B.E.

Fourth Semester Examination, Dec.-2005

ENERGY CONVERSION

Note : Attempt any five questions.

Q. 1. (a) Determine the height of chimney to produce a static draught of 20mm water. The mean flue gas temperature in the chimney is 250°C and the atmospheric air temperature is 20° C. Barometer reads 760 mm of Hg. The characteristic gas constant R for air is 287 Nm/kg°K and for chimney gas it is 255 Nm/kg°K.

Ans. Given : Draught in mm of $H_2O = h_w = 17cm$

$= 17mm$

Flue gas temperature $T_g = 250 + 273 = 523K$

Ambient Temperature, $T_a = 20 + 273 = 293K$

Using relations

$$h_w = \frac{176.5H}{T_a}$$

H = height of chimney

T_a = ambient temperature

So
$$H = \frac{h_w T_a}{176.5}$$

$$H = \frac{17 \times 293}{176.3}$$

$$H = 28.22m$$

Q. 1. (b) Give constructional and operational details of Lancashire Boiler.

Ans. Lancashier Boiler :

This boiler is reliable, has simplicity of design, ease of operation and less operating and maintenance costs. It is commonly used in sugar-mills and textile industries where alongwith the power steam and steam for the process work is also needed. In addition this boiler is used where larger reserve of water and steam are needed.

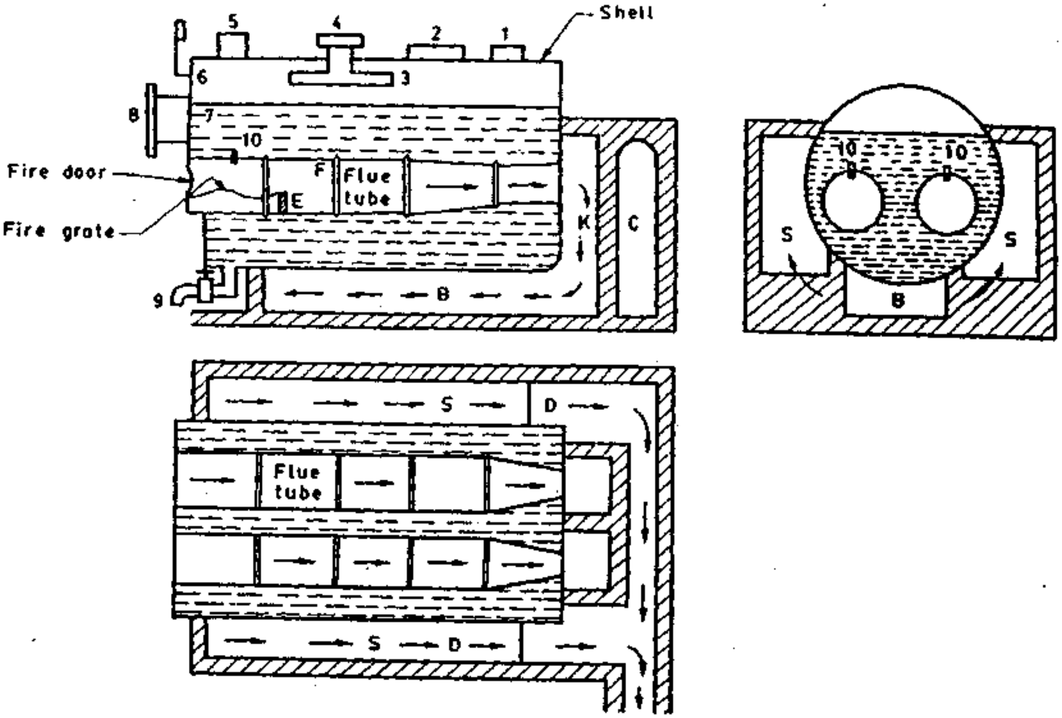
The specifications of Lancashire boiler are given below :

Diameter of the shell	....2 to 3 m
Length of the shell	.... 7 to 9 m
Maximum working pressure	...16 bar

Steam capacity ...9000 kg/hr

Efficiency .... 50 to 70%

Refer Fig. the Lancashire boiler consists of a cylindrical shell inside which two large tubes are placed. The shell is constructed with several rings of cylindrical from and it is placed horizontally over a brick work which forms several channels fro the flow of hot gases. These two tubes are also constructed with several rings of cylindrical form. They pass from one and of the shell to the other and are covered with water. The furnace is placed at the front end of each tube and they are known as furnace tubes. The coal is introduced through the fire hole into the grate. There is low brick work fire bridge at the back of the gate to prevent the entry of the burning coal and ashes into the interior of the furnace tubes.



B = Bottom flue
C = Chimney
D = Dampers
E = Fire-bridge
F = Flue tube
K = Main flue
S = Side

1. High steam low water safety valve
2. Man hole
3. Antipriming pipe
4. Steam stop valve
5. Safety valve
6. Pressure gauge
7. Feed check valve
8. Water gauge
9. Blow down cock
10. Fusible plug

Lancashire Boiler

The combustion products from the grate pass upto the back end of the furnace tubes and then in downward direction. Thereafter they move through the bottom channel or bottom flue upto the front end of the boiler where they are divided and pass upto the side flues. Now they move along the two side flues and come to the chimney flue from where they lead to the chimney. To control the flow of hot gases to the chimney. dampers (in the form of sliding doors) are provided. As a result the flow fair to the grate can be controlled. The various mountings used on the boiler are shown in Fig.

Note. In cornish and Lancashire boilers, conical shaped cross tubes known as galloway tubes (not shown) may be fitted inside the furnace tubes to increase their heating surfaces and circulation of water. But these tubes have now become absolete for their considerable cost of fitting. Moreover, they cool the furnace gases and retard ambustion.

Q. 2. (a) What are the sources of air leakage into the condenser? How its pressure is detrimental?

Ans. The main sources of air found in condenser are given below :

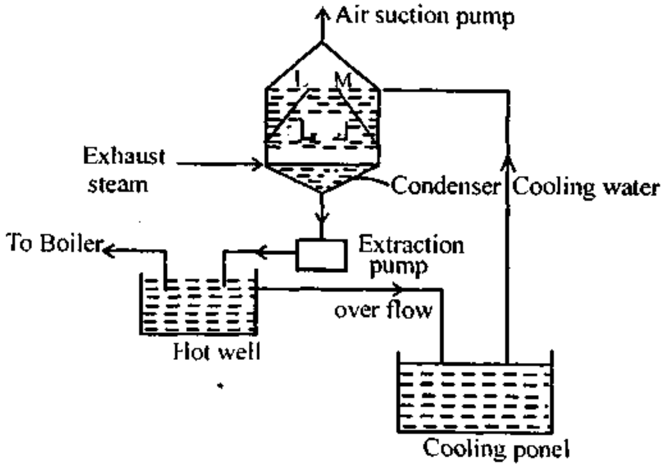
1. There is a leakage of air from atmosphere at the joints of the parts which are internally under a pressure less than that of atmosphere.
2. Air is also accompanied with steam from the boiler into which it enters dissolved in feed water. The quantity of air depends upon the treatment which the feed water receives before it enters the boiler. However, the amount of air which enters through this source is relatively small.
3. In it condensers, a little quantity of air a companies the injection water.

The following methods are used to find but the presence of air leakage.

1. Put the steam condenser under air pressure and not its effect on soap water at the prints where infiltration is likely to occur.
2. Put the pepprament oil on the suspected joint and make a check on the pepprament odour in the discharge of air ejector.
3. Large leakages in steam condenser under vacuum can be detected by moving/passing candle flame over possible openings.

Q. 2. (b) With the help of neat sketch, explain the working of low level jet condenser.

Ans. Low level jet condenser :



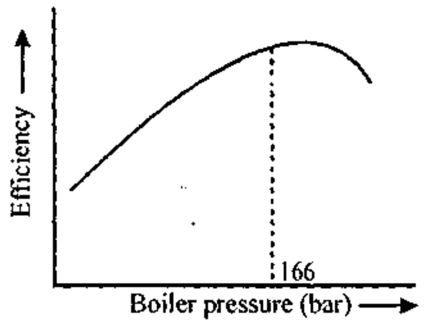
In the figure L, M, N are the perforated trays which break up water into its. The steam moving upwards comes in contact with water and gets condensed. The condensate and water mixture is sent to the hot well by means of an extraction pump and the air is removed by an air section pump provided at the top of condenser.

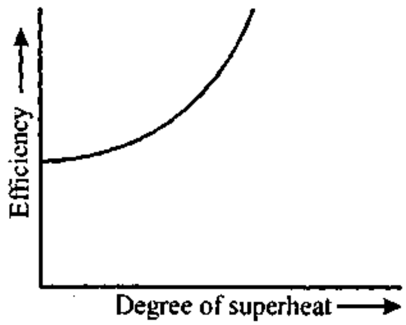
Q. 3. (a) Show the effect of initial pressure, initial temperature and back pressure on Rankine cycle.

Ans. 1. Increasing boiler pressure or initial pressure : It has been observed that by increasing the boiler pressure (other factors remaining the same) the cycle tends to rise and reaches a maximum valve at a boiler pressure of about 166 bar. [Fig. 15.5 (a)].

2. Super heating or initial temperature : All other factors remaining the same, if the steam is superheated before allowing it to expand the Rankine cycle efficiency may be increased [Fig. 15.5 (b)]. The use of super-heated steam also ensure longer turbine blade life because of the absence of erosion from high velocity water particles that are suspended in wet vapour.

3. Reducing condenser pressure or back pressure : The thermal efficiency of the cycle can be amply improved by reducing the condenser pressure [Fig. 15.5 (c)] (hence by reducing the temperature eat which heat is rejected), especially in high vacuums. But the increase in efficiency is obtained at the increased cost of condensation apparatus.





Q. 3. (b) What do you mean by binary vapour cycle? What are the advantages and disadvantages of mercury as a working fluid?

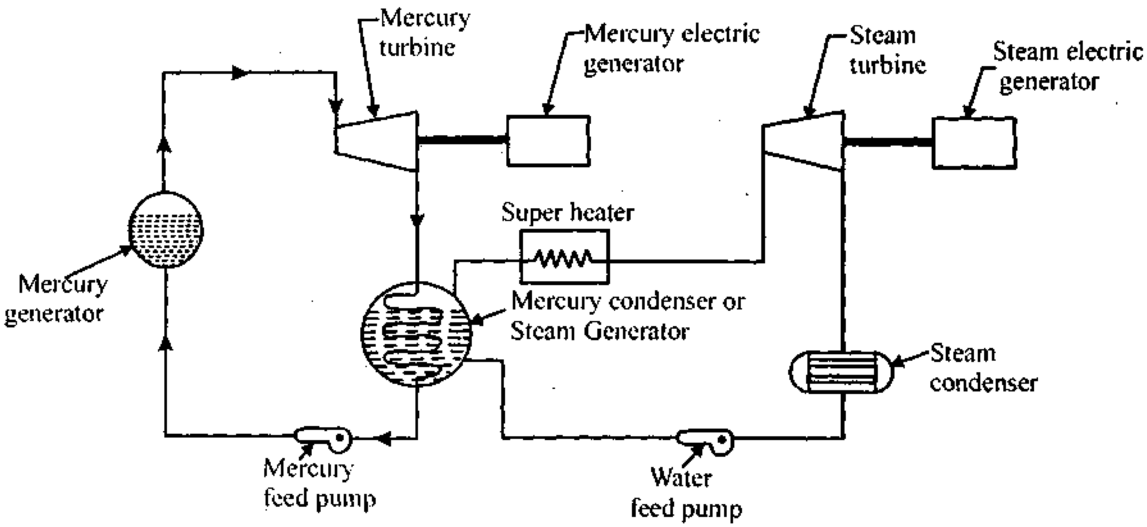
Ans. Advantage of mercury as a working fluid :

1. Its freezing point is –3.3°C C and boiling point is –354.4°C at atmospheric pressure.
2. The pressure required when the temperature of vapour is 540° C is only 12.5 bar (app.) and, therefore, heavy construction is not required to get high initial temperature.
3. Its liquid saturation curve is very steep, approaching the isentropic of the Carnot cycle.
4. It has no corrosive or erosive effects upon metals commonly used in practice.
5. Its critical temperature is so far removed from any possible upper temperature limit with existing metals as to cause no trouble.

Disadvantages :

1. Since the latent heat of mercury is quite low over a wide range of desirable condensation tempera-tures, therefore, several kg of mercury must be circulated per kg of water evaporated in binary cycle.

2. The cost is a considerable item as the quantity required is 8 to 10 times the quantity of water circulated in binary system.
3. Mercury vapour in larger quantities is poisonous, therefore, the system must be perfect and tight of binary vapour cycle using mercury and water as working .



Line diagram of binary vapour cycle

Q. 4. It is desired to compress air at 1 bar and 20°C and deliver it at 150 bar using multistage compression and intercoolers. The max. temp. during compression must not exceed 130° C and also the cooling in the intercooler is done so as not to drop the temperature below 39°C. The law If compression followed in $PV^{1.35} = C$ for all stages. Determine (i) Number of stages required (ii) Work input per kg of air (iii) The heat rejected in the intercoolers. Assume $R = 287 kJ/kg° K$, $C_v = 0.717 kJ/kg° K$.

Ans. Given

P_s = Section pressure = 1 bar.

T_s = Section temperature = 20 + 273 = 293AK

P_1 = delivery pressure from 1st stage

= energy pressure to 2nd stage.

T_1 = delivery temperature after every stage.

P_d = delivery pressure from (N + 1)th stage.

x = number of stages after the at stage.

T_{ratio} = Temperature ratios for 2nd, 3rd....nth stages

(i) Number of stages :

Thus $$\frac{P_1}{P_s} = \left(\frac{T_1}{T_s}\right)^{\frac{n}{n-1}}$$

$$= \left(\frac{130+273}{20+273}\right)^{\frac{1.35}{1.35-1}}$$

$$= \left(\frac{403}{293}\right)^{3.86} = 3.42$$

$$P_1 = P_s \times 3.42 = 1 \times 3.42 = 3.42 \text{bar}$$

Also $$\frac{T_2}{T_1} = \frac{T_3}{T_2} = \frac{T_4}{T_3} = \ldots\ldots \frac{T_x}{T_{x-1}} = T_{ratio}$$

or $$\frac{P_n}{P_1} = (T_{ratio})^{\frac{x^n}{n-1}}$$

and v

or $$\frac{150}{3.42} = (1.29)^{\frac{x \times 1.35}{1.35-1}}$$

$$43.86 = 1.29^{3.42x}$$

$$\log_e 43.86 = 3.42x \log_e 1.29$$

$$x = \frac{\log_e 43.86}{3.42 \times \log_e 1.29}$$

$$x = 4.34 \quad \text{or} \quad \text{say } 4$$

Hence number of stages $= 4 + 1 = 5$

(ii) Work done per kg of air

Pressure ratio is 1st stage $= 3.42$

Pressure ratio in the flowing stage $= \left(\frac{160}{3.42}\right)^{1/4}$

$= 2.61\text{bar}$

Temperature leaving 2nd, 3rd and 4th stage.

$$= 130 + 273 = 403\text{K}$$

Work done 1kg in 1st stage $= \frac{n}{n-1}\left\{RT_s\left[\left(\frac{P_1}{P_g}\right)^{\frac{n-1}{n}}\right] - 1\right\}$

$$= \frac{1.35}{135-1} \times 0.287 \times 293\left[(3.42)^{\frac{1.35-1}{1.35}} - 1\right]$$

$$= 121.64\text{kJ}$$

Work done in the following 2 stages

$$= 4 \times \frac{1.35}{1.35-1} \times 0.287 \times 312\left[(2.61)^{\frac{1.35-1}{1.35}} - 1\right]$$

$= 389.7\text{kJ}$

Total work done 1 Kg $= 121.64 + 389.7$

$= 51.34\ \text{kJ/kg}$

(iii) Heat rejected in the intercoolers

$= 4C_p(403 - 312)$

$= 3 \times (0.717 + .287)(403 - 312)$

$= 3 \times 1.004 \times 91$

$= 274.09\text{kJ/kg}$.

Q. 5. A steam nozzle supplied at 7 bar and 275° C discharges steam at 1 bar. If the delivering portion of the nozzle is 50 mm long and throat diameter is 4.5 mm, determine the cone angle of the divergent portion. Assume 10% of the total available enthalpy drop to be lost in friction in the diverging part. Also determine velocity and temp. of steam at the throat.

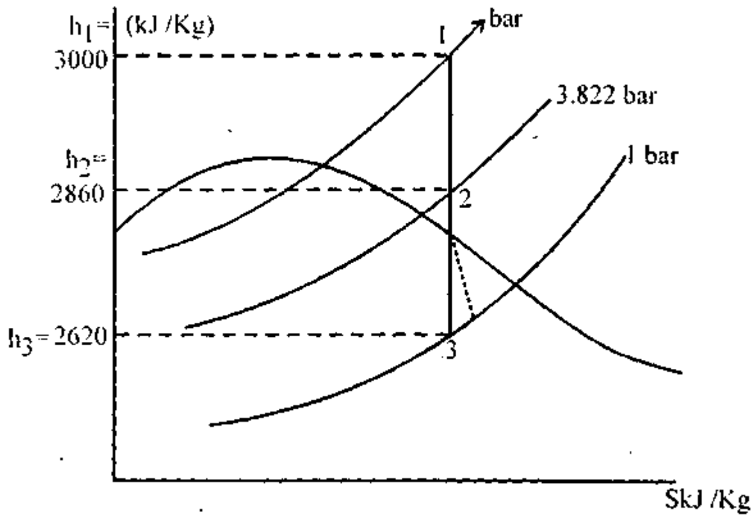
Ans. Given $P_1 = 7\text{bar}$, $T_1 = 275°\text{C}$

$P_3 = 1\text{bar}$, $K = 1 - 0.1 = 0.9$

When steam supplied to the nozzle is superheated, the pressure at throat,

$$\frac{P_2}{P_1} = \left(\frac{2}{n+1}\right)^{\frac{n}{n-1}} = \left(\frac{2}{1.3+1}\right)^{\frac{1.3}{1.3-1}} = 0.546$$

$$P_2 = P_1 \times 0.546 = 7 \times 0.546 = 3.822\text{bar}$$



From million chart.

$h_1 = 3000\,\text{kJ/kg}$, $h_2 = 2860\,\text{kJ/kg}$

$h_3 = 2620\,\text{kJ/kg}$, $T_2 = 200°C$

$v_2 = 0.55\text{m}^3\text{kg}$, $v_3 = 2\text{m}^3/\text{kg}$

From million chart

Temperature of the steam at throat = 200°C

Velocity of steam of throat

$$C_2 = 44.72\sqrt{h_d} = 44.72\sqrt{h_1 - h_2}$$

$$= 44.72\left(\sqrt{3000 - 2860}\right)$$

$$= 529.13\text{m/s}$$

From the conditions at nozzle throat mass flow rate

$$\dot{m} = \frac{A_2C_2}{V_2} = \frac{\frac{\pi}{4}\times\left(\frac{4.5}{1000}\right)^2 \times 529.13}{0.55}$$

$$= 0.015\,\text{kg/sec}.$$

At exit,

$$C_3 = 44.72\sqrt{kh_d} = 44.72\sqrt{0.9(h_1 - h_3)}$$

$$= 44.72\sqrt{0.9(3000-2620)}$$

$$= 827\,\text{m/s}$$

Exit area of the nozzle

$$A_3 = \frac{\dot{m}\times v_3^1}{C_3^1} = \frac{0.013\times 2}{827}$$

$$A_3 = 3.63\times 10^{-5}$$

i.e. $$\frac{\pi}{4}D_3^2 = 0.000031$$

$$D_3 = 0.0068\text{m}$$

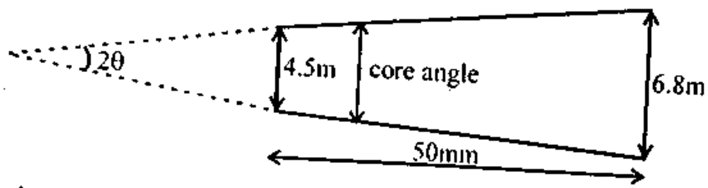
$$= 6.8\text{mm}$$

If θ be the core angle of nozzle

$$\tan\theta = \frac{6.8-4.5}{2\times 50} = 0.023$$

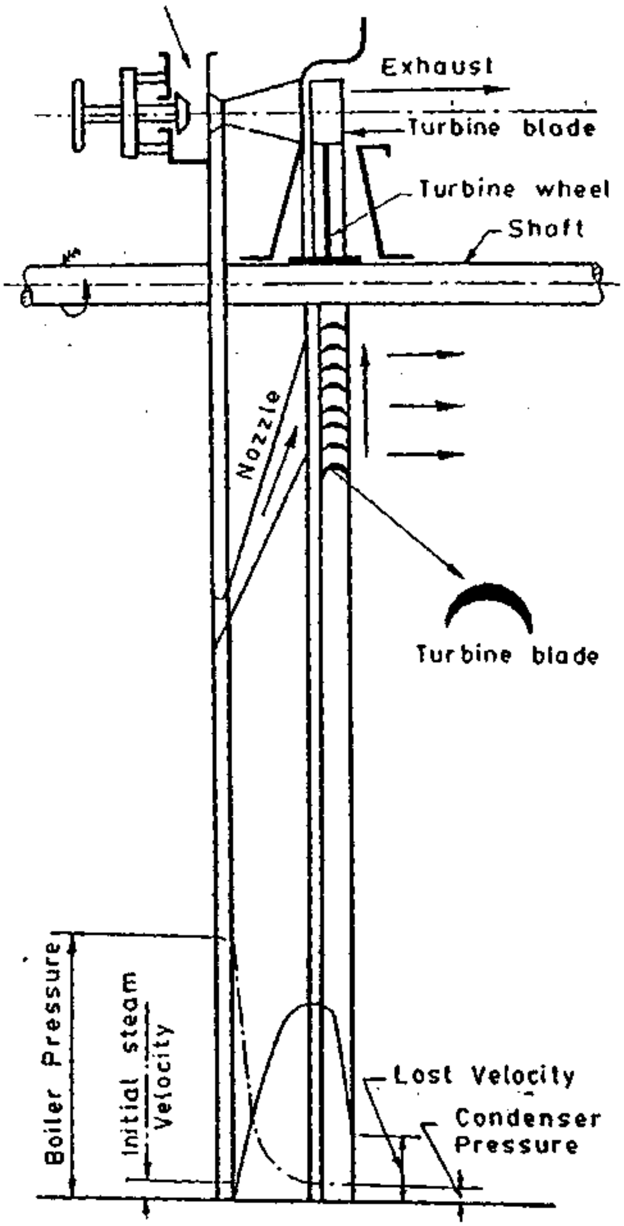
$$\theta = 1.32°$$

This cone angle $2\times 1.32 = 2.64°$



Q. 6. (a) What is degree of reaction? Explain the working of single stage reaction turbine. Also explain pressure and velocity variations along the axis of turbine.

Ans.



Simple impulse turbine

Fig. 1 shows a simple impulse turbine diagrammatically. The top portion of the figure is a longitudinal section through the upper half of the turbine, the middle portion shows one nozzles which is followed by a ring of moving blades, while lower part of the diagram indicates limitedly changes in pressure and velocity during the flow of steam through the turbine. This is called 'simple' impulse turbine since the expansion of the steam takes place in one set of nozzles.

As the steam flows through the nozzle its pressure falls from steam chest pressure to condenser are (or atmospheric pressure if the turbine is non-condensing). Due to this relatively higher expansion of steam in the nozzles the steam leaves the nozzle with a very high velocity. It is evident that the velocity of the steam leaving the moving blades is a large portion of minimum velocity of the steam when leaving the nozzle. The loss of energy due to this higher capacity is commonly the "carry over loss" or "leaving loss".

The principal example of this turbine is the well known 'Delaval turbine" and in this turbine the 'exit velocity' or 'leaving velocity' or 'lost velocity' may amount to 3.3 per cent of the nozzle outlet velocity. Also since all the kinetic energy is to be absorbed by one ring of the moving blades only, the velocity of wheel is too high (varying from 25,000 to 30,000 r.p.m.). This wheel or rotor speed however, can be reduced by different methods discussed in the following article.

Q. 6. (b) Explain the difference between Impulse turbine and Reaction turbine.

Ans. Difference between impulse and reaction turbines.

S. No.	Particulars	Impulse turbine	Reaction turbine
1.	Pressure drop	Only in nozzles and not in moving blades.	In fixed blades (nozzles) as well as in moving blades.
2.	Area of blade channels	Constant.	Varying (converging type).
3.	Blades	Profile type.	Aerofoil type.
4.	Admission of steam	Not all round or complete.	All round or complete.
5.	Nozzles/fixed blades	Diaphragm contains the nozzle.	Fixed blades similar to moving blades attached to the casing serve as nozzles and guide the steam.
6.	Power	Not much power can be developed.	Much power can be developed.
7.	Space	Requires less space for same power	Requires more space for same power.
8.	Efficiency	Low.	High.
9.	Suitability	Suitable for small power requirements.	Suitable for medium and higher power requirements.
10.	Blade manufacture	Not difficult.	Difficult.

Q. 7. (a) During a boiler test it was found that the flue gas leaving the boiler at a temp. of 275°C. The volumetric composition of the flue gas was 11.6% CO_2, 6.8% O_2 0.5% CO, and inlet air temperature was 30°C. If the coal supplied to the furnace has 78.5% by weight of carbon, estimate the heat carried away by the exit gases per kg of coal. Assume average specific heat of the flue gas to be 1.005 kJ/kg°K.

Ans. Weight of flux gases

$$= .116 \times \frac{11}{3} + .068 \times \frac{16}{6} + .005 \times \frac{7}{3}$$

$$= 2.25 kg$$

Heat taken away be flux gases.

$$= 2.25 \times 1.005(275 - 30)$$

$$= 554 kJ.$$

Q. 7. (b) Classify the fuels and define calorific value of fuel.

Ans. Classification of fuels :

Fuel can be classified according to whether.

1. They occur in nature called primary fuels or are prepared called secondary fuels.
2. They are in solid, liquid or gaseous state.

Calorific Value : The calorific value of the fuel is defined as the energy liberated by the complete ›xidation of a unit mass or volume of a fuel.

Q. 8. (a) Write short note on the following :

(a) Governing of steam turbines

(b) Analysis of fuel

(c) Surface condenser

(d) Low pressure and high pressure boilers.

Ans. (a) Governing of steam Turbine :

The objective of governing is to keep the turbine speed fairly constant irrespective of load.

The principal methods of steam turbine governing are as follows.

1. Throttle governing.
2. Nozzle governing
3. By pass governing
4. Combination of 1 and 2 and 1 and 3.

(b) Low pressure and high pressure boiler : The boiler which produce steam at pressure of 80 bar and ›ove are called high pressure boilers.

Examples : Babcock and wilcon, velox, Lamount, Benson boilers.

The boilers which produce steam at pressure below 80 bar are collect low pressure boilers examples : ›chran, Cornish, Lancashire and Locomotive boilers.

(c) Surface Condenser : In surface condenser, the exhaust steam and water do not come into direct ntact. The steam passes over the outer surface of tubes through which a supply of cooling water is mainned. There may be single pass or double pass. In single pass condensers, the water flows in one direction ly through all the tubes, while in two pass condenser the water flows in one direction through the tubes and urn through the remainder.