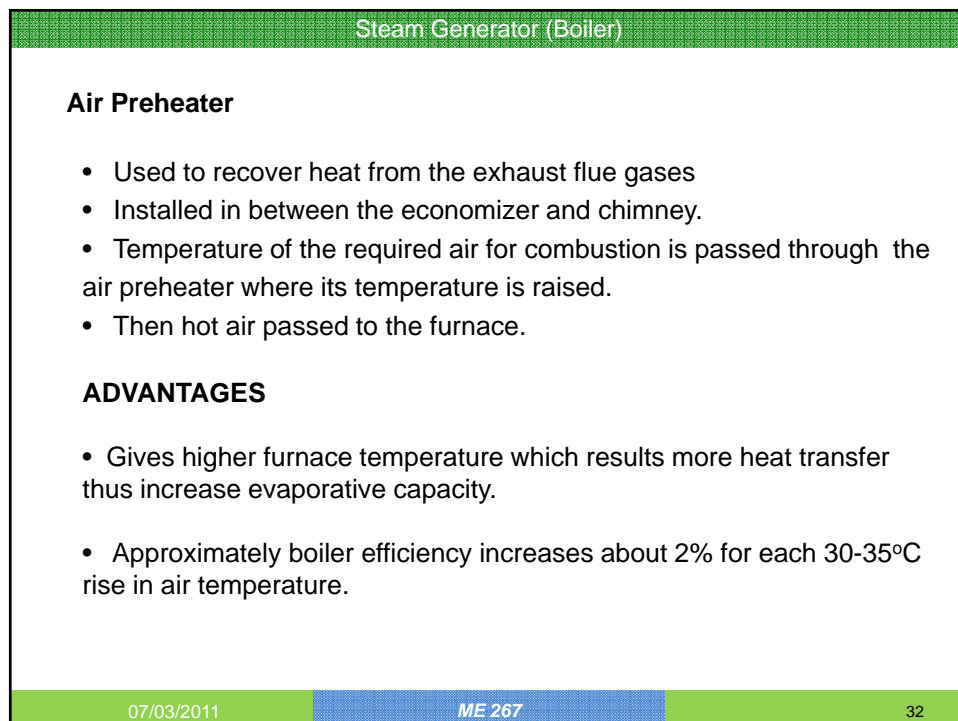
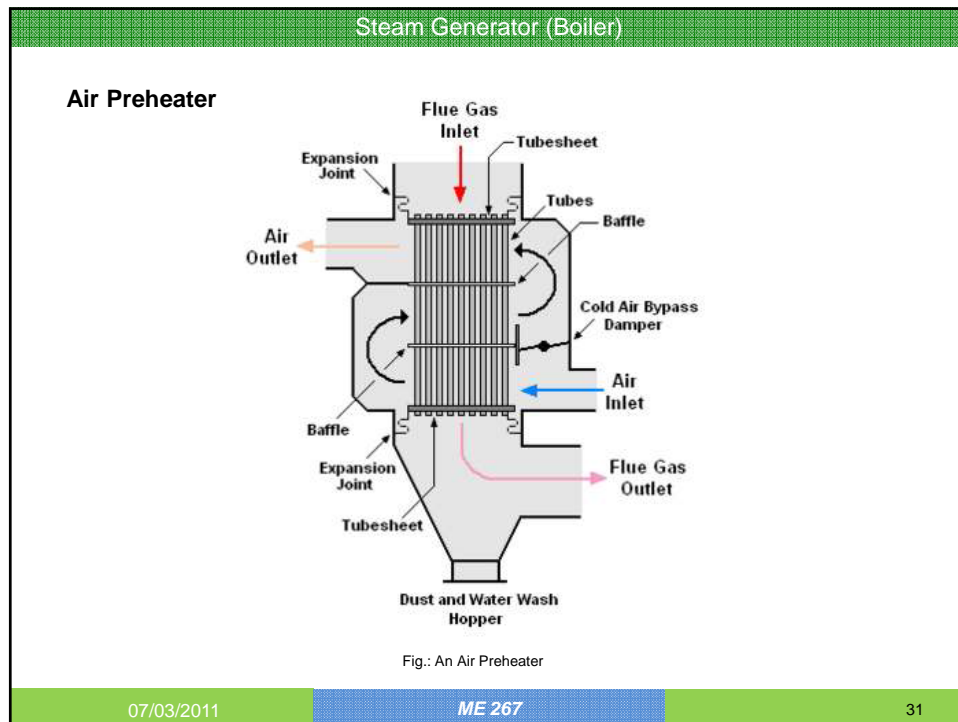
Economizer

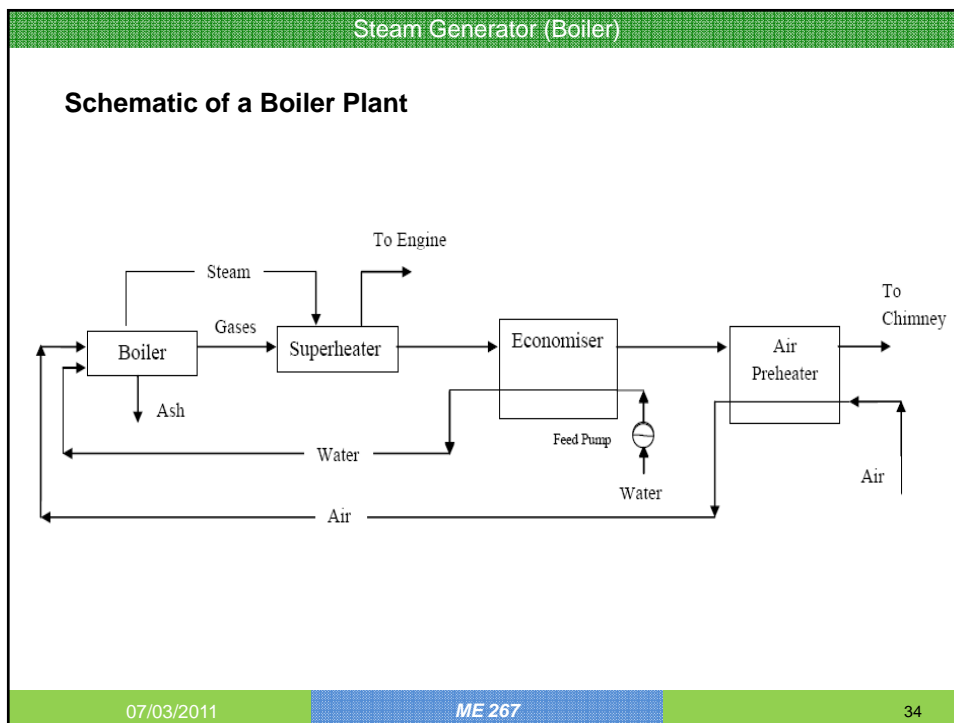
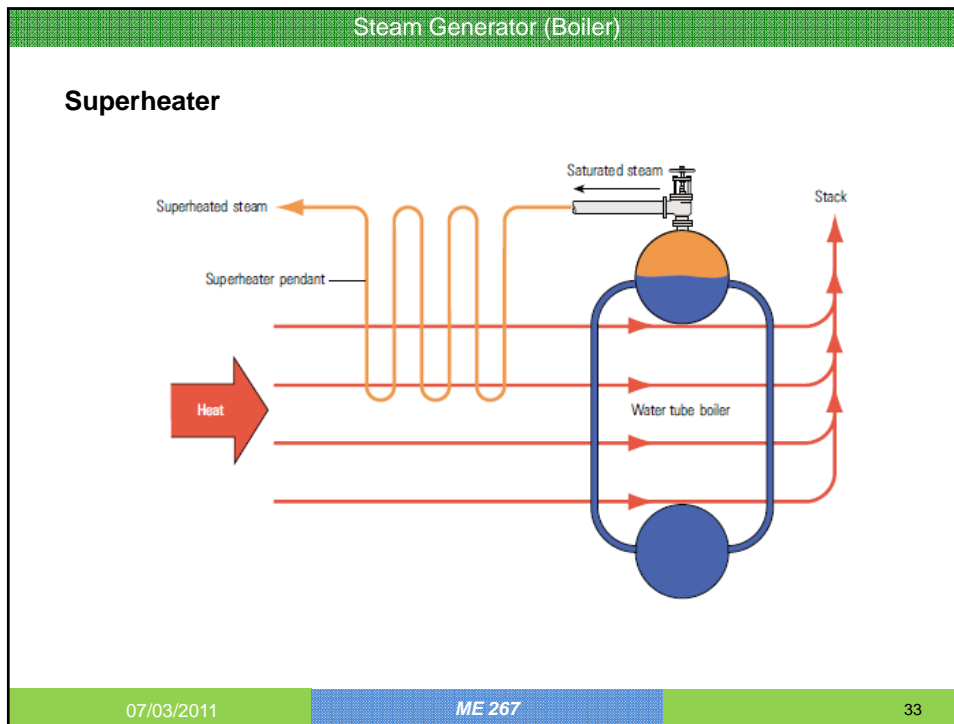


07/03/2011

ME 267

30





Steam Generator (Boiler)

Essential of a good boilers

1. The boiler should be capable of generating steam at the required pressure and of the required quality quickly and with minimum fuel consumption.
2. The initial cost, installation cost and the maintenance cost of the boiler should not be too high.
3. The boiler should be light in weight, should need the least amount of brick work construction and should occupy small floor area.
4. The boiler should meet the fluctuating demands or steam supply without being overheated
5. The different parts of the boiler should be easily approachable for repairs.
6. There should be no deposition of mud and other foreign particles on the heated surfaces
7. The boiler should conform to the safety regulations as laid down in the "Boilers Act".

07/03/2011

ME 267

35

Steam Generator (Boiler)

Boiler Performance

- As the function of a boiler is to generate steam, so the amount of water evaporated may be considered as a performance of the boiler.
- The quantity of steam which is actually produced in boiler at observed conditions is known as an **actual evaporation**.
- The observed conditions are the pressure, quality of steam and temperature of feed water.
- As the steam is usually generated in a boiler at constant pressure, so heat supplied by the fuel is equal to the enthalpy absorbed by the steam.
- If m_a be the mass of steam formed actually in a given time in kg (or sometimes per kg of fuel), then

$$Q = m_a (h_2 - h_1)$$

where Q denotes the amount of heat utilized and $h_2 - h_1$, denotes the amount of enthalpy absorbed per kg of steam.

07/03/2011

ME 267

36

Steam Generator (Boiler)

Boiler Performance

- Superheated steam: when the dry steam is further heated at constant pressure, thus raising its temperature, it is said to be superheated steam
- *Dryness fraction or Quality of steam:* It is the ratio of dry steam per kg of wet steam

$$x = m_s / (m_s + m_w)$$

m_s = mass of dry steam

m_w = mass of water in suspension

07/03/2011

ME 267

37

Steam Generator (Boiler)

Boiler Capacity

- Evaporation or equivalent evaporation per hour may be taken as a measure of boiler capacity. It is generally measured in tons or kg per hour.

07/03/2011

ME 267

38

Steam Generator (Boiler)

Boiler Efficiency

Efficiency of a boiler may be defined as the ratio of heat utilized for the generation of steam to heat supplied due to the burning of fuel.

$$\text{Boiler efficiency, } \eta = \frac{\text{Energy utilized}}{\text{Energy supplied}} = \frac{m_s(h-h_0)}{m_f \times HV}$$

m_s be the mass of steam evaporated in a given time

m_f be the mass of fuel burnt at the same time

HV be the heating value of fuel per unit mass

h be the enthalpy per unit mass of steam

h_0 be the enthalpy of feed water

07/03/2011

ME 267

39

Steam Generator (Boiler)

Selection of Boiler

- The selection of type and size of a boiler depends on the following factors
 - The power required and working pressure
 - The geographical position of the power house
 - Quality of the fuel and water available
 - Steam generation rate.

07/03/2011

ME 267

40