Chapter 2.2: Boilers

Part – I: Objective type Questions and Answers

1.	The minimum capacity of any closed vessel which generates steam under Indian Boilers Regulation Act is ___. a) 2.275 liters b) 22.75 kilo liters c) 227.5 liters d) 22.75 liters
2.	Steam is preferred medium for heating applications because: a) high latent heat b) temperature break down is easy c) Easy to control and distribute d) all the above
3.	For higher boiler efficiencies, the feed water is heated by ____. a. recuperator b. convective heater c. super heater d. economiser
4.	The type of firing used for a pulverised coal fired boiler is: a) over firing b) tangential firing c) vertical firing d) mixed firing for effective heat transfer
5.	The recommended TDS level in boiler drum, that can be safely maintained for the water tube boiler is: a) 3000 – 3500 ppm b) 2000 ppm c) 5000 ppm d) It can be anything
6.	An evaporation ratio (steam to fuel ratio) of an efficient oil fired boiler is in the range of ___. a) 5 – 6 b) 13 - 16 c) 1 d) 7 – 9
7.	Pick the boiler, which can be considered as most combustion efficient? a) fluidised bed combustion boiler b) lanchashire boiler c) Stoker fired boiler d) chain grate boiler
8.	The percentage excess air required for pulverised coal fired boiler is: a) 40 – 50% b) 15 – 20% c) 60 – 80% d) 30 – 40%
9.	Name the predominant loss component for furnace oil fed boiler. a) losses due to radiation and convention b) loss due to hydrogen in fuel c) loss due to dry flue gas d) loss due to moisture in fuel
10.	Controlled wetting of coal (during the coal preparation) would result in a) reduction in flue gas exit temperature b) decrease in the percentage of unburnt carbon c) improper combustion d) increase in the fines of coal

11.	A rise in conductivity of boiler feed water indicates ____ . a) drop in the contamination of feed water b) greater purity of feed water c) rise in the contamination of feed water d) it has got no relation with the contamination of feed water
12.	Demineralisation of water is the process to remove -------- a) dissolved oxygen b) dissolved salts c) corbondioxide d) chlorine
13.	The presence of calcium and magnesium bicarbonates in water to steam boiler would form: a) acidic solution b) alkaline solution c) neutral solution d) none of the above
14.	Water treatment for steam boiler is generally required to: a) remove hydrogen b) prevent formation of scales c) help improve combustion efficiency d) reduce stack temperature
15.	In a plant a boiler is generating a saturated steam of 2 tonnes/hour at a pressure of 7.0 kg/cm^{2}g. The feed water temperature is 70 °C and furnace oil consumption is 138 kg/h. What is the efficiency of the boiler by using direct method of efficiency evaluation? (calorific value of FO is 10,000 kCal/kg, enthalpy of steam is 660 kCal/kg. a) 65 b) 75 c) 85 d) 95
16.	The 'indirect method' of evaluating boiler efficiency is also called as "Heat Loss" method. – True or False?
17.	Good opportunity for energy savings from continuous blow down water of boiler is by ___. a) reusing the hot water so formed as make up water b) using the blow down steam to run steam turbine c) utilisation of flash steam in deaerator d) none of the above
18.	De-aeration of boiler feed water is referred to as: a) removal of dissolved gases b) removal of silica c) removal of scales by blow down d) phosphate treatment of feed water
19.	The percentage raise in boiler efficiency by a 20 degree centigrade raise in combustion air temperature is ___. a) 0.1% b) 0.2% c) 10% d) 1%
20.	The elements of ultimate analysis of fuel does not include a) carbon b) Hydrogen c) oxygen d) volatile matter

Part - II: Short type questions and answers

1.	What do you understand by 'water tube boilers' and 'fire tube boilers'? In water tube boilers the water passes through the tubes and the hot gases passes out side the tubes where as in case of fire tube boiler the hot gases passes through the tubes and the water passes over the tubes.
2.	What do you mean by IBR steam boiler. IBR Steam Boilers means any closed vessel exceeding 22.75 liters in capacity and which is used expressively for generating steam under pressure and includes any mounting or other fitting attached to such vessel, which is wholly or partly under pressure when the steam is shut off.
3.	What is the affect of sulphur in coal when used in boiler? Sulphur will get oxidised to SO_2 and fraction of SO_3 and will react with water to form sulphuric acid and this occurs at a temperature called the acid dew point which normally is about 120 ^oC. The sulphuric acid so formed corrodes the steel when it comes in contact with it.
4.	Write a short note on IBR steam pipe. IBR Steam Pipe means any pipe through which steam passes from a boiler to a prime mover or other user or both, if pressure at which steam passes through such pipes exceeds 3.5 kg/cm^2 above atmospheric pressure or such pipe exceeds 254 mm in internal diameter and includes in either case any connected fitting of a steam pipe.
5.	Why boiler blow-down is required? As the feed water evaporate into steam, dissolved solids concentrate in the boiler. Above certain level of concentration, these solids encourage carryover of water into steam. This leads to scale formation inside the boiler, resulting in localised over heating and ending finally in tube failure. Hence blow-down is very much required for boilers.
6.	What are the parameters required to estimate the boiler efficiency by 'direct method'? a) Steam flow rate b) GCV of fuel c) Fuel flow rate d) Steam conditions (pressure and temperature) e) Feed water temperature
7.	What is the principle of mechanical deaeration (pressure type) of boiler feed water? The pressure-type de-aerators operates by allowing steam into the feed water through a pressure control valve to maintain the desired operating pressure, and hence temperature at a minimum of 105 °C. The steam raises the water temperature causing the release of O_2 and CO_2 gases that are then vented from the system. This type can reduce the oxygen content to 0.005 mg/litre.
8.	What is the effect of boiler loading on boiler efficiency? • The maximum efficiency of the boiler does not occur at full load, but at about two-thirds of the full load. If the load on the boiler decreases further, efficiency also tends to decrease. • As the load falls, so does the value of the mass flow rate of the flue gases through the tubes. This reduction in flow rate for the same heat transfer area, reduced the exit flue gas temperatures by a small extent, reducing the sensible heat loss. • Below half load, most combustion appliances need more excess air to burn the fuel completely. This increases the sensible heat loss.

9.	What are the principle heat losses that occur in a boiler? The principle heat losses that occur in a boiler are: • Loss of heat due to dry flue gas • Loss of heat due to moisture in fuel and combustion air • Loss of heat due to combustion of hydrogen • Loss of heat due to radiation • Loss of heat due to unburnt fuel
10.	What do you meant by tangential firing with respect to pulverized coal fired boiler? The method of firing used for coal firing in pulverized fuel fired boiler is the tangential firing. In this type of firing four burners are used at the corner to corner to create a fire ball at the center of the furnace.
11.	What are the disadvantages of 'direct method' of boiler efficiency evaluation over 'indirect method'? Direct method a) Do not give clues to the operator as to why efficiency of system is lower b) Do not calculate various losses accountable for various efficiency levels
12.	List out the data required for calculation of boiler efficiency using 'indirect method'. The data required for calculation of boiler efficiency using indirect method are: • Ultimate analysis of fuel (H_2, O_2, S, C, moisture content, ash content) • Percentage of Oxygen or CO_2 in the flue gas • Flue gas temperature in ^0C (T_f) • Ambient temperature in ^0C (T_a) & humidity of air in kg/kg of dry air. • GCV of fuel in kcal/kg • Percentage combustible in ash (in case of solid fuels) • GCV of ash in kcal/kg (in case of solid fuels)
13.	Explain the different external water treatment methods. External treatment is used to remove suspended solids, dissolved solids (particularly the Calcium and Magnesium ions which is a major cause of scale formation) and dissolved gases (oxygen and carbon dioxide). The techniques include: o Precipitation processes, in which chemicals are added to precipitate calcium and magnesium as compounds of low solubility. The lime-soda process is typical of this class, but other precipitating agents such as caustic soda and sodium phosphate can be used when the composition of the raw water permits. o Ion-exchange progresses, in which the hardness is removed as the water passes through bed of natural zeolite or synthetic resin and without the formation of any precipitate. Ion exchange processes can be used for almost total demineralization if required, as is the case in large electric power plant boilers. o De-aeration, in which gases are expelled by preheating the water before entering the boiler system. Water normally contains approximately 10 mg/1 of dissolved oxygen at ambient temperature o Filtration, to remove suspended solids
14.	What are the salient features of a 'packaged boiler'? The features of package boilers are: • Small combustion space and high heat release rate resulting in faster evaporation.

	• Large number of small diameter tubes leading to good convective heat transfer. • Forced or induced draft systems resulting in good combustion efficiency. • Number of passes resulting in better overall heat transfer. • Higher thermal efficiency at lower capacity (say below 1 ton) levels compared with other boilers.
15.	What are the parameters to be monitored for evaluating 'direct efficiency' of boilers and what is the empirical relation used? Parameters to be monitored for the calculation of boiler efficiency by direct method are: • Quantity of steam generated per hour (Q) in kg/hr. • Quantity of fuel used per hour (q) in kg/hr. • The working pressure (in kg/cm^2(g)) and superheat temperature (^{o}C), if any • The temperature of feed water (^{o}C) • Type of fuel and gross calorific value of the fuel (GCV) in kcal/kg of fuel Boiler efficiency (η) = : $\frac{Q \times (hg - hf)}{q \times GCV} \times 100$ where, hg – Enthalpy of saturated steam in kcal/kg of steam hf - Enthalpy of feed water in kcal/kg of water
16.	What are the two main classification of a stoker fired boiler? 1. Chain grate or travelling grate stoker 2. Spreader stoker
17.	Calculate the blow down rate for a boiler with an evaporation rate of 3 tons/hr, if the maximum permissible TDS in boiler water is 3000 ppm and with 10 % make up water addition. The feed water TDS is around 300 ppm. Blow down (%) $= \frac{\text{Feed water TDS} \times \% \text{ Make up}}{\text{Permissible TDS in Boiler} - \text{Fee water TDS}}$ Percentage blow down $= \frac{300 \times 10}{3000 - 300} = 1.11\%$ If boiler evaporation rate is 3000 kg/hr then required blow down rate is: $= \frac{3000 \times 1.11}{100} = 3.33 \text{ kg/hr}$
18.	Indicate the different methods of efficiency evaluation of Boiler and describe it. – i. Direct Method ii. Indirect Method Direct Method: $Efficiency = \eta = \frac{E_{out}}{E_{in}}$ where Adsorbed heat $= E_{out}$ -The energy the feedwater has picked up

	Energy Input = E_{in} - The energy going into the boiler. Indirect Method: Most performance testing and commissioning of smaller and medium sized boilers is done by the indirect method measuring the losses and calculating the efficiency as $$\eta_{HHV} = 1 - \frac{\sum Losses}{E_{in}}$$
19.	Briefly explain the principle involved in 'reverse osmosis'? When solutions of differing concentrations are separated by a semi-permeable membrane, water from less concentrated solution passes through the membrane to dilute the liquid of high concentration. If the solution of high concentration is pressurised, the process is reversed and the water from the solution of high concentration flows to the weaker solution.
20.	What are the various methods available to control the 'excess air' in a boiler? Various methods are available to control the excess air: • Portable oxygen analysers and draft gauges can be used to make periodic readings to guide the operator to manually adjust the flow of air for optimum operation. Excess air reduction up to 20% is feasible. • The most common method is the continuous oxygen analyzer with a local readout mounted draft gauge, by which the operator can adjust air flow. A further reduction of 10-15% can be achieved over the previous system. • The same continuous oxygen analyzer can have a remote controlled pneumatic damper positioner, by which the readouts are available in a control room. This enables an operator to remotely control a number of firing systems simultaneously.

Part – III: Long type questions and answers

1.	a) What is the benefit of providing Economiser for a boiler? b) Calculate the fuel oil savings by providing an Economiser for a boiler. The performance data of the boiler are given as below: • Average quantity of steam generated : 5 T/h • Average flue gas temperature : 315 °C (without economiser) • Average steam generation / kg of fuel oil : 14 kg • Feed water inlet temperature : 110°C • Fuel oil supply rate : 314 kg/h • Flue gas quantity : 17.4 kg/kg of fuel • Gross calorific value of fuel : 10,000 kCal/kg • Rise in feed water temperature by providing economizer: 26 °C • Annual operating hours : 8600 a) By providing Economiser the exit flue gas losses can be reduced and hence the boiler efficiency can be increased. b) • Quantity of flue gases : 314 x 17.4 = 5463.6 kg/h

- Quantity of heat available in flue gas : 5463.6 x0.23 x(315-200)
  : 144512 kCal/h
- Rise in the feed water temperature : 26 ^{o}C.
- Heat required for pre-heating the feed water : 5000 x 1 x 26 = 130000 kCal/h
- Saving in terms of furnace oil : 130000/10000 = 13 kg/h
- Annual operating hours : 8600
- Annual savings of fuel oil : 8600 x 13 = 111800 kg

2. Evaluate the option of boiler replacement for the following boiler with a new boiler of 84% efficiency. The cost of new boiler is Rs 30.00 lakh

Data of present boiler:

- Average steam generation from the boiler: 5000 kg/h
- Fuel used: furnace oil
- Enthalpy gained by the steam in boiler: 600 kcal/kg of steam
- Cost of furnace oil: Rs 15000 per ton (Rs. 15 per kg)
- Gross calorific value of the fuel: 10000 kcal/kg
- Annual operating hours of the boiler: 6000 h
- Boiler efficiency: 80%

The boiler replacement option can be evaluated by considering the following

- Evaporation rate, kg of steam per kg of fuel
- Cost of steam, Rs. Per kg
- Annual Cost of steam

Evaporation ratio (kg of steam per kg of fuel) is given by:

$$= \left(\frac{Fuel\ \ calorific\ \ value,\ kcal/kg\ \ X\ boiler\ efficiency}{(Enthalpy\ \ gained\ by\ \ steam, kcal/kg} \right)$$

Cost of steam (Rs. Per kg of steam) is given by:

$$= \left(\frac{Cost\ \ of\ \ \ fuel, Rs.per\ kg}{(Evaopration\ rate, kg\ of\ \ steam\ \ per\ kg\ of\ \ fuel} \right)$$

Annual cost of steam, Rs. lakh =

$$\left(\frac{Cost\ of steam, Rs.per\ kg\ \ X\ \ steam\ \ gernation, kg/h\ X\ \ annualhours}{100000} \right)$$

Parameter	Present boiler	Proposed boiler
Boiler efficiency	75	84
Steam generation, kg/h	5000	5000
Gain in steam enthalpy, kcal/kg	600	600
Evaporation rate, kg of steam per kg of fuel	12.5	14
Cost of steam, Rs. Per kg	1.2	1.071
Annual cost of steam, Rs. lakh	360	321.0

	Annual cost savings by replacing the boiler = Rs. (360-321) lakh = Rs. 39 lakh Investment for the new boiler = Rs. 30 lakh Simple pay period = (Investment /Annual savings) = (30/39) = 0.72 years = 9.2 months
3.	Describe 'chain grate' and 'spreader stoker' type boiler. **Chain-Grate or Travelling-Grate Stoker Boiler** Coal is fed onto one end of a moving steel grate. As grate moves along the length of the furnace, the coal burns before dropping off at the end as ash. Some degree of skill is required, particularly when setting up the grate, air dampers and baffles, to ensure clean combustion leaving the minimum of unburnt carbon in the ash. The coal-feed hopper runs along the entire coal-feed end of the furnace. A coal grate is used to control the rate at which coal is fed into the furnace by controlling the thickness of the fuel bed. Coal must be uniform in size as large lumps will not burn out completely by the time they reach the end of the grate **Spreader Stoker Boiler** Spreader stokers utilize a combination of suspension burning and grate burning. The coal is continually fed into the furnace above a burning bed of coal. The coal fines are burned in suspension; the larger particles fall to the grate, where they are burned in a thin, fast-burning coal bed. This method of firing provides good flexibility to meet load fluctuations, since ignition is almost instantaneous when firing rate is increased. Hence, the spreader stoker is favoured over other types of stokers in many industrial applications.
4.	Explain the reasons for carrying out "blow down" in a boiler? Water contains certain percentage of dissolved solids. The percentage of impurities found in boiler water depends on the untreated feed water quality, the treatment process used and the boiler operating procedures. As a general rule, the higher the boiler operating pressure, the greater will be the sensitivity to impurities. As the feed water materials evaporate into steam, dissolved solids concentrate in the boiler either in a dissolved or suspended state. Above a certain level of concentration, these solids encourage foaming and cause carryover of water into the steam. This leads to scale formation inside the boiler, resulting in localised overheating and ending finally in tube failure. It is therefore necessary to control the level of concentration of the solids and this is achieved by the process of 'blowing down', where a certain volume of water is blown off and is automatically replaced by feed water - thus maintaining the optimum level of total dissolved solids (TDS) in the water. Blow down is necessary to protect the surfaces of the heat exchanger in the boiler.
5.	Write short notes on 'intermittent blow down' and 'continuous blow down' with respect to boilers. The 'intermittent blown down' is given by manually operating a valve fitted to discharge pipe at the lowest point of boiler shell to reduce parameters (TDS or conductivity, pH, Silica and Phosphates concentration) within prescribed limits so that steam quality is not likely to be affected. In intermittent blowdown, a large diameter line is opened for a short period of time, the time being based on a thumb rule such as "once a shift for 2 minutes". 'Intermittent blow down' requires l*arge* short-term increases in the amount of feed water put into the boiler, and hence may necessitate larger feed water pumps than if continuous blow down is used. Also, TDS level will be varying, thereby causing fluctuations of the water level in the boiler due to changes in steam bubble size and distribution which accompany changes in concentration of solids. Also substantial amount of heat energy is lost with intermittent blow down. 'Continuous Blowdown': There is a steady and constant dispatch of small stream of concentrated boiler water, and replacement by steady and constant inflow of feed water. This ensures constant TDS and steam

	purity at given steam load. Once blow down valve is set for a given conditions, there is no need for regular operator intervention. Even though large quantities of heat are wasted, opportunity exits for recovering this heat by blowing into a flash tank and generating flash steam. This flash steam can be used for pre-heating boiler feed water or for any other purpose. This type of blow down is common in high-pressure boilers.