UNIT 11 COMPRESSORS AND BLOWERS

Structure

11.1 INTRODUCTION

Compressed air is used extensively on construction projects for drilling rock or other hard formations, loosening earth, operating air motors, hand tools, pile drivers, pumps, mucking equipment, cleaning, etc. When air is compressed, it receives energy from the compressor. This energy is transmitted through a pipe or hose to the operating equipment, where a portion of the energy is converted into mechanical work. This unit describes the various types of air compressors.

Objectives

By the end of this unit you will be able to learn about

- the various types of compressors,
- the factors affecting compressor performance,
- planning for compressed air services,
- ratings of compressors,
- air line losses,
- air receivers,

- air consumption of tools, and
- blowers.

11.2 CLASSIFICATION OF COMPRESSORS

Air compressors are classified in a number of ways. They are classified

a) by the action as:

1) Single-acting compressor
2) Double-acting compressor

b) by the method of compressing air as:

1) Single-stage compressor
2) Two-stage compressor
3) Multi-stage compressor

c) by the mechanism of compressing as:

1) Axial compressor
2) Centrifugal compressor
3) Diving compressor
4) High pressure compressor
5) Reciprocating compressor
6) Rotary compressor
7) Screw compressor
8) Sliding vane rotary compressor

d) by the positioning as:

1) Stationary compressor
2) Portable compressor.

A single-acting compressor is a machine that compresses air at only one end of a cylinder.

The double-acting compressor is a machine that compresses air at both ends of a cylinder.

A single-stage compressor is a machine that compresses air from the atmospheric pressure to the desired discharge pressure in one single operation.

A two-stage compressor is a machine that compresses air in two separate operations. The first operation compresses the air to an intermediate pressure, while the second operation further compresses it to the desired final pressure.

A multi-stage compressor produces compressed air of the desired pressure through two or more stages.

A stationary compressor is a machine for long term needs. Because of its permanence, it may have a larger capacity than the portable unit and so it may well be larger and heavier than the portable unit. They may be powered by a wide variety of means such as electric motors, internal combustion engines, or even steam. A single stationary compressor may provide as much as 2.83 cumec or 6000 cfm (cubic feet per min) of free air. Need dictates the choice of a larger unit with long term central location as compared to the freedom of one or more relocatable smaller units. The larger units, with their prolonged use will require a more sophisticated long term piping system. Figure 11.1 shows a stationary compressed air system.

A portable compressor is a machine for immediate needs. It is usually powered by an internal combustion engine – either diesel or petrol – or an electric motor. This compressor could range from a mounting on fairly immovable skids to a mounting on either steel or rubber-tyred wheels. It is relocatable by towing over a wide area to satisfy job demands. The portable unit seldom exceeds 0.71 cumec (1500 cfm). Flexible hoses are adequate with portable units.

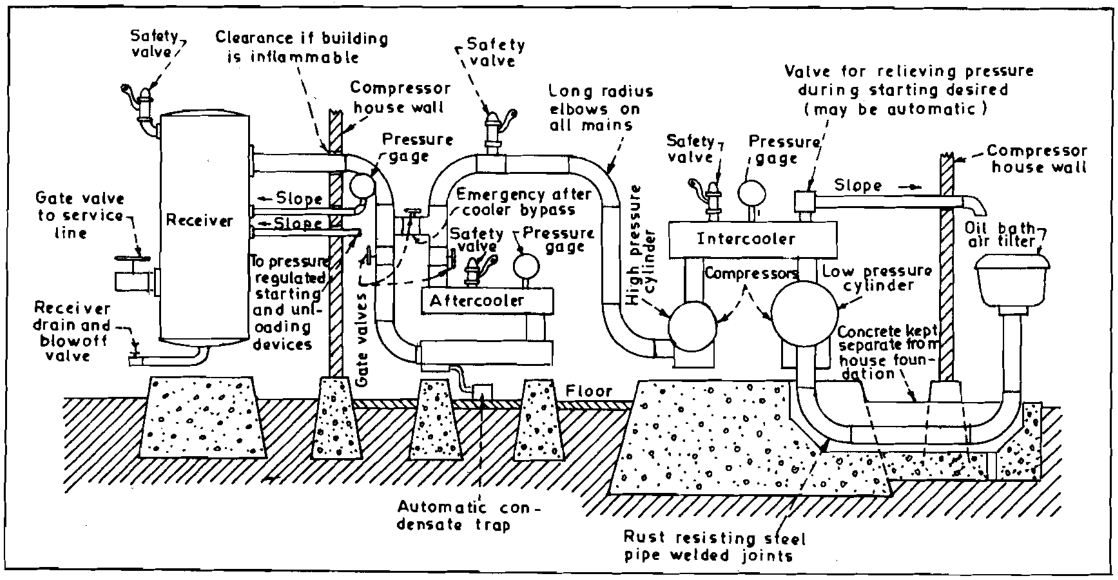
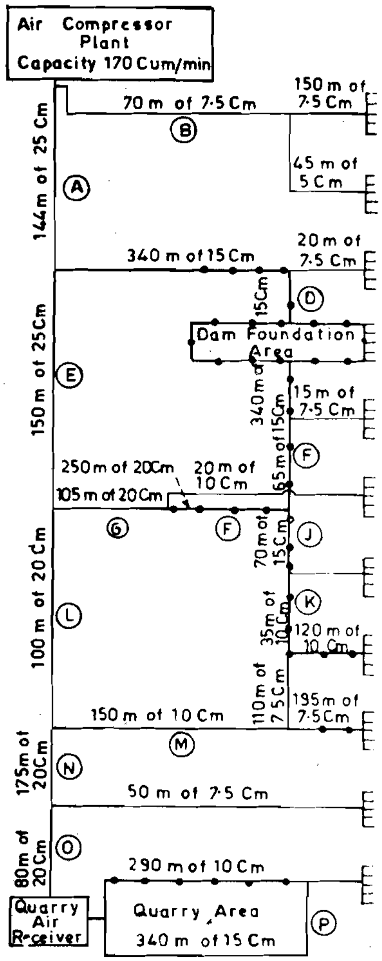


Figure 11.1 : Diagrammatic Layout of Stationary Air Compressor System

A compressed air system comprises the compressor with the prime mover, suction line and air filter, intercooler, safety valves, aftercooler, receiver and distribution system. The full benefits of a good compressed air system are derived only when it is properly planned in



SERVICE	Max Air Demand Cum/min	Max Line Discharge at cum/min	
Carpenter and machine shop	17·0	A	170
		B	17
Gas service station	8·5	C	51
Cableway head tower	17·0	D	51
Drilling grouting Cleanup and misc.	85·0	E	136
		F	51
Cableway tail tower	17	G	85
Cement silo	17	H	68
		J	42·5
Mixing plant service tap	8·5	K	25·5
Rim grouting area feeder	25·5	L	85·0
Aggregate screening and storage plant	17·0	M	[illegible]
		N	68
Aggregate crusher	17·0	O	59·5
Drilling blast holes	42·5	P	42·5

LINES PROVIDED WITH SERVICE TAPS.

LOOPING LINES ARE DESIGNED TO CARRY THE FULL LOAD FROM EITHER SIDE TO INSURE SERVICE IF THE LOOP IS BROKEN.

Figure 11.2 : Compressed Air Distribution System for Large Construction Job

respect of selection of equipment, its layout and control. Loss of air pressure or insufficient volume reaching the point of consumption would adversely affect not only the economy of operation of plant but also the construction schedule of the project. A typical piping system of a project using compressed air for various work sites is shown in Figure 11.2.

11.3 TYPES OF COMPRESSORS

A compressor is a primary machine used for pressurising air. Compressors may be classified as positive displacement type and non-positive displacement type or rotodynamic type.

There are various types of air compressors available for producing compressed air. They include the types described in the sub-sections that follow.

11.3.1 Axial Compressor

Axial compressors have axial flow (Figure 11.3). The air passes axially along the compressor through alternate rows of rotating blades (attached to a rotor) and stationary blades (fixed to the casing) which impart velocity and then pressure to the air. Axial compressors, having a minimum flow rate of 15 cumec, operate at higher speeds than centrifugal compressors due to their smaller diameter. The operating speed is usually 25% higher. Such compressors are commonly used for constant-flow applications and for moderate pressure. The maximum pressure ratio is 6 for each casing. They are best suited for plants requiring large but constant quantities of air. A typical application is blast furnace blowing.

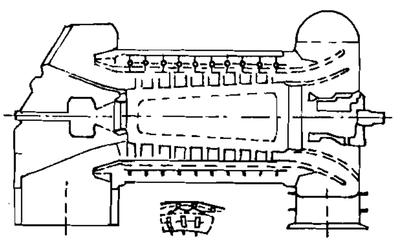


Figure 11.3 : Axial Compressor

11.3.2 Centrifugal Compressor

In the centrifugal compressor (Figure 11.4), the air enters one or more rotating impellers and a number of stationary diverging passages, called diffusers, in which the air is retarded. The impeller may be single- or double-sided. The air is sucked into the centre of a rotating wheel, the impeller eye, after which the vanes of the impeller throw the fluid into the diffuser channels by centrifugal force. After the kinetic energy has been converted

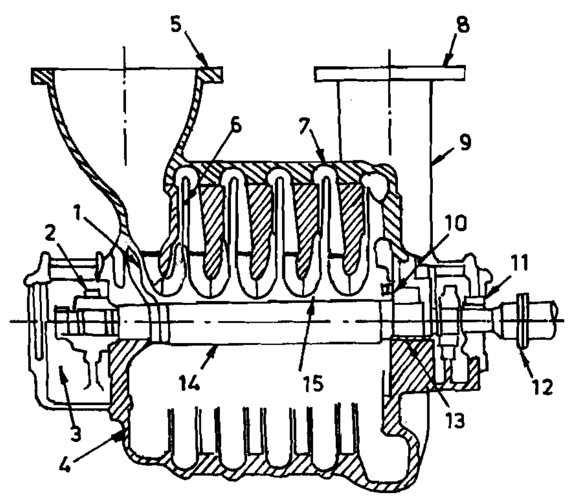


Figure 11.4 : Sectional Drawing of a Typical Five-stage, Uncooled, Horizontally Split Centrifugal Compressor 1) Guide Vane 2) Thrust Bearing 3) Bearing Housing 4) Casing 5) Inlet Flange 6) Diaphragm 7) Diffuser 8) Discharge Flange 9) Volute 10) Thrust Balancing Drum 11) Shaft Bearing 12) Coupling 13) Seal 14) Shaft 15) Impeller

to pressure, the air is ducted to the centre of the impeller and so on. The stage pressure ratio is determined by the amount of velocity change, and the density of air.

The stage pressure ratio is determined by the amount of velocity change and the density of air. Operating speeds are high compared to other compressors. Speeds of 50,000 to 100,000 rpm in aircrafts while commercial units operate around 20,000 rpm.

11.3.3 Reciprocating Compressor

A reciprocating compressor depends on a piston which moves back and forth in a cylinder, for the compressing action. The piston may compress air while moving in one or both directions. For the former it is known as single-acting, while for the latter it is defined as double-acting (Figure 11.5). A compressor may have one or more cylinders. Because the reciprocating compressor is not the most efficient of units, it is being replaced by the various types of rotary compressors.

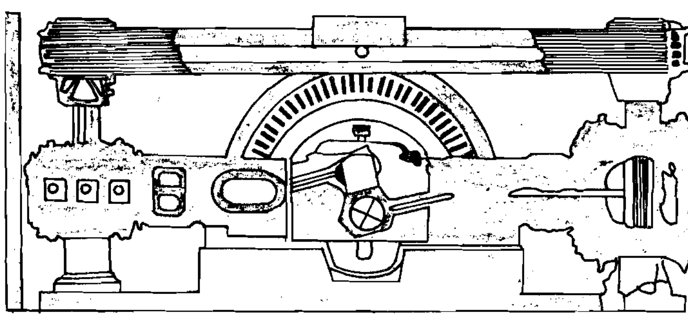


Figure 11.5 : Two-stage Reciprocating Compressor

11.3.4 Rotary Compressor

The rotary compressor (Figure 11.6) is one in which the compression is effected by the action of rotating elements. This machine offers several advantages compared with reciprocating compressors, such as compactness, light weight, uniform flow, variable output, carefree operation and long life. As the rotor turns continuously, there is an uninterrupted delivery of compressed air. This is in contrast to the pulsations provided by the reciprocating piston action of the reciprocating unit.

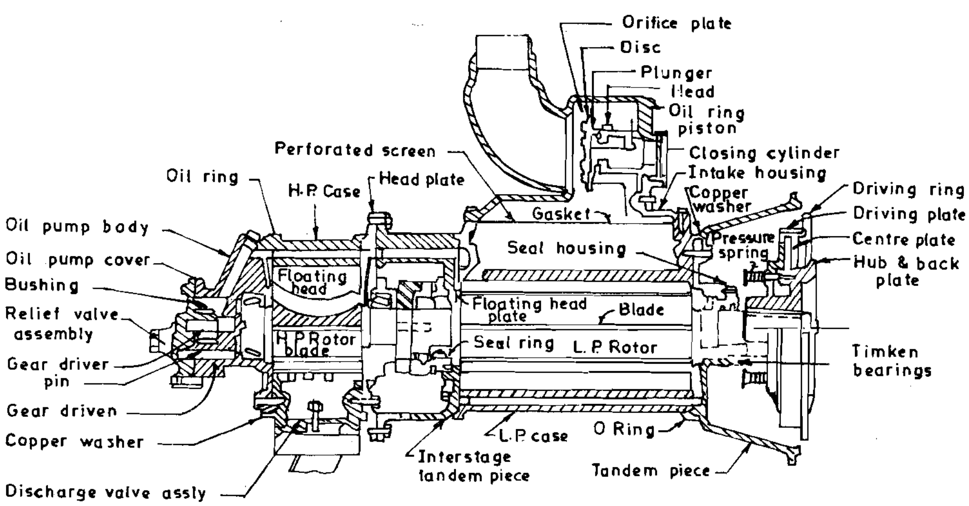


Figure 11.6 : Sectional View of Rotary Air Compressor

11.3.5 Screw Compressor

The working principle of a screw compressor is shown in Figure 11.7. Dry-type screw compressors use external timing gears to synchronise the counter-rotating male and female rotors. Since the rotors are synchronised in a three-to-two speed ratio by timing gears, they do not touch each other or the casing and, therefore, require no lubrication. The delivered air is free of oil. In operation, a compression compartment is formed as each male lobe meshes with its female counterpart; continued rotation transfers the compartment along the rotors to discharge at the opposite end. Since the rotors seal against the casing, the compression effect may be likened to a piston moving along each groove. Each of the

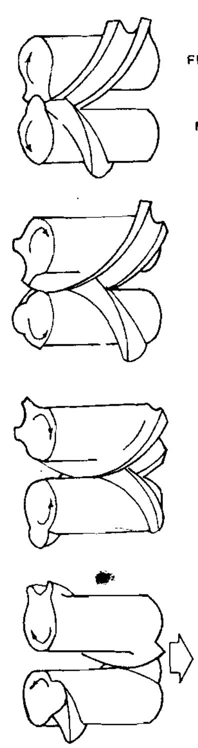


Figure 11.7 : Working Principle of a Screw Compressor (Simplified)

rotors is bored longitudinally to provide cooling by oil circulation, while the casing is also water-jacketed to remove the heat of air compression. The rotor bearing and timing gears are usually the only parts which require lubrication.

11.3.6 Sliding Vane Rotary Compressor

The sliding vane rotary compressor (Figure 11.8) has a slotted rotor which revolves in an eccentric housing and carries longitudinal vanes which are free to slide in and out. Centrifugal force causes the vanes to move outwards against the wall of the eccentric casing, forming a number of compartments which vary in volume as the rotor turns. As any compartment attains its maximum volume it passes an intake port, and air enters the compartment and is trapped. Further rotation decreases the volume and compresses the air for discharge at the exhaust.

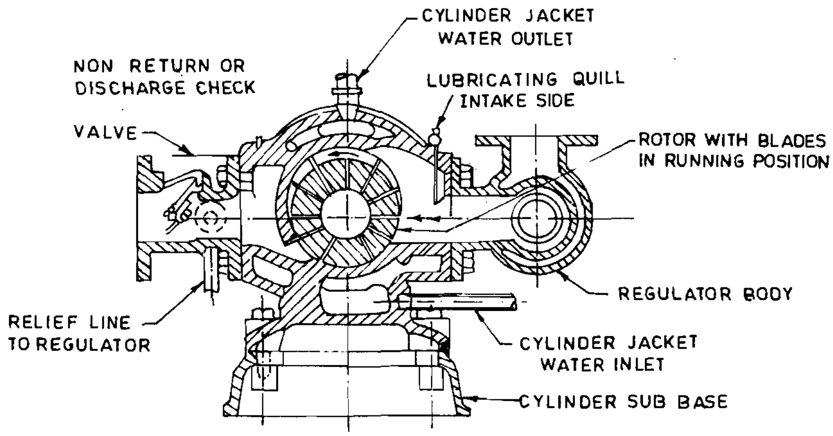


Figure 11.8 : Sectional End View of a Sliding Vane Rotary Compressor

SAQ 1

i) How are air compressors classified?

ii) What do you understand by stationary and portable air compressors?

SAQ 2

i) What is an axial compressor?

ii) Explain the working of a centrifugal compressor.

iii) How does a reciprocating compressor work?

11.4 FACTORS AFFECTING COMPRESSORS

A number of components and factors affect the working of a compressor. They are described in the following sub-sections.

11.4.1 Aftercooler

The aftercooler is installed sometimes at the discharge end of a compressor to cool the air to the desired temperature and to remove moisture from the air. It is highly desirable to remove excess moisture from the air, as it tends to freeze during expansion in air tools, and it washes out the lubricating oil of the tools, thereby reducing the lubricating efficiency. An aftercooler also reduces the pressure loss in distribution lines due to radiation, cooling, and contraction of air in the lines.

11.4.2 Air Density

The air density is weight of a unit volume of air, usually expressed as kg/cum (lbs/cft). The density varies with the pressure and the temperature of the air. The weight of air at

15.56°C (60°F) and 1.033 kg/sq cm (14.7 psi), absolute pressure is 1.22681 kg/cum (0.07658 lb/cft). The volume per kg (lb) is 0.3698 cum (13.059 cft).

11.4.3 Capacity

The capacity is the volume of air delivered by a compressor, expressed in cum/min (cft/min) of free air. Air compressors are rated by the piston displacement in cum/min. However, the capacity of a compressor will be less than the piston displacement because of valve and piston leakage and the air left in the end-clearance spaces of the cylinders.

The capacity of a compressor is the actual volume of free air drawn into a compressor in a minute. It is expressed in cum. For a reciprocating compressor in good mechanical condition the actual capacity should be 80 to 90 % of the piston displacement.

11.4.4 Compression Ratio

It refers to the ratio of the volumes within a reciprocating engine cylinder at the beginning and at the end of the compression stroke. The nominal value equals the displacement plus the clearance volume divided by the clearance volume, but the effective value is somewhat less, due to valve or port timing.

11.4.5 Discharge Pressure

The discharge pressure is the absolute pressure of the air at the outlet from a compressor. The rated discharge pressure is the highest pressure required to meet the conditions specified by the purchaser for the intended service.

11.4.6 Diversity Factor

While it is necessary to provide as much compressed air as will be required to supply the needs of all operating equipment, it is unnecessarily extravagant to provide more air capacity than will be needed. It is probable that all equipment used on a project will not be in operation at any given time. An analysis of the job is made to determine the maximum actual need prior to designing the compressed air system.

If 10 jackhammers are drilling, it is probable that not more than 5 or 6 will be consuming air at a given time. The others will be out of use temporarily for changes in bits or drill steel or moving to new locations. Thus, the actual amount of air demand will be based on 5 or 6 drills instead of 10. The same condition will apply to other pneumatic tools.

The diversity factor is the ratio of the average load to the maximum mathematical load that would occur if all tools were operating simultaneously. This ratio is also referred to as a capacity factor. For example, if a jackhammer required 2.5 cum/min of air, 10 jackhammers would need a total of 25 cum/min if they were all operated at the same time. However, with only 5 hammers operating at one time, the demand for air would be 12.5 cum/min. Thus the diversity factor would be 12.5/25 = 0.5.

An example is given to illustrate the application of diversity factors to a project.

Table 11.1 : Computing Air Required on a Project

Equipment	Air Needed per Unit, cfm	No. of Units On job	No. of Units Working	Max. Air Demand, cfm	Diversity Factor	Probable Air Demand cfm
Wagon drills	200	6	4	1200	0.67	800
Jack- hammers	100	16	8	1600	0.50	800
Drill sharpeners	160	2	1	320	0.50	160
Oil furnaces	80	2	2	160	1.00	160
Grinders	50	2	1	100	0.50	50
Sump pumps	160	3	2	480	0.67	320
Line loss	...	...	...	220	...	220
Total ...		...	...	4080	...	2510
Job diversity factor					0.80	
Total actual demand, 0.80 × 2510		...	...	...	...	2008

11.4.7 Effect of Altitude

The capacity of an air compressor is rated on the basis of its performance at sea level, where the normal absolute barometric pressure is about 1.033 kg/sq cm (14.7 psi). If a compressor is operated at a higher altitude, such as 1524 m (5000 ft) above sea level, the absolute barometric pressure will be about 0.858 kg/sq cm (12.2 psi). Thus, at the higher altitude there is less weight of air per unit volume than at sea level. If the air is discharged by the compressor at a given pressure, the compression ratio will be increased, and the capacity of the compressor will be reduced.

Example 11.1

If 2.834 cum (100 cft) of free air at sea level are compressed to 7.030 kg/sq cm (100 psi) with no change in temperature, what will be the volume at (a) sea level, and (b) at 1524 m (5000 ft) above sea level ?

Solution

a) Applying Boyle's law,

$$P_1V_1 = P_2V_2$$

where,

V_1 = 2.834 cum,

P_1 = 1.033 kg/sq cm (absolute),

P_2 = 7.030 + 1.033 = 8.063 kg/sq cm (absolute), and

$$V_2 = \frac{1.033 \times 2.834}{8.063} = 0.363 \text{ cum (12.81 cft).}$$

b) Applying Boyle's law, at 1524 m above sea level,

$$P_1V_1 = P_2V_2$$

where,

V_1 = 2.834 cum,

P_1 = 0.858 kg/sq cm (absolute),

P_2 = 7.030 + 0.858 = 7.888 kg/sq cm (absolute),

$$V_2 = \frac{0.858 \times 2.834}{7.888} = 0.308 \text{ cum (10.88 cft).}$$

11.4.8 Efficiency

The operations of compressing, transmitting, and using air will always result in a loss of energy, which will give an overall efficiency less than 100 %, sometimes considerably less.

Compressor efficiency is the ratio of the theoretical horsepower to the brake horsepower. Volumetric efficiency is the ratio of the capacity of a compressor to the piston displacement of the compressor.

Example 11.2

The manufacturer's specifications give the following information for a 8.92 cum/min two-stage portable compressor :

No. of low pressure cylinders	4
No. of high pressure cylinders	2
Diameter of low pressure cylinders	17.78 cm
Diameter of high pressure cylinders	14.61 cm
Length of stroke	12.7 cm
RPM	870

Determine the volumetric efficiency of the compressor.

Solution

Consider the piston displacement of the low pressure cylinders only as they determine the capacity of the unit.

Area of the cylinders = $\dfrac{\pi \times 17.78^2}{4} = 248.28$ sq cm

Displacement per cylinder per stroke = 248.28 × 12.7 = 3153.24 cc

Displacement per minute = $\dfrac{4 \times 3153.24 \times 870}{10^6} = 10.973$ cum

Specified capacity = 8.92 cum/min

Volumetric efficiency = 8.92 / 10.973 = 0.813 or 81.3 %.

11.4.9 Power Required to Compress

The theoretical horsepower is the horsepower required to compress adiabatically the air delivered by a compressor through the specified pressure range, without any provision for lost energy. Brake horsepower is the actual horsepower input required by a compressor.

Boyle's law is applicable if the temperature is kept constant. The process of expansion or compression of a gas is called "isothermal" and is assumed to take place without any change of temperature. But, if no heat is allowed to enter or leave the gas during the expansion or compression, the process is called "adiabatic" and a temperature change occurs. Since higher compression is achieved under isothermal conditions every effort is made to remove the heat produced by the process. In practice this cannot be fully achieved, and the production of compressed air will fall between isothermal and adiabatic. This is called a polytropic process, which follows the law

$$P_1 V_1^n = P_2 V_2^n = \text{constant, } k \qquad ...(11.1)$$

in which the effect of temperature is provided for by n, where

n = 1 for isothermal compression, and

n = 1.4 for adiabatic compression.

The horsepower required to compress V cft of free air from an absolute pressure of P_1 to P_2 psi under isothermal conditions is given by

$$\text{HP} = 0.1477\, V_1 \log\left(\frac{P_2}{P_1}\right) \qquad ...(11.2)$$

For adiabatic conditions, where n is not equal to 1, the horsepower required will be

$$\text{HP} = 0.0643\, V_1 \left(\frac{n}{n-1}\right)\left[\left(\frac{P_2}{P_1}\right)^{(n-1)/n} - 1\right] \qquad ...(11.3)$$

Example 11.3

Determine the theoretical horsepower required to compress 100 cft of free air per minute, measured at standard conditions, from atmospheric pressure to 100 psi gauge pressure under (a) isothermal conditions, and (b) adiabatic conditions.

Solution

a) From equation (11.2),

$$\text{HP} = 0.1477 \times 100 \times \log\left(\frac{14.73 + 100}{14.73}\right)$$
$$= 0.1477 \times 100 \times \log\,[\,7.7888\,]$$
$$= 13.17 \text{ or } 9.82 \text{ kW}$$

b) From equation (11.3),

$$\text{HP} = 0.0643 \times 100 \left(\frac{1.4}{0.4}\right)\left(7.7888^{0.4/1.4} - 1\right)$$
$$= 17.8 \text{ or } 13.28 \text{ kW.}$$

For air compressors used on construction sites, the compression will be performed under conditions between isothermal and adiabatic. Thus, the theoretical horsepower will be between 13.17 and 17.8, the actual value depending on the extent to which the compressor is cooled during operation. The difference in the horsepowers required shows the importance of operating an air compressor at the lowest practical temperature.

Compression of air from atmospheric pressure to the final delivery pressure is done in stages to control the temperature rise after compression. The number of stages for maximum economy is 5 – 6 with intercoolers interspersed between the stages. As the number of stages increase, capital and operating costs increase.

Two-stage Compression

The operating principle for a 2-stage compression is shown in Figure 11.9.

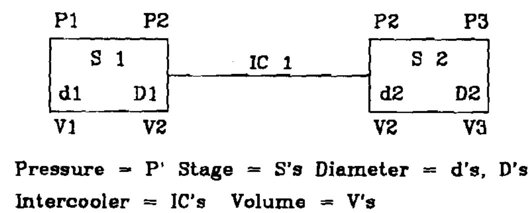


Figure 11.9 : Operating Principle of a Two-stage Compression

Pressure = P's Stage = S's Diameter = d's, D's

Intercooler = IC's Volume = V's

The compression ratio P_3/P_1 is split equally between the two stages such that equal work is done at each stage.

If,

P_1 = low pressure intake

P_2 = low pressure discharge, intercooler, and second stage intake

P_3 = high pressure discharge

R_t = overall compression ratio (= P_3/P_1), then

$$P_2 = (P_1 P_3)^{0.5} = P_1 \sqrt{R_t},$$

$$T_2 = T_1 R_t^{(n-1)/2n} \quad \text{and}$$

$$\text{HP} = 0.0643\, V_1 \left(\frac{n}{n-1}\right)\left(R_t^{(n-1)/n} - 1\right) \qquad \text{...(11.4)}$$

when the work done is divided equally between two stages $R_1 = R_2 = R_t$,

$$\text{HP} = 0.1286\, V_1 \left(\frac{n}{n-1}\right)\left(R_t^{(n-1)/2n} - 1\right) \qquad \text{...(11.5)}$$

Three-stage Compression

If the overall compression ratio exceeds 10, it is often recommended that another stage beyond 2-stage compression be introduced to reduce the temperature rise.

The principle of a three-stage compression is shown in Figure 11.10.

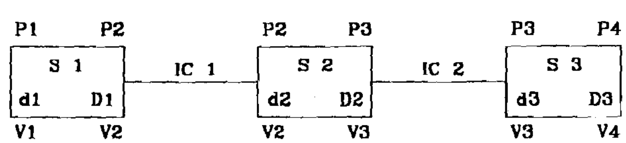


Figure 11.10 : Operating Principle of a Three-stage Compression

For equal work in each stage of a 3-stage compression,

$$R_1 = R_2 = R_3 = R_t^{1/3} \qquad \text{...(11.6)}$$

The pressure in the first intercooler becomes

$$P_2 = P_1 \left(\frac{P_4}{P_1} \right)^{1/3} = P_1 \left(R_t \right)^{1/3} \qquad \text{...(11.7)}$$

In a similar manner, the pressure in the second intercooler is

$$P_3 = P_1 \left(R_t \right)^{2/3} \qquad \text{...(11.8)}$$

and the temperature rise in a 3-stage compression is

$$T_2 = T_1 R_t^{(n-1)/3n} \qquad \text{...(11.9)}$$

where T_1 and T_2 are the initial and final absolute temperatures in each stage.

The power required in a 3-stage compression is

$$\text{HP} = 0.1929 \, V_1 \left(\frac{n}{n-1} \right) \left(R_t^{(n-1)/3n} - 1 \right) \qquad \text{...(11.10)}$$

Four-stage Compression

For extremely high compression ratios, 4-stage compression often is used (Figure 11.11).

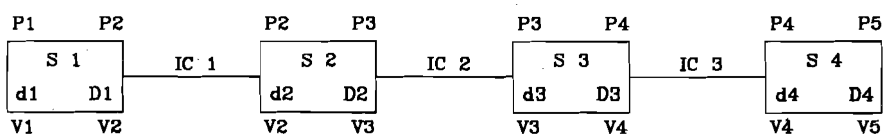


Figure 11.11 : Operating Principle of a Four-stage Compression

In the case of equal work at each stage,

$$R_1 = R_2 = R_3 = R_4 = R_t^{1/4} \qquad \text{...(11.11)}$$

By substituting in pressures for the compression ratios, the expression for the pressure in each cooler can be obtained. For the first intercooler,

$$P_2 = P_1 R_t^{1/4} = \left(P_1^3 P_5 \right)^{1/4} \qquad \text{...(11.12)}$$

For pressure in the second intercooler,

$$P_3 = \left(P_1 P_5 \right)^{1/2} = P_1 \sqrt{R_t} \qquad \text{...(11.13)}$$

And, for the pressure in the third intercooler,

$$P_4 = \left(P_1 P_5^3 \right)^{1/4} = P_1 R_t^{3/4} \qquad \text{...(11.14)}$$

The increase in temperature 4-stage compression is

$$T_2 = T_1 R_t^{(n-1)/4n} \qquad \text{...(11.15)}$$

The power required for 4-stage compression is

$$\text{HP} = 0.2572 \, V_1 \left(\frac{n}{n-1} \right) \left(R_t^{(n-1)/4n} - 1 \right) \qquad \text{...(11.16)}$$

where V_1 is in cfm.

Determining Number of Stages

The theoretical work of compression becomes minimum when the compression ratios R are identical in each stage; that is,

$$R = \left(\frac{P_k}{P_1} \right)^{1/z} \qquad \text{...(11.17)}$$

where,

Z = number of stages,

P_k = final pressure, and

P_1 = initial pressure.

In practice, because of pressure losses between stages (in valves, intercoolers, etc.) the pressure ratios in each stage is somewhat higher than the theoretical prediction. To account for these losses, an empirical correction factor is used to adjust equation (11.17)

$$R = \alpha\left(\frac{P_k}{P_1}\right)^{1/z} \qquad ...(11.18)$$

where,

α – 1.1 - 1.15 is a coefficient accounting for pressure losses between stages.

The number of compression stages required may be determined from the relation

$$Z = \frac{\log P_k - \log P_1}{\log R - \log \alpha} \qquad ...(11.19)$$

To maintain the final air temperature within allowable limits, a pressure ratio in the range of 2.5 - 3.5 may be assumed. This range generally provides the effective use of the cylinder volume, increases the compressor volumetric coefficient, and decrease the energy consumption.

11.4.10 Inlet Pressure

The absolute pressure of the air at the inlet to a compressor is known as the inlet pressure. It is usually the atmospheric pressure which is equal to 1 bar (= 1.036 kg/sq cm or 14.73 psi).

11.4.11 Intercooler

Intercoolers are provided for cooling the air between two stages of compression in a multi-stage compressor. This cooling reduces the temperature and consequently volume of the air before it enters the high pressure cylinder for further compression. The cooling also results in condensation of water vapour and, thus, in removing moisture from the air. Compressing air to 7 kg/sq cm without intercooling would result in a temperature rise of about 250°C effecting increase in air volume, needing more power for compression and hampering proper lubrication.

SAQ 3

i) What are aftercooler and intercooler in an air compressor?

ii) How do density, capacity, compression ratio, discharge pressure, diversity factor, altitude, efficiency, power required to compress and inlet pressure affect the performance of an air compressor?

11.5 PLANNING FOR COMPRESSED AIR SERVICES

Construction operations require the use of compressed air in large quantities. It is a universal source of power for rock drilling equipment, hoists and pile drivers, power shop tools, impact wrenches, hammers, etc. Compressed air can transport materials in pipes effectively. Air is frequently used to transport cement and is common as the medium of concrete placement in tunnels. It is needed for sand blasting, for shotcreting and for spray painting. An effective cleaning tool is a combination of compressed air and water jet where the mixing of water and air can be controlled by valves on each feed line. Effective job planning of compressed air services requires knowledge of the great variety of uses in which compressed air power provides advantages over other power sources. It is common for a job superintendent to add powered equipment as the job progresses until compressed air demands are substantially beyond the originally estimated needs. This aspect must be considered in planning.

In determining the air requirements for a job an estimate is made of the consumption of all tools required, on the basis of their expected staggered operation, to arrive at a probable peak demand.

SAQ 4

How is compressed air services planned for a construction project?

11.6 RATINGS OF COMPRESSORS

The normal capacity of air compressors is usually given as the cum of free air per minute that the unit can deliver as compressed air at a stated pressure. This is not a consistent, precise rating for all conditions as it refers to free air at the point of use. The pressure, humidity, and temperature of the free air affect the amount of compressed air delivered and the power consumed for any given compressor. For the types of compressors usually employed in construction, a delivery pressure of 7 kg/sq cm is used to qualify the standard rating. Most construction air tools demand about 7 kg/sq cm for efficient operation, and most compressors intended for construction services are designed for efficient delivery of air at this pressure or slightly higher. Higher pressures are required when feed lines to air operated equipment are long or when several units are pumping into a common distribution system. For such cases, it is common to regulate the compressors to about 8.79 kg/sq cm, either through motor controls or by safety release valves or by both. Especially with reciprocating units, it is essential to provide and maintain safety release valves that exhaust air from a system subjected to more than a safe pressure.

SAQ 5

i) How are compressors rated?

ii) What factors affect the compressed air delivered from a compressor?

11.7 LOSS OF PRESSURE IN PIPE DUE TO FRICTION

The loss in pressure due to friction as air flows through a pipe or a hose is a factor to be considered in selecting the size of a pipe or hose. As the pressure drops the efficiency of pneumatic equipment falls. When the cost of lost efficiency exceeds the cost of providing a larger line, it is good economy to install a larger line. The manufacturers specify the minimum air pressure at which the equipment will function satisfactorily. However, these values should be considered as minimum and not desirable operating pressures. The actual pressure should be higher than the specified minimum.

Pressure losses are incurred in transferring the compressed air to the tools, and they depend upon:

a) length of pipe – increasing pipe length increases the friction losses,

b) air pressure at point of entry,

c) pipe diameter – larger the diameter, lesser the friction loss,

d) rate of flow – greater flow increases friction loss, and

e) bends, fittings, valves, etc. – all of which increase the loss.

The formula for estimating the pressure drop for a particular length of pipeline is given by:

$$dp = \frac{c\,L\,Q^{1.85}}{p\,d^{5}} \qquad \text{...(11.20)}$$

where,

dp = pressure drop in bar (1 bar = 14.7 psi),

c = coefficient (82000 for steel pipes),

L = pipe length (m),

Q = volume of flow of free air (cum/min),

p = initial absolute pressure (bar), and

d = pipe diameter (mm).

SAQ 6

i) What effect does loss of pressure have on a pneumatic equipment?

ii) Why do pressure losses occur?

11.8 AIR RECEIVER

The functions of an air receiver are to absorb the pulsations in the discharge line and thus, to avoid their being passed on to the service lines; to serve as a reservoir of air for meeting fluctuations in demand; and to remove moisture from air by condensing it, if some of it is carried from the aftercooler. The air inlet to the receiver is near the top and the outlet is near the bottom.

A receiver of capacity 1/10 of the compressor FAD (Free Air Delivery) should be enough for average systems using constant speed control. The receiver size can be 1/6 of FAD if provided with an automatic start-stop control. The receiver size can be reduced with increasing compressor capacity.

The fittings on a receiver include safety valves, pressure gauges, cleaning holes, drain valves and its supporting frame. In stationary installations the receiver is installed outside the compressor house but near it. In portable compressors it is carried on the frame attached to one side of the chassis. The safety valves are set at the working pressure stamped on the receiver. To provide a margin of safety it is desirable to keep actual working pressure of air at about 5 % lower than the safety valve blow-off pressure.

SAQ 7

i) What are the functions of an air receiver?

ii) What fittings are part of an air receiver?

11.9 AIR CONSUMPTION OF TOOLS

The approximate quantities of compressed air required by some pneumatic equipment and tools are given in Table 11.2. The quantities are based on the continuous operation at a pressure of 6.33 kg/sq cm (90 psi) gauge.

Table 11.2 : Quantities of Compressed Air Required by Pneumatic Equipment and Tools

Equipment or Tools	Air Consumption, cum/min at 7 bar Gauge Pressure
Clay digger (spade type)	0.9 – 1.25
Concrete breaker, heavy	2.5
Concrete breaker, light	1.0
Concrete breaker, medium	1.5
Drill hole flushing	≤ 5
Feedleg drills	4 – 6
Hand held sinker drills	2 – 4
Hoists and winches	≤ 10
Picks	1 –1.2
Pile hammers	1 –50
Pumps	2 – 5
Rig mounted rotary and rotary-percussive drills	5 – 10
Small tools	0.5 – 1
Vibrators	1 – 2

SAQ 8

How are air consumption of tools considered in computing the capacity of an air compressor plant?

11.10 BLOWERS

The term blower is usually restricted to denote rotary compressors which give delivery pressures of 2.5 kg/sq cm or less.

The operation of a single-stage centrifugal blower is shown in Figure 11.12. The casing (1) houses the rotating wheel (2) with blades similar to a centrifugal pump. The wheel is inserted inside the diffuser (3), where the velocity generated is converted into pressure, partially in the wheel and partially in the diffusers following the wheel. The diffusers consist of two circular disks connected by curved blades having a slope opposite to that of the wheel. Air enters the blower through the nozzle (4) and leaves through the discharge nozzle (5).

Figure 11.13 shows the operating scheme of a multi-stage blower. Contained in the casing (1) are several (usually 3 or 4) wheels (2). The air passing through the first wheel enters into the guiding diffusers (3) and return channel (4), through which it is guided to the following wheel. The return channel has fixed guiding diaphragms, which impart to the air velocity and direction. Constant wheel diameters are used in multi-stage blowers; however, wheel widths decrease in the direction from the first to the last wheel according to the air volume at compression. Thus, air compression is possible without changing the velocity of rotation or the form of the blades. In general, the compression ratio of centrifugal blowers does not exceed 3- 3.5, and so there is no need for cooling.

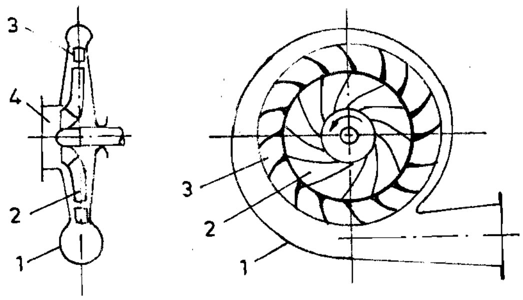


Figure 11.12 : Centrifugal Single-stage Blower
1) Casing 2) Guiding Diffuser 3) Nozzle
4) Discharge Nozzle

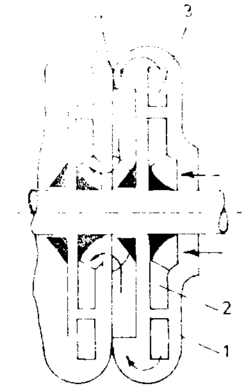


Figure 11.13 : Operating Scheme for a Multi-stage Blower
1) Casing 2) Wheel 3) Guiding Diffuser 4) Return Channel

SAQ 9

i) What is a blower?

ii) How does a single-stage blower operate?

iii) How does a multi-stage blower operate?

11.11 SUMMARY

In this unit you learnt about the various types of air compressors and blowers. The factors that affect the functioning of a compressor have been explained. Air receivers are needed to maintain a continuous supply of air to the tool even when the compressor produces air in pulses. Tools requiring compressed have to be supplied air at a specified pressure and this is possible by means of an air receiver. Effects of air density and altitude of a place also affect the output of a compressor. All these aspects would be clear to you by now.

11.12 ANSWERS TO SAQs

Read through the various sections and find the answers.