COMPRESSOR SELECTION GUIDE

PERMAWELD PVT LTD

Introduction

Air Compressors are one of the important utilities in any given industry. Compressors are designed to compress the air into smaller volume at certain pressure level. Energy is used to compress the air and the same energy is used at end user by expanding the volume of air. The advantage of compressed air is that it has high power-to-weight or power-to-volume ratio. It is the utility that is generated in house which means owners have complete control over it than any other utility. With all the different options available on modern air compressors, the proper selection can be a guessing game without the right set of guidelines. There are nearly as many different air compressor and option combinations as there are types of applications. Making a mistake in the selection process can cost you efficiency, extra service and even production. If you are struggling to find your suitable type of compressor then you are at the right place...!!

Compressor Types

Compressors are broadly classified as: Positive Displacement Compressor and Dynamic Compressor. Positive displacement compressors increase the pressure of the gas by reducing the volume. Dynamic compressors increase the air velocity, which is then converted to increase pressure at the outlet. The flow and pressure requirements of a given application determine the suitability of a compressor.

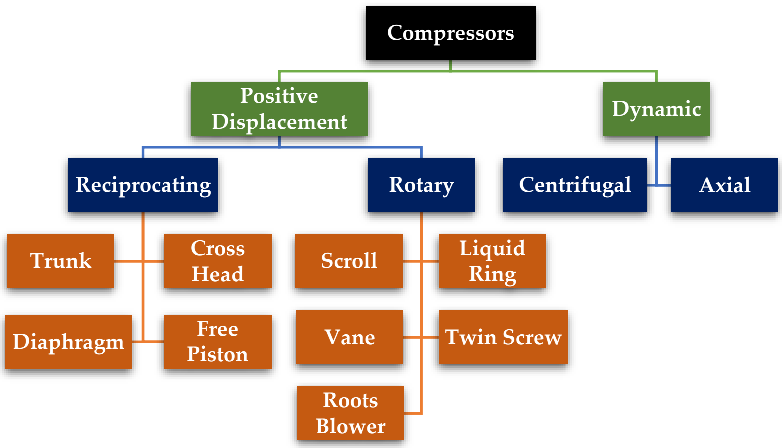

Fig 1.1.a. Types of Compressor

Positive Displacement Compressors

Reciprocating Compressors

Reciprocating compressors are the most widely used type for air compression. They are characterized by a flow output that remains nearly constant over a range of discharge pressures. Also, the compressor capacity is directly proportional to the speed. The output, however, is a pulsating one.

Reciprocating positive displacement compressors have a piston in a cylinder or a diaphragm operating in a shaped cavity to compress the gas. Reciprocating compressors are available in many configurations, the four most widely used of which are horizontal, vertical, horizontal balance-opposed and tandem. Vertical type reciprocating compressors are used in the capacity range of 50 – 150 cfm. Horizontal balance opposed compressors are used in the capacity range of 200 – 5000 cfm in multi-stage design and up to 10,000 cfm in single stage designs.

Reciprocating compressors are also available in variety of types:

- Lubricated and non-lubricated
- Single or multiple cylinder
- Water or Air cooled
- Single or Multistage

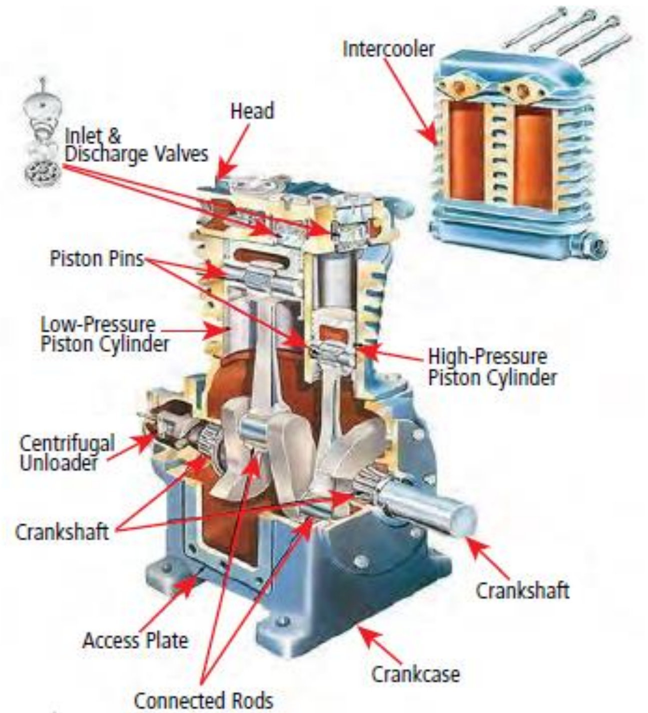

Fig 1.1.b. Reciprocating two stage, two cylinders

In the case of lubricated machines, oil has to be separated from the discharge air. Non-lubricated compressors are especially useful for providing air for instrumentation and for processes which require oil free discharge. However non-lubricated machines have higher specific power consumption (kW/cfm) as compared to lubricated types.

Single cylinder machines are generally air-cooled, while multi-cylinder machines are generally water cooled, although multi-stage air-cooled types are available for machines up to 100 kW. Water-cooled systems are more energy efficient than air-cooled systems.

Two stage machines are used for high pressures and are characterized by lower discharge temperature (140 to 160°C) compared to single-stage machines (205 to 240°C). In some cases, multi-stage machines may have a lower specific power consumption compared to single stage machines operating over the same total pressure differential. Multi-stage machines generally have higher investment costs, particularly for applications with high discharge pressure (above 7 bar) and low capacities (less than 25 cfm). Multi staging has other benefits, such as reduced pressure differential across cylinders, which reduces the load and stress on compressor components such as valves and piston rings.

Rotary Compressors

Rotary compressors have rotors in place of pistons and give a continuous, pulsation free discharge air. They are directly coupled to the prime mover and require lower starting torque as compared to reciprocating machine. They operate at high speed and generally provide higher throughput than reciprocating compressors. Also, they require smaller foundations, vibrate less, and have a lower number of parts - which means less failure rate.

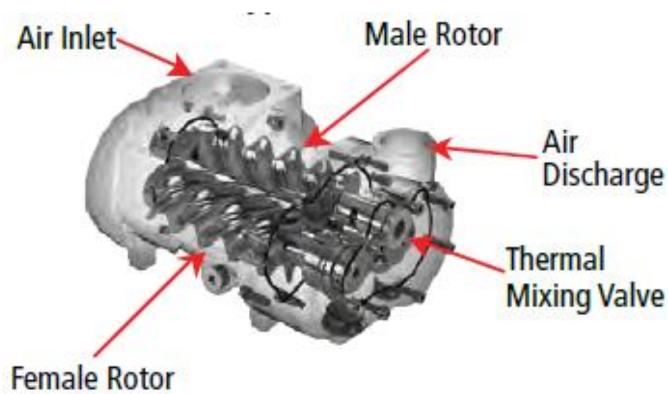

Fig 1.1.c. Rotary Helical Screw type

Among rotary compressor, the Roots blower (also called as lobe compressor) and screw compressors are among the most widely used. The roots blower is essentially a low-pressure blower and is limited to a discharge pressure of 1 bar in single-stage design and up to 2.2 bar in two stage design.

The most common rotary air compressor is the single stage helical or spiral lube oil flooded screw air compressor. These compressors consist of two rotors, within a casing where the rotors compress the air internally. There are no valves. These units are basically oil cooled (with air cooled or water-cooled oil coolers) where the oil seals the internal clearances. Since the cooling takes place right inside the compressor, the working parts never experience extreme operating temperatures. The oil has to be separated from discharge air. Because of the simple design and few wearing parts, rotary screw air compressors are easy to maintain, to operate and install.

The oil free rotary screw air compressor uses specially designed air ends to compress air without oil in the compression chamber producing true oil free air. These compressors are available as air-cooled or water-cooled types and provide the same flexibility as oil flooded rotary compressors.

There is a wide range of availability in configuration and in pressure and capacity. Dry types deliver oil-free air and are available in sizes up to 20,000 cfm and pressure up to 15 bar. Lubricated types are available in sizes ranging from 100 to 1000 cfm, with discharge pressure up to 10 bar.

Dynamic Compressors

Centrifugal Compressors

Dynamic compressors are mainly centrifugal compressors and operate on similar principles to centrifugal pump. Centrifugal compressors impart velocity to the gas through rotating impellers. The gas is introduced at the eye of the impeller and discharged radially at the outer circumference (impeller tip) at a higher velocity and kinetic energy. The gas then passes through a stationary diffuser where its velocity is reduced, and its kinetic energy is converted to static pressure. Part of the static pressure rise occurs in the impeller and part in the diffuser.

These compressors have appreciably different characteristics as compared to reciprocating machines. A small change in compression ratio produces a marked change in compressor output and efficiency. Centrifugal machines are better suited for applications requiring remarkably high capacities, typically above 12,000 cfm.

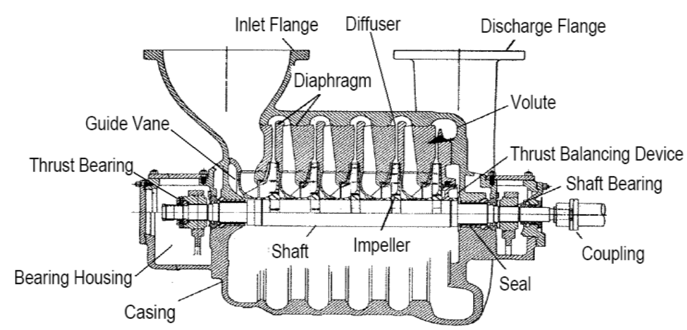

Fig 1.1.d. Multistage Centrifugal Compressor

The centrifugal air compressor is an oil free compressor by design. The oil-lubricated running gear is separated from the air by shaft seals and atmospheric vents. The centrifugal is a continuous duty compressor, with few moving parts, and is particularly suited to high volume applications, especially where oil free air is required.

A single-stage centrifugal machine can provide the same capacity as a multi-stage reciprocating compressor. Machines with either axial or radial flow impellers are available.

The major limitation of centrifugal compressor is that it operates at peak efficiency at design point only and any deviation from the operating point penalizes efficiency. When selecting centrifugal compressors, close attention should be paid during system design to ensure that at high pressure, with the consequent reduction in flow, the surge point or zone of unstable operation is not reached.

Axial Flow Compressors

Axial flow compressors are suitable for higher compression ratios and are generally more efficient than radial compressors. Axial compressors typically are multi-stage machines, while radial machines are usually single-stage designs.

In Axial Compressors, gas moves axially along the compressor shaft (parallel to the machine axis) through alternating rows of rotating and stationary blades. Each set of blades (one rotating row followed by one stationary row) represents a stage of compression. The rotating blades impart velocity to the gas; the stationary blades slow the gas and direct it into the next row of rotating blades. As the gas passes through each stage, its pressure and temperature are further increased until it finally exits the compressor at the required pressure and associated temperature.

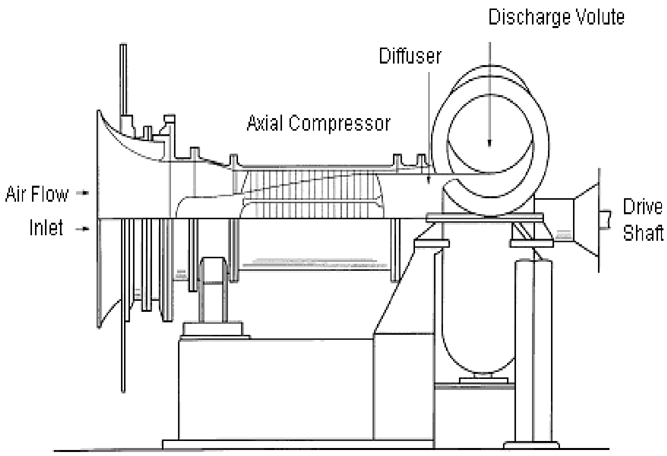

Fig 1.1.e. Axial Compressor

Comparison of different Compressors

The power consumption of various compressors depends on the operating pressure, free air delivery and efficiency etc. The variations in power consumption during unloading/part load operation are more significant and depend on the type of compressor and method of capacity control. The relative efficiencies and part load consumption of different compressors are given in Table 1.1.a.

Table 1.1.a. Efficiency of different Compressors

Efficiency	Reciprocating	Centrifugal	Rotary Vane	Rotary Screw
Full Load	High	High	Medium-high	High
Part Load	High	Poor below 60% of full load	Poor below 60% of full load	Poor below 60% of full load
No Load	High (10-25% of full load power)	High-Medium (20-30% of full load power)	Medium (30-40% of full load power)	High-Poor (25-60% of full load power)

In case of reciprocating machines, the unload power consumption is in the order of 25% of full load power. While in screw compressors, the unload power consumption is marginally higher compared to reciprocating machines.

It is preferable to use screw compressors for constant air requirement. If screw compressors have to be installed for fluctuating loads, it is desirable to have screw compressor with variable speed drive to further optimize unload power consumption.

Some of the plants have adopted the strategy of operating screw compressor at full load for meeting the base-load requirement and reciprocating compressor for fluctuating load to optimize on unload power consumption.

The general selection criteria for compressor is given in the table 1.1.b.

Table 1.1.b. Selection Criteria for Compressors

Compressor	Capacity (m3/h)		Pressure (bar)	
	From	To	From	To
Roots Blower Single Stage	100	30000	0.1	1
Reciprocating				
Single Stage	100	12000	0.8	12
Multistage	1000	12000	12	700
Screw				
Single Stage	100	2400	0.8	13
Multistage	100	2200	0.8	24
Centrifugal	600	300000	0.1	450

The table 1.1.c. below shows the advantages and disadvantages of different compressors.

Table 1.1.c. Advantages and Disadvantages of Compressors		
Centrifugal	• Wide operating range • High reliability and low maintenance	• Instability at reduced flow • Sensitive to changes in gas composition • Susceptible to rotor-dynamics problems • Sensitive to liquids in the gas stream
Axial	• High capacity for a given size and high efficiency • Heavy duty and low maintenance	• Low compression ratios • Limited turndown
Reciprocating (Piston)	• Wide pressure ratios • High efficiency	• Heavy foundations required due to unbalanced forces • Flow pulsation can cause vibration and structural problems • High maintenance compared to dynamic compressors • Sensitive to liquids in the gas stream
Screw	• Wide range of applications • Wet screw has high efficiency and high-pressure ratio • Dry screw insensitive to changes in gas composition and can handle dirty gases	• Noisy • Wet screw not suitable for corrosive or dirty gases

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References

- "Energy Efficiency in Electrical Utilities", Fourth Edition, 2015, by Bureau of Energy Efficiency.
- "PIP REEC001 Compressor Selection Guidelines, April 2013, by Process Industry Practices.