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INDUSTRIAL PLANTS II

Chapter one (part 1):

Piping – Fluid distribution plants – Plants for the production and distribution of compressed air

DOUBLE DEGREE MASTER IN

"PRODUCTION ENGINEERING AND MANAGEMENT"

SEAT OF PORDENONE

UNIVERSITY OF TRIESTE

Plants for the production and distribution of compressed air

Generality

The use of compressed air in industry has grown in recent decades, so that there is no plant that does not use this servo-means for the control and regulation of utilities, motive power for machinery and equipment, tools and servo-control.

The production of compressed air is obtained by compressors, aspiring atmospheric air, the pressure required to compress and feed it to the distribution network.

The capacities of the compressors are measured in volumes of free air per unit of time, namely in a quantity of air per unit of time reported to the pressure and temperature existing intake, although often it must contain at normal conditions of 1 bar and 0°C.

The operating pressure of the air for normal loads technological industrial establishments is of 6 - 7 bar, although in some cases higher pressures are required.

Work of compression of the air

The equation that characterizes the air compression is the:

$$p \cdot v^m = \text{costant}$$

(polytropic compression), where m is the exponent of the polytropic.

In the case m = 1 one has the isothermal compression ($p \cdot v$ = constant) and for m = 1.4 one has the isentropic or adiabatic compression ($p \cdot v^{1,4}$ = costant). The work required for the compression increases from an isothermal transformation at an isentropic and that is with the increase of m (parallel increases the final temperature of the compressed air).

The internal work to compress the unit mass of air from the pressure p_1 to the pressure p_2 is given by the relation:

$$L_i = \int_{p_1}^{p_2} v \cdot dp + L_w$$

where:

v = volume specifico o massa;

L_w = working of mass of the passive resistances encountered by the air in the machine.

Work of compression of the air

Assuming an ideal compressor (L_w = 0), in which the air undergoes compression according to one isentropic of isothermal transformation, the corresponding works of mass ideals are provided by:

$$L_{is} = R \cdot T_1 \cdot \ln \beta \qquad\qquad L_{ad} = \frac{k}{k-1} \cdot R \cdot T_1 \cdot (\beta^{\frac{k-1}{k}} - 1)$$

where:

R = constant of elasticity of the air (= 29,3 m/K);

T_1 = inlet air temperature (K);

$\beta = p_1/p_2$ = rapporto di compressione, con p_1 atmospheric pressure;

k = isentropic exponent (= 1,4).

It is so that:

$$L_{is} < L_{ad}$$

Work of compression of the air

To reduce, to equality a compression ratio, the internal work Li, trying to bring as much as possible compression in a isothermal transformation by subtraction of heat to the air during compression: this can be achieved by splitting in more compression stages and cooling the air between one stage and the next one with heat exchangers to water or small units to air.

In practice the compression of a gas takes place according to a polytropic transformation $p \cdot v^m$ = costant, with $1 < m < 1{,}4$. The work inside the compressor has to make during this transformation is:

$$L_i = \frac{m}{m-1} \cdot R \cdot T_1 \cdot (\beta^{\frac{m-1}{m}} - 1) + L_w = \frac{k}{k-1} \cdot R \cdot T_1 \cdot \left[\beta^{\frac{k-1}{k \cdot \eta_y}} - 1 \right]$$

where:

η_y= polytropic efficiency or hydraulic, referring to the single-stage compression:

$$\eta_y = \frac{L_i - L_w}{L_i} = \frac{k-1}{k} \cdot \frac{m}{m-1}$$

Work of compression of the air

Subdividing the compression between multiple stages, the compressor is the optimal number of compression stages to be taken.

In practice compressions are carried out in a single stage for compression ratios of 4 - 5, a two-stage up to 15 - 20 and three or more stages than this values.

Types of compressors

They are divided into two categories:

- **volumetrics**;
- **dynamics** o **turbocharges**.

In positive displacement compressors, the air is sucked into a compression chamber, whose light extraction is then closed; decreasing the volume of the chamber, causes the compression of the air. When the pressure in the chamber has reached the preset value, opens a valve or a light and the air contained in the compression chamber can escape.

In dynamic compressors, an impeller provides air kinetic energy which is then converted into pressure energy.

They identify the following types of compressors:

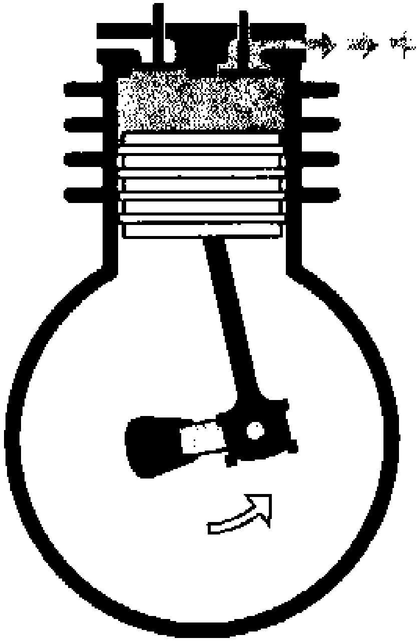
- **volumetric**: alternative (piston), rotary (vane, liquid ring and at gears such as a screw or Roots);
- **dynamics** o **turbocharges** (radials or centrifugals and axials).

Types of compressors

Volumetric compressors

Alternatives at piston

It is composed of a cylinder, equipped with intake valves and discharge, in which slides a piston, driven by a connecting rod-crank or by a cam and tappet.



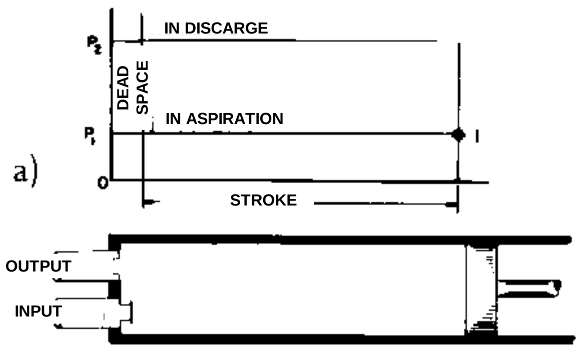
The phases characteristics are:

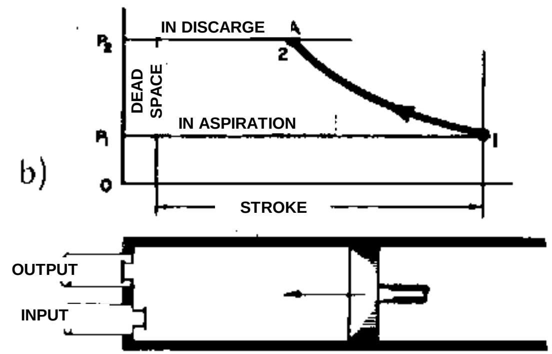
- compression;
- discharge;
- expansion;
- aspiration.

Types of compressors

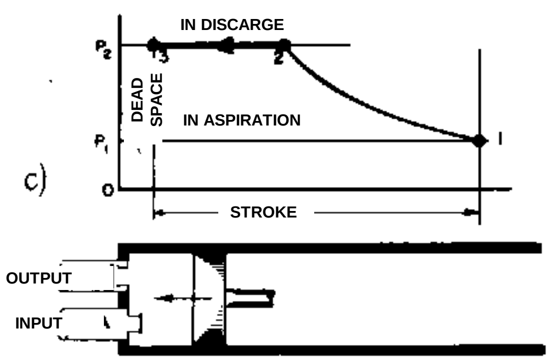
Volumetric compressors

Alternatives at piston

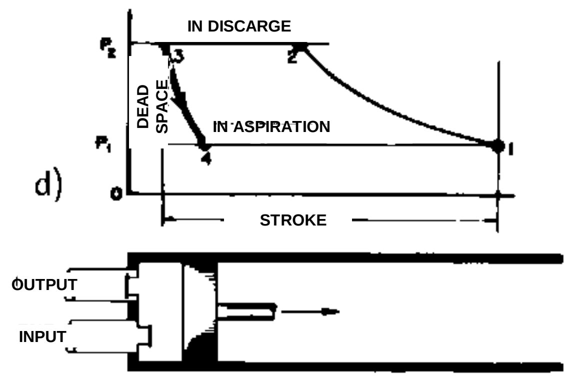




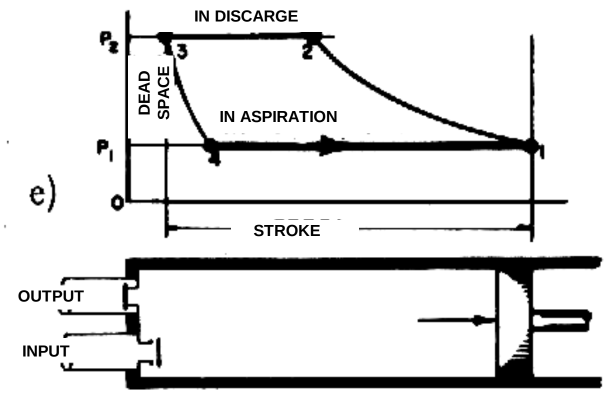
COMPRESSION



EXHAUST



EXPANSION



ASPIRATION

Types of compressors

Volumetric compressors

Alternatives at piston

You can build reciprocating compressors or one or more plungers and one or more stages.

The plungers can be simple or double effect (both faces of the piston are active). The arrangement of the cylinders is vertical or horizontal axis in the case of single plunger, V, W and X in the case of multiple pistons, and sometimes opposed cylinders.

Reciprocating compressors are used for applications up to 100 m^3/min.

The advantage of these compressors is in operation and can be adapted to the request of compressed air. It can operate at full load at partial load or at empty; running at partial load efficiency is decreased.

With plungers lubricated has the advantage of providing compressed air containing suspended particles of oil: they are not suitable for users requiring clean air.

Types of compressors

Volumetric compressors

Alternatives at piston

Were introduced not lubricated reciprocating compressors ("at dry"), in which the traditional sealing rings between the piston and cylinder are replaced by rings of Teflon or graphite or from devices labyrinth.
The power of these compressors is:

$$N = \frac{\gamma_a \cdot A \cdot L_i}{102 \cdot \eta_m} \quad [kW]$$

where:

γ_a = weight in the unit volume of air at intake (kg/m^3);
A = air flow at intake (m^3/s);
η_m = mechanical efficiency of the compressor (0,88 – 0,95);
L_i = work (kgm/kg).

Types of compressors

Volumetric compressors

Alternatives at piston

The costs of compression of the air with these compressors are referable:

- amortization of compressors and masonry related (purchase and installation of compressor, number of hours of operation, amortization period, interest rate, capital spending);
- consumption of electricity for the operation of the compressors (depends directly on the amount of air produced);
- cooling water (depends on the type of compressor used, the final pressures of the air, by cooling system in the hollow of the cylinders and by temperature of the water available);
- lubricating oil (depending on the type of machine and goes between 0,02 – 0,05 g/m^3);
- labor service and maintenance (varies with the number, the type and characteristics of the machines).

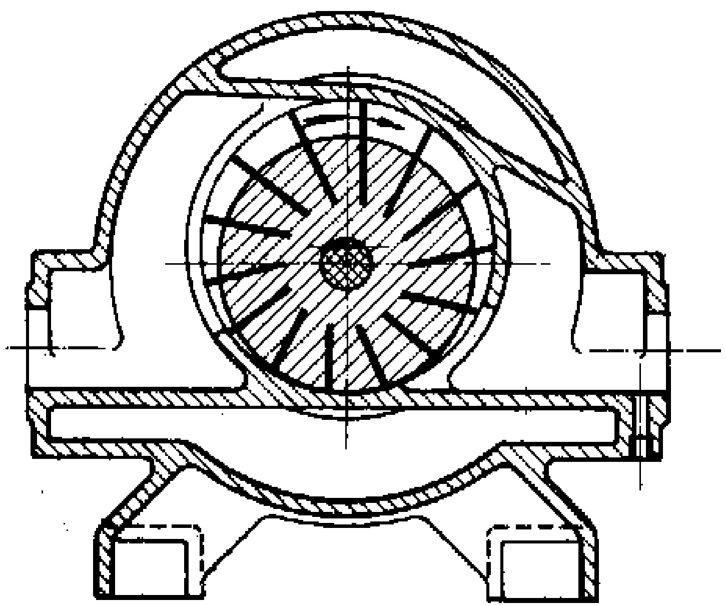
Types of compressors

Volumetric compressors

Rotative at vane

It has a rotor, mounted eccentrically with respect to the axis of the fixed cylinder, which is fitted with vanes sliding within guides formed in the rotor itself; when the rotor rotates, the blades (centrifugal effect), following the inner profile of the stator and form of cells whose volume varies progressively determining the air compression.

The same vanes act as valves when they pass in correspondence with the lights formed in the walls of the stator.

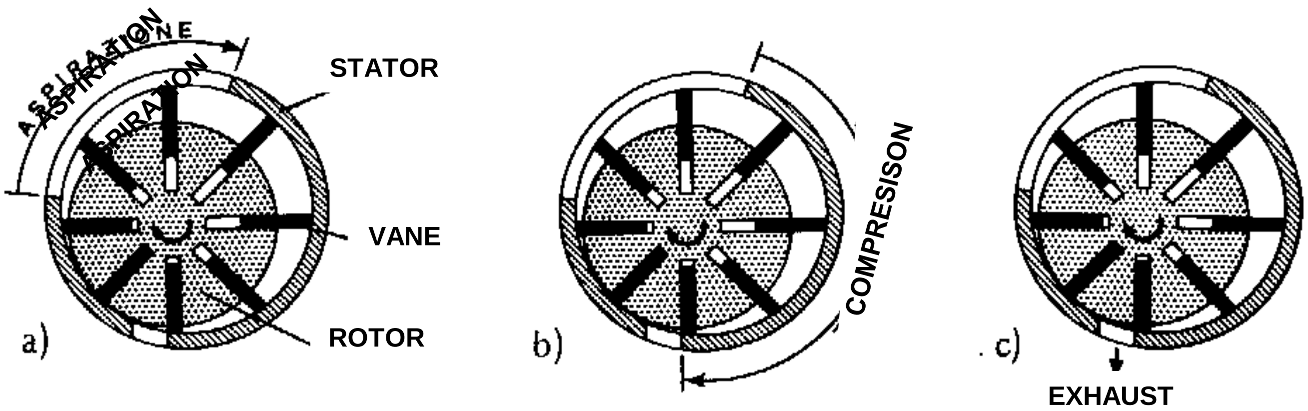


Types of compressors

Volumetric compressors

Rotative at vane

The working cycle is similar to that of the reciprocating compressor piston.



The power consumption can be evaluated with the expressions previously seen.

These compressors are suitable for direct coupling to the three-phase asynchronous electric motors (1000-1500 revolutions/min). Their performance is not very high and are used for low pressures.

Types of compressors

Volumetric compressors

Rotative at vane

The maximum flow rate of intake air is less than100 m^3/min.

The flow adjustment is obtained by a valve "at all or nothing", which throttles the suction completely when the discharge pressure exceeds the required value: the compressor at this stage operates empty.

To ensure cooling, the sealing and the lubrication of the moving parts is introduced into the cylinder lubricating oil. Much of this oil is retained by a separator, embedded in the compressor; the remaining part protrudes from the compressor, in the form of particles in suspension, mixed in the compressed air, even if they are not tolerated for certain industrial utilities.

The actual consumption of oil ranges from 0.10 to 0.15 g/h per m^3 of air sucked. The use of filter cartridges in fibers of very fine borosilicate, applied directly on the compressors, allows to reduce the consumption of oil to values of about 0,01 g/Nm^3.

Types of compressors

Volumetric compressors

Rotative at vane

For compressors at two-stage and per final pressures of 7-8 bar, the need for water cooling to 15°C for only the compressor varies from 2 to 3.5 dm^3/m^3 of sucked air.

Regarding costs, we highlight the differences with respect to those previously highlighted:

- the rotary vane compressors cost less and is less the amount of annual depreciation;
- the portion related to the cost of the oil is greater because the consumption is higher;
- the yield of the rotary vane compressors is lower and therefore is greater the consumption of electric energy.

Types of compressors

Volumetric compressors

Rotative at vane

Please note that:

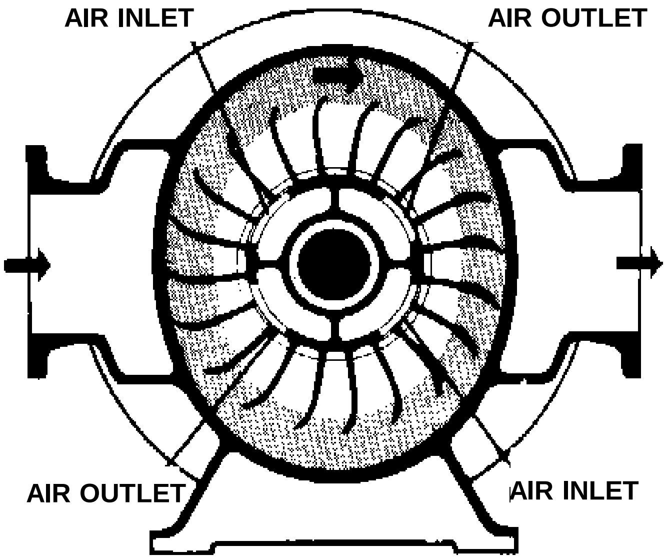
- the rotary vane compressors have greater simplicity of construction and are lighter and less noisy than those plunger;
- the air flow of the rotary vane compressors is more regular than that provided by compressors to plunger;
- the compressed air produced in the rotary vane compressors contains higher percentages of oil in suspension.

Types of compressors

Volumetric compressors

Rotative at liquid ring

It has a stator, having an elliptical shape, in which is mounted a rotor with fixed blades which rotationally drives a liquid (usually water) and projects it by centrifugal force against the wall of the stator, giving shape to a rotating ring; The liquid assumes a movement such as to vary the volume of the compartment between pallet and pallet, compressing the air contained in it.



Types of compressors

Volumetric compressors

Rotative at liquid ring

The distribution takes place through lights provided in the heads of the stator or the rotor cavity practiced in the tree: the air flows between the vanes, is compressed and then expelled when the rotor in its rotation exceeds the compression zone.

For each revolution of the rotor are obtained two cycles of compression.

The working cycle is very similar to that of the vane compressor.

The air to be compressed is in direct contact with the liquid contained in the machine and since the rotation speed is high, a certain amount of liquid is mixed with the compressed air. The compressor must be equipped with a separator filter on the delivery side and a device for maintaining constant the liquid level in the compression chamber.

Types of compressors

Volumetric compressors

Rotative at liquid ring

The adjustment is obtained for rolling at the intake, coupled with a reflux between discharge and aspiration.

These compressors are designed for flow rates up to 80 m^3/min.
The amount of energy required to compress the air varies depending on the model and the size of the compressor; however, is high because of the losses due to entrainment of the liquid.
The compressor does not require lubrication inside the compression chamber.

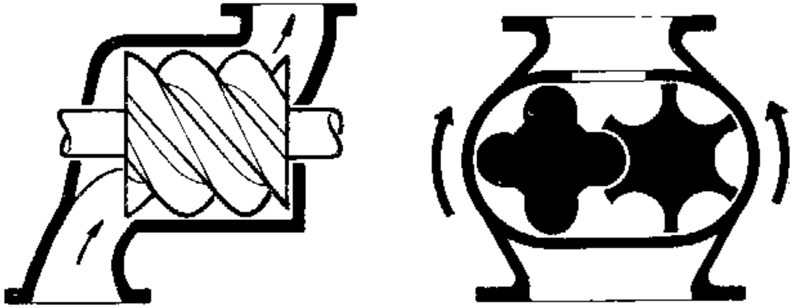
Types of compressors

Volumetric compressors

Rotative at gears

Sometimes referred to as pumps, are found:

- **screw compressors**;
- **compressors Roots**.



Screw compressors are constituted by two rotors, one with two convex lobes and the other with concave lobes, rotating in opposite directions inside a stator.

The synchronization of the motion between the two rotors is entrusted to a pair of gears. The air is sucked from light for acceptance in the space that is formed between the lobes of the two rotors; in rotation continues, the space in which it is contained is isolated from the inlet port, then reduced in volume, giving rise to compression. Then the air is pushed toward the light output and then discharged.

Types of compressors

Volumetric compressors

Rotative at gears

The diagram (p, v) is similar to that of reciprocating compressors.
The power consumption is calculated for the compression stage, the report:

$$N = \frac{A \cdot H}{102 \cdot \lambda_v \cdot \eta_m} \quad [kW]$$

where:

A = air intake flow (m^3/s);

H = prevalence of the compressor (N/m^2);

η_m = mechanical efficiency of the compressor (0,88 – 0,95);

λ_v = filling coefficient (0,6 – 0,8).

These compressors can operate at very high speeds and are capable of compressing air flow rates greater than at 500 m^3/min.

Types of compressors

Volumetric compressors

Rotative at gears

Since it lacks all contact between the rotors and between these and the compression chamber within which rotate, the tolerances must be very small to achieve efficient operation, the construction of this type of compressor requires high precision.

The absence of contacts allows to realize a machine in which the parts licked by do not require lubrication, and then the compressed air is free of oil: very important requirement for many applications.

The adjustment of the flow is obtained by means of a valve which partializes light suction. The light outlet is equipped with a non-return valve, which prevents backflow of the compressed air in the compressor stopped.
The flow rate control is also achieved by varying the number of revolutions of the motor that drives the compressor.

Types of compressors

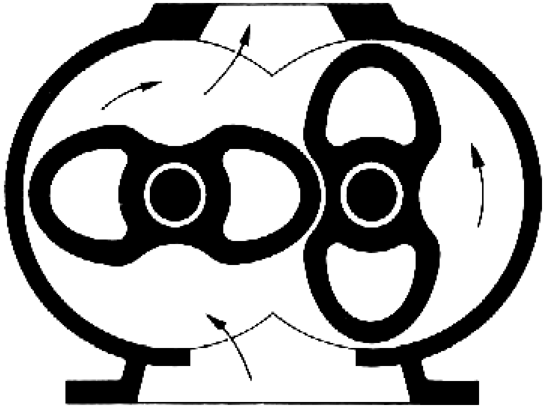
Volumetric compressors

Rotative at gears

The screw compressor is economical for capacities between 20 and 500 m^3/min and for pressures between 7 and 10 bar, which employs high numbers of revolutions.

The compressor has few wearing parts, requires bases inexpensive and takes up little space. Because of its low weight, it may be mobile (on wheels).

The compressor Roots (called blower) is formed by a stator in which are housed two counter-rotating rotors, equipped with two or three lobes each. The air is pushed from the lobes to the discharge, where it undergoes a sudden increase of pressure.

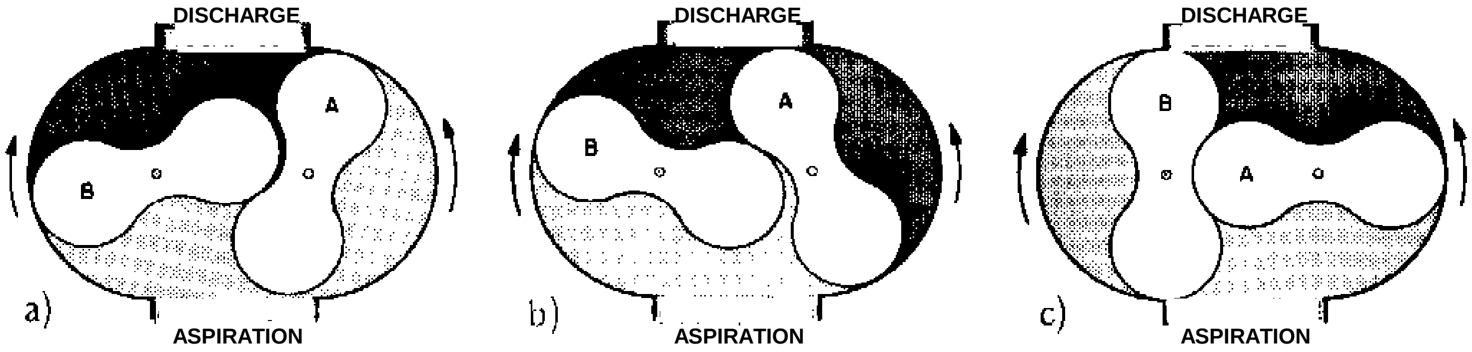


Types of compressors

Volumetric compressors

Rotative at gears

The compression does not happen for a progressive reduction in the volume before connection with the inlet, but for backflow of air into the compressor. The yield is so low.



The compressors Roots are not usable for high working pressures (1 bar for types single stage and 2.6 bar types in a two-stage).

Types of compressors

Volumetric compressors

Rotative at gears

The movement of the two rotors is synchronized by means of gears so as to have no contact between the rotors or between the rotors and the casing. These parts do not require lubrication, and then the compressed air is oil-free.

These compressors are air cooled and have 4 feeds per revolution of the rotor.

The power absorbed has the same relationship of rotary screw compressors.

Types of compressors

Dynamic compressors and turbochargers

The air is brought up to high speed in one or more impellers with vanes and then discharged into a diffuser having the task of transforming into pressure energy most of the kinetic energy acquired from the air.

Turbochargers are divided into **radial** or **centrifugal** and **axial**: the former are characterized by air trajectories approximately normal to the impeller shaft, while the latter with trajectories approximately parallel to the said shaft. Such machines can be in one or more stages, while the drive is entrusted to electric motors and gas turbines or steam directly coupled to the shaft. In order to maintain a constant supply pressure to vary consumption, we resort to the solution which provides, at a decrease of air demand, a system of control of the pressure that gradually closes the intake valve; beyond a certain partialization comes into operation a valve which discharges into the atmosphere the excess of air in order to avoid the phenomenon of "**pumping**".

Types of compressors

Dynamic compressors and turbochargers

The operation of the turbochargers is similar to that of centrifugal pumps for liquids: the compressed air flows vary with the working pressure.

Centrifugal compressors are not suitable for flow rates of less than a few thousand of Nm^3/h and until another 100,000 Nm^3/h, while the axial compressors are used for higher flow rates (approximately 500,000 Nm^3/h).

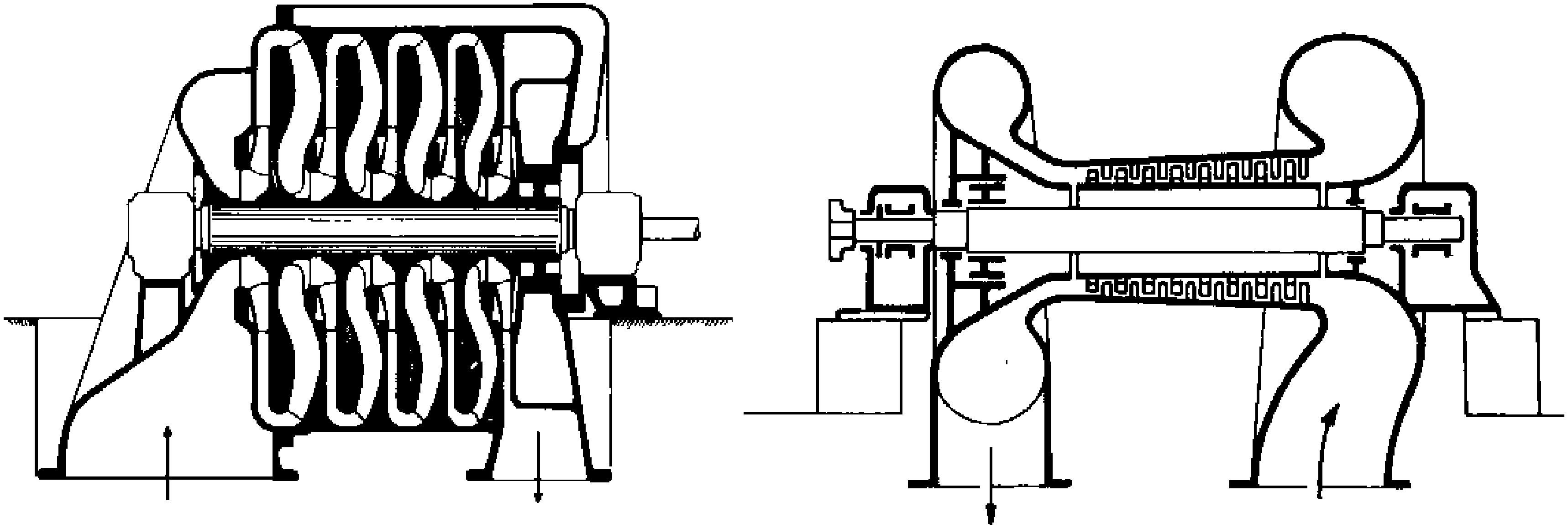
Centrifugal compressors are used for pneumatic transport, while the axial are used for the aeration basins of biological treatment of wastewater cloacal (turbine aerators).

Even for these compressors, the considerations on compression costs. These have a negligible oil consumption, since it is not in contact with the air, but it serves to reduce the friction of the mechanical organs.

Plants for the production and distribution of compressed air

Types of compressors

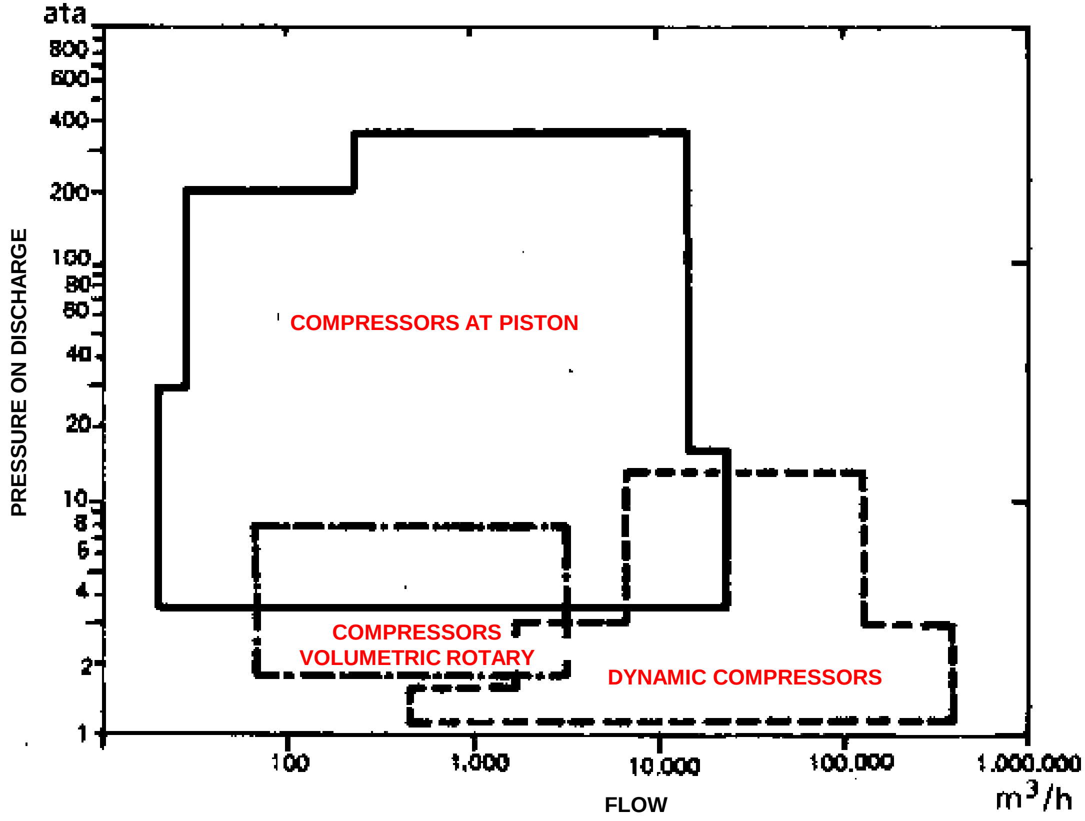
Dynamic compressors and turbochargers



Mulltistage centrifugal compressor and multistage axial

Types of compressors

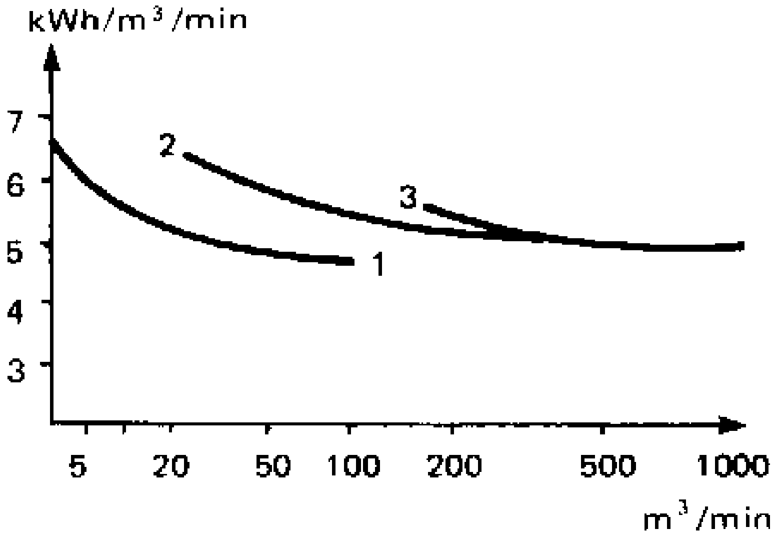
Shows the field of use of certain types of compressors as a function of air intake flow and operating pressure.



Choice of compressors

The choice depends on technical and economic considerations.
After seeing the scope of some compressors, other parameters of evaluation and choice are reliability, overall, the characteristics of the basements and the presence of oil in the compressed air, operational flexibility, the cost of air compressed etc.

The cost of energy consumed in a compressor system has a significant effect on the financial management of the plant.
To reduce this cost must select the compression plant that, for the same characteristics of the air produced, involving the minimum energy absorption.



1- at plunger 2- at screw 3- dynamic

Plants for the production and distribution of compressed air

Choice of compressors

The specific energy consumption of the air cooled compressors is 3-5% higher than that of the water-cooled compressors.

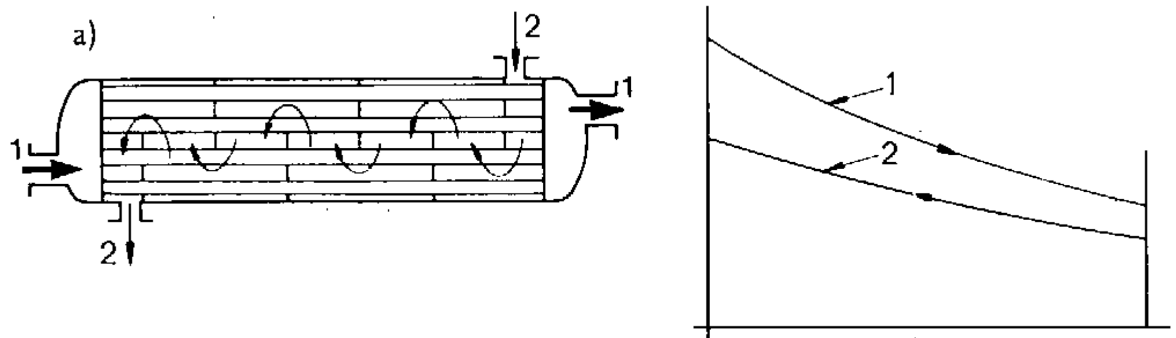
As regards the electrical energy absorbed at vacuum compared to that absorbed at full load, for flow rates near zero piston the compressors absorb 7-12% of energy required at full load, while the rotary compressors require 12-15% and turbochargers require 15-17%.

Final coolers and compressed air tanks

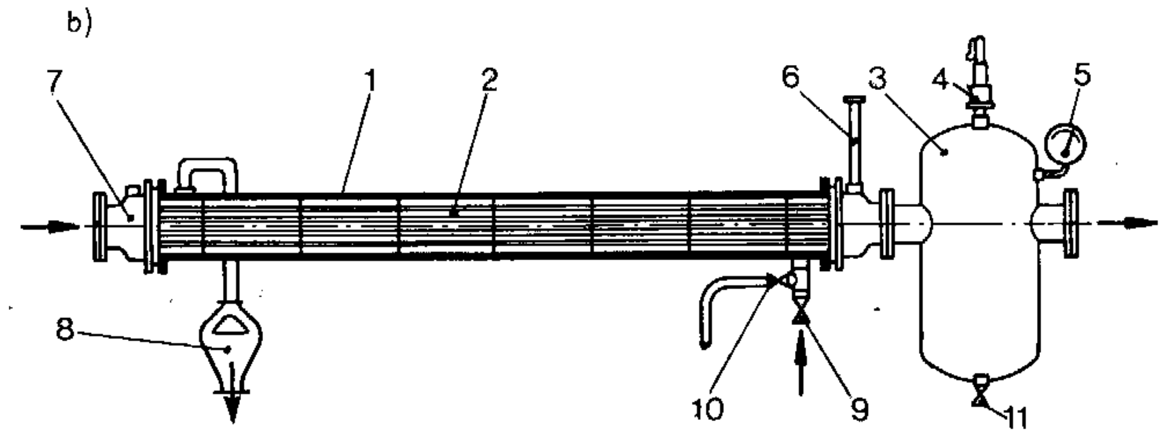
Compressors is normally coupled the final cooler.

In such equipment, the cooling air is obtained by entering the air in a tube bundle lapped externally by water at the minimum possible temperature. The condensate is collected in a separator and is discharged into the sewer. In output detects a temperature of 15°C higher than the temperature of the cooling fluid available.

Final coolers and compressed air tanks



1 - fluid to be cooled, 2 - cooling medium



1 – Body of the chiller, 2 – Pipe, 3 – Condensate separator, 4 – Safety valve, 5 – Gauge, 6 – Thermometer, 7 – Air inlet, 8 – Cooling water outlet, 9 – Cooling water inlet, 10 – Drain tap water cooling, 11 – Condensate drain cock

Final coolers and compressed air tanks

To determine the size of the tank is necessary to make some considerations on the scope of the compressor and on the control system. The control cycle of the compressor must not be too short to not provide excessive wear of different organs of the same compressor, the motor and the electrical equipment.

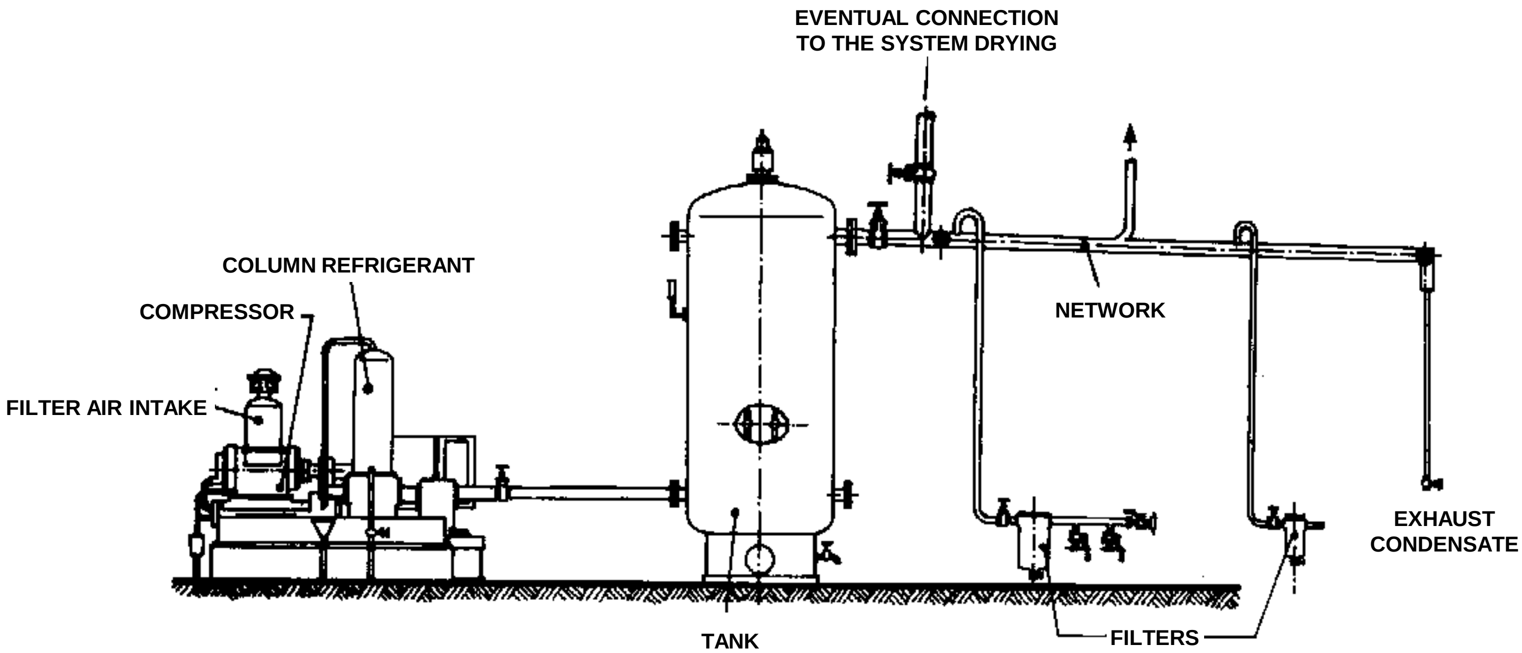
For compressors with maximum working pressure of 7-8 bar and under normal conditions of air consumption, the capacity of the tank (m^3) must be at least 1/10 of volumetric flow rate of the compressor (m^3) and referring to the minute.

The adjustment takes place thanks to a valve by-pass: the motor is operated continuously, in part load and part at wacuum. Is appropriate that the valve does not react to short time frame with a suitable proportioning of the entire system: the difference between the pressures of idling and under load must not be less than 0.4 bar.

Plants for the production and distribution of compressed air

Final coolers and compressed air tanks

The plant production and distribution of compressed air presents the following scheme



Final coolers and compressed air tanks

In the case of automatic starting and stopping of the motor controlled by the same air pressure, you must install a tank of larger capacity. With this control system a tank undersized may be due to excessively frequent startingS, this back not only to the detriment of the contacts of the equipment, but also of the motor windings.

A series of starts too frequent creates overloading in the supply network.

The evaluation criterion of the minimum capacity of the air tank as indicated above, refers to the case of a single compressor or functioning of a compressor having a flow rate prevailing on that of other compressors also functional. In the case of compressors of the same type of parallel, it is advisable to increase the capacity of 30%.

Drying of the compressed air

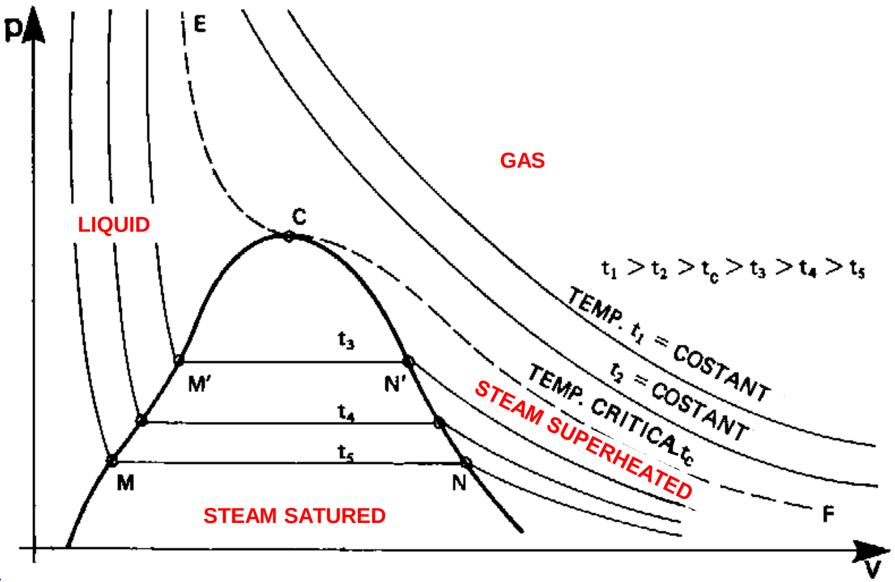
The atmospheric air is a mixture of various gases (oxygen, nitrogen etc..) and water vapor (moist air).

The vapor in the humid air can be saturated and superheated steam.

To this mixture is Dalton's law: the pressure of a mixture of two or more gases is the sum of the pressures that each component would exert if occupied by only the entire space concerned by the mixture itself.

The physical properties of the gases are summarized by the curves of the isothermal plane (p, v):

- isotherms characterized by a horizontal straight portion (critical isotherm);
- isotherms without horizontal straight portion (temperatures higher than the critical).



Drying of the compressed air

Along the horizontal straight portion of an isotherm with temperature lower than the critical temperature, the volume of the fluid varies without a corresponding change in pressure.

Compressing isothermally a fluid, the processing undergone by the steam is such that the volume decreases in the pressure increases.

At a certain pressure value, the vapor reaches the saturation pressure and is then saturated; following a subtraction of heat it condenses, reducing the volume occupied, but without pressure increase (% of the condensed steam is proportional to the ratio between v_{final} and $v_{iniziale}$, provided that the condensation has been removed).

Continuing to subtract heat, you could have the total condensation of the vapor.

Drying of the compressed air

During the isothermal compression both the air and the steam undergo a reduction in volume, while the partial pressure of the air can increase indefinitely, that of the steam increases only up to the saturated vapor pressure at the temperature of the mixture.

Continuing the isothermal compression, the partial pressure of the steam remains constant, but it begins to condense part of the vapor contained in the compressed air.

The compression is never isothermal, but polytropic. In this way, the compression involves a considerable increase of temperature of the air, for which you do not have any separation of condensate in the compressor.

A separation takes place, however, in chillers intermediate between the compression stages of a multistage compressor, the aftercooler and the network of air distribution.

Drying of the compressed air

The cooling temperature at which the humid air tablet begins to deposit the condensate is, at constant pressure of the compressed air and of thermo-hygrometric conditions of the intake air, the same temperature considered in the experience carried out with the container at piston.

This **temperature** is called of **dew** or **dew point** of the compressed air at the pressure considered.

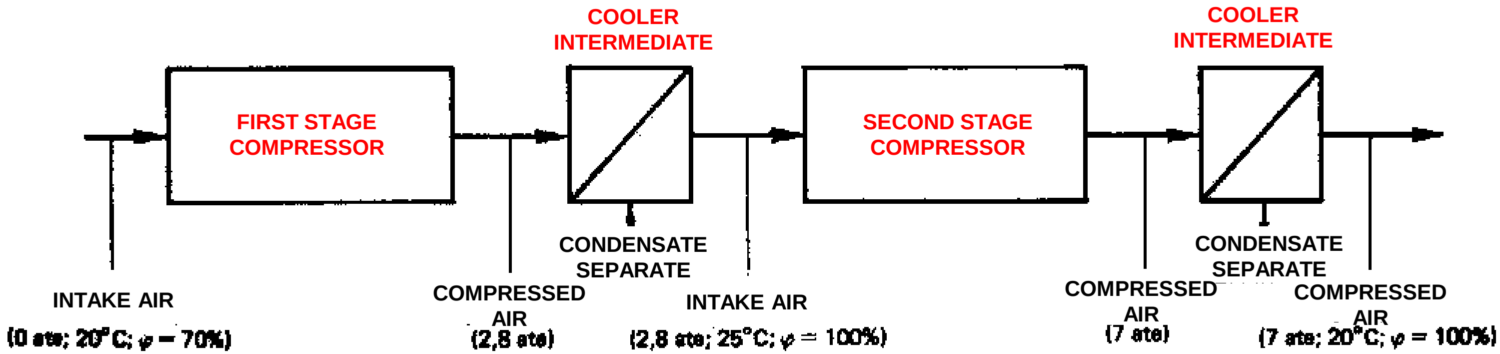
The formation of condensate in the network must be prevented as much as possible, because the condensation, entrained by the air to the users, may cause drawbacks (corrosion of the piping and equipment, increases the cost of maintenance etc.).

To prevent the occurrence of such incidents, it should be removed before placing the compressed air network, the condensation in the air itself.

Drying of the compressed air

The amount of moisture that can be released from a compressed air system as a result of the cooling of the same is calculated in the following way.

A two-stage compressor is equipped with two chillers, an intermediate between the stages and one final after the second stage.



The conditions along the air-compression cycle cooling are those of the schema where it is revealed:

Drying of the compressed air

a) conditions of the air intake of the first stage: p = 0 bar, t = 20°C and φ = 70%;

b) pressure of the compressed air outlet of the first stage: 2,8 bar;

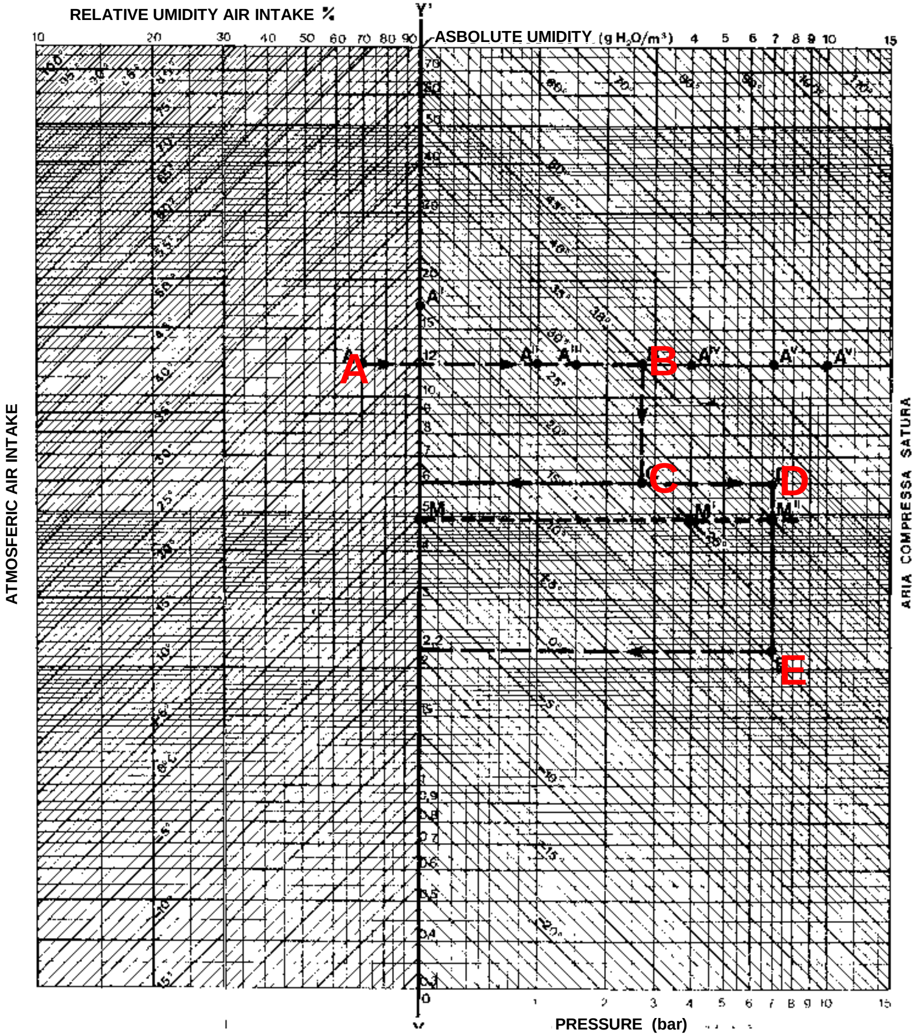
c) conditions of the compressed air outlet of the intercooler intermediate and inlet of the second stage (regardless of the pressure losses through the chiller): p = 2,8 bar, t = 25°C e φ = 100%;

d) pressure of the compressed air exiting the second stage: 7 bar;

e) conditions of the compressed air output of the intercooler final and the placing on the network (regardless of the pressure drop through the chiller): p = 7 bar, t = 20°C e φ = 100%.

From the psychrometric chart of air compressed is identify the significant points of the various conditions of moist air. The conditions a) are represented by point A, the cross between +20°C isotherm and the vertical corresponding to φ = 70%. The ordinate of A, read the axis YY ', gives x = 12 g/m^3 of air (absolute or specific humidity of the intake air).

Drying of the compressed air



Drying of the compressed air

The point B, cross between the horizontal straight line relative to the value of ordinate x = 12 g/m^3 and the vertical line corresponding to the pressure of the air coming from the first stage identified dall'isoterma + 38°C, which is the dew point temperature of air coming from the first stage and entering the intercooler intermediate.

The point C, intersection between the vertical relative to the pressure of the outgoing air from the intercooler and the isotherm +25°C (temperature of the outgoing air from the intercooler), allows to determine on the axis YY‘ the absolute humidity (x= 6 g/m^3 of air aspirate) from the air outgoing from said chiller.

Drying of the compressed air

The point D, cross between the horizontal straight line relative to the value of ordinate x = 6 g/m^3 and the vertical line corresponding to the pressure of the air coming from the second stage, identifies the isotherm +37°C, which is the dewpoint temperature of air coming out of the second stage and entering the cooler final.

Point E, the intersection of the vertical pressure on the air coming out of the chiller and the isotherm +20°C (temperature of the air coming out of the cooler) allows to determine the axis YY' the absolute humidity (x = 2,2 g/m^3 of air) of the outgoing air from said chiller.

Drying of the compressed air

The condensate is separated in the system is considered:

- in intercooler intermediate
  (12 – 6) g/m^3 = 6 g/m^3 of sucked air;
- in intercooler final
  (6 – 2,2) g/m^3 = 3,8 g/m^3 of sucked air;
- overall
  (6 + 3,8) g/m^3 = 9,8 g/m^3 of sucked air.

Drying of the compressed air

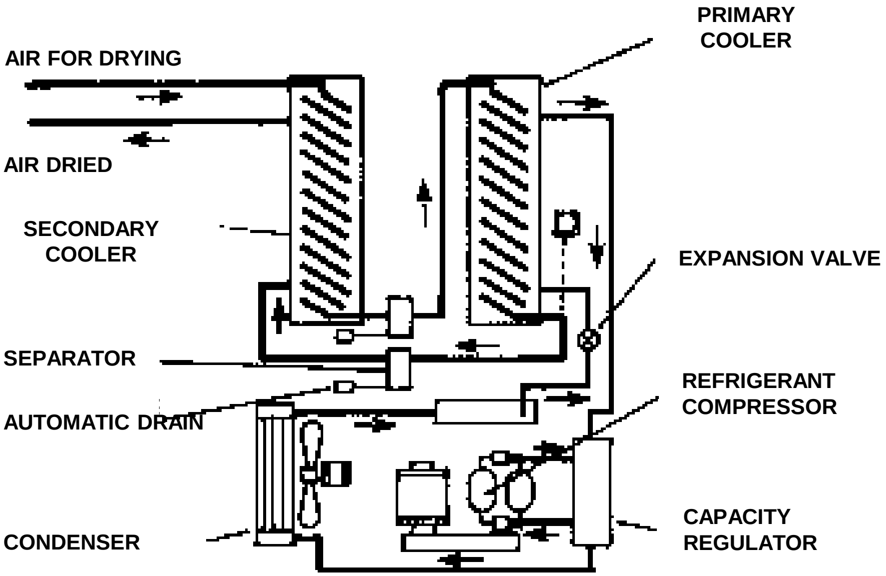
The compressed air which exits of the post-cooler and from the tank-lung installed downstream of the compressor, has a dew point not lower than 30°C; then the air fed into the network at that temperature (ad example 20°C) gives rise to the formation of non-negligible quantity of condensate inside the distribution network, by condensation of the water vapor contained in the air.
To avoid this phenomenon, we resort to drying plants that reduce the moisture contained in the compressed air.

The drying systems are of the type **to refrigeration**, **to absorption**, **to deliquescence** and **mixed** or **combined**.

Drying of the compressed air

Dryers to refrigeration

Are based on the principle that the amount of condensate separated increases with the lowering of the temperature. To achieve a cooling pushed, it employs a refrigeration unit consists of a compressor, two heat exchangers (one air-to-air and air-to-one refrigerant) and a condenser of the refrigerant.



Drying of the compressed air

Dryers to refrigeration

The plant is a refrigeration in two stages: the first stage comprises a cooling by circulating in countercurrent air coming from the second stage, where heat has transferred to the refrigerant fluid circulating in a closed circuit.

The air exits from such facilities at a temperature of 20-25°C and with a residual moisture content corresponding to a dew point temperature of 2-3°C: at that temperature, whereas an operating pressure of 7 bar, the residual content of water is OF 0,5 g/m^3 of free air.

Drying of the compressed air

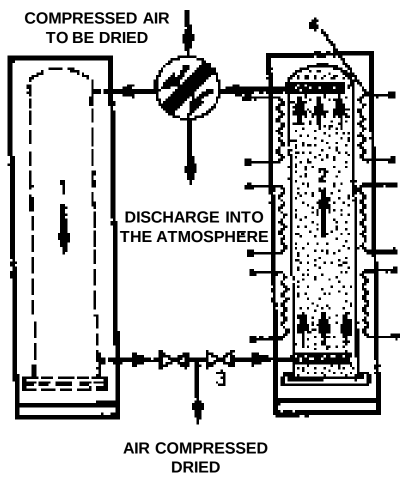
Dryers to refrigeration

The cooling air eliminates the parties less volatile oil present in the air; however, remain more volatile parts, which hardly condense, that, if the air is intended to delicate mechanisms, it is necessary to separate it in some way.
It uses ceramic filters installed close to the load or to a different drying plant, based on an absorption system, in which you can reach dew points lower (but be careful to cost).

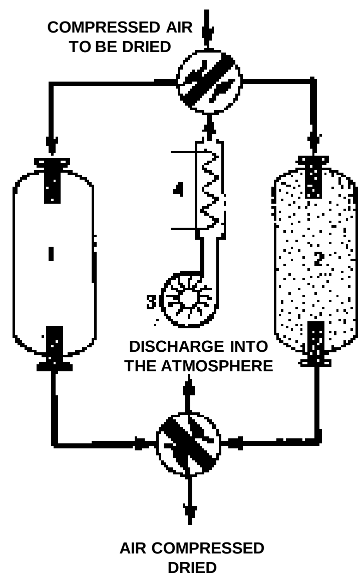
Drying of the compressed air

Dryers to absorbition

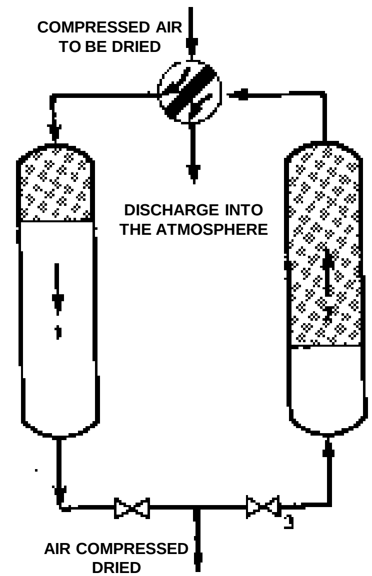
Are based on the principle that the air coming from the cooler final must pass through a bed of desiccant material.



1 - Column of drying crossed by the compressed air (for drying), 2 - Column of drying in regeneration, 3 - Valve open to bleed compressed air dried, 4 - Electrical resistance of heating



1 - Column of drying crossed by the compressed air (for drying), 2 - Column of drying in regeneration, 3 - Ventilator of circulation of atmospheric air, 4 - Heat exchanger to resistance



1 - Column of drying crossed by the compressed air (for drying), 2 - Column of drying in regeneration, 3 - Valve open to bleed compressed air dried

1 - with regenerator through dry air, 2 - through atmospheric air heated, 3 - through cold dry air

Drying of the compressed air

Dryers to absorbition

As desiccants are used active alumina, activated carbon etc.

The main properties of these materials are:

- if they are crossed by moist air, adsorb water vapor and let air pass through;
- once saturated with water vapor absorbed, if subjected to appropriate processes of drying (regeneration), return to its initial condition ready to adsorb again humidity.

Drying of the compressed air

Dryers to absorbition

The dew points reached with these dryers are of -30 ÷ -50°C depending on the chemical substance used, although in industrial applications there stops at -20°C.

An adsorption dryer is composed of two columns filled with adsorbent material, both connected to the supply line of the moist air and discharge air dry. While a column dries the compressed air, the other is being regenerated and this at predetermined intervals.

Drying of the compressed air

Dryers to absorbition

There are three types of adsorption systems, differentiated by the regeneration mode:

- to hot with bleed of compressed air;
- a caldo to hot with external air fed by a fan;
- to cold with spillage of dry compressed air.

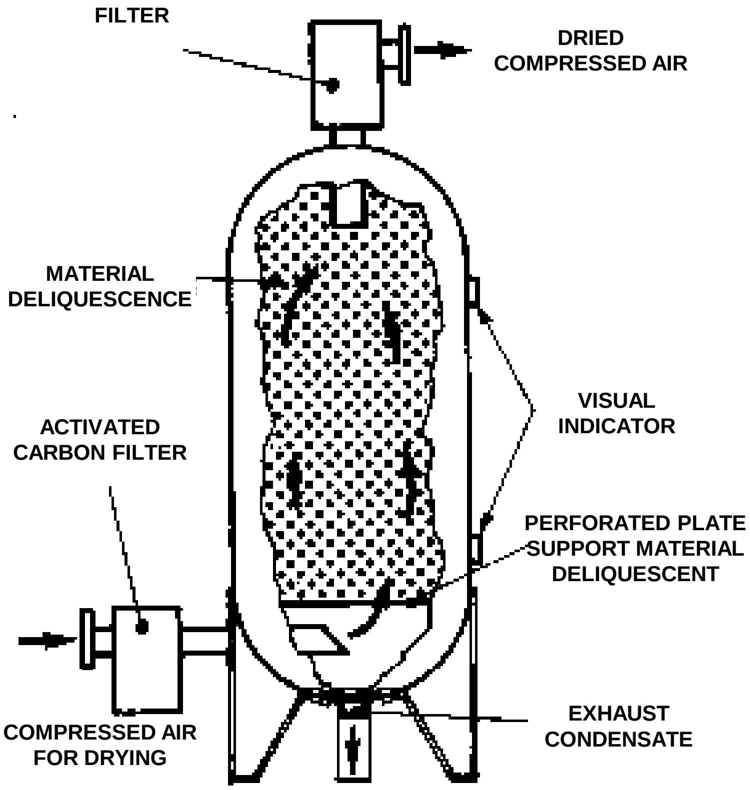
The first is used for flow rates up to 10 m^3/min, the second for higher flow rates, in which the loss of dry air, even if contained in percentage, is not tolerable, while the third for small capacities.
A upstream of the plant install a filter capable for retaining the oil particles carried by the air, which would damage the adsorbent.
Another filter is required downstream of the dryer to prevent the transport of the powder of the adsorbent in the compressed air distribution piping.

Drying of the compressed air

Dryers to deliquescence

They are distinguished by the simplicity of conduction, require the charging of the absorbing medium to long intervals of time, but have modest performance and are used to lower a few degrees the dew point of large air masses.

They consist of a pressure vessel, within which, above a perforated plate support, is contained the deliquescent material (sodium chloride or calcium phosphate), that melts slowly in contact with the moisture contained in the air and which must be renewed periodically.



Drying of the compressed air

Dryers to deliquescence

In go back the outlet pipe, the air passes between the interstices of the deliquescent material that, being highly hygroscopic, absorbs the moisture that gradually melts and is deposited on the bottom of the tank, which is periodically purged.

In addition to water vapor, the deliquescent material also retains most of the oil vapors passed through the pre-filter with activated carbon, normally installed upstream of the system to avoid an excessive presence of oil vapors (greater than 20 mg/Nm^3), that would cause the collapse of the deliquescent material. A downstream of installing a filter capable of retaining particles of hygroscopic substances, which have corrosive properties.

The dew point depends on the temperature of the compressed air: for air to +30°C, the dew point at 7 bar is 0°C, while at +40°C and at the same pressure is 8°C.

Drying of the compressed air

Dryers to deliquescence

The deliquescent material consumption is about 1 kg per 100,000 Nm^3 of air treated. The capacity of the tank is chosen so that the amount of deliquescent substance ensures a few months of continuous operation. If a visual indicator indicates the near exhaustion, the implant can be recharged during the interruption of the operation of the compression.

Numerous manufacturers of drying plants realize driers which couple the principles of informational systems described (for example an adsorption system with one to deliquescence).

The adoption of these systems depends on the requirements of combined drying and flow to be treated.

It is evident that the more air must be dry and clean, the more increases the cost of plant and operating costs which are encountered; therefore the type of purification and drying air should be chosen among those mentioned above according to the needs of users.

Drying of the compressed air

Dryers to deliquescence

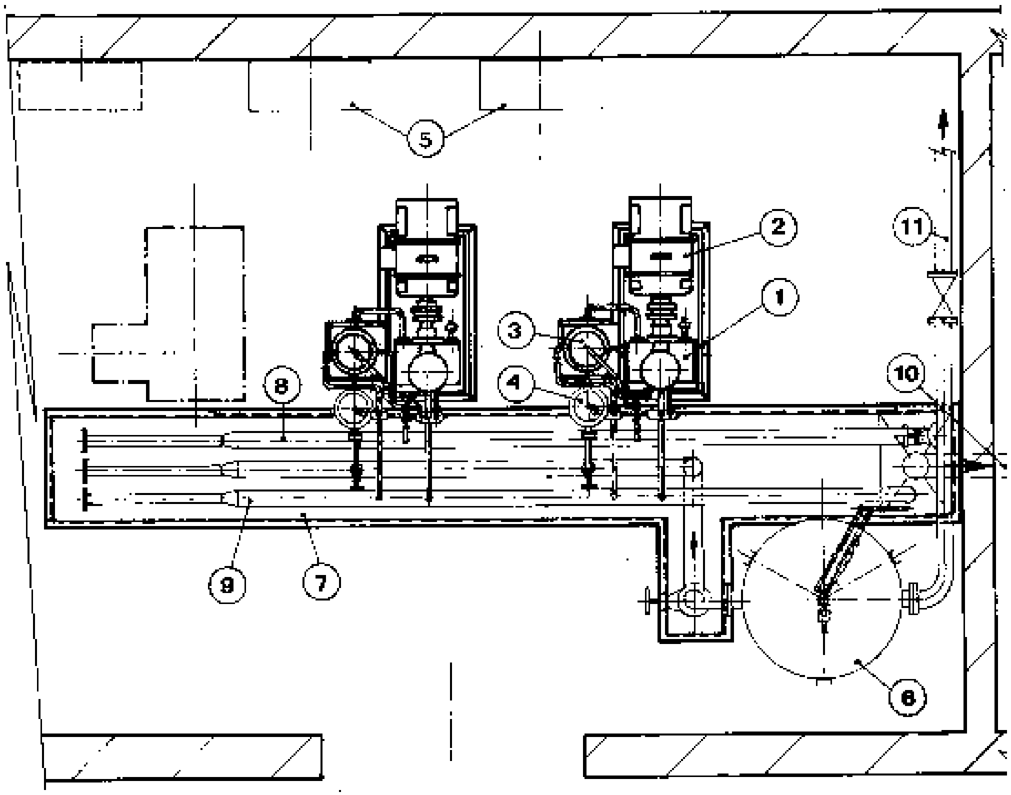
Not advisable to provide a drying plant that reaches dew points is not necessary in relation to the uses where the compressed air is destined.

For drying plants must be kept in mind in the choice of the various items of expense which they occur:

- depreciation;
- energy consumption;
- loss of load;
- maintenance.

Compressor room

A plant for the production and distribution of compressed air can be schematized as follows.



1 - Compressor, 2 - Electric motor, 3 - Refrigerator, 4 - Condensate separator, 5 - Electric paintings, 6 - Tank-lung, 7 - Tunnel, 8 - Power water of cooling, 9 - Drain of water, 10 - Exhaust sewer, 11 - Flow line compressed air

Compressor room

The drying plant is scheduled for the air produced or only the portion allocated to the users who have special needs.

It is advisable to take the air outside the compressor room, so as not to cause depressions in the room itself and to save on heating ambient air. It is important that the intake air is clean and free of solid and gaseous impurities that may be malicious.

To obtain the maximum efficiency of the compressors is necessary that the air is cold as much as possible, a decrease of temperature of 3°C causes an increase in the weight of sucked air and the volume of air compressed by approximately 1%.

It is for this reason that the compressor room is located to the north. However, whatever the arrangement of said room, should be provided for each compressor of an air inlet duct, comprising a filter and an air intake which sometimes incorporates a silencer.

Compressor room

The group of suction air must be sized so that the pressure drop is low: a pressure drop of 100 Pa in the suction unit, causes a reduction of 1% of the capacity of the compressor, since the weight of 'unit volume of air sucked decreases with decreasing pressure.

The air filter of a compressor must meet the following requirements:

- high efficiency of filtration;
- ability to collect a considerable amount of impurities without decreasing the filtration efficiency (depending, however, by the intervals of time between subsequent cleaning);
- low resistance to air passage that varies depending on the type of filter (filters oil bath have a pressure drop of up to 150 P, while the other between 10-15 Pa);
- robust construction.

The filter is placed as close as possible to the compressor.

Compressor room

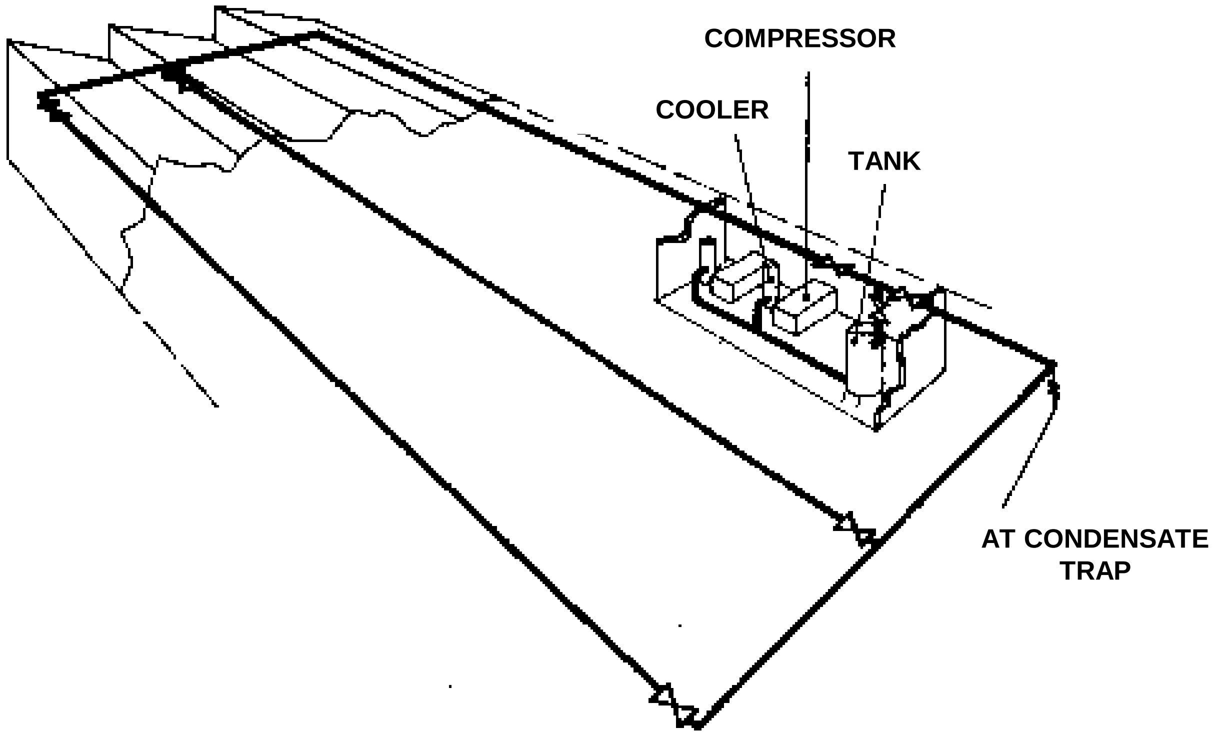
In dusty areas (quarries, cement plants etc.) is must install a pre-filter to delay the clogging of the filter. The rooms of compressors should be ventilated in order to reduce (in summer) the excessive heating caused by motors and compressors, and there are large windows with transoms applied in a position close to the ceiling on roof fans for ventilation.

The layout of the compressor room should take into account:

- leave enough space around the compressor for assembly and maintenance (is installed inside a crane);
- be possible in the future to increase the room with the installation of other units;
- allow the exclusion of one or more compressors without interrupting the operation of the other;
- adopt the silencers on the intake, the closure of machines in cabins suitable to limit the noise to the outside, isolate each compressor in a separate space in which the operator enters only if necessary and by using suitable means of protection.

Distribution networks

The compressor room, the air passes into the distribution network. This is usually a mesh, that is a closed loop with cross connections intercepted by valves (ball or straight through) installed at the ends.



Distribution networks

When you must serve departments or manufactured separated from each other, the networks of these are fed by the main pipe with derivations on which are expected valves.

In departments, the derivations to utilities not fixed, we resort to quick coupler valves.

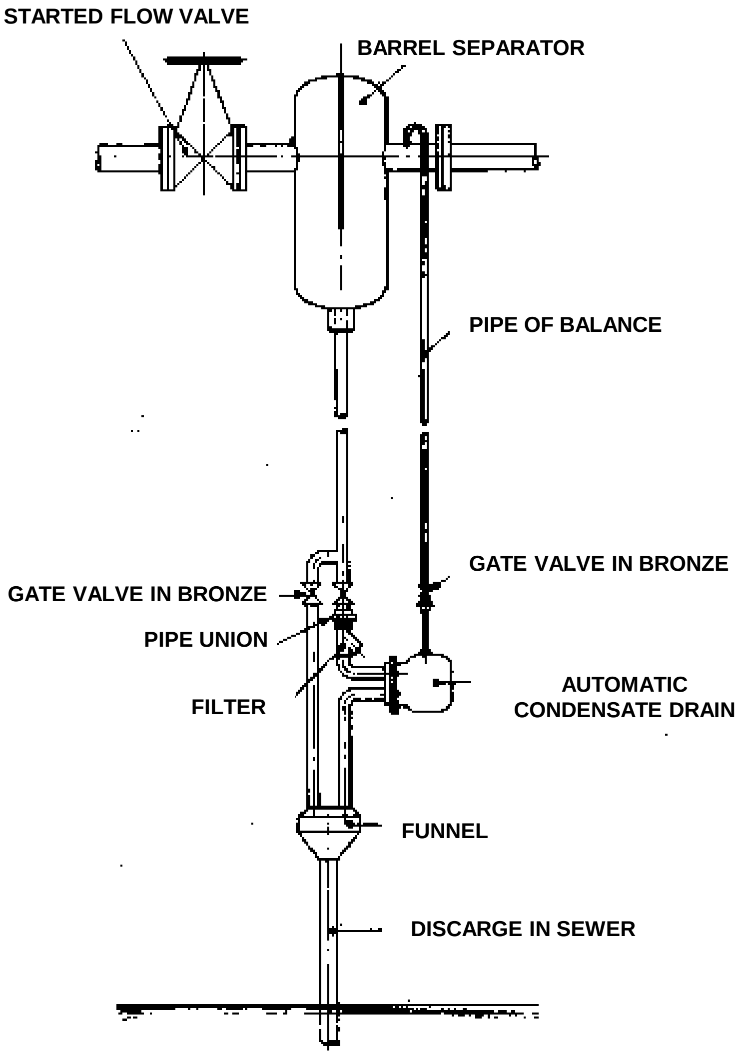
To avoid clogging in the tubes, due to the presence of residual moisture in the air, the network is realized with a slope of between 0.2 - 0.5% in the direction of air movement. All the air intakes for the utilities depart from the upper part of the supply pipe, in order not to remove the condensate accumulated in the pipes.

It is appropriate for this purpose does not distinguish between air dried and dried air.

Distribution networks

- **air not dried**

In low points of the distribution network you are installing special devices for the condensate drain, which discharges into the sewer through a funnel that allows for visual inspection. Two valves and a by-pass ensures the ability to discharge into drains the condensate even when the separator is broken or by review.

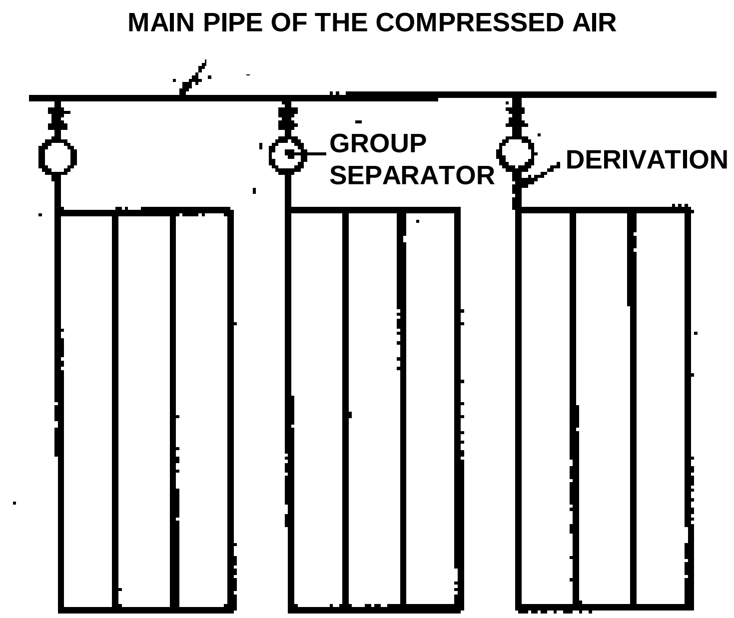


Plants for the production and distribution of compressed air

Distribution networks

- **air not dried**

The figure shows the position in which the separator must be provided in the case of a distribution network in departments or manufactured separated from each other, but fed by a single main pipe. Such separators allow recovery of a portion of the piping. The size of the groups arresters depend on the flow rate and pressure of air.

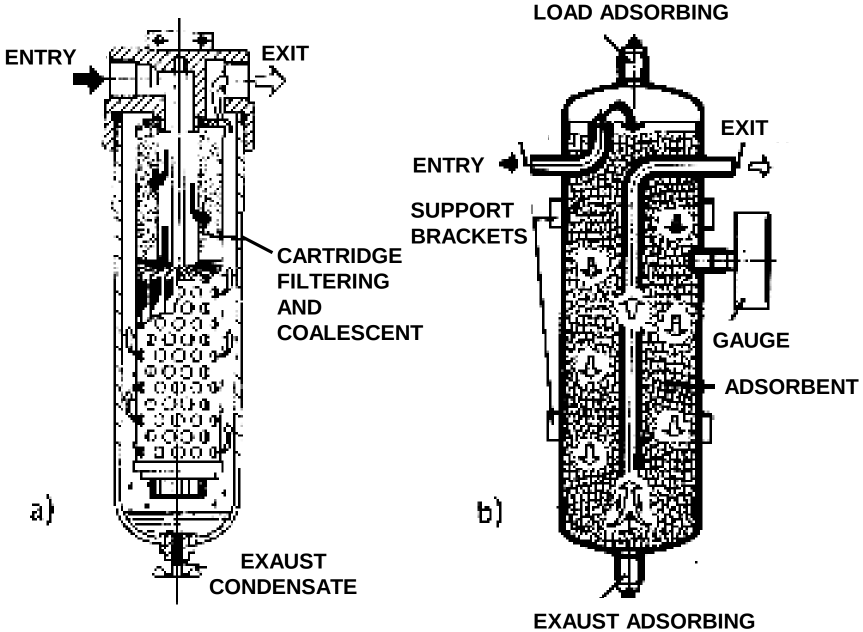


Distribution networks

- **air not dried**

Suitable filters are installed immediately upstream of those utilities that require air devoid of water and oil and which, being limited in number, do not justify the installation of a drying plant centralized.

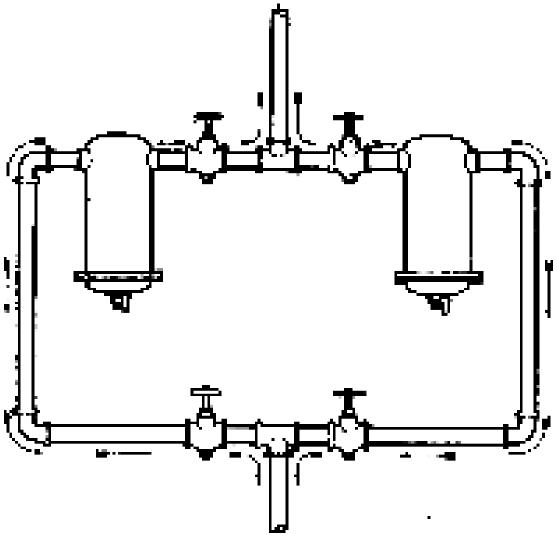
The filters or separators of end condensation are of the type or coalescence to adsorbent solids (activated alumina, calcium sulfate, silica gel, activated carbon).



Distribution networks

- **air not dried**

Since the capacity adsorbents of such materials are reduced with the use, is should proceed to a regeneration, that can be obtained with jets of hot air, blown by a special fan and heated electrically or by steam, gas, methane, etc. In order to ensure continuity of operation of the machines that use the compressed air, it is convenient to install two parallel end condensate separators, of which only one functioning.



It is advisable to install these separators as close as possible to the users of compressed air, limiting the fittings downstream of the equipment and providing a valve upstream for disassembly and repair.

Distribution networks

- **air dried**

It is no longer essential to provide long the network of the steam traps. Only in the case of specific users (painting plants, pharmaceutical plants) are installed, upstream of the loads of coal or ceramic filters for retaining solid particles (rust) that may be present in the air.

The calculation of the pressure drops in the pipes are calculated with the formula:

$$\Delta p = \lambda \cdot \gamma_a \cdot \frac{v^2}{2 \cdot g} \cdot \frac{L}{D}$$

where:

Δp = pressure drop (bar);

λ = coefficient of friction of the air movement inside the tubes;

γ_a = weight per unit of volume of air (kg_f/m^3);

v = air velocity (m/s);

D = internal diameter of the pipe (m);

L = equivalent length of the pipe (m).

Distribution networks

- **air dried**

One can also apply the experimental formula:

$$\Delta p = 1{,}6 \cdot 10^{8} \cdot \frac{Q^{1{,}85}}{p_o} \cdot \frac{L}{d^{5}}$$

where:

Δp = pressure drop (bar);

Q = air flow (m^3/min);

d = internal diameter of the pipe (mm);

L = equivalent length of the pipe (m);

p_o = initial pressure (bar).

Distribution networks

- **air dried**

The length L comprises the resistances due to accidental variations of section of direction, valves, branches etc. it takes account of such localized losses, whereas the equivalent lengths of pipe, which are added to the effective length of the tubes on which the resistors themselves are localized.

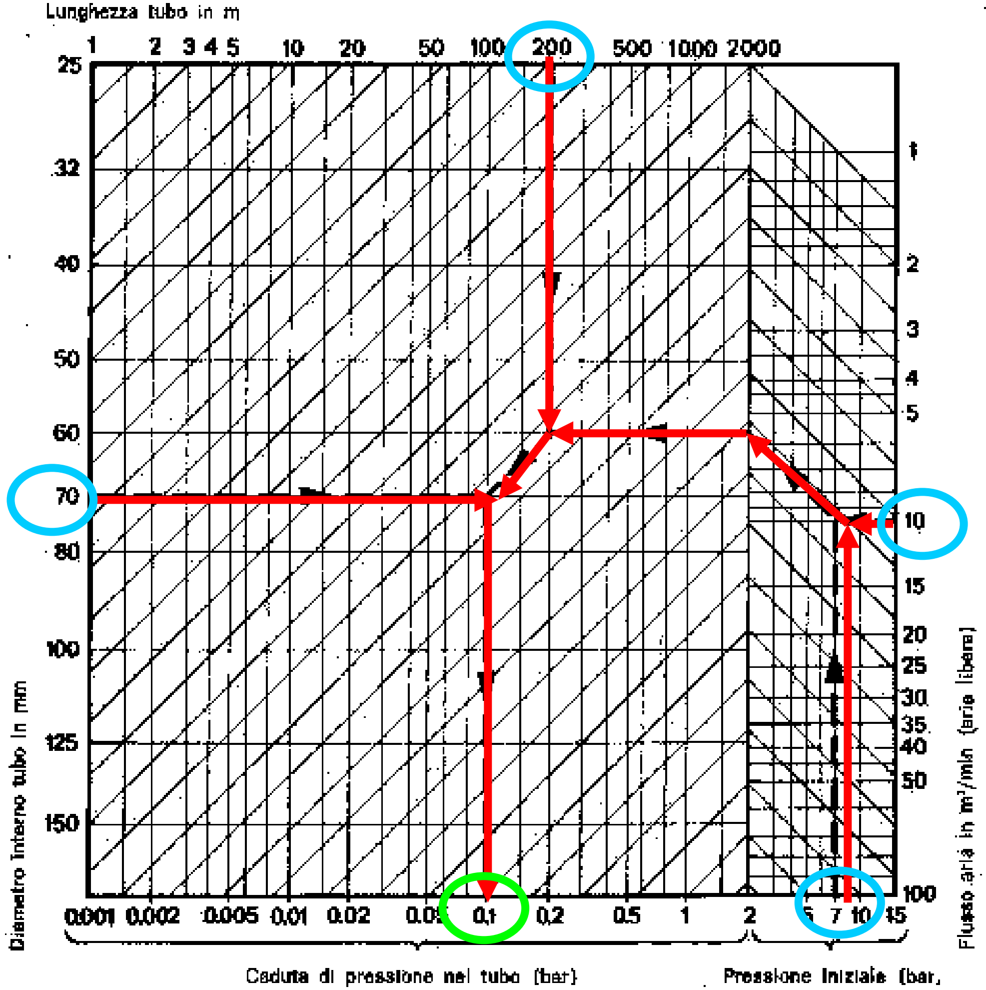
The equivalent lengths are provided by graphs or tables. It is evident the advantage that derives from curves of large radius and fittings without abrupt changes in direction and cross section.

Appropriate diagrams provide the pressure drop as a function of air flow rate, its pressure, the equivalent length and diameter of the tubes.

Plants for the production and distribution of compressed air

Distribution networks

- **air dried**



Distribution networks

- **air dried**

Even networks of compressed air, such as those for water, it is possible to apply methods for sizing based on the concept of maximum total economy.

The air velocity in the pipe should never exceed 10-15 m/s, while the maximum pressure drop between the compressor and the ends of the network should be contained within 0.5 bar, 0.2 bar including the lost in the dryer.

The starting point is the need for compressed air: it is assumed that as the sum of the needs of individual users, and then multiplying this sum by a reduction coefficient (less than 1), contemporaneity coefficient, which takes into account the fact that not all the users of compressed air work simultaneously at maximum load.

Distribution networks

- air dried

The table gives an indication of the consumption of some pneumatic equipment currently used in industrial activity.

Denomination	Main characteristics	Consumption (dm^3/min)
Pneumatic starters	For screw from 25 to 35 mm	900 – 1350
Pneumatic drills	For holes up to ϕ 20 in steel	900 – 1300
Pneumatic grinders	Grinder ϕ 150 x 25 mm	1000 – 1500
Pneumatic sanders		1000 – 1400
Guns for spray painting	Medium	200 – 300
Pneumatic hammers	Medium - heavy	500 – 750
Pneumatic hoits	From 150 to 1500 kg	700 – 2000
Lifts of trucks	Service station	500 – 700

Distribution networks

- **air dried**

  You must consider the air leaks, sometimes significant, that occur in correspondence of the various servo-means and other points in the network.

  Being known the air pressures required to utilities, it is possible to determine the diameters of the pipes and the load losses in the network.

  You finally choose the type, the number and the characteristics of the compressors.

  When a plant is necessary the compressed air at different pressures (for example 3, 7 and 25 bar) is necessary keep separate the various power supply networks.

Distribution networks

- **air dried**

For pressures of current use (7-8 bar) using commercial steel tubes externally coated in the case in which they are buried.

For higher pressure at 15-16 bars should employ tubes of quality and greater thicknesses (testing at 40 bar).

In the first part of the network and especially when the air comes from a drying plant, agrees insulate the pipes with insulating antistillicidio.