Pneumatic Air Compressor

INTRODUCTION:

English word Pneumatic is derived from the greek word 'pneuma' meaning "breath".Pneumatic control system operate on a supply of compressed air, which must be made available in sufficient quantity and at a pressure to suit the capacity of the system. A compressor is a machine which takes in air, gas or vapors at a certain pressure and delivers the fluid at a higher pressure.

Everything on earth is subjected to the absolute atmospheric pressure(pa), this pressure cannot be felt.The prevailing atmospheric pressure is therefore regarded as the base and any deviation is termed "gauge pressure".

Absolute pressure = Atmospheric pressure + gauge pressure

Absolute pressure is approximately one bar greater than the gauge pressure.

Charecteristics of interest on a compressor are,

Delivery volume or capacity of the compressor

Compression ratio : Compressor capacity is usually expressed as air volume at ambient conditions at the compressor intake, namely in units of metercube per minute or litres per minute.

Compression ratio is expressed by the discharge pressure measured in the generally accepted unit of bars. Compressors should be installed in a separate room. Special care is required to ensure that the compressors will be able to take in air that is preferably cool but above all dry and substantially dustfree.

At locations where clean suction air is not available, the installation of a separate intake filter can answer this requirement. Piping leading from the filter to the compressor intake should be amply dimensioned. In this way it is also possible for clean suction air to be supplied to a multiple number of compressors via a common intake duct.

Unnecessary costs in the production of compressed air can be avoided by functional and expert planning

Clean condition of the suction air is one of the factors decisive to life of a compressor. Warm and moist suction air will result in increased precipitation of condensate from the compressed air.

The amount of moisture condensing out of compressed air is a function of the relative humidity of the intake air and the temperature. Relative humidity is the amount of water vapor present in a given volume of air, whereas the humidity at saturation is the total amount of water vapor which that same volume of air can absorb at the given temperature.

One meter cube of compressed air is only capable of holding the same amount of water vapor as one metercube of atmospheric air. Discharge pressure of the compressor should not be appreciably higher than the working pressure required for operation of the pneumatic control devices. Delivering air at higher pressure will cost more for compression and will cause higher losses at leakage points. Air receivers are installed directly downstream of the compressors to receive the compressed air delivered, thereby balancing out pulsations in the air flow. Mostly they are also intended to serve as storage reservoirs for the overall air mains, thus additionally helping to cool the compressed air and separate condensate before it is distributed further. In large compressor systems an after collar incorporating a moisture separator will be installed between compressor and receiver so that a large part of the condensate will be removed before the air enters the receiver. Size of the receiver is governed by the rate at which compressed air is consumed and the capacity of the compressor.

Volumetric capacity of the receiver in metercube equals the delivery capacity of the compressor in meter cube per minute. But it is cheaper to use an air receiver or accumulator whose capacity is too large than one too small.

Pressure-volume product is calculated by multiplying the volumetric capacity of the receiver in liters by multiplying the volumetric capacity of the receiver in liters by the working pressure in bars.

Pressure-volume product = p * v

Air receivers should be installed outdoors (preferably on the shady side of the building). This contributes to better cooling of the compressed air and thus better separation of condensate, while avoiding overheating of an enclosed space that might be too small. Good ventilation must be provided if the receiver is setup indoors.

Air accumulators are secondary receivers installed at intermediate locations to equalise pressure variations within the system so as to ensure that operating pressure is as constant as possible for all consumers. Such intermediate accumulators should be provided for each of several consumers. Pressure drops in long lines are thus compensated and flow velocity in the piping can be maintained at the optimum. Without intermediate accumulator, sudden large consumption of air may cause temporary breakdown of line pressure, resulting in abnormally high flow velocities in the air main, excessive cooling of air, and thus increased condensation at these points. AIR MAIN is the piping system into which the compressed air is led from the receiver. It is permanently installed system of interconnected pipes carrying the air to the connections for the various consumers. Main criteria to be considered are,

flow velocities

pressure drop in piping

tight joints throughout the main

PIPE SIZE: Pipe sizing is governed by

permissible flow velocity

permissible pressure drop;

working pressure

number of flow restrictors in piping

length of piping

"Rate of flow", that is the air consumption rate, is a quantity that must be determined in advance by the planning engineer. Flow velocity and pressure drop are closely related to one another. Roughness of the inside walls of piping and the number of fittings installed will also affect pressure drop. "Flow velocity" of compressed air in the mains should be between 6 and 10 m/sec. Every effort should be made to keep the velocity below 10 m/sec. Pipe elbows, valves, reducers and hose couplings cause the flow velocity to rise above the permissible figures at many points. Temporary increase in flow velocity also on actuating devices using air at a high rate." Pressure drop" should preferably not exceed 0.1 bar. Another measure used in practice is 5% of working pressure. "Flow restrictions" are formed in air mains by the valves, bends and tees installed. For calculation of the inside pipe diameter such restrictions must therefore be converted to the equivalent pipe length, which is then added to the remaining pipe length of the main. Permanently installed air mains piping should be accessible from all sides. Horizontal runs of air pipe should be slope downwards 1-2 % in the direction of flow. Vertical main lines should not terminate at a consumer take-off, but should run further down so that condensate precipitated in the main will collect at the lowest point of the branch line where it can be drained off and will not pass to the consumer.

Air mains are preferably constructed of steel pipe with welded joints. In the long run welds are more durable than any screwed joint. A drawback associated with welding is the formation of scale during welding, with the tendency of the weld to rust in time. The advantage of welding pipe lies in the tight sealing of joints and lower cost.

Isolating valves(gate valves) must be installed to divide the air main into sections so that it will not be necessary to shutdown and depressurize the entire main when maintenance or repairs become necessary.

WHAT IS THE COST PER CFM?

Let us assume that
motor service factor = 110%
power factor = 0.9
A typical compressor produces 4 CFM per 1 HP
1 HP = 110% x 0.746 KW/0.9 = 0.912KW
Therefore, 1 CFM =0.228KW
At 0.06 $KW/HR, 1CFM = $0.0137/hr
Therefore, 10 CFM over 8000 hr will cost : 10 x 8000 x 0.137 = $1096
In a typical plant, air leaks account for 20% of the total air usage !!
One 1/4" air leak will result in 100 CFM loss

IMPORTANCE OF DRY COMPRESSED AIR :

The atmospheric air taken in by the compressor always contains a proportion of moisture in the form of water vapour. The higher the air temperature, the greater the quantity of water vapour which it can take up, expressed in percentage of relative humidity. If the saturation point of RH 100% is reached, the water is precipitated in the form of droplets. The effects of this process can be explained by means of an example. A compressor with a delivery of 10 m /min. takes in approximately 36 litres of water with air at 7 bar pressure (at 20°C and 50% RH). Because of the com pression heat, the water is first taken up completely (the absorption capacity of air increases as the temperature rises).

When the air is cooled to 40°C, 5.1 litres of con densate are precipitated out immediately after the compressor. In the course of further cooling, a further 21.6 litres are precipitated out at 20°C. If this moisture is allowed to e nter the pneumatic system, the consequences would be as follows:Corrosion in pipes,cylinders and other components. This increases wear and maintenance costs.The basic lubrication in the cylinders is washed out.The switching function of valves is impaired, ie., more malfunctions during the operating sequence.Contamination and damage at points where the compressed air comes directly in contact with sensitive materials (e.g. in paint-shops, food industry).

Rust and scale formation within pipelines
Sluggish and inconsistent operation of air valves and cylinders
Freezing in exposed lines during cold weather
Further condensation and possible freezing of moisture at the exhaust whenever air devices are rapidly exhausted.

It therefore follows that the water must in all cases be removed from the compressed air before it can cause damage; i.e. the air must be dried. Before discussing about various types of driers, let us familiarise ourselves with a few terminologies.

Dew point = Temperature at which air is saturated with water vapour (Relative Humidity 100%).
Pressure dew point = Dew point at operating pressure.
Atmospheric dew point = Absolute humidity of compressed air referred to dew point (relative humidity of air).

The measure employed in drying of air or gases is the dew point, which is the temperature at which air is fully saturated with moisture. Cooling below the dew point will cause condensation of the water vapor.

The lower the dew point, the less moisture the air is able to absorb or hold. Absorptive capacity of air for moisture in the form of water vapor is a function of volume and temperature only, not of pressure, but it is still necessary to consider the working pressure of the system when comparing different facilities for the dehydration of air. This brings in thet term "pressure dew point", which means the temperature representing the dew point at the respective operating pressure. In drying air by refrigeration, pressure dew point defines the lowest air temperature attainable in the dryer at the operating pressure of the system.Another term encountered in drying of air is atmospheric dew point. This assumes that, for example, compressed air of a given volume and a given pressure dew point contains an amount of water vapor corresponding to the dew point of the air. Since the volume changes with a reduction in pressure, the dew point also changes, decreasing in accordance with the initial pressure and the corresponding proportional change of volume.Drying of compressed air can be performed by three processes Absorption Adsorption Refrigeration

DRYING BY REFRIGERATION:

Reduction of the dew point means that the capacity of the air to absorb moisture is reduced also.This is the principle applied in drying of air by refrigeration, the compressed air thereby being cooled to temperatures between about 1.7 and 5 degrees celcius. The equipment required for this method is a refrigerating unit and a heat exchanger.

Drying by refrigeration is only suitable for pressure dew points over 0 degree celcius Adsorption drying is the most expensive method when regeneration of the adsorbent is performed with cold air, but the second cheapest with hot-air regeneration. Absorption drying costs almost as much as adsorption drying with cold air regeneration, but is comparable with the hot-air-regeneration version when the pressure dew point is allowed to increase to 17 degrees celciius. Refrigeration drying is the least expensive of these processes, running to about 13% of the cost of the most expensive method. As a general guide, the cost of drying compressed air can be placed at approximately 10 - 20 % of the cost of compressing the air. Drying by refrigeration will remove oil approx. 80%. An oil separating filter should always be installed upstream of the air consumption points. More recent designs of ultrafilters are capable of separating oil and water aerosols down to a size of 0.01 micron.Production of compressed air free from oil to the greatest extent for pneumatic applications requires the combination of either drying the air by refrigeration or production of oil-free air by non-lubricated compressor and the use of non-lubricated compressor and the use of ultrafilters in the air line.

ABSORPTION DRYING:

Absorption drying is purely a chemical process. Absorb is to take up a gaseous substance in a solid or liquid substance. A prefilter separates larger drops of water and oil from the compressed air. On entering the device, the compressed air is made to swirl.The drying chamber is filled with a flux(drying agent) which extracts the water drops contained in the air. The flux combines with the water and passes into the collection chamber at the bottom. In the drying chamber, the flux is slowly used up. It must therefore be replaced at regular intervals.The consumption of flux is kept smallest if the inlet temperature of the air is kept at 20 degree centigrade. The special features of the absorption process are: simple installation of the equipment low mechanical wear(no moving parts) no external energy requirement

ADSORPTION DRYING:

Adsorption drying is based on a physical process.Adsorption means substances are deposited on the surface of solid bodies. This process is also known as regenerative drying. The drying agent is a granual material. The porous surface of the granules are filled with liquid when the compressed air flows through.

The saturated gel bed is regenerated by a simple method. Warm air is blown through the dryer and takes up the moisture. As a rule, two dryers are connected in parallel. While one of this drying the air, the other is regenerated. The capacity of gel bed is limited. Under normal conditions, it will be necessary to replace the drying agent every 2 to 3 years.

PNEUMATIC CYLINDERS:

The component in a pneumatic control system which performs the work or functions as the actuator is the air cylinder.An air cylinder is an operative device in which the static input energy of compressed air, i.e pneumatic power, is converted into mechanical output power by reducing the pressure of the air to that of the atmosphere.

Following are the different types of pneumatic cylinders

Single acting cylinders
double acting cylinders
special type cylinders

Single acting cylinder is only capabale of performing an operating motion in one direction.

Double acting cylinders are capable of performing an operation motion in both directions of piston travel. Single acting cylinders require only about half the air volume consumed by a double acting cylinder for one operating cycle. Opposed thrust or multi-position cylinders, rotary cylinders, impact cylinders etc. are some special type cylinders.

CYLINDER THRUST:

The thrust developed in the cylinder, that is the piston power, is a function of the piston diameter, the operating air pressure and the frictional resistance.

Thrust = (piston area) * (air pressure)

AIR CONSUMPTION:

The compressed air supplied to a pneumatic cylinder is consumed with its energy being converted into a power output. On reversal of the piston stroke in the cylinder, the consumed air is exhausted to the atmosphere.

Air consumption = compression ratio * piston area * Stoke length
compression ratio = (1.033 + operating pressure in bar)/ 1.033

PISTON VELOCITY:

Factors governing the velocity of the piston are operating pressure opposing forces inside diameter length of air line between control valve and cylinder size of control valve

The piston velocity may additionally be affected by any throttle or quick-exhaust valve installed.
With single-acting cylinder, the advance movement can be throttled only by throttling the supply air.
The return speed of a single-acting cylinder can be increased by using a QUICK EXHAUST VALVE.
Fan Laws allow us to predict compressor and expansion turbine performance as their speed changes. Changing the speed of an impeller affects the pressure ratio (Head) and the flow, which in turn effects the horsepower. Speed change is the most efficient way to operate at off-design points. By observing the Fan Laws we can pick the correct speed to match an off-design point. This is particularly important when you have a variable speed driver, such as a steam turbine.
Fan Laws state that the flow is directly proportional to the speed. Therefore if the speed decreases to 90% of design speed, the compressor will operate at 90% of design flow.
Speed change ---------Flow change
The head of the compressor is proportional to the speed^2 or the square root of the speed. This will yield the head change. Therefore if the speed decreases to 90% of design speed, the compressor will operate at 81% head.
SQRT(SPEED CHANGE) ------------Head change
The power of the compressor is proportional to the speed^3 or the cube root of the speed. This again will yield the power change. Therefore if the speed decreases to 90% of design speed, the compressor will operate at 73% power.
cube rute(speed change)-------------Power change
The above reflects the relationship of flow, head and power to speed. Once again, by understanding this equation, you are able to set your compressor at the right speed to provide the most efficient operating condition.

ENERGY SAVING IN COMPRESSOR:

The three major areas are
Compressed Air generation
Compressed Air distribution
Compressed Air Utilisation

GENERATION:

The following points to be considered The compressor type,(single stage or multi stage), capacity required and capacity utilizations Screw and centrifugal compressors are suitable for base load or full load applications but not for part load operations. Reciprocating compressors are suitable for variable loads where no-load power is 10 to 12% of the full load power.
minimum and maximum pressure required
type of cooling required
space requirement
type of capcacity control
On/Off control
Load and Unload
Throttling control
Speed control
initial cost
Where there are more than one compressor then modulation should be based on
If all are of similar size then one compressor should handle load variation
If all are of different size then smallest compressor is allowed to modulate
IF all are of different type then allow screw/centrifugal compressors to run on full load
In general allow the compressor whose no-load power consumption is less to modulate

DISTRIBUTION:

Efficient air distrubution
Air Receiver installation
Optimum pipe sizes
Avoiding leaks and wastage
Avoiding unnecessary pressurization of piping system system
Proper location of moisture separators and drain valves

UTILISATION:

Use of blower air instead of compressed air
Use of PRV for low pressure air requirement
Use of electrical tools instead of pneumatic tools
Replacing pneumatic conveying by mechanical conveying
Avoiding misuse of compressed air
Misuses such as body cleaning, liquid agitaion, floor cleaning,drying, equipement cooling, and other similar uses have to be discouraged to save compressed air and energy.