AIR GENERATION, TREATMENT & DISTREBUTION PART 1

Dr. Ahmad Al-Mahasneh

Pneumatics and Hydraulics

REVIEW OF THE LAST LECTURE

- Why pneumatics?
- Industrial applications of pneumatics
- Structure and signal flow of pneumatic systems
- Physical fundamentals
- Characteristics of air: Boyle-Mariotte's Law: $P_1 V_1 = P_2 V_2$
- Gay-Lussac law : $\frac{P_1}{T_1} = \frac{P_2}{T_2}$
- General gas equation $\frac{p_1 \bullet V_1}{T_1} = \frac{p_2 \bullet V_2}{T_2} = \text{Constant}$
- Flow vs. pressure drop: $Q = \frac{\Delta P}{R}$

OUTLINE

- Air preparation
- Pressure level
- Air compressors
- Compressor types
- Flow regulation
- Reservoirs
- Air dryers

AIR PREPARATION

For the continuing performance of control systems and working elements it is necessary to guarantee that the air supply is:

1. At the required pressure.
2. dry.
3. clean.

- The generation of compressed air starts off with compression.
- The compressed air flows through an entire series of components before reaching the consuming device.
- The type of compressor and its location to a lesser or greater degree affect the amount of dirt particles, oil and water which enter a pneumatic system.

AIR PREPARATION

The equipment to be considered in the generation and preparation of air include:

- Inlet filter
- Air compressor
- Air reservoir
- Air dryer
- Air filter with water separator
- Pressure regulator
- Air lubricator as required
- Drainage points

AIR PREPARATION

Poorly-prepared compressed air will inevitably lead to malfunctions and may manifest itself in the system as follows:

- Rapid wear of seals and moving parts in the cylinders and valves
- Oiled-up valves
- Contaminated silencers
- Corrosion in pipes, valves, cylinders and other components
- Flushing out of lubrication of moving components
- In the case of leakage, escaping compressed air may impair the materials to be processed (e.g. food).

PRESSURE LEVEL

- As a rule, pneumatic components are designed for a maximum operating pressure of 800 to 1000 kPa (8-10 bar).
- Practical experience has shown, however, that approximately 600 kPa (6 bar) should be used for economic operation.
- Pressure losses of between 10 and 50 kPa (0.1 and 0.5 bar) must be expected due to the restrictions, bends, leaks and pipe-runs, depending on the size of the piping system and the method of layout.
- The compressor's system should provide at least 650 to 700 kPa (6.5 to 7 bar) for a desired operating pressure level of 600 kPa (6 bar).

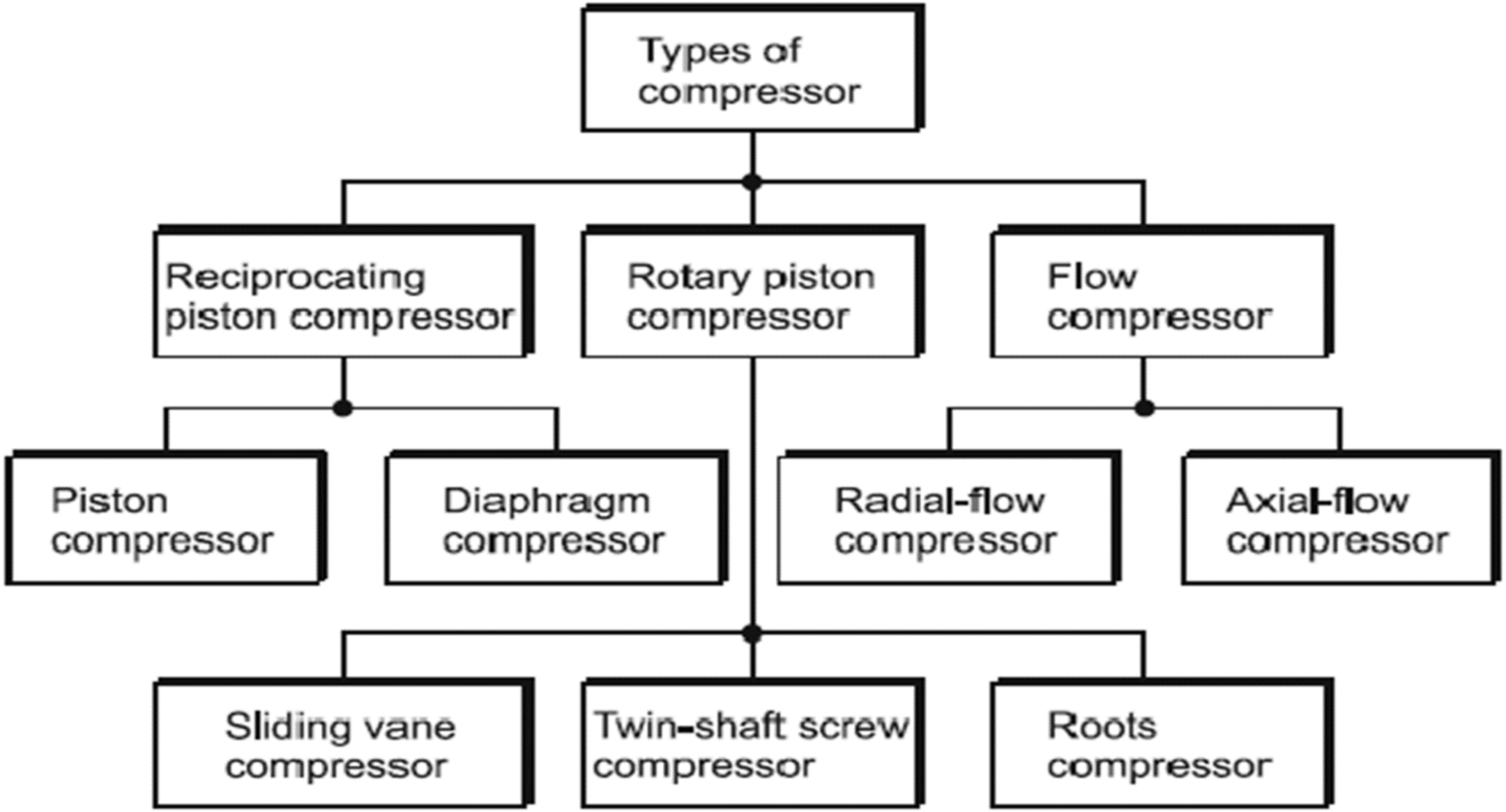
AIR COMPRESSORS

The selection from the various types of compressors available is dependent upon:

- Quantity of air,
- Pressure,
- Quality and cleanliness
- How dry the air should be.

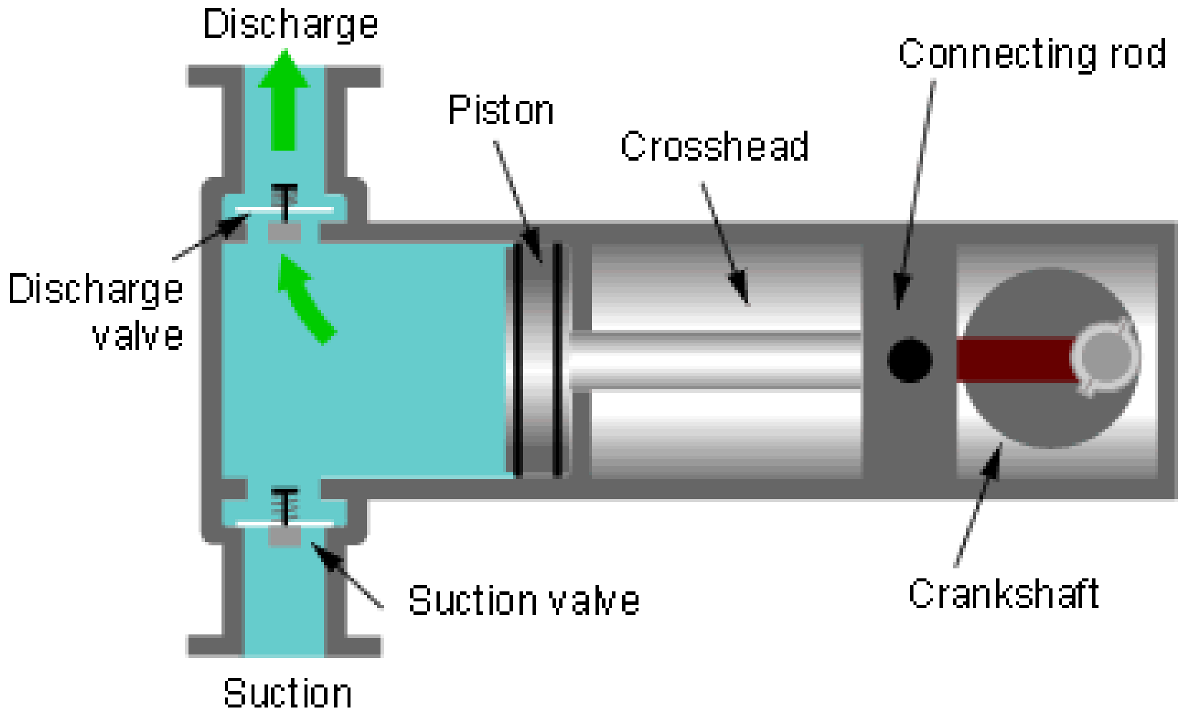
There are varying levels of these criteria depending on the type of compressor.

COMPRESSOR TYPES



RECIPROCATING PISTON COMPRESSORS

- A piston compresses the air drawn in via an inlet valve. The air is passed on via an outlet valve.
- Reciprocating compressors are very common and provide a wide range of pressures and delivery rates.
- For higher pressures multistage compression is used with intercooling between each stage of compression.



RECIPROCATING PISTON COMPRESSORS

- The optimum range of pressures for reciprocating compressors are approximately:

Optimum pressure range in kPa	In bar	Type
up to 400	4	Single stage
up to 1500 kPa	15	Double stage
over 1500 kPa	>15	Triple or multistage

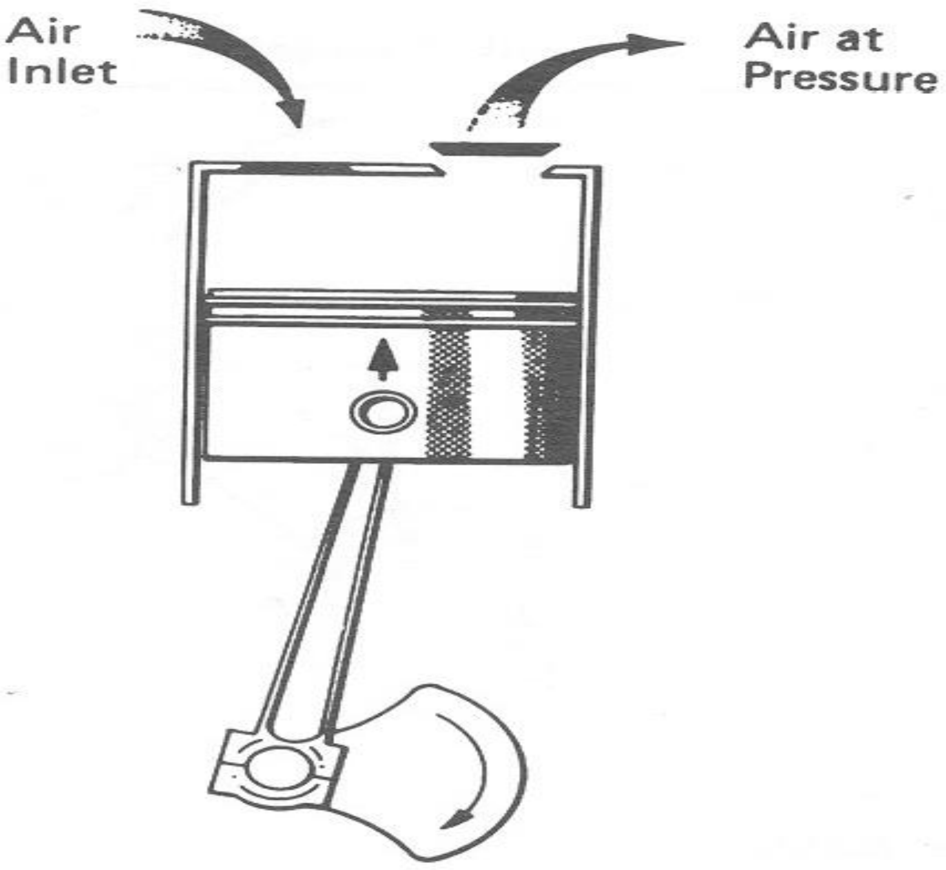
RECIPROCATING PISTON COMPRESSORS

- It is possible but not necessarily economic to operate in the following ranges:

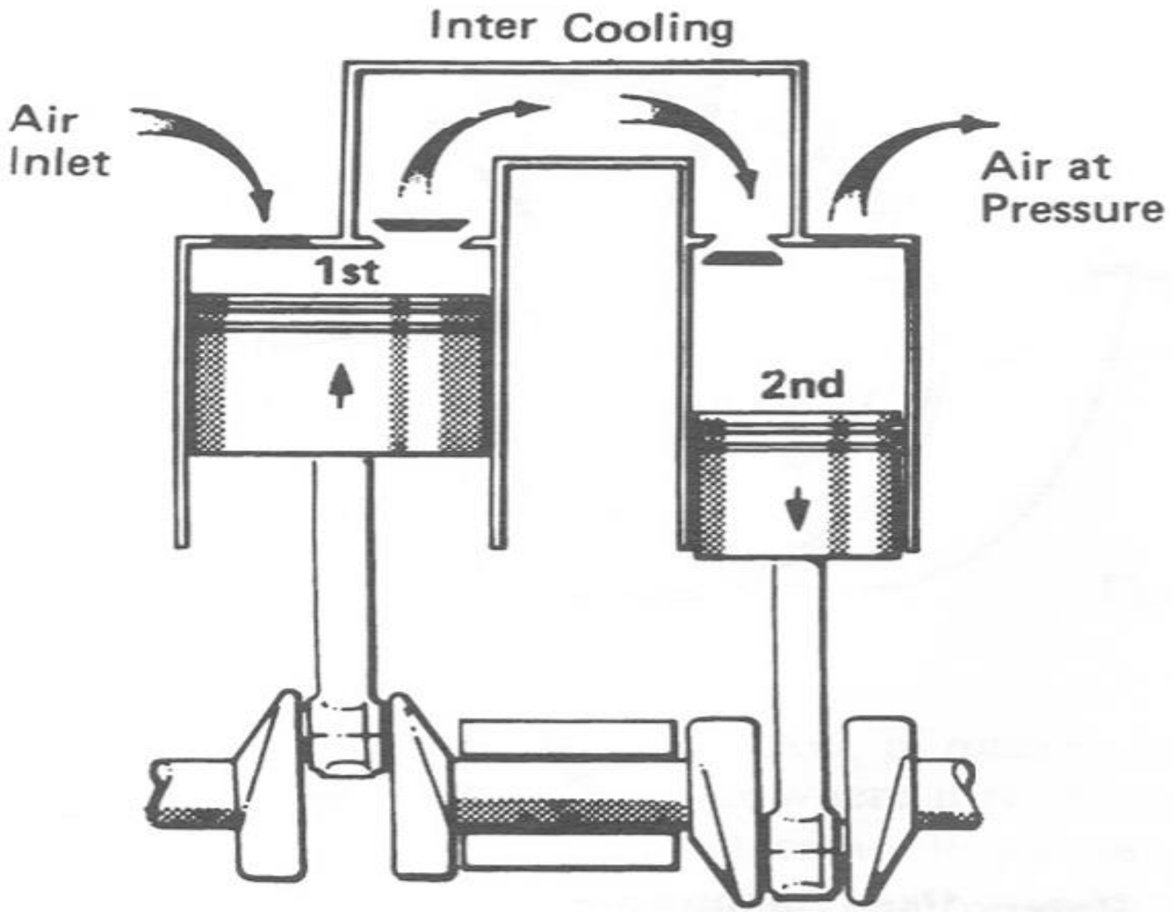
Optimum pressure range in kPa	In bar	Type
up to 1200 kPa	12	Single stage
up to 3000 kPa	30	Double stage
over 3000 kPa	>30	Triple or multistage

Single acting, single stage, vertical, reciprocating compressor:

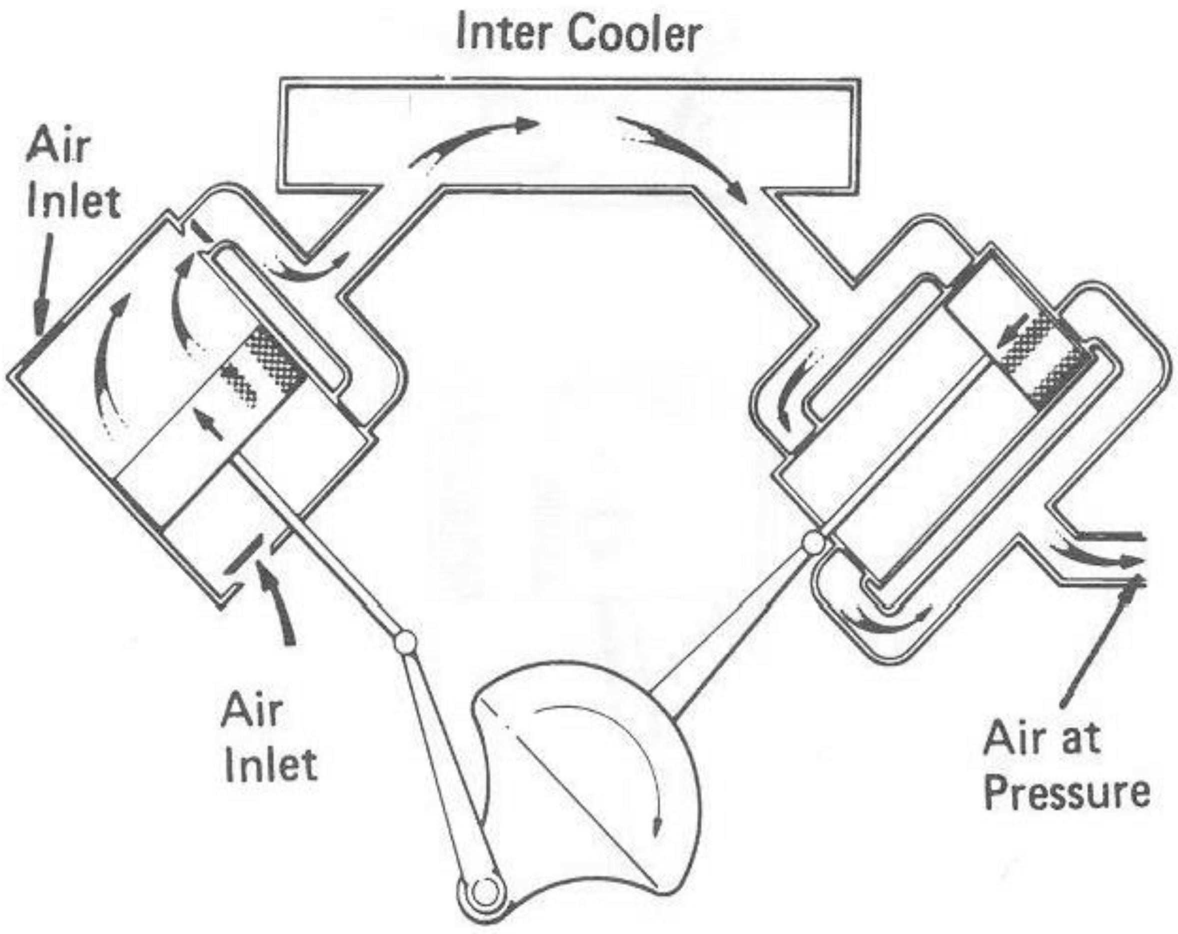
SINGLE ACTING, SINGLE STAGE, VERTICAL, RECIPROCATING COMPRESSOR:



SINGLE ACTING, TWO STAGE, VERTICAL, RECIPROCATING COMPRESSOR:

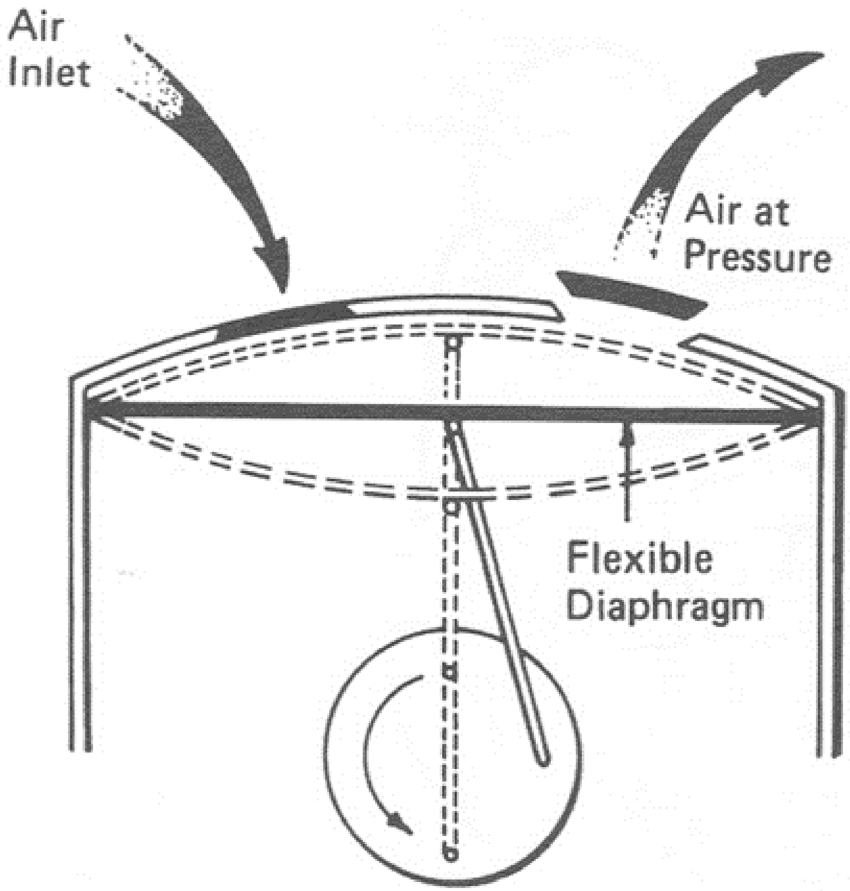


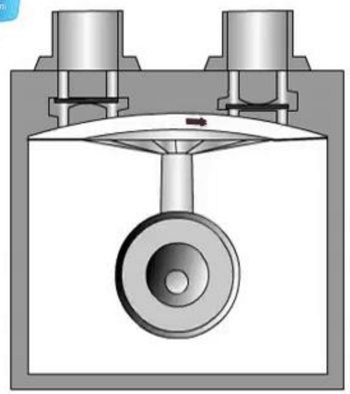
DOUBLE ACTING, TWO STAGE, V SHAPE, RECIPROCATING COMPRESSOR:



DIAPHRAGM COMPRESSOR

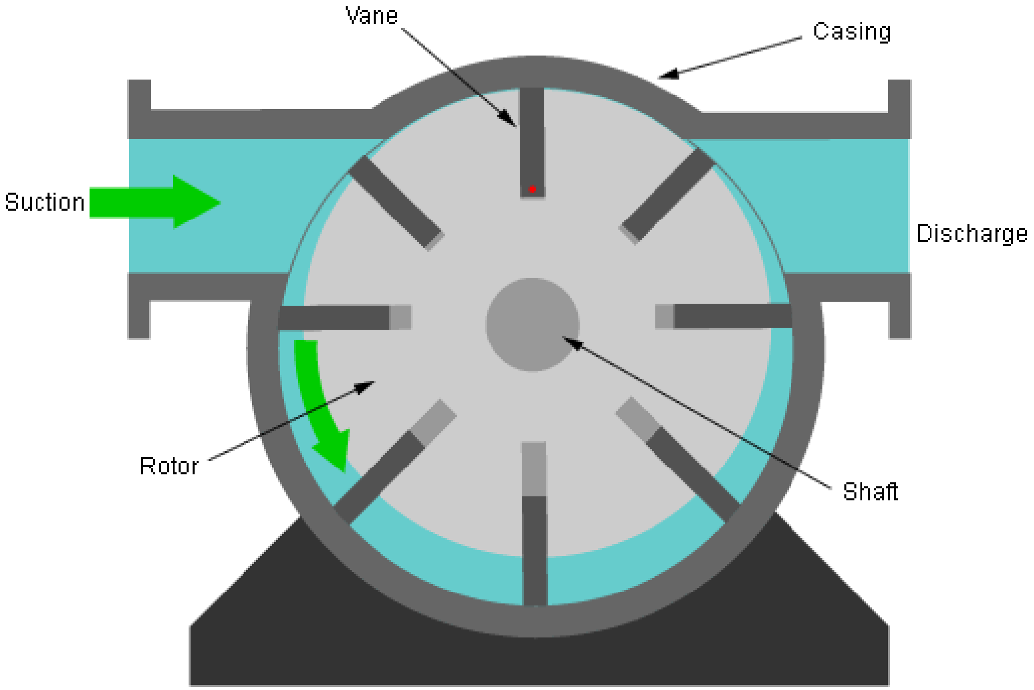
- The diaphragm compressor belongs to the reciprocating piston compressor group.
- The compressor chamber is separated from the piston by a diaphragm.
- The advantage of this is that no oil can enter the air flow from the compressor.
- The diaphragm compressor is therefore used where oil is to be excluded from the air supply, for example in the food, pharmaceutical and chemical industries.

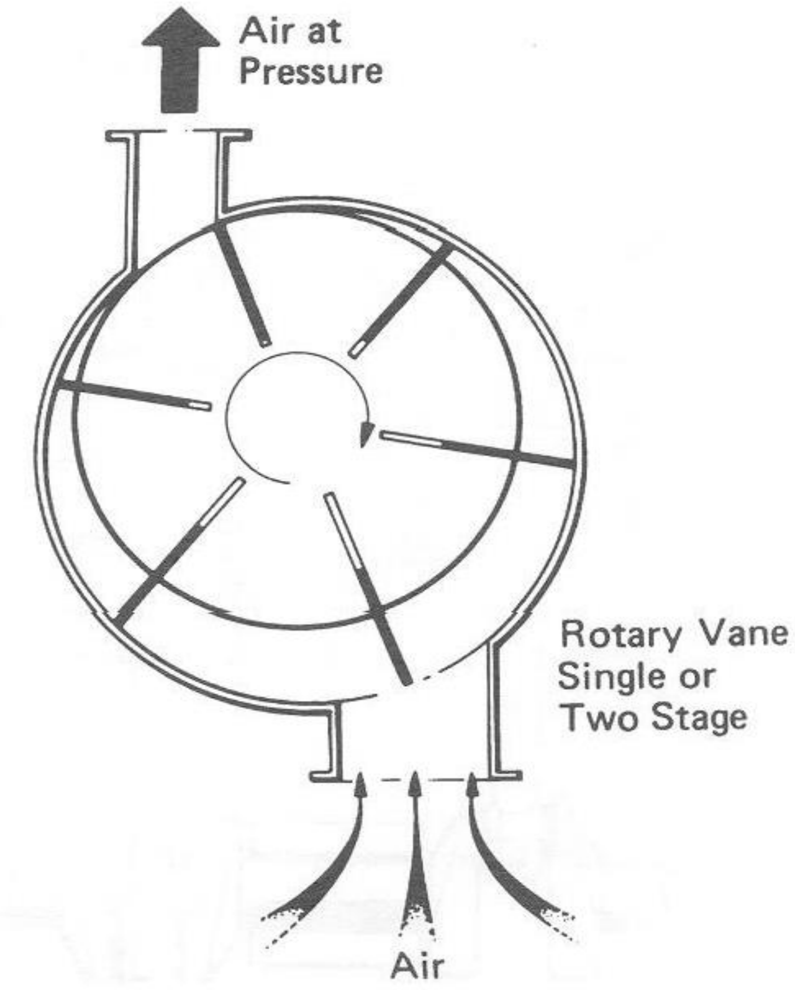




ROTARY PISTON COMPRESSOR

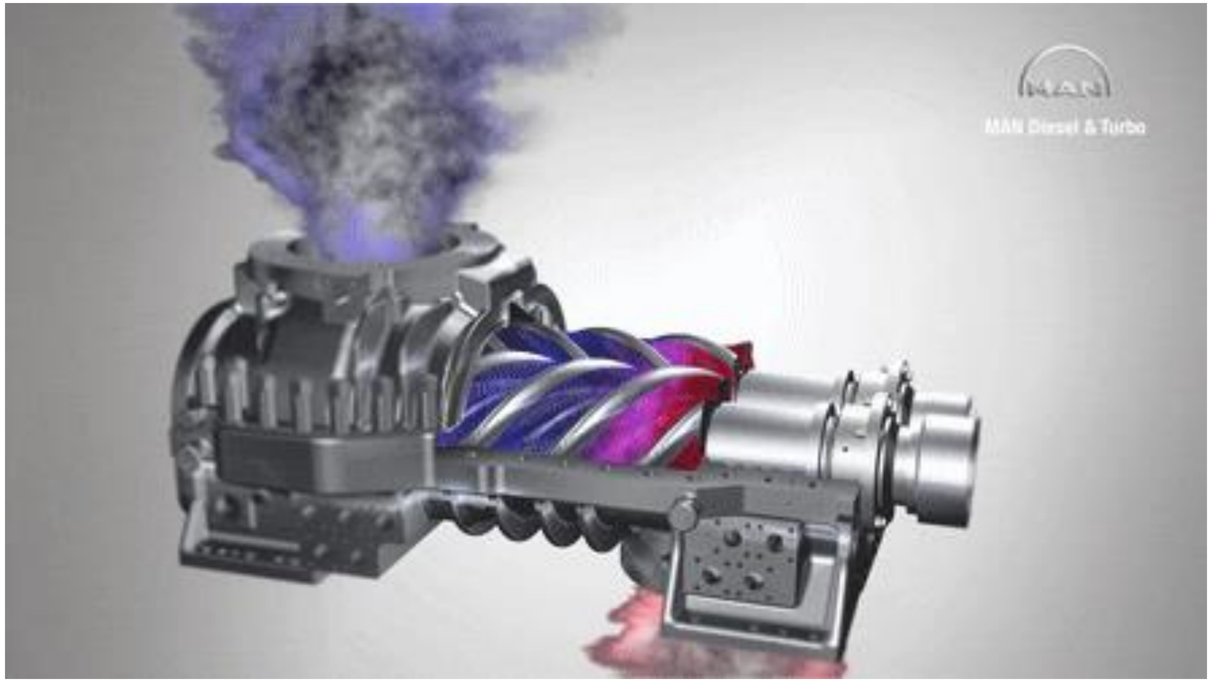
- The rotary group of compressors use rotating elements to compress and increase the pressure of the air.
- During the compression process, the compression chamber is continually reduced.

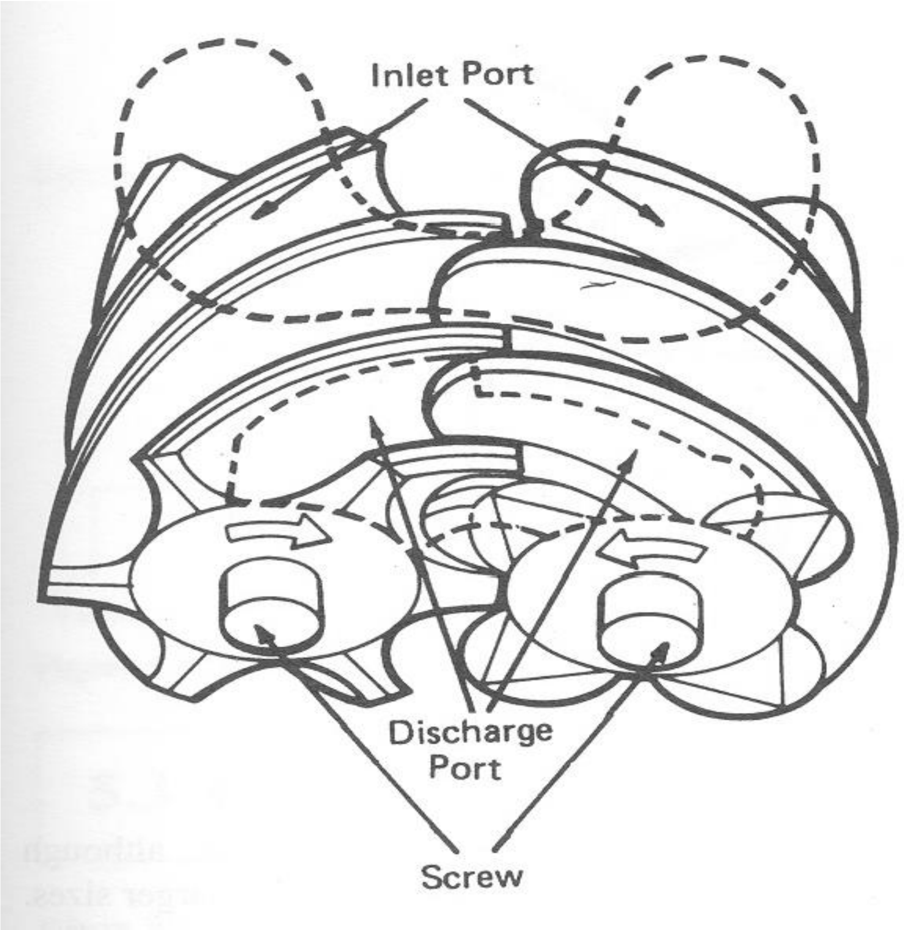




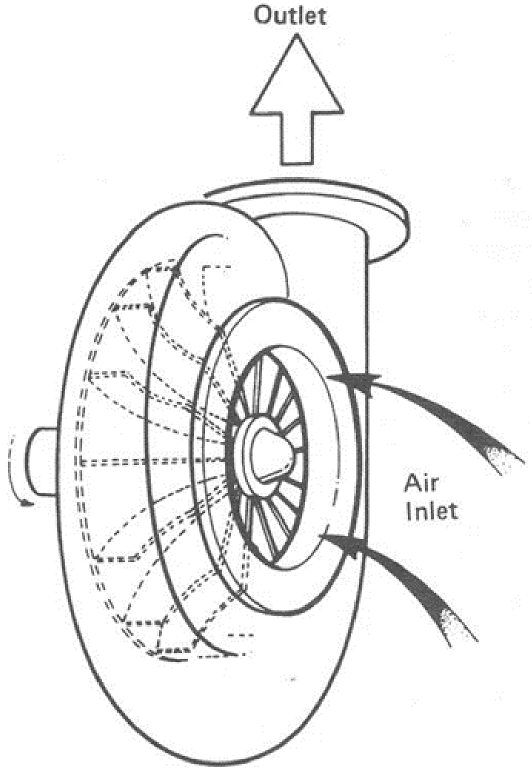
SCREW COMPRESSOR

- Two screw-shaped shafts (rotors) turn in opposite directions.
- The meshed profile of the two shafts causes the air to flow which is then compressed.

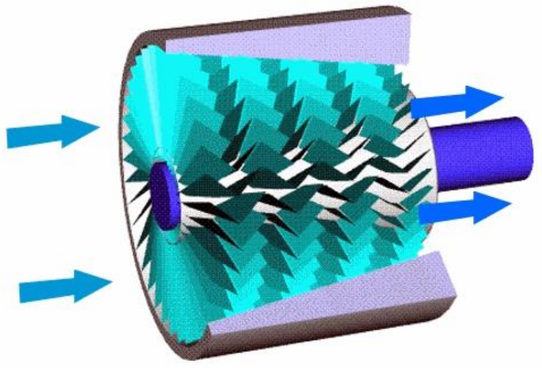




FLOW COMPRESSOR



- These are particularly suitable for large delivery quantities.
- Flow compressors are made in axial or radial form.
- The air is made to flow by means of one or several turbine wheels.
- The kinetic energy is converted into pressure energy.
- In the case of an axial compressor, the air is accelerated in the axial direction of flow by means of blades.



Compresor Axial

cocho57

REGULATION

▪In order to adapt the delivery quantity of the compressor to the fluctuating demand, it is necessary to regulate the compressor.

▪ The delivery quantity is regulated between the adjustable limits for maximum and minimum pressure.

▪There are a number of different types of regulation:

▪Idling regulation

- Relief regulation
- Shut-off regulation
- Claw regulation

▪Part-load control

- Speed adjustment
- Suction throttle control

▪Intermittent control

IDLING REGULATION

- In the case of relief regulation, the compressor operates against a pressure-relief valve.
- When the set pressure is reached, the pressure-relief valve opens and the air is exhausted to atmosphere.
- A non-return valve prevents the emptying of the tank.
- This type of regulator is only used for very small installations.
- With shut-off regulation the suction side is shut off.
- The compressor cannot take in air.
- This type of regulation is mainly used in the case of rotary piston compressors.
- With larger piston compressors, claw regulation is used.
- A claw holds the suction valve open; the compressor cannot compress any air.

PART-LOAD CONTROL

- In the case of speed adjustment, the speed of the drive motor of the compressor is controlled dependent on the pressure reached.
- With suction throttle control, control is affected by means of a restrictor in the suction connection of the compressor.

INTERMITTENT CONTROL

- With this type of control, the compressor assumes the operational conditions ‘full load’ and ‘normal‘.
- The drive motor of the compressor is switched off when p_{max} is reached and switched on when p_{min} is reached.

DUTY CYCLE

- It is recommended that a duty cycle of approx. 75 % is achieved for a compressor.
- To do so, it is necessary to determine the average and maximum air requirement of a pneumatic system and to select the compressor on the basis of this.
- If it is anticipated that the air requirement will increase as a result of system expansions, then the compressor air supply section should be designed larger, since subsequent expansion is associated with high costs.

RESERVOIRS

- A reservoir is configured downstream of a compressor to stabilize compressed air.
- A reservoir compensates the pressure fluctuations when the compressed air is taken from the system.
- If the pressure in the reservoir drops below a certain value, the compressor will compensate until the set higher value is reached again.
- This has the advantage that the compressor does not need to operate continuously.
- The large surface area of the reservoir cools the air. Thus, a portion of the moisture in the air is separated directly from the reservoir as water, which has to be regularly drained via a drain cock.

RESERVOIRS

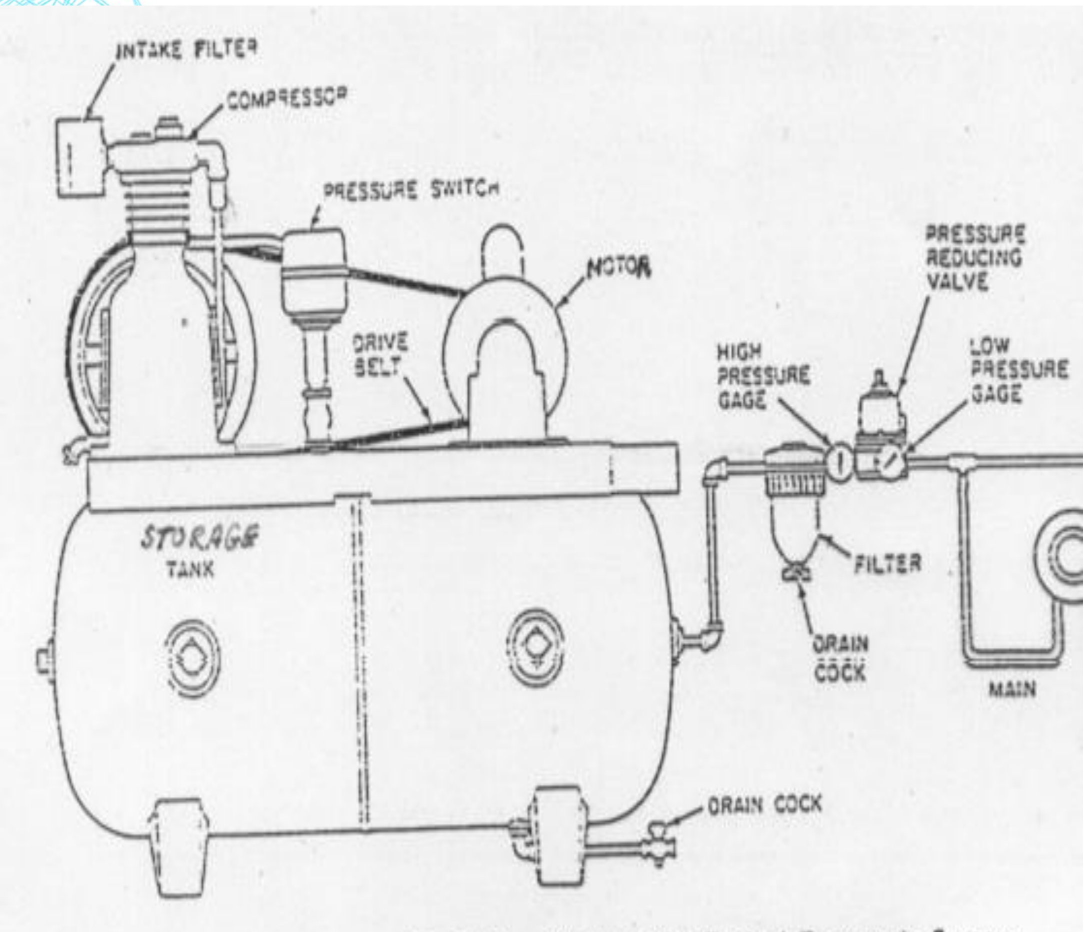
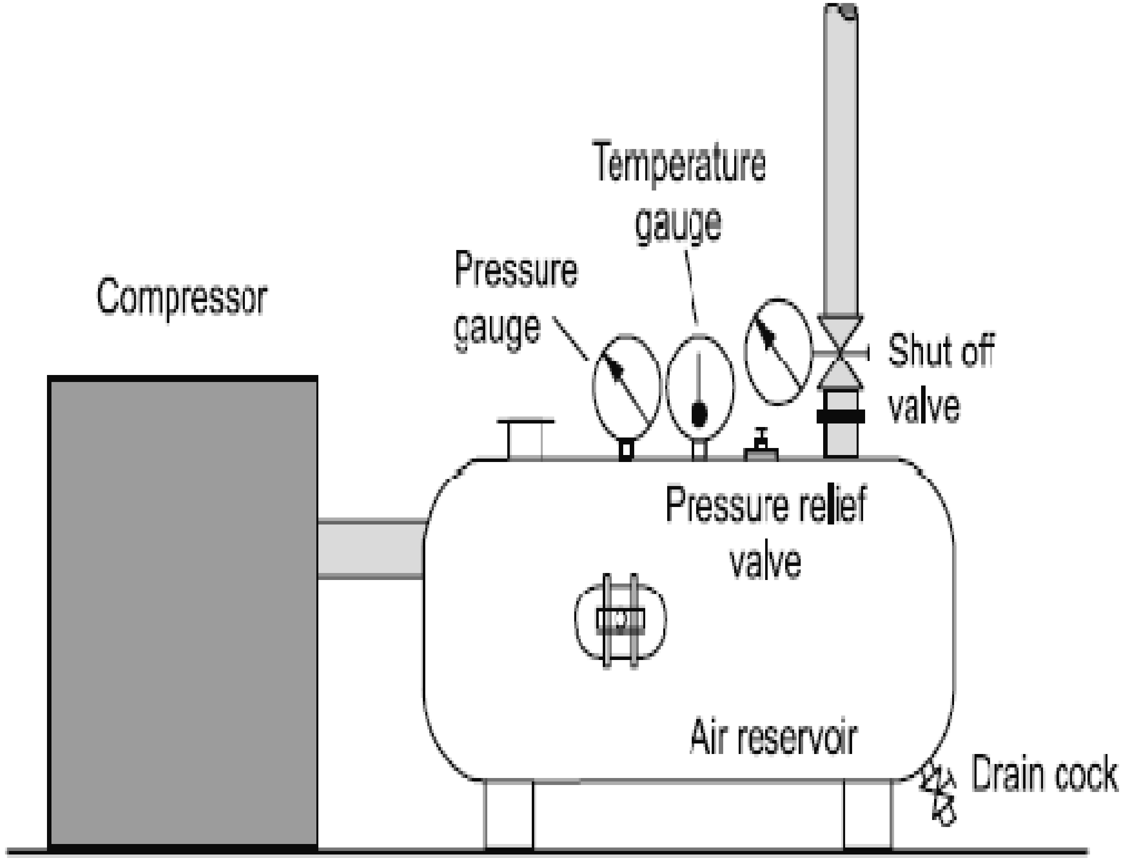


Fig. 1-C1—Diagram of a Typical Pneumatic System.

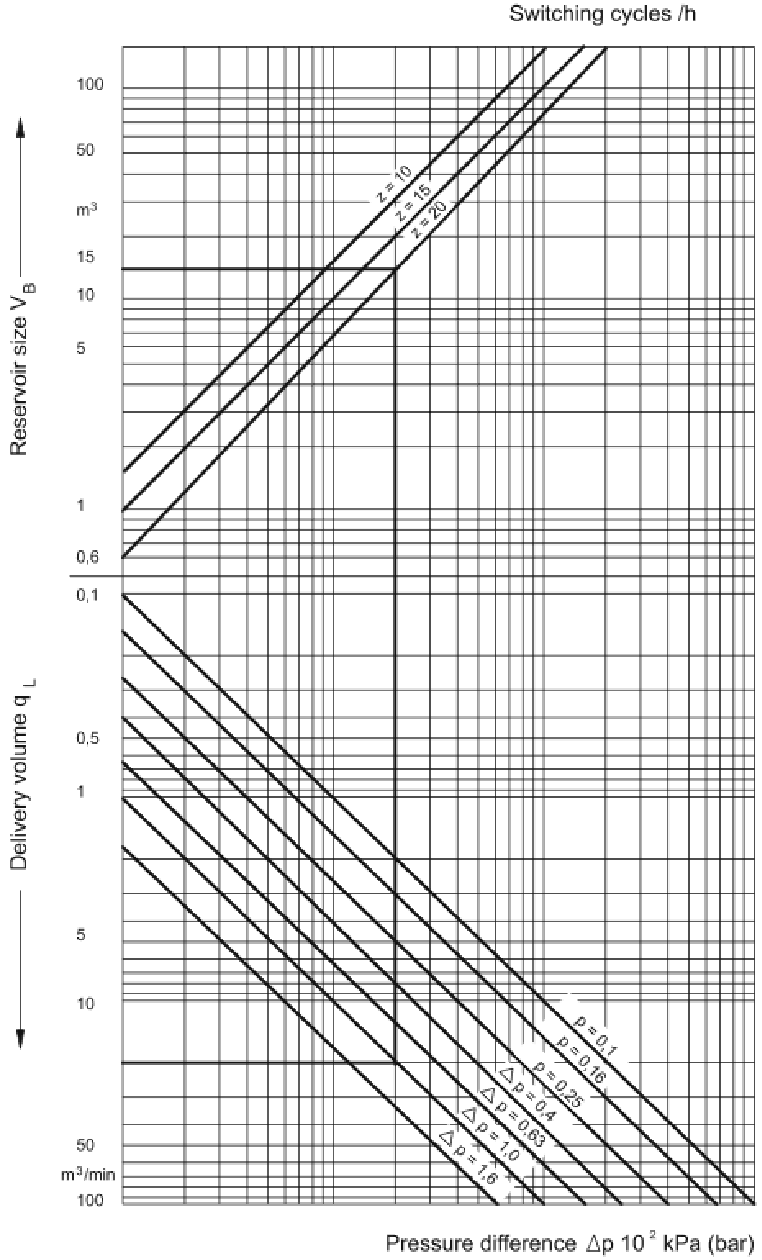


RESERVOIRS

The size of a compressed air reservoir depends on the:

- Delivery volume of the compressor
- Air consumption for the applications
- Network size (any additional requirements)
- Type of compressor cycle regulation
- Permissible pressure drop in the supply network

RESERVOIRS



Delivery volume	q_L	= 20 m^3/min	*Example*
Switching cycles per hour	z	= 20 1/h	
Differential pressure	Δp	= 100 kPa (1 bar)	

Result: Reservoir size V_B = 15 m^3 (refer to the chart)

RESERVOIRS

Example:

Delivery volume q_L = 20 m^3/min
Switching cycles per hour z = 20 1/h
Differential pressure Δp = 100 kPa (1 bar)
Result: Reservoir size VB = 15 m^3 (refer to the chart)

RESERVOIRS

- Condensate (water) enters into the air network through the air intake of the compressor.
- The accumulation of condensate depends largely on the relative air humidity.
- The relative air humidity is dependent on the air temperature and the weather situation.
- The absolute humidity is the mass of water vapor, actually contained in one m^3 of air.
- The saturation quantity is the mass of water vapor, which one m^3 of air can absorb at the respective temperature.

AIR DRYERS

The following formula applies if the relative air humidity is specified in percent:

$$\text{Relative humidity} = \frac{\text{absolute humidity}}{\text{saturation quantity}} \bullet 100\%$$

- Since the saturation quantity is dependent on temperature, the relative humidity changes with the temperature, even if the absolute humidity remains constant.
- If the dew point is reached, the relative humidity increases to 100%.

DEW POINT

- The dew point temperature is the temperature at which relative humidity is 100%.
- The lower the dew point the more the water will condense and reduce the amount entrapped in the air.
- The service life of pneumatic systems is considerably reduced if excessive moisture is carried through the air system to the components. Therefore it is important to fit the necessary air drying equipment to reduce the moisture content to a level which suits the application and the components used.
- There are three auxiliary methods of reducing the moisture content in air:

1. Low temperature drying
2. Adsorption drying
3. Absorption drying

PRESSURE DEW POINT

- To be able to compare different types of drying systems, the operating pressure of the system must be taken into account. The term ‘pressure dew point’ is used in this context.
- The pressure dew point is the air temperature reached during drying at operating pressure.
- The pressure dew point of the dried air should be approx. 2 to 3 °C under the coolest ambient temperature.
- The additional cost of installing air drying equipment can be amortized over a short period due to the reduction in maintenance costs, reduced downtime and increased reliability of the system.

LOW TEMPERATURE DRYING

- The most common type of dryer today is the refrigeration dryer. With refrigerated drying, the compressed air is passed through a heat exchanger system through which a refrigerant flows.
- The aim is to reduce the temperature of the air to a dew point which ensures that the water in the air condenses and drops out in the quantity required.
- The air entering the refrigeration dryer is pre-cooled in a heat exchanger by the escaping cold air.
- It is then cooled in the cooling unit to temperatures between + 2 and + 5°C.

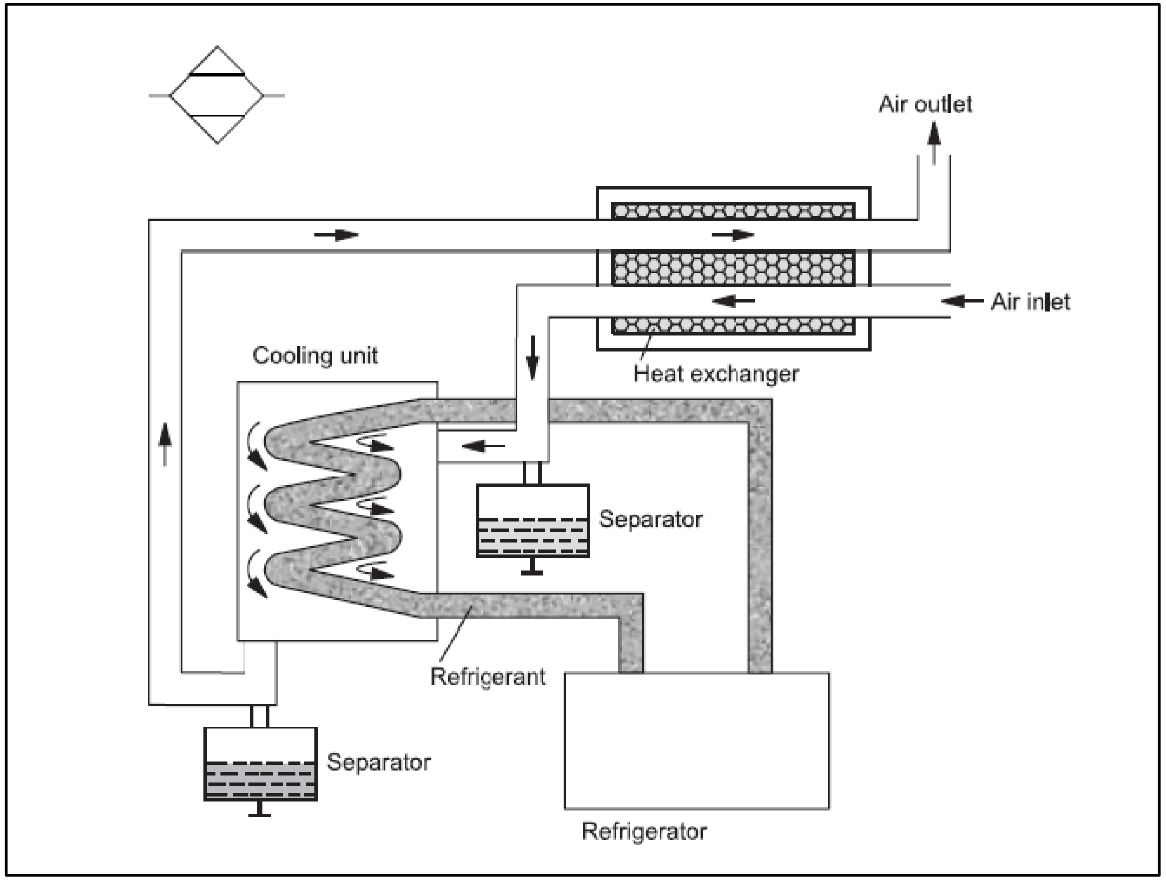
LOW TEMPERATURE DRYING

- The dried compressed air is filtered.
- Before the compressed air is output into the network, the air is heated to bring the air back to ambient conditions.
- Using refrigeration methods, it is possible to achieve dew points of between + 2 and + 5 °C.

ADSORPTION DRYERS

Adsorption: water is deposited on the surface of solids.

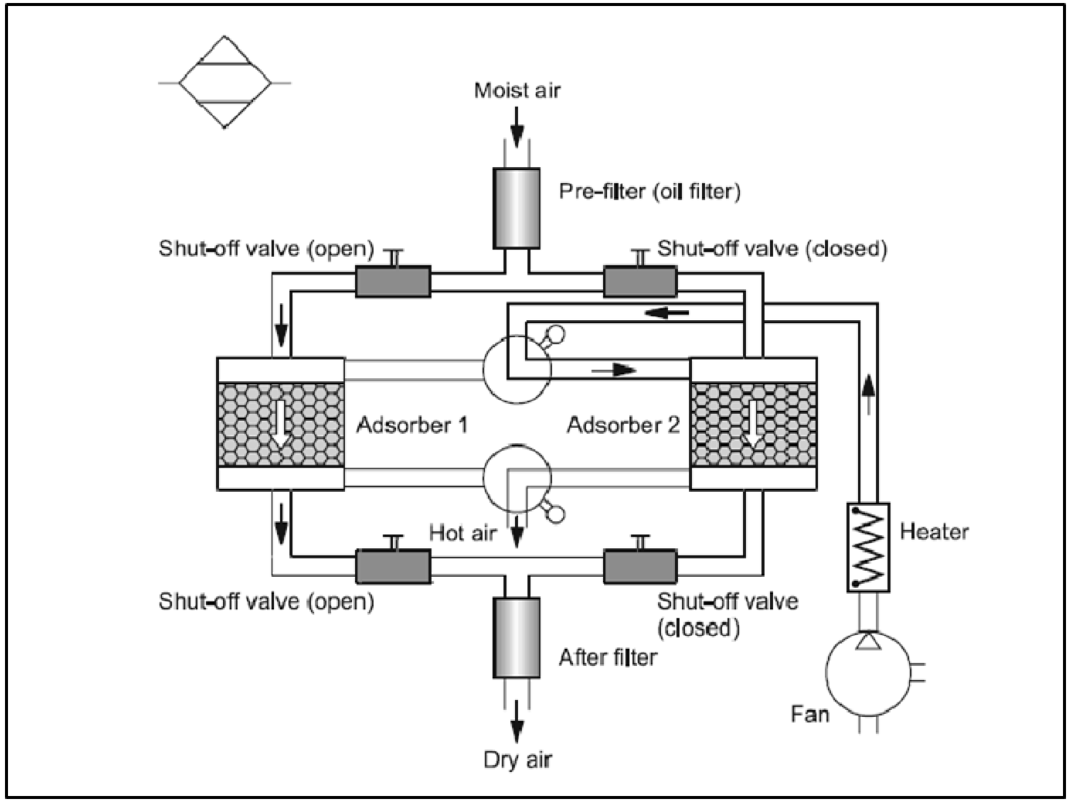
- The drying agent is a granular material (gel) consisting almost entirely of silicon dioxide.
- Usually two tanks are used. When the gel in one tank is saturated, the air flow is switched to the dry, second tank and the first tank is regenerated by hot-air drying.
- The lowest equivalent dew points (down to – 90 °C) can be achieved by means of adsorption drying.



ABSORPTION DRYERS

Absorption: A solid or liquid substance bonds a gaseous substance.

- Absorption drying is a purely chemical process.
- Absorption drying is not of major significance in present-day practice, since the operating costs are too high and the efficiency too low for most applications.
- Oil vapor and oil particles are also separated in the absorption dryer.
- The moisture in the compressed air forms a compound with the drying agent in the tank.



ABSORPTION DRYERS

- This causes the drying agent to break down; it is then discharged in the form of a fluid at the base of the tank.
- The mixture must be regularly drained and the fluxing agent must be regularly replaced.
- The features of the absorption process are :
- Simple installation of the equipment
- Low mechanical wear because there are no moving parts in the dryer
- No external energy requirements.