Lecture 35

COOLING AND DRYING OF COMPRESSED AIR.

Learning Objectives

Upon completion of this chapter, Student should be able to

- Explain the importance of secondary treatment of compressed air
- List the various functions of an after cooler
- Describe the functions of air and water coolers
- Explain the theory of air dryers
- Describe various types of air dryers used in pneumatic Industry
- List the various functions of Air receiver
- Differentiate Air receiver and Air accumulators
- Size the Air receiver and compressor

1.1 IMPORTANCE OF SECONDARY TREATMENT

Compressed air is an essential power source that is widely used throughout industry. This safe, powerful and reliable utility is the most important part of production process. However, compressed air will contain water, dirt, wear particles and even degraded lubricating oil which all mix together to form an unwanted condensate. This condensate often acidic, rapidly wears tools and pneumatic machinery, blocks valves and orifices causing high maintenance and costly air leaks. It also corrodes piping systems and can bring production process to an extremely expensive standstill.

The quality of air required throughout a typical compressed air system can vary. It is highly recommended that the compressed air is treated prior to entry into the distribution system as well as at each usage point or application. This approach to system design provides the most cost effective solution to system purification as it not only removes the contamination already in the distribution system, it ensures that only the most critical areas receive air treated to the highest level. In many instances the compressed air system will be supplying air to more than one application and although the purification equipment specified in the compressor room would remain unchanged, the point of use protection will vary depending upon the air quality requirements of each application. In many cases this action alone is not enough, as modern production systems and processes demand an even higher level of air quality.

Where required, “point of use” filtration, refrigeration or desiccant air dryers can provide the correct air quality, without the need for drying the complete compressed air installation, which can be both costly and totally unnecessary.

The three desirable qualities of compressed air are:

a) **Compressed air must be cleaned**: Dirty or contaminated air may cause seals to wear. Dirt can wedge into clearance between moving parts or block air passages which may cause faulty operation or component failure
b) **Compressed air must be cooled:** Heat is undesirable due to the fact that if this hot air is passed directly into the pipes, they would elongate die to the heat. Contraction would occur when compressor is shut down. This recurring process would cause the joint to leak and reduce efficiently. Therefore, flexibility must be built in. Instead of discharging air from the compressor outlet directly into the air receiver for storage, the air is passed through the after cooler
c) **Compressed air must be dried**: water in compressed air lines can wash away lubricant from pneumatic tool parts causing rapid wear increased air consumption, and increased maintenance costs. Moisture can freeze at the exhaust of tools and interfere with their efficient operation. In applications like paint spraying, air agitation of liquid etc. moisture can cause rejections and scrap work. There are several ways to remove moisture from compressed air before it can damage. Generally, the least expensive is after cooling.

1.2 AFTER COOLER

Air compression process may be designed to either to be adiabatic or to involve heat transfer, depending on the purpose for which the gas is compressed. If the compressed air is to be used promptly in engine, adiabatic compression may be required. In much application, however, air is stored in a tank for use as needed. The air in the tank loses heat to the surroundings and reaches room temperature when finally used. In this case the overall effect of compression and storage is to increase pressure of gas without change of temperature. In can be shown that if the gas is cooled during compression, instead of after the process, the work required will be less than for adiabatic compression. A further advantage of cooling is the reduction of volume and the consequent reduction of pipe line losses. For this reason, since cooling during compression is not very effective, after coolers are often used to cool the gas leaving the compressor.

The compressed air discharged from an air compressor is hot. Compressed air at these temperatures contains large quantities of water in vapour form. After coolers are heat exchangers for cooling the discharge from a air compressor. They use either air or water and are an effective means of removing moisture from compressed air.

After coolers control the amount of water vapour in a compressed air system by condensing the water vapour into liquid form. In a distribution or process manufacturing system, liquid water can cause significant damage to the equipment that uses compressed air. An after cooler is necessary to ensure the proper functionality of pneumatic or air handling devices that are a part of process manufacturing systems

About 75 % of the moisture can be removed using after cooler. A moisture separator installed at the discharge of the after cooler removes most of the liquid moisture and solids from the compressed air. Utilizing centrifugal force, moisture and solids collect at the bottom of the moisture separator. An automatic drain should be used to remove the moisture and solids

1.2.1 Functions of compressed air after coolers

- Cool air discharged from air compressors via the heat exchanger
- Reduce risk of fire (Hot compressed air pipes can be a source of ignition)
- Reduce compressed air moisture level
- Increase system capacity
- Protect downstream equipment from excessive heat

Coolers are usually sized with a CTD (Cold Temperature Difference) of 2.7°C, 5.5°C, 8.3°C, or 11°C. This means that the compressed air temperature at the outlet of the after cooler will be equal to the cooling medium temperature plus the CTD when sized at the specified inlet air temperature and flow.

1.2.2 Types of after coolers.

There are two basic types of air after coolers:

1. Air-cooled
2. Water-cooled.

Compressor manufacturers may include after coolers within the compressor package. In general these compressors are referred to as integral after coolers. A stand-alone or freestanding after cooler is a separate unit installed downstream of the compressor.

1.2.2.1 Air-Cooled After cooler

Air-Cooled After coolers provide economical cooling by using ambient air to cool the hot compressed air from an air compressor. They cool the hot compressed air leaving the compressor at a temperature of approximately 100°C to 150°c to the desired inlet temperature of an air dryer which is approximately 35°c to 50°c. As the compressed air cools, about 75% of the water vapour present condenses into liquid water which should be immediately removed from the system with a separator. Air-Cooled After coolers can be sized to cool the hot compressed air to within -15°c to -5°F of the ambient air temperature. They are available in capacities from 500 LPM to100000LPM

1.2.2.2 Water-Cooled Pipe Line after cooler

The most common style for compressed air service is a Shell and Tube Heat Exchanger. The pipe line after cooler consists of a shell with a bundle of tubes fitted inside. Typically the compressed air flows through the tubes in one direction as water flows on the shell side in the opposite direction. Heat from the compressed air is transferred to the water. Water vapor forms as the compressed air cools. The moisture is removed by the moisture separator and drain valve. The tube bundles can be fixed or removable. Fixed tube bundles cost less but are more difficult to maintain than bundles that can be removed for cleaning or service.

The disadvantages of a water-cooled after cooler include high water usage and difficult heat recovery. Advantages to using a water-cooled after cooler include better heat transfer and no required electricity

1.3 DRYING OF COMPRESSED AIR

Function: is to lower the dew point of the compressed air by removing the moisture from it. For simple applications, to remove excess humidity, we need simple after cooler, an air receiver, and a filter with condensate traps. However, to get high quality compressed air additional means of dehydration must be provided using dryer.

1.3.1 TYPES OF AIR DRYERS

Generally four basic types of air dryers are used in Industries.

1. Absorption type dryer
2. Adsorption type dryer
3. Refrigeration dryer
4. Membrane dryer

1.3.1.1 Absorption type dryer

Absorption drying is a purely chemical process. The moisture in the compressed air forms a compound with drying agent like phosphoric pentaoxide in the tank. This causes the drying agent to break down. It is then discharged in the form of a fluid at the base of the tank. Schematic diagram of absorption dryer is shown in Figure 1.1

Oil vapour and oil particles are also separated in the absorption dryer. Large quantities of oil have an effect on the efficiency of the dryer. Therefore it is advisable to include a fine filter in front of the dryer.

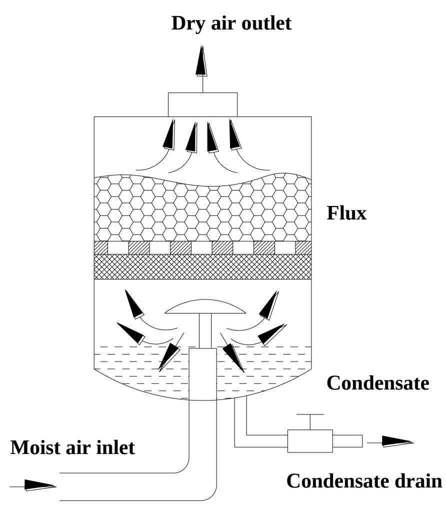

Figure 1.1 Absorption dryer

Advantages of Absorption dryer

1. Simple to install
2. Low mechanical wear because there is no moving parts
3. No external energy requirement

Disadvantages of Absorption dryer

1 Maintenance cost is high

2. Low efficiency

3. Consumable cost is high

1.3.1.2 Adsorption type dryer

Adsorption is a physical process of moisture removal on the porous surface of certain granular materials. Gaseous molecules are attracted to certain solid surfaces by van der walls forces and this causes the adsorption. The degree of attraction or adsorption depends on properties of gaseous molecules and desiccant. Most commonly used desiccants re activated alumina, molecular sieves and silica gel.

Figure 1.2 shows the various parts of adsorption dryer. Wet incoming compressed air after passing through a pre-filter is directed to the adsorption chamber containing the desiccant. Water vapour in the compressed air is absorbed by the desiccant. Thereafter dry air is allowed to pass to the application through the after filter.

Adsorption dryers usually have two desiccant filled chambers with interconnecting piping and switching valves. The valves permit removal of the collected moisture from one chamber while the other chamber is used to purify the compressed air. The twin tower design facilitates simultaneous compressed air drying and saturated desiccant regeneration for non-stop production. A contaminated desiccant bed can be regenerated by either elevating its temperature or by decreasing its pressure and purging.

The capacity of the desiccant bed is limited owing to abrasion and contamination of the adsorption medium by oil and other substances. Under normal conditions, it is required to replace the drying agent once in 2 to 3 years.

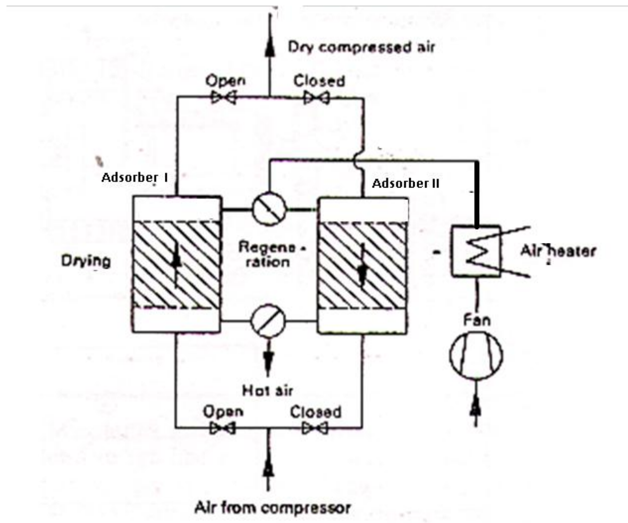

Figure 1.2 Adsorption type dryer

1.3.1.3 Refrigerated dryer

The layout of a typical refrigerated air dryer is shown in **Figure 1.3** It is composed of a heat exchanger (stage1) and a refrigerating unit (Stage2) to reduce the temperature of the compressed air. The incoming warm and humid air is first passed through the air –to-air heat exchanger, and then through the refrigerating unit to reduce the temperature of the compressed to as low as +2℃ . This drying method is based on the principle that if the compressed air is cooled to a temperature below the dew point, condensation talks place and water is precipitated. Almost all the water and oil particles get condensed, and collected in the water traps provided at appropriate points. The cooled compressed air is then filtered to remove from it the suspended solid particles and most of the oil mist. The pressure dew point of 2℃ is possible with this type, which is sufficient enough for the smooth operation of the most of the industrial and process applications.

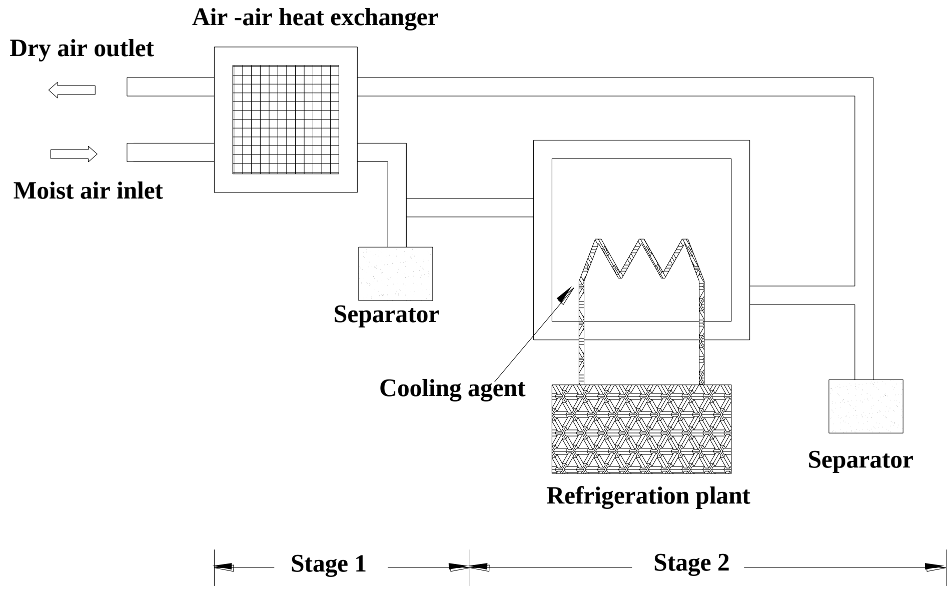

Figure 1.3 Refrigerated dryer

In most cases, the type of dryer needed is determined by the pressure dew point required in the systems. **Table 1.1** gives the summary of advantages and disadvantages of the dryers.

Table 1.1 Comparison of three types of dryer

Type	**Advantages**	**Disadvantages**
Absorption	Pressure dew point + 16 °C	Inlet temperature must not exceed 30 °C
	Low capital cost	Drying agents are consumables and therefore must be regularly replenished. Highly corrosive chemical are used. They are not environmental friendly
Refrigeration	+ 3 °C pressure dew point	Output dew point will vary with approach temperature at the inlet and cleanliness of heat exchanger
	Input temperature can be as high as 16 °C	
Adsorption	Achievable pressure dew point of -40 °C	High capital cost

		High operating cost
		Use of micro filters adds cost to prevent the residue from chemicals.

1.3.1.4 Membrane dryer

Membrane dryers are yet another type of dryer to remove moisture from compressed air. It consists of three stages.

Stage 1: Contains a filter which removes the water and contaminants down to 5 micron.

Stage 2: High efficiency coalescing filter removes oil and sub micron particles down to 0.01 micron

Stage 3: membrane module removes the remaining moisture in the vapour form

In this of dryer, pre-cleaned compressed air is passed through a bundle of hollow fibres in the membrane module. The hollow fibres constitute a membrane layer specially designed to attract the water vapour inside. This water vapour diffuses through the very thin selective layer until it reaches the outside of the membrane due to partial pressure difference between inside and outside of the membrane. The permeated water vapour is then swept away by a small amount of dry air fed back along the length of the membrane fibre through a purging valve.

Advantages of Membrane dryer

1. Membrane dryers typically maintain a pressure dew point of 0 ℃
2. Membrane dryers are simple and compact
3. Dryers run almost noiseless
4. There is no need for regeneration because membranes never gets saturated
5. They do not require electric supply
6. Low operating cost

3.3.2 Theory of drying

Air taken from the atmosphere contains moisture which in normal circumstances is precipitated as condensate within the system through which it passes, namely in the compressor after cooler, the air receiver, collecting points in the piping and the filter of the service unit ahead of the air consumers.

Compressed air will always contain as much water as it is capable of absorbing at the lowest temperature assumed by the air on its passage from the compressor to the consumption point. Typical values of water vapour saturation capacity of an air at selected atmospheric temperatures is given in Table 1.2

Table 1.2 Water vapour saturation capacity of air at selected atmospheric temperatures

Temperature ℃	-10	0	5	10	15	20	30	50	70	90
Water vapour, g/m^3	2.1	4.9	7	9.5	13	17	30	83	198	424

For example, at 20℃ one cubic meter of compressed air will still contain 17 grams of moisture. Existing in the form of water vapour, this moisture is not separated in the filter of the service unit either; rather it is entrained by the air into all the downstream control and operating components. Due to the centrifugal action taking place in the filter and increased flow velocity resulting there from, the air stream is cooled a certain amount relative to the ambient temperature, which does cause a small portion of condensate to be separated in the filter.

Since the control and operating elements of the pneumatic systems will normally be at ambient temperature, no further condensate will be precipitated at these points. Therefore, the remaining moisture passes out with the external air released to the atmosphere. As observed above, the low residual moisture content of the air will hardly constitute a potential hazard to standard pneumatic control and operating components.

In the case of specialised applications and used of compressed air, however, as in spray painting, intricate low-pressure control systems, the chemical and pharmaceutical industries, food industry, pneumatic instruments and pneumatic conveying, the situation is different. Everywhere that the compressed air comes into direct contact with the process medium in such instances, simple conditioning of the air by the means described usually will not be sufficient. It is then necessary to provide additional means of dehydrating and filtering the compressed air.

1.3.2.1 Humidity and relative humidity

Water vapour is constantly evaporating from lakes, rivers and seas and is absorbed by the atmosphere and carried across vase distances by winds, finally being deposited in the form of rain, mist, etc. Atmospheric air therefore, is nature's way of transmitting large quantity of water vapour all over the earth.

Relative humidity(RH): it is ratio of amount of water present in a given quantity of air, to the maximum possible amount which it can contain under the same conditions of pressure and temperature and ratio is usually expressed as percentage. The amount of moisture condensing out of compressed air is a function of the relative humidity of the intake air and temperature.

$$\text{Relative humidity of air} = \frac{\text{Absoulte humidity}}{\text{humidity at saturatrion}} \times 100$$

In other words, relative humidity is the amount of water vapour present in a given volume of air, whereas the humidity at saturation is the total amount of water vapour which that the same volume of air can absorb at the given temperature. **Table 1.3** gives the mass of water in kg per 100 m^3 of free saturated air. **Table 1.4** gives the amount of condensate in g/m^3 of air at various temperature and Relative humidity

Table 1.3 Mass of water in kg per 100 m^3 of free saturated air.

Temperature °C	Gauge pressure (bar)				
	0	2	4	6	8
0	0.48	0.17	0.10	0.07	.05
20	1.73	0.576	0.346	0.247	0.192
40	5.10	1.7	1.02	.728	.567
60	12.95	4.32	2.59	1.85	1.44

80	29.04	9.68	5.81	4.15	3.23
100	56.00	19.33	11.76	8.40	6.53
120	0.00	36.73	22.04	15.74	12.24
140	0.00	0	37.74	29.96	20.97

Mass of water in in kg per 100 m^3 of free saturated air

Table **1.4** Amount of condensate in g/m^3 of air at various temperature and RH

Temp ℃	Percentage relative humidity (RH)									
	10	20	30	40	50	60	70	80	90	100
-12	0.179	0.354	0.533	0.709	0.888	1.066	1.2503	1.421	1.600	1.780
0	0.483	0.965	1.451	1.933	2.426	2.906	3.387	3.867	4.348	4.830
10	0.934	1.865	2.790	3.730	4.670	5.606	6.520	7.460	8.400	9.337
15	1.313	2.617	3.816	5.063	6.386	7.795	9.029	10.158	11.631	17.957
21	1.826	3.661	5.469	7.300	9.131	11.946	12.793	14.600	16.431	18.698
27	2.494	4.980	7.516	10.069	12.521	15.012	17.582	20.024	22.757	25.634
32	3.307	6.614	10.061	13.548	16.835	20.276	23.486	27.0044	30.451	33.721
35	3.936	7.872	11.808	15.744	19.681	23.617	27.554	31.489	35.426	39.248
37.8	4.531	9.039	13.571	18.102	22.611	27.141	31.673	36.489	39.900	45.248
43.3	6.018	12.037	18.056	24.075	30.094	36.112	42.131	48.150	54.160	60.371
49	7.895	15.790	23.686	31.580	39.476	47.370	55.267	63.166	78.910	78.928
55	10.161	20.322	30.583	40.650	50.805	61.200	71.127	81.3	91.504	101.656

The condensate, as the precipitated water in the compressed air line is termed, causes the damage if it is not removed properly. Corrosion in pipes and tubes, corrosion in control and working elements and corrosion in machine parts. If the condensate gets into the pneumatic equipment, proper functioning may be prevented. Solid particles such as dust, rust, and scale can also have an adverse effect on the function of the various items of pneumatic equipment.

Oil residues from the compressor can produce together with the compressed air a mixture of oil mist and air (gas mixture) which can cause explosions at higher temperatures (above 353k)

Problem 1.1 : A compressor delivers 400 m^3 of free air per hour at a pressure of 6 bar gauge and a temperature of 40℃ . Atmospheric air at compressor intake has a relative humidity of 80 % and a temperature of 20℃. Determine the amount of water that can be extracted from the compressor plant per hour.

Solution: Refer to Table 1.3

At 20 ℃ and zero bar gauge pressure, 100 m^3 of free saturated air contains 1.73 kg of water. From the definition of RH

$$\text{Relative humidity} = \frac{\text{Amount of water actually present in air}}{\text{Amount of water present in saturated air}} \times 100$$

$$80 = \frac{\text{Amount of water actually present in air}}{1.73} \times 100$$

Amount of water actually present in air = 1.384 kg

Since 400 m^3 is delivered, water content of air entering the compressor = 1.384 × 4 =5.536 kg

From the Table 1.3, corresponding to 40 ℃, and 6 bar compressor output pressure, amount of water per 100 m^3 of free saturated air is given by 0.728

Since 400 m^3 is delivered, water content of air leaving the compressor = 0.728 × 4

=2.912 kg

Therefore the amount of water extracted from the compressor plant per hour is

5.536-2.912 = 2.62 kg

1.3.2.2 Dew point temperature

The temperature at which air is fully saturated with moisture (that is 100 % humidity) is the dew point. Simply put, dew point is the temperature where condensation begins. Cooling below dew point will cause condensation of the water vapour. Lower the dew point, the less moisture the air is able to absorb or hold. For example 1 m3 of air has 17 grams of water at 20 ℃ and at -10℃

water vapour it is 2.1 grams. The capacity of holding water in air is a function of volume and temperature it does not depend on pressure. But still it is necessary to consider the working pressure of the systems when comparing different facility for the dehydration of air. This brings in the term pressure dew point.

a) Pressure dew point: Temperature representing the dew point at the respective operating pressure of the dryer is known as pressure dew point. The air is a compressible gas and the dew point temperature changes with the pressure. More precisely it is not the pressure but volume that matters. When the gas is pressurized, the volume is reduced and the air has less capacity to hold moisture. We can say with the increasing pressure and reduced volume, the dew point temperature also increases. In drying air by refrigeration, pressure dew point defines the lowest air temperature attainable in the dryer at the operating pressure of the system.

b) Atmospheric dew point:

As discussed above, Compression and expansion of air affects its dew point. Generally speaking, compression increases dew point, and expansion (i.e. de-compression) lowers dew point. For example, consider compressed air leaving a dryer at 15 bar with a pressure dew point of -40 ºC @ 15bar. If the pressure is eventually reduced to 7.5bar, the pressure dew point will fall to -45 ºC @ 7.5 psig. If the air is further expanded to 5 bar, the pressure dew point becomes -60º C @ 0.4 bar. For this reason, the phrase pressure dew point (PDP) is commonly used. This term usually refers to the dew point of the compressed air at full line pressure. Conversely the phrase atmospheric dew point refers to what the dew point would be if fully depressurized to atmospheric conditions. Figure 1.4 shows the relationship between atmospheric dew point versus pressure dew point for various pressures ranging from 0 MPa to 1.5 MPa

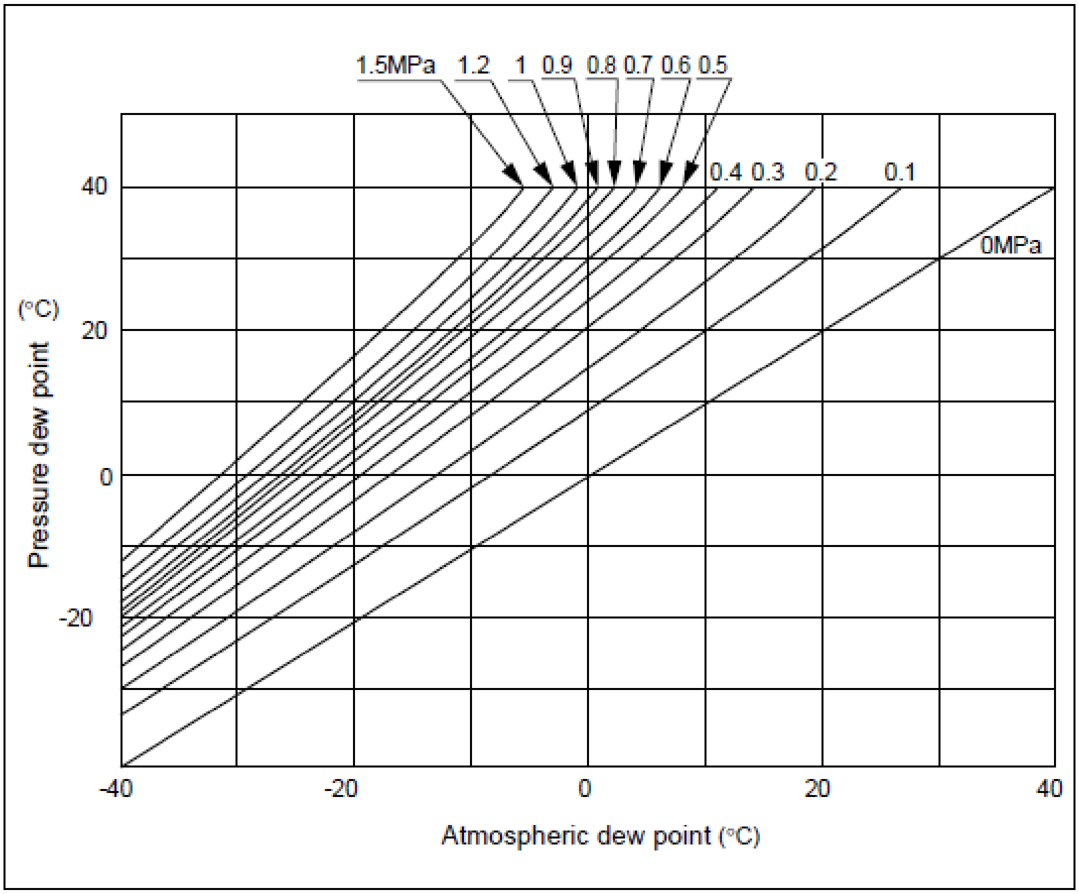

Figure 1.4 Atmospheric dew point versus Pressure dew point

Problem 1.2 : Find the atmospheric dew point where pressure is 0.7 MPa and pressure due point is 5 ℃

Solution

Refer to Figure 1.4, Corresponding to 0.7 MPa and pressure dew point of 5 ℃ we get atmospheric dew point as -20 ℃

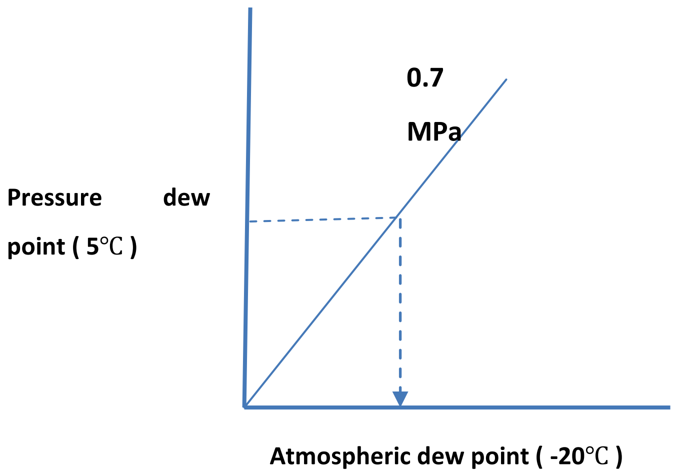

Figure 1.5

Problem 1.3 : Find the amount of condensate per shift in a plant, if air is compressed to 6 bar (gauge) receiver pressure. Assume the initial condition of air at sea level at 21 ℃ and 60 % Relative humidity (RH). Assume 35 ℃ temperature of compressed air in the receiver. Flow rate of the compressor is given as 20 $\mathrm{m}^3/\mathrm{min}$

Solution:

Refer to Table 1.4

Given that the initial condition of air at sea level at 21 ℃ and 60 % Relative humidity (RH).

1 m^3 of air has 11.946 grams of the water vapour

Compression ratio reveals how many m^3 of ambient air is to be used to produce 1 m^3 of compressed air at that pressure.

$$\text{compression ratio} = \frac{6+1}{1} = 7$$

It means 7 m^3 of free air is required. From the Table 1.4 each m^3 of air contains 60 % RH and 21℃ , 11.946 grams of moisture.

Hence the amount of water in 6.9 m^3 is

7 ×11.946 = 83.622 grams of water

Let us assume 35 °C temperature of compressed air in the receiver.

From the table, 1 m^3 of air at 35 °C and 100 % RH amount of water is 39.248 grams.

Therefore, amount of water condensed and separated

= 83.622-39.248 =43.374 grams

Therefore, there will be $\frac{43.364}{7} = 6.2$ grams of water for each m^3 of ambient air

Flow rate of the compressor is given as 20 m^3/min

Amount of water for 20 m^3/min = 6.2 × 20 = 124 grams in one minute

Amount of water for one hour = 124 × 60 = 7440 grams

Amount of water in 8 hours shift = 7440 × 8 = 59520 grams ≅ 60 kg.

Problem 1.4 : Find the amount of condensate in one hour if 22 kW compressor operates under the following condition a) Air at 60% relative humidity and 30°C ambient temperature is pressurised to 7 kg/cm^2(7 bar). It is then cooled to 25 °C. Compressor output is 3 Nm3/min at 7 kg/cm^2(7 bar)

Solution

Refer the nomogram given in the **Figure 1.6**, locate point 1 which corresponds to inlet temperature of the compressor and erect a perpendicular line to meet 60%RH line. And then draw the horizontal line to cut 7 bar pressure line. We get pressure dew point temperature as 60°C.(1 → 2 → 3 → 4 → 5)Since the air is cooled to 25 erect a vertical line to cut 7 bar pressure line. (6 → 7 → 8 → 3) From the nomogram water liquid collected is 20.7-3.2 = 17.5 g/Nm^3

Which amounts to 17.5x3x60=3150 grams per hour. More than 3 litres of water is produced each hour.

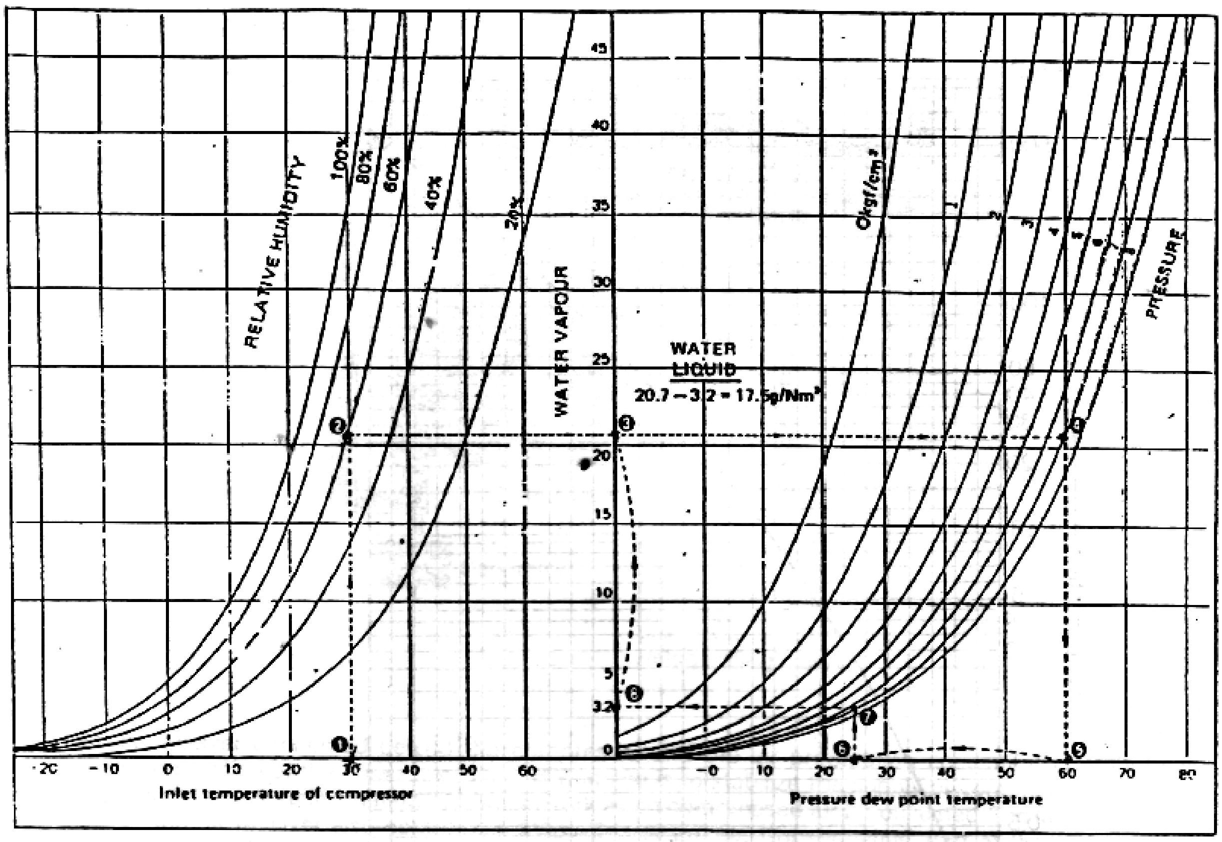

Figure 1.6: Pressure dew point nomogram.

Problem 1.5 : Using nomogram, Find the amount of water vapour saturation capacity of an air at 20°C and compare with Table 1.2

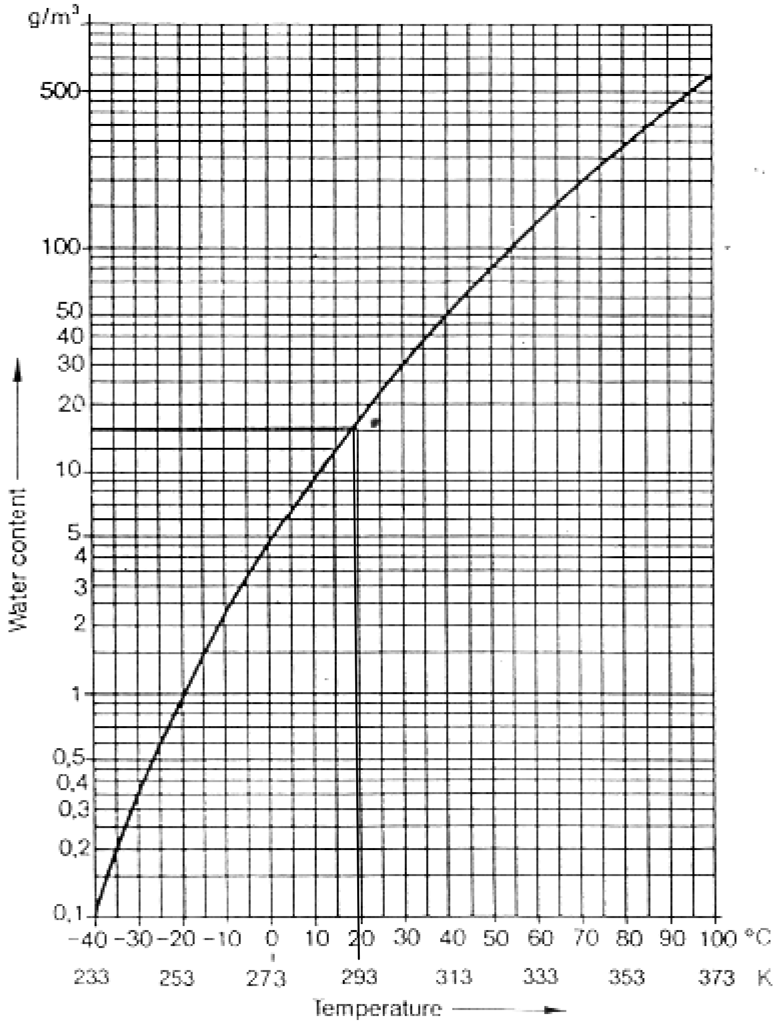

Figure 1.7: Dew point chart (saturation chart)

For nomogram, at 20°C one cubic meter of compressed air will still contain 16 grams of moisture. It closely matches with typical values of water vapour saturation capacity of an air at 20°C given in Table 1.2

1.4 STORAGE OF COMPRESSED AIR

1.4.1 AIR RECEIVER

Receivers perform several functions in compressed air systems. Firstly, they provide a larger system capacity, which increases the cycle time of compressor control systems. This makes less difficult the elimination of unstable and overcorrecting control cycles.

The receiver also dampens pulsations from reciprocating compressors, acts as a reservoir to prevent excessively temporary pressure drop during sudden short-term demand, and can be used to smooth air flow through dryers, separators and other air conditioning equipment. Because the air entering the receiver is reduced in velocity and cooled, some of the moisture may condensate and fall to the bottom of the receiver where it can be removed by a valve or preferably, a trap. Such a receiver can reduce further the amount of moisture which must be removed by a subsequent drying stage. The receiver always equipped with a pressure relief valve.

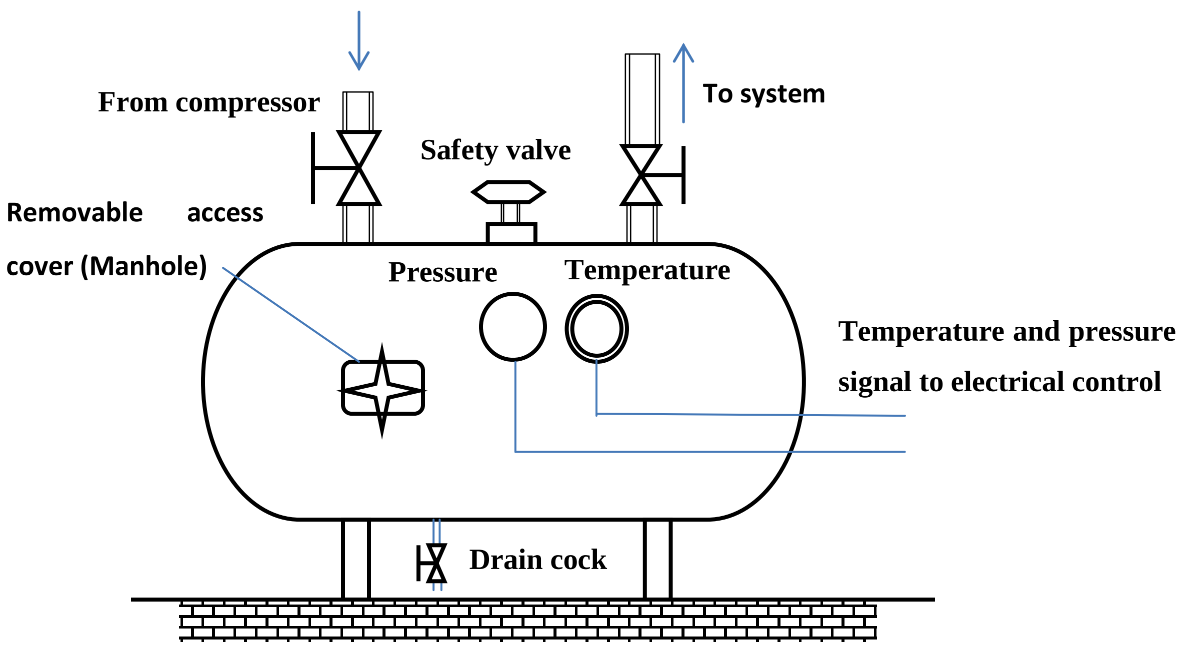

Figure 1.8 Components of Air receiver

Figure 1.8 shows essential features of a receiver. They are usually of cylindrical construction fabricated out of steel. Receiver is basically a pressure vessel and attracts the safety of testing requirement as per factory act. A safety valve is necessary to release the excess pressure of air stored. A pressure gauge and temperature gauges are provided and usually coupled with pressure switches to control on-off of the compressor and for remote alarms.

A drain cock allows removal of condensed water. Access via a manhole allows cleaning. Obviously, removal of manhole cover is hazardous with a pressurized receiver and safety routines must be defined and followed to prevent accidents.

Installation of accumulator within a pneumatic system will depend on the specific air consumers and will only be necessary when large volume of air are consumed in short periods, that is intermittent peak load.

Figure 1.9 shows diagram of compressed air installation with air receiver and accumulator.

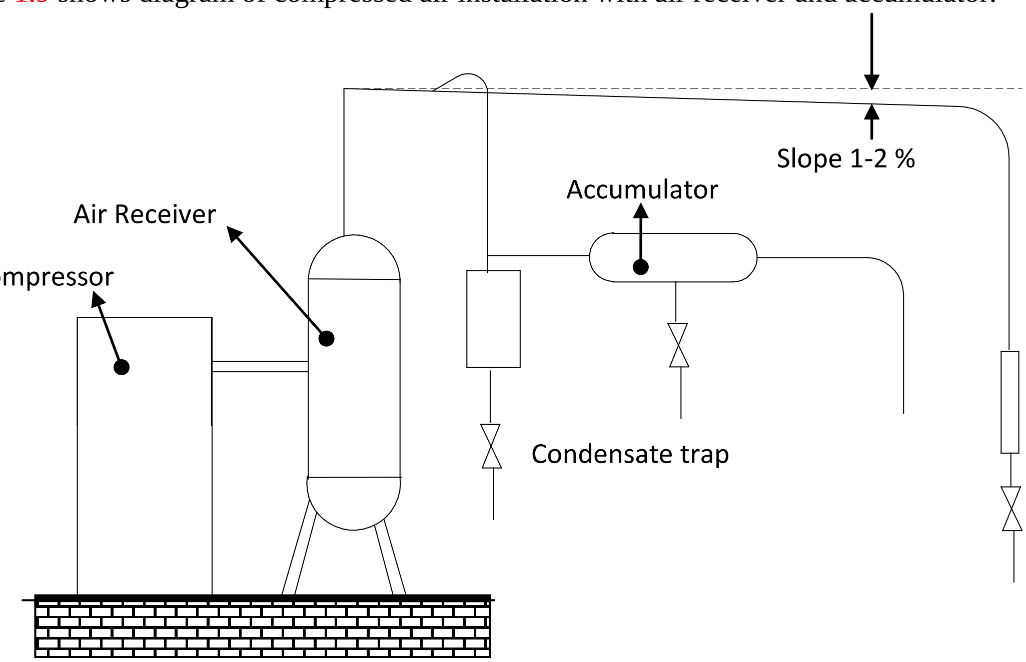

Figure 1.9 Diagram of compressed air distribution system with branch line with accumulator

1.4.2 Analysis sizing of Air Receivers

The receiver size in cubic feet normally should be atleast 12 seconds of compressor capacity in small units, to not less than 8 seconds of compressor capacity for larger units. Empirical rule suggest that the receiver volume should be 1/10 of FAD per minute to 1/6 FAD per minute for small compressor.

Sometimes small compressors are mounted upon a receiver and the receivers serve as a basic mounting frame for the assembly of the compressors and their accessories. Under these and some other circumstances, the only pressure relief valve frequently located upon the receiver. When this mounting procedure is employed, care must be taken to assure that no other valve is between the compressor and the receiver, and that support members or frames are not welded into the receiver tank seam welds.

1.4.2.1 Empirical relations to size the compressor

The sizing of air receivers requires taking into account parameters such as system pressure and flow rate requirements, compressor output capability, and the type of duty of operations. Basically a receiver is an air reservoir. The receiver must be capable of handing transient demand.

Case 1 : No air is supplied to the receiver during the time interval in which air is being drawn off

In such cases we can find the capacity of receiver as

$$V_r = \frac{101\ t\ [Q_r]}{[p_{max} - p_{min}]}$$

Case 2 : Air is supplied to the receiver during the time interval in which air is being drawn off

Then, The air receiver size can be determined by using the following empirical equation

$$V_r = \frac{101\ t\ [Q_r - Q_c]}{[p_{max} - p_{min}]}$$

V_r = receiver size (m^3)

t = time that receiver can supply required amount of air , (min)

Q_r = consumption rate of pneumatic system (standard m^3/min)

Q_c = outflow rate of pneumatic system (standard m^3/min)

p_{max} = maximum pressure level in receiver (kPa)

p_{min} = maximum pressure level in receiver (kPa)

Case 3 : Compressor with offloading/loading regulation The following relation applies when dimensioning the receiver’s volume. Note that this relation only applies for compressors with off loading/loading regulation

$$V_r = \frac{0.25\ T_r\ Q_{fad}}{f_{max}[p_{max} - p_{min}]T_c}$$

V_r = receiver size (liter)

T_r = temperatur of compressed air in receiver , (K)

Q_{fad} = compressor fad (l/second)

T_c = Maximum ambient temperature , compressor inlet temperature (K)

p_{max} = maximum pressure level in receiver (bar

p_{min} = maximum pressure level in receiver (bar)

f_{max} = maximum loading frequency , usually 1cycle every 30 seconds

1.4.2.2 Requirement on Air receiver according to Factory act 1973 section 39

Air receiver are classified as pressure vessels and become subject to periodical inspection and test under the factory acts. Every owner of an air receiver must be acquainted with the requirement of factory act relating to receiver, and a summary of these rules is given below-

- Every air receiver and its fittings shall be of sound construction
- Each air receiver under pressure shall be protected by a suitable safety valve adjusted to prevent the pressure exceeding the maximum working pressure
- Safety valve should be constructed so as to permit the air to escape without increasing the pressure beyond 10 percent above the blow off pressure with the compressor running at full capacity
- It must be fitted with an accurate pressure gauge
- I t must be fitted with a suitable appliances for draining the receiver
- It must be provided with a manhole , hand hole or other means to allow thorough cleaning of the interior
- Where there is more than one receiver in the factory bear a distinguishing mark which shall easily be visible
- Every receiver shall be thoroughly cleaned and examined at least once every twenty four months by a competent authority.
- All welded receivers must be hydraulically tested twice the working pressure
- Each receiver must be permanently marked with the following

a) Maker’s identification number
b) Date of test
c) Specification number
d) Hydraulic test pressure
e) Maximum working pressure

1.4.2.3 Analysis of power requirement to drive compressor

Another important design consideration is to determine the power required to drive an air compressor to meet system pressure and flow rate requirements. The following empirical relationship can be used to find the theoretical power requirement.

$$Theoretical\ power = \frac{p_1 Q}{17.1}\left(\left(\frac{p_2}{p_1}\right)^{0.286} - 1\right)$$

$p_1 = Inlet\ pressure\ of\ compressor\ \ (kPa)$

$p_2 = Outlet\ pressure\ of\ compressor\ (kPa)$

$Q = flow\ rate\ (m^3/min)$

To find the actual power, the theoretical power is divided by the overall compressor efficiency.

$$Actual\ \ power = \frac{Theoretical\ power}{overall\ efficiency}$$

$$Actual\ power = \frac{\frac{p_1 Q}{17.1}\left(\left(\frac{\mathrm{p}_2}{\mathrm{p}_1}\right)^{0.286} - 1\right)}{Overall\ efficiency}$$

Problem 1.4 : Air is used at a rate of 1 m^3/min from a receiver at 40℃ and 1000 kPa (gauge). If the atmosphere pressure is 101 kPa (abs) and the atmospheric temperature is 20 ℃. How many m^3/min of free air (standard m^3/min) must the compressor provide?

Solution

$\mathrm{p}_2 = 1000\ \mathrm{kPa(gauge)} = 1101\ \mathrm{KPa(absoulte)}$

$\mathrm{p}_1 = 101\ \mathrm{KPa(absoulte)}$

$\mathrm{T}_2 = 40℃ = 40 + 273 = 313\ \mathrm{K}$

$\mathrm{T}_1 = 20℃ = 20 + 273 = 293\ \mathrm{K}$

$$V_2 = 1\,\frac{m^3}{min},$$

Using General gas law

$$\frac{p_1 V_1}{T_1} = \frac{p_2 \ V_2}{T_2}$$

$$\frac{101 \times V_1}{293} = \frac{1101 \times 1}{313}$$

Solving we get $V_1 = 10.20$ standard $\frac{m^3}{min}$

Problem 1.5 : a. Calculate the required size of the receiver that must supply air to pneumatic system consuming $0.850\ m^3/min$ for 10 minutes between 828 kPa and 690 kPa before the compressor resumes operation **b**. what size is required if the compressor is running and delivering at $0.170 m^3/min$

Solution:

The air receiver size can be determined by using the following equation

$$V_r = \frac{101\ t\ [Q_r - Q_c]}{[p_{max} - p_{min}]}$$

Part a

V_r = receiver size (m^3)

t = time that receiver can supply required amount of air , (min) = 10 min

Q_r = consumption rate of pneumatic system $\left(\text{standard}\,\frac{m^3}{min}\right) = 0.850\ m^3/min$

Q_c = outflow rate of compressor $\left(\text{standard}\,\frac{m^3}{min}\right) = 0\ m^3/min$

p_{max} = maximum pressure level in receiver (kPa) = 828 kPa

p_{min} = maximum pressure level in receiver (kPa) = 690 kPa

$$V_r = \frac{101 \times\ 10\ [0.850 - 0]}{[828 - 690]}$$

Solving we get $V_r = 6.22\ m^3$

Part b

The required size of the compressor when the compressor is running and delivering air at $0.170m^3/min$

$$\mathrm{V_r} = \frac{101 \times\ 10\,[0.850 - 0.170]}{[828 - 690]}$$

Solving we get $\mathrm{V_r} = 4.977\ \mathrm{m^3} \cong 5\mathrm{m^3}$

Objective Type Questions

1. About ------ of the moisture can be removed using after cooler

2. Adsorption is a --------- process of moisture removal on the porous surface of certain granular materials.

3. Absorption drying is a purely ------- process. The moisture in the compressed air forms a compound with drying agent like phosphoric pentaoxide in the tank

4. -------------- is to lower the dew point of the compressed air by removing the moisture from it

5. Temperature representing the dew point at the respective operating pressure of the dryer is known as ---------- dew point.

State True or False

1. In adsorption process gaseous molecules are attracted to certain solid surfaces by van der walls forces

2.. High Pressure dew point values indicate small amounts of water vapour in the compressed air.

3. It is important to remember that atmospheric dew point can be compared with PDP when comparing different dryers.

4. Installation of accumulator within a pneumatic system will depend on the specific air consumers and will only be necessary for intermittent peak load.

5. Membrane dryers do not require electric supply

Review Questions

1. State the adverse effects of moisture content compressed air

2. What is the function of an after cooler?

3. What are the different methods of drying compressed air

4. Explain the working of absorption dryer with a neat sketch

5. Explain the working of adsorption dryer with a neat sketch

6. Explain the working of regenerative dryer with a neat sketch

7. Why two drying chambers are used in adsorption dryer

8. Explain the functional and constructional features of a refrigerated dryer

9. List the advantages and disadvantages of absorption dryer

10. List the advantages and disadvantages of membrane dryer

11. List the advantages and disadvantages of refrigeration dryer

12. List five functions of Air receiver

13. Why must receiver tank be drained periodically?

14. Name three fittings used on all air receiver

15. What are the important maintenance activities to be carried out on air receiver

16. What are thumb rules we follow in selecting air receiver

Answers

Fill in the Blanks

1. 70-85%
2. physical
3. chemical
4. After cooler
5. Pressure

State True or False

1. True
2. False
3. False
4. True
5. True