1.12. TWO MARK QUESTIONS AND ANSWERS

1. What are the various types of nozzles and their functions?

[Anna Univ. Apr'04 & Apr'05]

1. Convergent nozzle:

In convergent nozzles, the cross sectional area decreases from inlet section to outlet section.

2. Divergent nozzle:

In divergent nozzles, the cross sectional area increases from inlet section to outlet section.

3. Convergent-Divergent nozzle:

In a *convergent-divergent nozzle*, the cross-section of a nozzle first decreases from inlet section to throat and then it will increase from its throat to the outlet section.

2. State the relation between velocity of steam and heat during any part of a steam nozzle.

[Anna Univ. May'11 & May'12]

The heat drop is converted into kinetic energy when the steam flows through nozzle.

$$\text{Velocity, } C = \sqrt{2000 \times (h_1 - h_2)}$$

where $h_1 - h_2$ = Heat contained in steam

3. Derive the expression for the critical pressure ratio in a steam nozzle.

[Anna Univ. Nov'02]

There is only one value of the ratio (called *critical pressure ratio*) $\frac{p_2}{p_1}$ which will produce the maximum discharge. It can be obtained by differentiating 'm' with respect to $\left(\frac{p_2}{p_1}\right)$ and equating it to zero. Other quantities except the ratio $\frac{p_2}{p_1}$ are constant

$$\frac{d}{d[p_2/p_1]}\left[\left(\frac{p_2}{p_1}\right)^{\frac{2}{n}} - \left(\frac{p_2}{p_1}\right)^{\frac{n+1}{n}}\right] = 0$$

$$\frac{2}{n}\left[\frac{p_2}{p_1}\right]^{\frac{2}{n}-1} - \frac{n+1}{n}\left[\frac{p_2}{p_1}\right]^{\frac{n+1}{n}-1} = 0$$

$$\frac{2}{n}\times\left(\frac{p_2}{p_1}\right)^{\frac{2}{n}-1}=\frac{n+1}{n}\left(\frac{p_2}{p_1}\right)^{\frac{1}{n}}$$

$$\left(\frac{p_2}{p_1}\right)^{\frac{2-n}{n}}=\frac{n}{2}\times\frac{n+1}{n}\left(\frac{p_2}{p_1}\right)^{\frac{1}{n}}$$

$$\left(\frac{p_2}{p_1}\right)^{2-n}=\left[\frac{n+1}{2}\left(\frac{p_2}{p_1}\right)^{\frac{1}{n}}\right]^n=\left(\frac{n+1}{2}\right)^n\left(\frac{p_2}{p_1}\right)$$

$$\frac{\left(\frac{p_2}{p_1}\right)^{2-n}}{\left(\frac{p_2}{p_1}\right)}=\left(\frac{n+1}{2}\right)^n$$

$$\left(\frac{p_2}{p_1}\right)^{2-n-1}=\left(\frac{n+1}{2}\right)^n$$

$$\left(\frac{p_2}{p_1}\right)^{1-n}=\left(\frac{n+1}{2}\right)^n$$

$$\frac{p_2}{p_1}=\left(\frac{n+1}{2}\right)^{\frac{n}{1-n}}$$

Critical pressure ratio of steam nozzle,

$$\frac{p_2}{p_1}=\left(\frac{2}{n+1}\right)^{\frac{n}{n-1}}$$

4. ***Draw the shape of a supersonic nozzle.*** ***[Anna Univ. May'16]***

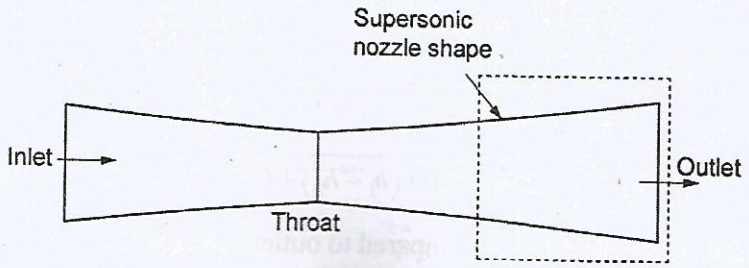


Figure 1.15 Supersonic nozzle shape

5. ***What are the effects of friction on the flow through a steam nozzle?***

[Anna Univ. Apr'03, Nov'04, Nov'07, Nov'10, May'11, May'14 & May'18]

1. The expansion is no more isentropic and the enthalpy drop is reduced thereby resulting the reduced exit velocity.
2. The final fraction of the steam is increased as the part of the kinetic energy gets converted into heat due to friction and absorbed by steam within increase in enthalpy.
3. The specific volume of steam is increased as the steam becomes dried due to this frictional reheating.

6. ***What are the factors reducing the final velocity of steam in nozzle flow?***

[Anna Univ. Dec'10]

1. The friction between nozzle surface and steam.
2. The internal fluid friction in steam
3. Shock losses.

7. ***Write the general energy equation for a steady flow system and from this obtain the energy equation for nozzle.*** ***[Madras University Oct'96]***

Steady flow energy equation,

$$h_1 + \frac{1}{2}mC_1^2 + mgz_1 + Q = h_2 + \frac{1}{2}mC_2^2 + mgz_2 + W$$

If mass flow rate is unit, $m = 1$

$$h_1 + \frac{1}{2}C_1^2 + gz_1 + Q = h_2 + \frac{1}{2}C_2^2 + gz_2 + W$$

For nozzle, there is no heat transfer, no work transfer and no potential energy difference. So,

$$Q = 0,\ W = 0 \quad \text{and } g\,z_1 = g\,z_2$$

$$h_2 + \frac{1}{2}C_1^2 = h_2 + \frac{1}{2}C_2^2$$

$$C_2 = \sqrt{2(h_1 - h_2) + C_1^2}$$

$$C_2 = \sqrt{2000\,(h_1 - h_2) + C_1^2} \qquad [\because h \text{ unit is } kJ/kg]$$

Inlet velocity C_1 is negligible as compared to outlet velocity C_2.

$$C_2 = \sqrt{2000\,(h_1 - h_2)} = 44.72\ \sqrt{h_1 - h_2}$$

8. ***Define nozzle efficiency.*** **[*Anna Univ. Nov'03, Apr'04, Nov'10, Dec'11 & Dec'13*]**

Co-efficient of Nozzle or *nozzle efficiency* is defined as the ratio of actual enthalpy drop to isentropic enthalpy drop.

$$\text{Nozzle efficiency} = \frac{\text{Actual enthalpy drop}}{\text{Isentropic enthalpy drop}}$$

9. ***If the enthalpy drop in a steam nozzle of efficiency 92% is 100 kJ/kg, determine the exit velocity of steam.*** ***[Anna Univ. May'17]***

Given data:

$h_1 - h_2 = 100$ *kJ/kg*

Nozzle efficiency, $\eta = 92\% = 0.92$

☺ ***Solution:***

Velocity of steam at exit by considering the nozzle efficiency,

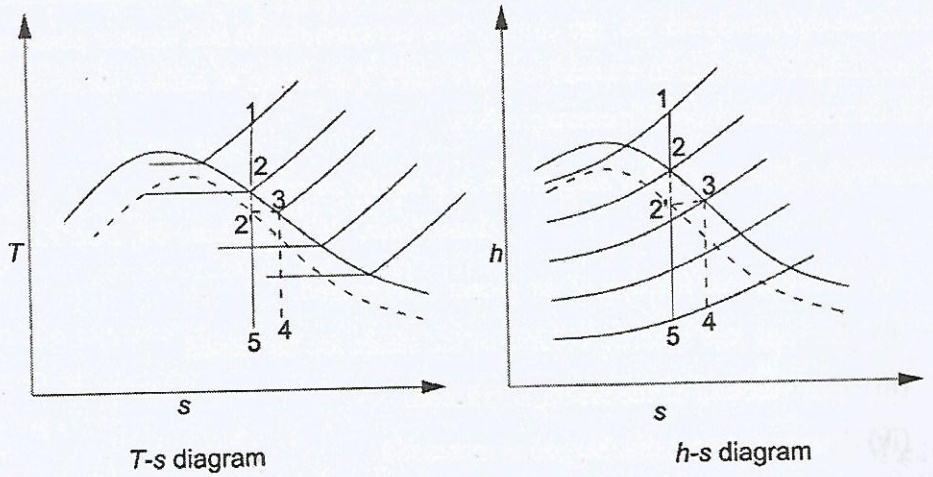
$$C_2 = \sqrt{2000 \times (h_1 - h_2) \times \eta}$$

$$= \sqrt{2000 \times 100 \times 0.92} = \mathbf{428.95\ m/s} \qquad \textbf{Ans.}$$

10. ***Define critical pressure ratio.*** **[*Anna Univ. Nov'03, Apr'04, Nov'10, May'17 & Dec'17*]**

Critical pressure ratio is one only value of the ratio (p_2/p_1) which produces the maximum discharge from the nozzle. The ratio is called *critical pressure ratio*.

11. ***Draw T-s and h-s plot of supersaturated expansion of steam in a nozzle.*** ***[Anna Univ. Apr'05]***



T-s diagram *h-s* diagram

Figure 1.16

12. Calculate the value of critical pressure ratio for saturated and supersaturated steam.

[Anna Univ. Apr'08, Dec'12 & Dec'13]

(i) For saturated steam $n = 1.135$, critical pressure ratio

$$\frac{p_2}{p_1} = \left(\frac{2}{n+1}\right)^{\frac{n}{n-1}}$$

$$\frac{p_2}{p_1} = \left(\frac{2}{1.135+1}\right)^{\frac{1.135}{1.135-1}}$$

Critical pressure ratio, $\frac{p_2}{p_1} = 0.577$

(ii) For super heated steam $n = 1.3$

$$\frac{p_2}{p_1} = \left(\frac{2}{n+1}\right)^{\frac{n}{n-1}}$$

$$\frac{p_2}{p_1} = \left(\frac{2}{1.3-1}\right)^{\frac{1.3}{1.3-1}}$$

Critical pressure ratio, $\frac{p_2}{p_1} = 0.546$

13. What are the conditions that produce super saturation of steam in nozzles?

[Anna Univ. Nov'04, Dec'08 & May'15]

When the supersaturated steam is expanded in the nozzle, the condensation should occur in the nozzle. Since the steam has a great velocity, the condensation does not take place at the expected rate. So, the equilibrium between liquid and vapour phase is delayed and the steam continues to expand in a dry state. The steam in such a set of conditions is said to be supersaturated or metastable flow.

14. What are the effects of super saturation in a steam nozzle?

[Anna Univ. Nov'02, June'09, Dec'12 & Nov'15]

(i) The dryness fraction of the steam is increased.

(ii) Entropy and specific volume of the steam are increased

(iii) Exit velocity of the steam is reduced.

(iv) Mass of stream discharged is increased.

15. ***What are the differences between supersaturated flow and isentropic flow through steam nozzles?***

Supersaturated flow	*Isentropic flow*
1. Entropy is not constant.	Entropy is constant.
2. It reduces enthalpy drop.	There is no reduction in enthalpy drop.
3. Mollier diagram cannot be used to solve problems.	Mollier diagram can be used to solve problems.

1.13. SOLVED QUESTIONS

1. Derive an expression for mass flow rate through the nozzle.

Refer chapter **1.5** in Page **1.3**.

2. Derive the condition for maximum discharge or maximum flow rate in a steam nozzle. [*Anna Univ. June'09, Dec'12 & May'18*]

Refer chapter **1.6** in Page **1.6**.

3. What are the effects of friction in a nozzle? Explain. [*Anna Univ. May'13*]

Refer chapter **1.7** in Page **1.8**.

4. Derive the equation for critical pressure ratio in steam nozzle. [*Anna Univ. Dec'17*]

Refer chapter **1.8** in Page **1.9**.

5. Explain the metastable expansion of steam in a nozzle with help of *h-s* diagram. [*Anna Univ. Apr'04 & May'15*]

Refer chapter **1.9** in Page **1.10**.

6. What are the effects of super saturation?

Refer chapter **1.9.1** in Page **1.11**.

7. Explain the physical significance of Wilson's line as referred to supersaturated flow through steam nozzles. [*Anna Univ. May'11 & May'12*]

Refer Page **1.11**.

2.18. TWO MARK QUESTIONS AND ANSWERS

1. Define boilers.

Boiler is a closed vessel in which the steam is generated from water by applying heat. The heated or vaporized fluid exits the boiler for the use in various processes or heating applications. A boiler or steam generator is used where a source of steam is needed.

2. State how the steam boilers are classified. *[Anna Univ. Dec'14]*

Steam boilers are classified on the basis of boiler pressure, fuel, boiler material, boiler tube type, circulation, method of combustion, type of support, furnace construction, furnace position, use, erection, mobility, ASME code and heat source.

3. Compare water tube boilers and fire tube boilers.

S. No.	*Water tube boiler*	*Fire tube boiler*
1.	The water is circulated through a large number of tubes and the hot gases pass outside the water.	The hot gases are passed through the tubes and the water circulates around the tubes.
2.	Working pressure is up to 165 *bar*.	Working pressure is up to 25 *bar*.
3.	The rate of generation of steam is high.	The rate of generation of steam is low.
4.	It is suitable for large power plants.	It is not suitable for large power plants.
5.	Construction is simple.	Construction is difficult.
6.	More skill is required for efficient operation.	Less skill is required for efficient operation.
7.	Treatment of feed water is essential.	Treatment of feed water is not very essential.
8.	Operating cost is high.	Operating cost is less.
9.	Overall efficiency is 90%.	Overall efficiency is 75%.

4. What is called high pressure boiler?

A boiler which generates steam at a pressure of 85 *bar* or above is termed a *high pressure boiler*. The high pressure boilers working pressure is much higher than the critical pressure of steam. These boilers are either water tube or fire tube and it may be classified as natural and forced circulation boilers.

5. ***What are the salient features of Benson boiler?***

1. It can be comparatively erected in a smaller floor area.
2. As there are no drums, the total weight of boiler is 20% less than other boilers.
3. It can be quickly started.
4. Circulating pump and down comers are dispensed.
5. The furnace walls of the boiler can be more efficiently protected by using smaller diameter and close pitched tubes.
6. Easy transportation is possible.
7. It can be most economically operated by varying the temperature and pressure at partial loads and overloads.
8. It has only 4% of blow down losses.
9. No special starting arrangement superheater is required.

6. ***List out the major advantages of high pressure boilers in modern thermal power plants.*** ***[Anna Univ. Dec'12 & Dec'13]***

(i) The tendency of scale formation is eliminated due to high velocity of water through tubes.

(ii) Light weight tubes with better heating surface arrangement can be used. The space required is less. The cost of foundation and time of erection are minimised due to less weight of tubes used.

(iii) Due to use of forced circulation, there is more freedom in the arrangement of surface, tubes and boiler components.

(iv) All parts are uniformly heated. So, the danger of overheating is reduced and the thermal stress problem is simplified.

(v) The difference in expansion is reduced due to uniform temperature and circulation. There is a greater flexibility in components arrangement.

7. ***Define super critical boilers.*** ***[Anna Univ. Nov'07]***

Boilers only with economiser and superheater are called *super critical boilers*.

8. ***What is super-critical boiler?*** ***[Anna Univ. June'13 & Dec'15]***

If boilers incorporate only economiser and superheater, they are called *supercritical boilers*. The super critical boilers are above 300 *MW* capacity units available.

Example: Velox boiler and Loeffler boiler.

9. *Name any two boiler accessories and state their functions.* ***[Anna Univ. Apr'04]***

1. Economiser:

It is used for heating feed water by utilizing the heat in the exhaust flue gases before leaving through the chimney.

2. Super heater:

The function of a super heater is to increase the temperature of the steam above its saturation temperature.

10. *Define boiler mountings and accessories.* ***[Anna Univ. May'11]***

The devices which are used for functioning the safe operation of a boiler are called *boiler mountings*. The devices which are used to increase the efficiency of the boiler are called *boiler accessories*.

11. *What are the advantages of once-through boilers?*

(i) It is more suitable for sliding pressure operation.

(ii) Steam temperature can be easily maintained for a wide load range.

(iii) It conserves the fuel resources.

(iv) It needs only shorter start up time.

(v) It improves the efficiency of the boiler.

12. *What are called fluidized bed combustion?*

Boilers which are used to produce steam from fossil and waste fuels by using the technique *Fluidized Bed Combustion (FBC)* are called *fluidized bed combustion boilers*.

13. *Mention the advantages of fluidized bed combustion system.*

1. It can use solid, liquid or gaseous fuel or mix as well as domestic and industrial waste.
2. Solid mixing is rapid. So, high heat transfer rates can be obtained from the surface immersed in bed and more effective use of tube surface owing to its immersion within the bed. It can lead to saving of 75% of power for tubes.
3. Combustion temperature can be actually controlled and it can be low enough to minimse the volatisation of ash constituents such as alkali materials because the temperature is well below the melting point of most gas-borne solid particles.
4. It is simple in arrangement, small in size of the plant and reduced corrosion or erosion of gas turbine blades.

5. Higher sulphur content coals can be used due to the presence of SO_2 by the combustion of sulphur.
6. High ash containing coal can be efficiently burnt in FBC.

14. State the functions of fusible plug.

The fusible plug is used to extinguish the fire in the event of the boiler shell failing below a certain specified limit. Thus, the explosion is avoided which may take place due to overheating of the tubes and shell.

15. Why are superheaters used in steam power plants? ***[Anna Univ. Dec'12]***

The steam produced in the boiler is in the state of saturated condition. The moisture in the steam will affect turbine blades and cause corrosion. To avoid it, the superheater is used. It is used to increase the temperature of steam and to improve the efficiency.

16. What is the necessity of feed pump in thermal power plant? ***[Anna Univ. Dec'11]***

Feed pump is a pump which is used to deliver the feed water to the boiler. The quantity of water supplied should be at least equal to the amount of evaporation which is supplied to the engine.

17. Mention the two types of feed water heaters in a steam power plant.

[Anna Univ. Dec'10]

(i) Open feed water heater

(ii) Closed feed water heater.

18. What is the function of deaerator in a thermal power plant? ***[Anna Univ. May'12]***

Dearearator is a device widely used for the removal of air and other dissolved gases from the feed.

19. Write the use of water level indicator in boiler. ***[Anna Univ. Dec'13]***

The water level indicator constantly determines the level of water in the boiler shell.

20. What are the accessories used in a boiler? ***[Anna Univ. May'13]***

(1) Feed water pump

(2) Injector

(3) Pressure reducing valve

(4) Economiser

(5) Air pre heater

(6) Superheater

(7) Steam drier or separator

(8) Steam trap.

21. Distinguish between fouling and slagging. ***[Anna Univ. May'05***

Slagging is the formation of molten or partially fused deposits on furnace walls or convection surfaces exposed to radiant heat.

Fouling is defined as the formation of deposit on convection heat surfaces such as superheater and reheaters.

22. State the advantages of liquid fuels.

1. It has higher calorific value.
2. It requires lesser space in use.
3. It keeps cleanliness surroundings.
4. It eliminates wear and tear of grate.
5. It is easy to control of combustion.
6. It is easy to handle and supply.

23. State the purpose of boiler testing and trial.

(i) To estimate the steam production capacity of the boiler at full load.

(ii) To find the thermal efficiency of the boiler and

(iii) To prepare a heat balance sheet for the boiler.

24. Define the terms "accounted heat loss and unaccounted heat loss".

The heat losses which can be determined by the observations made during the trial are known as *accounted heat losses*.

The heat losses which cannot be accurately determined are known as *unaccounted heat losses*.

25. List down the various heat losses considered to calculate the heat balance.

1. Heat carried away by dry flue gas (Q_g).
2. Heat lost due to moisture present in fuel (Q_m).
3. Heat lost due to unburnt coal falling through grate bars (Q_u).
4. Heat lost due to incomplete combustion of carbon (Q_c).
5. Heat lost due to radiation (Q_r).

6. Heat carried away by excess air (Q_a).
7. Heat lost due to hydrogen present in fuel (Q_h).

26. *Define the following terms "Boiler efficiency, heat rate and steam rate".*

Boiler efficiency is defined as the ratio of heat energy used in steam formation to the heat energy supplied by burning of fuel in the same period.

Heat rate is the amount of heat required to produce per *kWhr* of work.

Steam rate is the amount of network produced per *kg* of fuel.

27. *Calculate the cycle efficiency of boiler having a heat rate of 10285.72 kJ/kWhr.*

$$\text{Heat rate} = \frac{\text{Heat supplied}}{\text{Net work done}}$$

$$\text{Efficiency} = \frac{\text{Net workdone}}{\text{Heat supplied}}$$

$$\text{So, efficiency} = \frac{1}{\text{Heat rate}} = \frac{1}{\frac{10285.72}{3600}} \times 100 = 35\%$$ **Ans.**

28. *What is meant by boiler inspection?*

Inspection of boilers comprises the activities which are necessary for getting the correct knowledge regarding a physical condition of all parts of boiler and accessories.

29. *List any four important areas to be checked during inspection of boiler.*

1. Checking the tubes for corrosion and pitting.
2. Checking the knuckle heads, shells, welds, rivets and tubes for grooving.
3. Checking the seams, nut heads and shell plates for cracks.
4. Checking the feed pipe whether it is clean or partially clogged.

30. *Mention any four procedures of inspection.*

1. Inspection for registration
2. Hammer test
3. Hydraulic test
4. Steam test.

31. *What is the safety regulations used in boilers?*

1. The boiler should be fitted with all necessary mountings and they should be checked for proper functioning.

2. Danger of explosion or fire should be avoided. Fire-fighting equipment must be kept in ready conditions for use at any time.
3. Safety devices must be used by workers to avoid cuts, burns, falls and bruises to workmen.
4. Guards, railings, steps and floor must be kept clean.
5. Constant watch on the mountings such as water level indicator is necessary.

2.19. SOLVED QUESTIONS

1. Classify boilers.

Refer chapter **2.1.1** in Page **2.1**.

2. With a neat sketch explain the working principle of Cochran boiler.

Refer chapter **2.2** in Page **2.5**.

3. Describe the working of Lancashire boiler with its neat sketch.

Refer chapter **2.3** in Page **2.6**.

4. Enumerate the working of locomotive boiler with its neat sketch.

Refer chapter **2.3** in Page **2.6**.

5. Explain the working of Cornish boiler.

Refer chapter **2.5** in Page **2.8**.

6. With a neat sketch explain the working principle of Babcock and Wilcox boiler.

Refer chapter **2.6** in Page **2.9**.

7. Compare the characteristics features of a fire tube boiler and water tube boiler.

[APJ AKTU June'17]

Refer chapter **2.7** in Page **2.10**.

8. Explain with neat sketch the construction and working of La Mont Boiler.

[Anna Univ. (Mech.) Dec'05, May'06 & May'13]

Refer chapter **2.8.1** in Page **2.11**.

9. Draw a neat line diagram of Benson boiler and discuss its relative merits and demerits.

[Anna Univ. (Mech.) Dec'04, Dec'14 & (EEE) June'13]

Refer chapter **2.8.2** in Page **2.13**.

stages of the turbine when the load exceeds the economic load. Nozzle control governing is not preferable because of small enthalpy drop in the first stage of a high-pressure turbine.

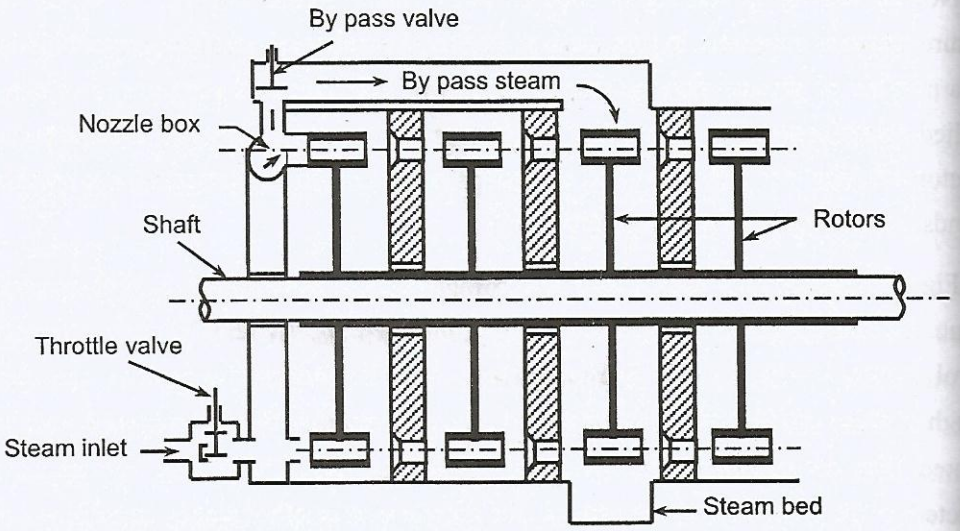


Figure 3.47 By-pass governing

Further, in the case of higher loads, the extra steam required cannot be admitted through additional nozzles in the first stage due to many practical reasons. Those difficulties are overcome by using by-pass governing. Figure 3.47 shows an arrangement of a by-pass governing system. Steam through a throttle valve enters the nozzle box or steam chest. The throttle valve is controlled by a speed regulator or governor. In general, up to economic load the governing of steam turbine speed is done by throttling. For loads greater than the economical load, a by-pass line is provided in such a way that steam passes directly from the first stage nozzle box into a latter stage. The by-pass of steam is automatically controlled by the lift of the valve. This valve is controlled by the speed governor for different loads within this range.

3.28. TWO MARK QUESTIONS AND ANSWERS

1. What is a steam turbine?

Steam turbine is a device which is used to convert the kinetic energy of steam into mechanical energy.

2. State the use of large sizes and small sizes turbines.

In large sizes, it is used for driving electric generators. In small sizes, it is used to drive pumps, fans, compressors etc.

3. ***Classify steam turbines.***

Steam turbines are classified as follows:

1. On the basis of method of steam expansion
   - (a) Impulse turbine
   - (b) Reaction turbine
   - (c) Combination of impulse and reaction turbine.
2. On the basis of number of stages
   - (a) Single stage turbine
   - (b) Multi-stage turbine.
3. On the basis of steam flow directions
   - (a) Axial turbine
   - (b) Radial turbine
   - (c) Tangential turbine
   - (d) Mixed flow turbine.
4. On the basis of pressure of steam
   - (a) High pressure turbine
   - (b) Low pressure turbine
   - (c) Medium pressure turbine.

4. ***How does impulse turbine work?***

The high velocity jet of steam which is obtained from the nozzle impinges on blades fixed on a rotor. The blades change the direction of the steam flow without changing its pressure. It causes the change in momentum and the force developed drives the turbine rotor.

5. ***What are the principles of impulse and reaction turbines?*** ***[Anna Univ. Dec'11]***

In impulse turbines, the high velocity jet of steam which is obtained from the nozzle impinges on blades fixed on a rotor. The blades change the direction of the steam flow without changing its pressure. It causes the change in momentum and the force developed drives the turbine rotor.

In reaction turbines, there is no sudden pressure drop. There is a gradual pressure drop and it continuously takes place over the fixed and moving blades. A number of

wheels are fixed to the rotating shaft. Fixed guide ways are provided in between such pair of rotating wheels.

6. ***State the function of fixed blades.***

The function of fixed blades is to guide steam as well as to allow it for expansion to a large velocity.

7. ***State the function of moving blades.***

1. It converts the kinetic energy of the steam into useful mechanical energy.
2. The steam expands while flowing over moving blades and thus, it gives reaction to moving blades. Hence, the turbine is called *reaction turbine*.
3. The velocity of the steam decreases as the kinetic energy of the steam is absorbed.

8. ***What is the fundamental difference between the operation of impulse and reaction steam turbines?*** ***[Anna Univ.Nov'03, Apr'04, Dec'10, May'11, May'16 & May'18]***

S. No.	*Impulse turbine*	*Reaction turbine*
1.	It consists of nozzles and moving blades.	It consists of fixed blades and moving blades.
2.	Pressure drop occurs only in nozzles not in moving blades.	Pressure drop occurs in fixed as well as moving blades.
3.	Steam strikes the blade with kinetic energy.	Steam passes over the moving blades with pressure and kinetic energy.
4.	It has constant blade channels area.	It has varying blade channels area.
5.	Due to more pressure drop per blade, the number of stages required is less.	Number of stages required is more due to more pressure drop.

9. ***Define the term compounding in turbines.*** ***[Anna Univ. Nov'10 & Dec'1***

Compounding is a method of absorbing the jet velocity in stages when the steam flows over moving blades.

10. ***Explain the need of compounding in steam turbines.***

[Anna Univ. Apr'03, Nov'04, Apr'08 & Nov'1

In a simple impulse turbine, the expansion of steam from the boiler pressure to condenser pressure takes place in a single stage turbine. The velocity of steam at the exit

of turbine is very high. Hence, there is a considerable loss of kinetic energy (i.e. about 10 to 12%). Also, the speed of the rotor is very high (i.e. up to 30000*rpm*). There are several methods of reducing this speed to lower value. *Compounding* is a method of absorbing the jet velocity in stages when the steam flows over moving blades.

11. *How are fixed blades and moving blades arranged in velocity compounding?*

A number of moving blades are arranged in the form of rings of fixed blades keyed in series on a common shaft.

12. *State any two advantages and disadvantages of velocity-compounded turbines.*

Advantages:

1. Its initial cost is less because of few numbers of stages.
2. Less space is required.

Disadvantages:

1. Frictional losses are high due to high initial velocity. Hence, the efficiency is low.
2. The ratio of blade velocity to steam velocity is not optimum for all wheels. It also reduces the efficiency.

13. *What is pressure compounding?*

[Anna Univ. May'15]

The pressure is reduced in each stage of nozzle rings and hence, it is called *pressure compounding*.

14. *What is the optimum blade ratio of impulse turbine for maximum blade efficiency?*

$$\frac{C_b}{C_1} = \frac{\cos\alpha}{2}$$

where α be the nozzle outlet angle

C_b be the blade velocity and C_1 be the absolute velocity of steam.

15. *What is blading efficiency?*

[Anna Univ. Nov'07]

Blade efficiency is defined as the ratio between work done on the blade and energy supplied to the blade.

$$\eta_b = \frac{\text{Workdone on the blade}}{\text{Energy supplied to the blade}} = \frac{2C_b\left(C_{w_1} + C_{w_2}\right)}{C_1^2}$$

16. *Define degree of reaction.*

[Anna Univ. Apr'04 & May'14]

Degree of reaction is defined as the ratio of isentropic heat drop in moving blades to isentropic heat drop in the entire stage of the reaction turbine.

$$R = \frac{\text{Enthalpy drop in moving blades}}{\text{Enthalpy drop in the entire stage}} = \frac{h_2 - h_3}{h_1 - h_3}$$

17. *What is meant by the term governing in turbines?*

The method of maintaining the speed of the turbine is constant irrespective of variation of the load on the turbine known as *governing of turbines*.

18. *What is the function of governors in steam turbine?* ***[Anna Univ. Dec'08]***

Maintaining the speed of the turbine is constant irrespective of variation of the load on the turbine known as *governing of turbines*. The governors regulate the supply of steam to the turbine in such a way that the speed of the turbine is maintained constant as far as possible under varying load conditions.

19. *What are the different methods of governing steam turbines?*

[Anna Univ. Nov'04 & May'13]

1. Throttle governing
2. Nozzle control governing
3. By-pass governing
4. Combination of throttle and nozzle governing or throttle and by-pass governing.

20. *How is throttle governing done?*

Steam pressure at inlet to a steam turbine is reduced by throttling process to maintain the speed of the turbine constant at part load.

21. *Enumerate the energy losses in steam turbines.*

[Anna Univ. June'09, May'11 & May'12]

1. Losses in regulating valves
2. Losses due to steam friction
3. Losses due to mechanical friction
4. Losses due to leakage
5. Residual velocity losses
6. Carry over losses
7. Losses due to wetness of steam
8. Losses due to radiation.

4.16. TWO MARK QUESTIONS AND ANSWERS

1. ***Define cogeneration.***

Cogeneration is also called *combined heat power*. Cogeneration works based on the concept of producing two different forms of energy by using a single source of fuel. In other words, *cogeneration* is defined as the arrangement of producing more than one useful form of energy. Out of these two forms, one must be heat or thermal energy and other one is either electrical or mechanical energy.

2. ***Write down the need for cogeneration.***

(i) Cogeneration helps to improve the efficiency of the plant.

(ii) Cogeneration reduces air emissions of particulate matter, nitrous oxides, sulphur dioxide, mercury and carbon dioxide which would lead to greenhouse effect.

(iii) It reduces the cost of production. Also, it improves the productivity.

(iv) Cogeneration system helps to save water consumption and water costs.

(v) Cogeneration system is more economical as compared to conventional power plants.

3. ***Mention the various circumstances under which cogeneration system are preferred.***

Cogeneration is to be most attractive under the following circumstances:

(i) The demand for both steam and power is balanced. Power output ratios can be obtained from a suitable cogeneration plant.

(ii) A single plant or group of plants has sufficient demand for steam and power to permit economies of scale to be achieved.

(iii) Peaks and troughs in demand can be managed or adequate backup supplies can be obtained from the utility company.

4. ***List down the types of cogeneration power plants.***

(i) Topping cycle power plant

(ii) Bottoming cycle power plant.

5. ***What are the configurations of cogeneration plants?***

(i) Gas turbine combined heat power plants which uses the waste heat in the flue gas emerging from gas turbines.

(ii) Steam turbine combined heat power plants use the heating system in which the steam jet is used for the steam turbine.

(iii) Molten-carbonate fuel cells have a hot exhaust which will be more suitable for heating.

(iv) Combined cycle power plants can be adapted for combined heat and power.

6. *State the factors influencing cogeneration.*

(i) Base electrical load matching

(ii) Base thermal load matching

(iii) Electrical load matching

(iv) Thermal load matching

(v) Heat-to-Power ratio

(vi) Quality of thermal energy needed

(vii) Fuel availability

(viii) System reliability

(ix) Retrofit versus new installation.

7. *Define utilization factor.*

Utilization factor (ε) of a cogeneration plant is the ratio of the energy utilized for a useful purpose to the total energy supplied. It could be unity for a plant that it does not produce any power. It is also defined as the ratio of sum of net work and process heat to the heat supplied in a boiler. The utilization factor of cogeneration plant is calculated by

$$\varepsilon_{cogen} = \frac{\text{Energy utilized for a useful purpose}}{\text{Total heat supplied}} = \frac{W_{net} + Q_p}{Q_s}$$

8. *What is meant by trigeneration cycle?*

A plant producing electricity, heat and cold is called a *trigeneration cycle* or *polygeneration plant*. The utilization factor of trigeneration plant is calculated by

$$\varepsilon_{trigen} = \frac{\text{Net work or Power output + Heat output + Cooling output}}{\text{Total heat supplied}}$$

$$\varepsilon_{trigen} = \frac{W_{net} + Q_p + Q_{cooling}}{Q_s}$$

In trigeneration systems, electricity generation is 45%, heating and cooling is 40%, heat loss is 13% and electrical line loss is 2%.

9. *Define work ratio.*

The term work ratio is useful parameter for power plant cycles. It is defined as the ratio of network transfer in a cycle to the positive work transfer or turbine work in the cycle.

$$\text{Work ratio} = \frac{\text{Net work transfer}}{\text{Positive work transfer}} = \frac{\text{Net work output}}{\text{Turbine output}}$$

10. *What is meant by back work ratio?*

Back work ratio is defined as the ratio of work input to the pump to the work output of the turbine. It represents the percent of the turbine work output which is used just to drive the pump.

$$\text{Back work ratio} = \frac{\text{Work input to the pump}}{\text{Work output of the turbine}} = \frac{W_p}{W_T}$$

11. *List down the applications of cogeneration technology.*

(a) Prisons
(b) Hospitals
(c) Hotels
(d) Leisure
(e) Data centres
(f) Industrial sectors
(g) Military applications
(h) Waste water treatment
(i) District heating
(j) Mixed developments
(k) Horticulture
(l) Education establishments.

12. *Write down any two advantages and disadvantages of cogeneration.*

Advantages of cogeneration:

1. Cogeneration reduces cost of production and improves productivity.
2. Cogeneration system helps to save water consumption and water costs.
3. Cogeneration system is more economical as compared to conventional power plant.
4. Cogeneration reduces dependency on non-renewable energy sources.

Disadvantages of cogeneration:

1. Cogeneration systems are only suitable for sites where there is a need for heating and hot water systems.

2. The capital and maintenance costs for a cogeneration system is higher than those for a conventional plant which can make it expensive for smaller scale (non-domestic) installations.
3. In order for cogeneration plants to be most feasible a certain match between electricity and heating needs is required.
4. It is also only suitable for use where both hot water and electricity are needed, and at consistently high and sustained levels.

13. Define residual heat.

Residual heat or *waste heat* is the heat that is produced by a machine or other process using energy as a byproduct of doing work. In other words, the residual heat is heat which is generated in a process by the way of fuel combustion or chemical reaction and then "dumped" into the environment even though it could still be reused for some useful and economic purpose.

14. Mention the benefits of residual heat recovery.

(i) Reduction in pollution

(ii) Reduction in equipment sizes

(iii) Reduction in auxiliary energy consumption.

15. State the applications of residual heat recovery.

(i) Preheating (of combustion air, boiler feedwater, water)

(ii) Load preheating

(iii) Power generation

(iv) Steam generation (for use in power generation, mechanical power, process steam)

(v) Space heating

(vi) Transfer to liquid or gaseous process streams.

16. Classify residual heat energy based on temperature range.

(i) Ultra low temperature

(ii) Low temperature

(iii) Medium temperature

(iv) High temperature

(v) Ultra high temperature.

17. Write down the sources of residual heat in major industries.

(i) Steam generation

(ii) Fluid heating

(iii) Calcining

(iv) Drying

(v) Heat treating

(vi) Metal heating

(vii) Metal and non-metal melting

(viii) Smelting, agglomeration etc.

(ix) Curing and forming

(x) Other heating.

18. What are the residual heat sources from process heating equipment?

(i) Hot gases

(ii) Sensible-latent heat in heated product

(iii) Cooling water or other liquids

(iv) Radiation-convection heat loss

(v) Hot air or gas from cooling/heating system

(vi) Heat losses in providing chilled water or in the disposal of chilled water

(vii) Heat stored in products leaving the process.

19. What are Three "R"s of residual heat?

(i) Waste heat REDUCTION within the system or equipment

(ii) Waste heat RECYCLING within the process or the heating system itself and

(iii) Waste heat RECOVERY within the plant or industrial complex.

20. State the methods to utilize residual heat.

(i) In-process recycling

(ii) In-plant recovery

(iii) Electricity generation.

21. Name the different methods to covert residual heat to power.

(i) Conventional plant using a steam power plant called *Rankine cycle*

(ii) Organic Rankin Cycle (ORC) plant

(iii) Ammonia-water systems (i.e. Kalina, Neogen systems)

(iv) Thermo-electric power generation (TEG).

22. Write down the applications of residual heat utilization.

(i) Iron and steel industry

(ii) Cement and building material industry

(iii) Food and beverage processing industry

(iv) Pulp and paper industry

(v) Chemical industry

(vi) Petroleum industry

(vii) Landfill gas energy systems and

(viii) Oil and gas production.

23. Mention the industrial applications of heat pipes.

(i) Processing space heating

(ii) Process to process heating

(iii) Cooling system

(iv) Preheating of boiler combustion air

(v) Recovery of waste heat from furnaces

(vi) Reheating of fresh air for hot air driers.

24. Define recuperator.

Recuperators are counter flow heat exchangers in which heat transfer take place between waster flue gases and air through metallic or ceramic walls. Ducts or tubes carry the air to be preheated in the combustion chamber whereas the other side contains the waste heat stream.

25. What is called regenerator?

Regenerator is a type of heat exchanger where heat from the hot fluid is intermittently stored in a thermal storage medium before it is transferred to the cold fluid. To accomplish this, the hot fluid is brought into contact with the heat storage medium and then the fluid is displaced with the cold fluid which absorbs the heat.

26. Define heat pipe.

Heat pipe is a thermal energy absorbing and transferring system which does not have moving parts. Therefore, it needs minimal maintenance. It can transfer up to 100 times more thermal energy than copper which is the best-known conductor.

17. ***Define heat pump.***

Heat pump is a device which is used to supply heat to a hot system. In other words, it is used to maintain the temperature of the body higher than the surroundings.

4.17. SOLVED QUESTIONS

1. Write short notes on cogeneration.

Refer chapter **4.2** in Page **4.2**.

2. Explain topping cycle cogeneration with its neat sketch.

Refer chapter **4.4.1** in Page **4.4**.

3. Describe bottoming cycle cogeneration with its neat sketch.

Refer chapter **4.4.2** in Page **4.5**.

4. Enumerate the effect of turbine and pump efficiency on net power developed, process heat and utilization factor.

Refer chapter **4.7.1** in Page **4.12**.

5. Write down the applications of cogeneration.

Refer chapter **4.8** in Page **4.54**.

6. Explain the advantages and disadvantages of cogeneration.

Refer chapter **4.9** in Page **4.55**.

7. Discuss the benefits of residual heat recovery.

Refer chapter **4.10.1** in Page **4.58**.

8. Describe the residual heat sources from process heating equipment.

Refer chapter **4.10.5** in Page **4.60**.

9. Explain in-process recycling with a neat sketch.

Refer chapter **4.11.1** in Page **4.61**.

10. Discuss the working of in-plant recovery with a neat sketch.

Refer chapter **4.11.2** in Page **4.64**.

11. Explain how conventional steam power plant can be used as residual heat recovery system with a neat sketch.

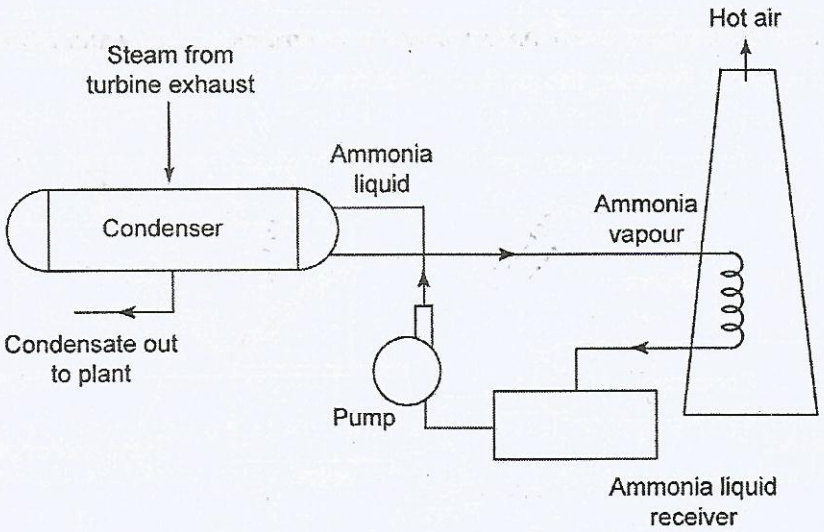


Figure 5.138 Indirect cooling tower using ammonia

5.28. TWO MARK QUESTIONS AND ANSWERS

1. ***Which thermodynamic cycle is used in air conditioning of airplanes using air as refrigerant?*** ***[Anna Univ. June'09]***

Air cycle refrigeration with reverse Brayton cycle (Gas turbine cycle) is mainly used as an air-conditioning system in airplanes due to the reason of readily available compressed air.

2. ***What are the requirements of a refrigerator?*** ***[Anna Univ. Dec'17]***

A refrigerator is essential equipment in the kitchen for keeping foods safe. When the power goes off or the unit fails, putting our food's safety in jeopardy to our daily lives. Refrigeration slows bacterial growth. Bacteria exist everywhere in nature. They are in the soil, air, water and the foods what we eat. When they have nutrients (food), moisture and favorable temperatures, they grow rapidly in increasing numbers to the point where some types of bacteria can cause illness. Especially, bacteria grow most rapidly in the range of temperatures between 4.4°*C* and 60°*C*. So, a refrigerator can be set at 4.4°*C* or below will protect most foods.

3. ***Define tonne of refrigeration.***

[Anna Univ. May'04, May'06, Dec'06, Nov'10, May'14 & May'15]

A *tonne of refrigeration* is defined as the quantity of heat to be removed from one tonne of water (1000 *kg*) at 0° *C* to convert that into ice at 0° *C* in 24 *hours*.

1 *tonne of refrigeration* = 210 *kJ/min* = 3.5 *kW*

4. *Show the air-refrigeration cycle on p-V and T-s diagrams.* *[Anna Univ. Nov'03]*

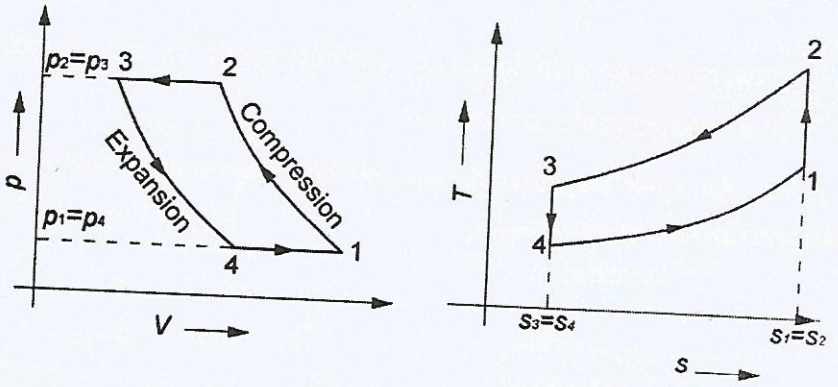


Figure 5.139 p-V and T-s diagrams

5. *Define tonne of refrigeration. Heat is removed from a space at a rate of 42,000 kJ/h. Express this heat removal rate in tons.* *[Anna Univ. May'05]*

Definition is same as previous Q3.

Heat removed, $Q = 42000\ kJ/h = 700\ kJ/min$

1 tonne of refrigeration $= 210\ kJ/min = \dfrac{700}{210} = 3.33$ *tonnes* **Ans.**

6. *Define the COP of refrigerators.* *[Anna Univ. Nov'07 & Dec'10]*

Coefficient of performance (COP) is defined as the ratio of heat absorbed by the evaporator or refrigeration effect to the compressor work.

$$\text{COP} = \frac{\text{Refrigeration effect}}{\text{Work done}}$$

7. *A Carnot refrigerator requires 1.3 kW per tonne of refrigeration to maintain a region at low temperature of – 38° C. Determine the COP of the refrigerator and the higher temperature of the cycle.* *[Anna Univ. May'07]*

1 tonne of refrigeration = 3.5 *kW* of heat will be removed

Heat required $= 1.3\ kW$

$$\text{COP} = \frac{\text{Refrigeration effect}}{\text{Work done}} = \frac{3.5}{1.3} = 2.69$$

$$\text{Carnot COP} = \frac{T_2}{T_1 - T_2} = \frac{235}{T_1 - 235}$$

$$\therefore \quad T_1 = 322.36\ K = 49.36°C$$ **Ans.**

8. *How does the actual vapor compression cycle differ from that of the ideal cycle?* ***[Anna Univ. Apr'05]***

1. In actual cycles, pressure losses occur in both condenser and evaporator.
2. Friction losses occur in compressor.

9. *Sketch the T-s and p-h diagrams for the vapour compression cycle when the vapour after compression is dry saturated.* ***[Anna Univ. Dec'11 & May'16]***

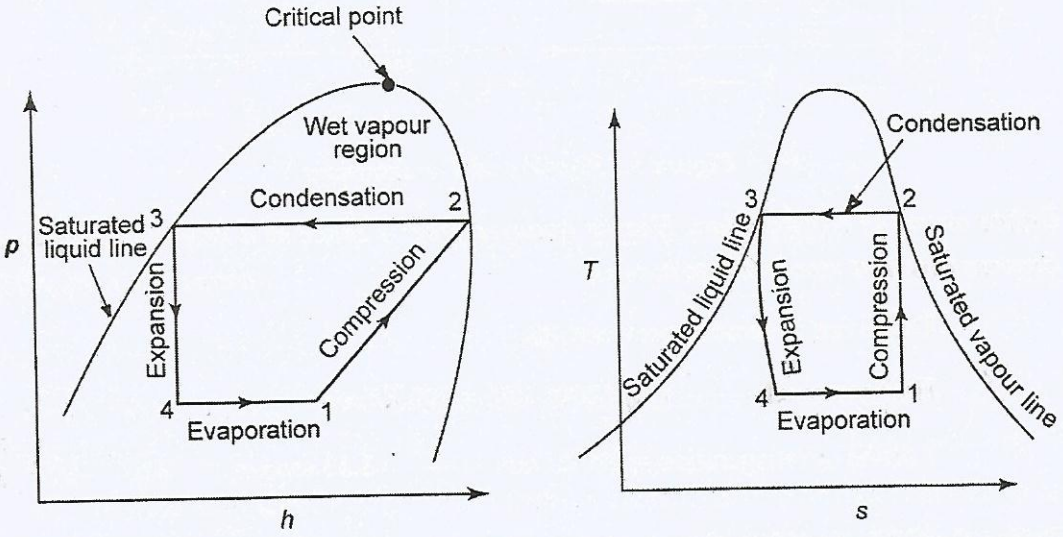


Figure 5.140

10. *What is meant by refrigeration?* ***[Anna Univ. Nov'10]***

Refrigeration is the process of providing and maintaining the temperature in space below atmospheric temperature.

11. *What is the function of the throttling valve in vapour compression refrigeration system?* ***[MU-Oct'99]***

The function of throtting valve (Expansion valve) is to allow the liquid refrigerant under high pressure and temperature to pass at controlled rate after reducing its pressure and temperature.

12. *Name any four commonly used refrigerants.* ***[MU-Oct. 2000]***

1. Ammonia (NH_3)
2. Carbon dioxide (CO_2)
3. Sulphur dioxide (SO_2)
4. Freon - 12

13. What are the expansion devices used in a vapour compression plant? When are they used? ***[Anna Univ. Dec'12]***

Two widely used expansion devices in a vapour compression plant are:

1. Throttling valve
2. Capillary tubes.

Capillary tubes are used only for small plants. In these tubes, once the length and size are fixed, no modification in operation can be made since the evaporative pressure is fixed. Throttling valves are used in larger plants because they regulate the flow of the refrigerant according to the load on the evaporator.

14. Why throttle valve is used in place of expansion cylinder for vapour compression refrigerant machine. ***[Oct'95]***

In throttling process, enthalpy remains constant and pressure is reduced. So, a throttle valve is used.

15. What are the effect of superheat and subcooling on the vapour compression cycle? ***[Anna Univ. May'03]***

Superheating increases the refrigeration effect and COP may be increased or decreased but subcooling always increase the COP of refrigeration and also decrease the mass flow rate of refrigerant.

16. Define refrigerant. ***[Oct'96]***

Any substance capable of absorbing heat from another required substance can be used as refrigerant.

17. What are the properties of good refrigerant? ***[Anna Univ. May'03, Oct'02, May'06, Dec'13 & May'14]***

1. The refrigerant should have low freezing point.
2. It must have high critical pressure and temperature to avoid large power requirements.
3. It should have low-specific volume to reduce the size of the compressor.
4. It should be nonflammable, non-explosive, non-toxic and non-corrosive.
5. It should give high COP in the working temperature range. It is necessary to reduce the running cost of the system.
6. It must have low specific heat and high latent heat.

18. What are the advantages and disadvantages of air refrigeration system?

[Anna Univ. May'03 & Dec'04]

Advantages:

1. The refrigerant used namely air is cheap and easily available.
2. There is no danger of fire or toxic effects due to leakages.
3. The weight to *tonne* of refrigeration ratio is less as compared to other systems.

Disadvantages:

1. The quantity of refrigerant used per *tonne* of refrigeration is high as compared to other systems.
2. The COP of the system is very low. Therefore, running cost is high.
3. The danger of frosting at the expander valves is more as the air contains moisture content.

19. What is the objective of undercooling? Sketch the process in T–s diagram? [Oct' 95]

or

What is meant by subcooling in vapour compression system?

[Anna Univ. Dec'04 & May'12]

The process of cooling the liquid refrigerant below its saturation temperature in the condenser is known as *subcooling*. This process is shown in Figure 5.141 as 3-3'.

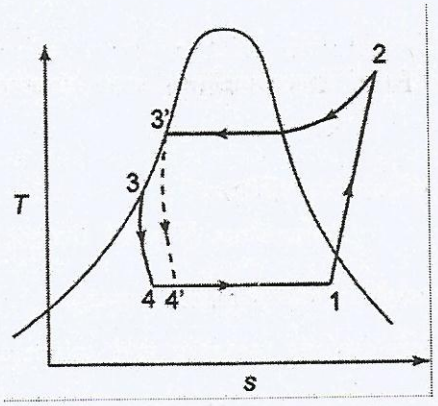


Figure 5.141 T-s diagram

20. What are the methods to obtain subcooling of refrigerant? [Anna Univ. May'11]

1. Suction-liquid heat exchanger
2. Two stage reciprocating and centrifugal compressors with economizer.

21. What is net refrigerating effect of the refrigerant? ***[Apr' 97]***

Refrigerating effect is the total heat removed from the refrigerant in the evaporator.

$$\text{COP} = \frac{\text{Refrigeration effect}}{\text{Work done}}$$

Refrigeration effect = COP × Work done

22. Name the various components used in simple vapour absorption system.
[Anna Univ. Apr'96 & Dec'13]

1. Absorber
2. Pump
3. Generator
4. Condenser
5. Throttle valve
6. Evaporator.

23. What types of condensers are in common used for vapour absorption refrigeration system? ***[Oct'96]***

Water-cooled condensers are commonly used for vapour absorption refrigeration system.

24. What is the function of analyzer and rectifier in an absorption system?

Analyser prevents water vapours from entering the condenser. It helps in preventing the choking of pipelines. Even after passing through the analyzer if any water vapours present that will be removed in the rectifier.

25. What is the purpose of generator assembly in vapour absorption refrigeration system?
[Anna Univ. Nov'10]

The function of generator is to heat the strong solution to form vapour of the refrigerant.

26. What is the difference between wet compression and dry compression?
[Anna Univ.Apr'08, May'11 & May'12]

In wet compression, the compression starts between saturated liquid and saturated vapour region. The vapour enters the compressor at wet vapour conditions.

In dry compression, the compression starts with saturated vapour. The vapour enters the compressor at dry vapour conditions.

27. Write the advantages and disadvantages of vapour absorption system. ***[Anna Univ. Dec'12]***

Advantages:

(i) There is no need of electric power.

(ii) Wear and tear is less.

(iii) Tonne of capacity is high.

(iv) There is no leakage of refrigerant.

(v) Heat energy is supplied.

(vi) Space requirement is less.

(vii) Energy requirement is high.

Disadvantage:

Charging of refrigerant is difficult.

28. Compare vapour compression and adsorption systems. ***[Anna Univ. May'18]***

S. No.	*Vapour compression system*	*Vapour absorption system*
1.	Electric power is needed to drive the system.	There is no need of electric power.
2.	Wear and tear is more because of moving components.	Wear and tear is less.
3.	Tonne capacity is low.	Tonne capacity is high.
4.	Charging of refrigerant is simple.	Charging of refrigerant is difficult.
5.	More chances for leakage of refrigerant.	There is no leakage of refrigerant.
6.	Mechanical energy is supplied.	Heat energy is supplied.
7.	Performance at part load is poor.	At part loads, the performance is not affected.
8.	Space requirement is more.	Space requirement is less.
9.	Energy requirement is low.	Energy requirement is high.

29. Define Air-conditioning. ***[Anna Univ. Nov'10 & May'18]***

Air conditioning is the process of supplying sufficient volume of clean air containing a specific amount of water vapour and maintaining the predetermined atmospheric condition with in a selected enclosure.

30. List out the basic elements of an air conditioning system. ***[Anna Univ. May'16]***

(i) Compressor
(ii) Condenser coil
(iii) Fan
(iv) Evaporator coil
(v) Air handling unit
(vi) Air filters
(vii) Drainage system and pan.

31. Define the term "apparatus dew point". ***[Anna Univ. May'11]***

For dehumidification, the cooling coil is to be kept at a mean temperature which is below the dew point temperature (DPT) of the entering. This temperature of the coil is called *ADP temperature*.

32. What is dew point temperature? ***[Anna Univ. May'07, Dec'08 & Dec'10]***

It is the temperature at which the water vapour present in air begins to condense when the air is cooled known as *dew point temperature*.

For saturated air, the dry bulb, wet bulb and dew point temperature are all same.

33. Define wet bulb temperature and degree of saturation. [Anna Univ. Dec'06 & Nov'07]

Wet bulb temperature (WBT) (t_w):

It is the temperature of air measured by a thermometer when its bulb is covered with wet cloth and it is exposed to a current rapidly moving air. It is denoted by t_w.

Degree of saturation:

It is defined as the ratio of specific humidity of the most air to the specific humidity of saturated air at the same temperature.

Degree of saturation (or) percentage humidity (or) saturation ratio

$$\mu = \frac{\text{Specific humidity of moist air}}{\text{Specific humidity of saturated air}}$$

34. Define specific humidity. ***[Anna Univ. Dec'06]***

It is defined as the mass of water vapour present in one *kg* of dry air. It is the ratio of the mass of water vapour to the mass of dry air in a given volume of the moisture.

$$\text{Specific humidity, } \omega = \frac{\text{Mass of water vapour}}{\text{Mass of dry air}} = \frac{m_v}{m_a}$$

35. Define Relative humidity of air. ***[Anna Univ. May'13 & May'17]***

Relative humidity plays a major role in the comfort air conditioning and industrial air conditioning to compare with specific humidity. It is defined as the ratio of the actual mass of water vapour present in the moist air to the mass of water vapour present in saturated air at the same temperature and pressure.

$$\text{Relative humidity, } \phi = \frac{\text{Mass of water vapour present in the moist air}}{\text{Mass of water vapour present in the saturated air}} = \frac{m_v}{m_s}$$

36. Define 'Wet bulb depression'. ***[Anna Univ. June'09]***

Wet bulb depression is the difference between dry bulb temperature and wet bulb temperature

WBD = DBT – WBT

The value of wet bulb depression is zero when the air becomes saturated.

37. Name some Psychrometric processes and represent them on the Psychrometric chart.

Various psychrometric processes are represented on Psychrometric chart below:

(i) Sensible heating (0 – 1)
(ii) Sensible cooling (0 – 2)
(iii) Humidifying (0 – 3)
(iv) Dehumidifying (0 – 4)
(v) Heating and humidifying (0 – 5)
(vi) Heating and dehumidifying (0 – 6)
(vii) Cooling humidifying (0 – 7)
(viii) Cooling dehumidifying (0 – 8).

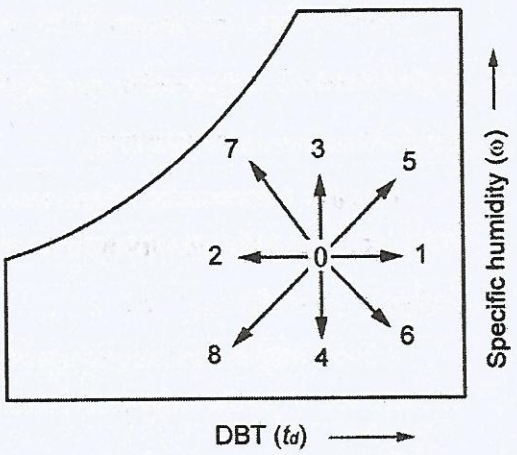


Figure 5.142

38. What is sensible heating or cooling? ***[Anna Univ. Dec'12]***

Sensible heating:

Air is heated at constant specific humidity. It means, heating is done without adding moisture. During heat addition, the dry bulb temperature increases from t_{d_1} to t_{d_2}. So, $\omega_1 = \omega_2$ but $t_{d_2} > t_{d_1}$.

Sensible cooling:

In sensible cooling processes, refrigerant is sent inside the coil instead of steam to cool the air. During this process, the dry bulb temperature reduces from t_{d_1} to t_{d_2}. So, the heat present in the air is extracted by refrigerant. But, there is no addition of moisture in the air. So, $t_{d_1} > t_{d_2}$ and $\omega_1 = \omega_2$.

39. *Explain adiabatic humidification of air.* ***[Anna Univ. Dec'08]***

The air is passed through an insulated chamber. This insulating chamber has sprays in which water is maintained at a temperature higher than the dew point temperature of entering air but lower than its dry bulb temperature. So, both cooling and humidification are done without supplying or rejecting heat from the water spray. At the same time, the same water is recirculated again and again.

40. *Atmospheric air with dry bulb temperature of 28° C and a wet bulb temperature of 17°C is cooled to 15° C without changing its moisture content. Find (a) original and final relative humidity (b) final wet bulb temperature. (Use psychometric chart).*

[Anna Univ. Dec'11]

Given data:

Dry bulb temperature, $t_{d_1} = 28°C$

Wet bulb temperature, $t_{w_1} = 17°C$

Dry bulb temperature, $t_{d_2} = 15°C$

☺ ***Solution:***

Corresponding to Dry bulb temperature, $t_{d_1} = 28°C$ and wet bulb temperature, $t_{w_1} = 17°C$ in Psychrometric chart,

The original relative humidity, $\phi_1 = 34\%$ **Ans.**

The final relative humidity, $\phi_2 = 72.5\%$ **Ans.**

The final wet bulb temperature, $t_{w_2} = 13.2° C$ **Ans.**

41. *How are air-conditioning systems classified?*

(a) Based on construction of components:

(i) Unitary system

(ii) Central system

(iii) Package system

(iv) Split units.

(b) Based on fluid flow methods:

(i) Direct expansion (DX) system

(ii) Chilled water (DX) system

(iii) Chilled water air washer system.

42. How does humidity affect human comfort? ***[Anna Uni. Apr'03 & Nov'15]***

If the humidity is above a certain level, water vapour from human body moisture cannot be absorbed by the atmospheric air. It results in discomfort because of sweating.

43. What are the various sources of heat gain of an air-conditioned space?

(i) Solar gain through glass planes

(ii) Solar gain through roof and walls

(iii) Heat gain from occupants

(iv) Heat gain from appliances and lights

(v) Duct leakage

(vi) Infiltration

(vii) Vapour transmission.

44. On a Psychrometric chart, show all the property lines.

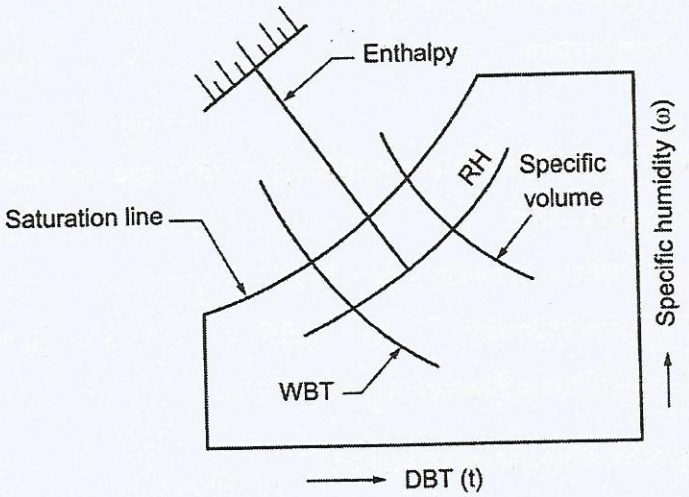


Figure 5.143

45. What do you mean by the term "Infiltration" in heat load calculations? ***[Anna Univ.Apr'03]***

In an air conditioning system, the heat that is coming into the system by the door opening, cracks in buildings, cracks and gaps in the windows are known as *infiltration*.

46. *Define RSHF and RTH.* ***[Anna Univ. Apr'03, Apr'08, May'14 & Dec'17]***

RSHF (Room Sensible Heat Factor) is the ratio of Room Sensible Heat (*RSH*) to the Room Total Heat (RTH).

$$i.e., \quad RSHF = \frac{RSH}{RTH} = \frac{RSH}{RSH + RLH}$$

RTH (Room Total Heat) is the sum of Room Sensible Heat and Room Latent Heat.

$$i.e., \quad RTH = RSH + RLH$$

47. *What is the significance of RSHF in summer air conditioning?* ***[Anna Univ. May'17]***

For the given room sensible and latent cooling loads, the supply condition must always lie on this line so that the it can extract the sensible and latent loads on the conditioned space in the required proportions.

48. *Define the term GSHF.* ***[Anna Univ. Apr'08, May'15 & Dec'17]***

GSHF (Gross or Grand Sensible Heat Factor) is the ratio of total sensible heat (TSH) to the grand total heat (GTH).

$$i.e., \quad GSHF = \frac{TSH}{GTH} = \frac{TSH}{TLH + TSH}$$

49. *Define the terms gross sensible heat factor and effective sensible heat factor.* ***[Anna Univ. May'15]***

Effective sensible heat factor (*ESHF*) is the ratio of effective room sensible heat to the effective room total heat.

$$i.e., \quad ESHF = \frac{ERSH}{RTH}$$

50. *Define bypass factor (BPF) of a coil.*

The ratio of the amount of air which does not contact the cooling coil (amount of bypassing air) to the amount of supply air is called *BPF*.

$$i.e., \quad BPF = \frac{\text{Amount of air bypassing the coil}}{\text{Total amount of air passed}}$$

51. *State the effects of very high and a very low bypass factor.*

Very high bypass factor:

(i) It requires lower ADP. Refrigerant plant should be of larger capacity.

(ii) It requires more air. Larger fan and motor are required.

(iii) It requires less heat transfer area.

(iv) It requires more chilling water. Larger piping is required.

Very low by pass factor:

(i) Higher ADP is to be employed.

(ii) It requires less air. Fan size and motor size are reduced.

52. *What factors affect bypass factor?*

1. Pitch of fins
2. Number of coil tubes
3. Air velocity over the coil
4. Direction of air flow.

53. *What are the requirements of comfort A/C?*

1. Supply of O_2 and removal of CO_2.
2. Removal of heat of occupants.
3. Removal of moisture of occupants.
4. Good air distribution.
5. Maintaining air purity.

54. *Define effective temperature (ET).*

Effective temperature is defined as that temperature of saturated air at which the subject would experience the same feeling of comfort as experienced in the actual unsaturated environment.

55. *What factors affect effective temperature?*

1. Climatic and seasonal differences
2. Clothing
3. Age and sex
4. Activity and Stay duration
5. Air velocity.

56. *What are the general comfort conditions during summer and winter?*

Summer:

Inside temperature $24° \pm 1°C$

RH 50 – 60% and air movement 4.5 – 7.5 *m/min*

Winter:

Inside temperature 20° ± 1°C

RH 35 – 40% RH.

57. *Distinguish summer and winter air conditioning.* ***[Anna Univ. Nov'15]***

S. No.	*Summer air conditioning*	*Winter air conditioning*
1.	Heat is removed from the air by humidification process.	Heat is added to the air by dehumidification process.
2.	Dry space will be cooler than humid space at the same temperature.	Humid space will be cooler than dry space at the same temperature.
3.	Moisture will evaporate quickly from skin.	Moisture will not evaporate on skin.

58. *Enumerate the components of cooling load estimate. [Anna Univ. May'11 & May'12]*

(i) Heat flow through the exterior walls, ceilings, floors, doors and windows.

(ii) Heat by solar radiation.

(iii) Heat received from the occupants.

(iv) Heat received by infiltrated air *etc.*, adds to the amount of heat into the room and hence, it may be considered as a 'load'. The A/C system should be capable of handling this heat load. In this context, the heat load estimation is assumed as important one and it has to be accurately arrived at.

59. *What are the factors affecting cooling of water in cooling tower?*

[Anna Univ. (EEE) May'10]

(i) The exposing time

(ii) Amount of water surface exposed

(iii) Relative humidity of air

(iv) Velocity of air

(v) Accessibility of air to various parts of cooling tower.