

Mechanical Equipment - Course 430.1

COMPRESSORS - DYNAMIC AND POSITIVE DISPLACEMENT

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GENERAL

Until this point in time, the discussion has primarily focused on pumps, devices which move liquids. Understandably, there are also devices used to move air and gases. These devices are either compressors, blowers, fans or vacuum pumps. As indicated in Table 1, The American Society of Mechanical Engineers has devised a classification system to help us differentiate these devices. This system is based on discharge pressure.

Table 1

ASME CLASSIFICATION

<u>DEVICE</u>	<u>DISCHARGE</u>	<u>PRESSURE</u>
1. Compressor	greater than 69 kPa(g)	(10 psig)
2. Blower	13.8 kPa(g) to 69 kPa(g)	(2 to 10 psig)
3. Fan	0 - 13.8 kPa(g)	(0 to 2 psig)
4. Vacuum Pump	suction below atmospheric pressure	

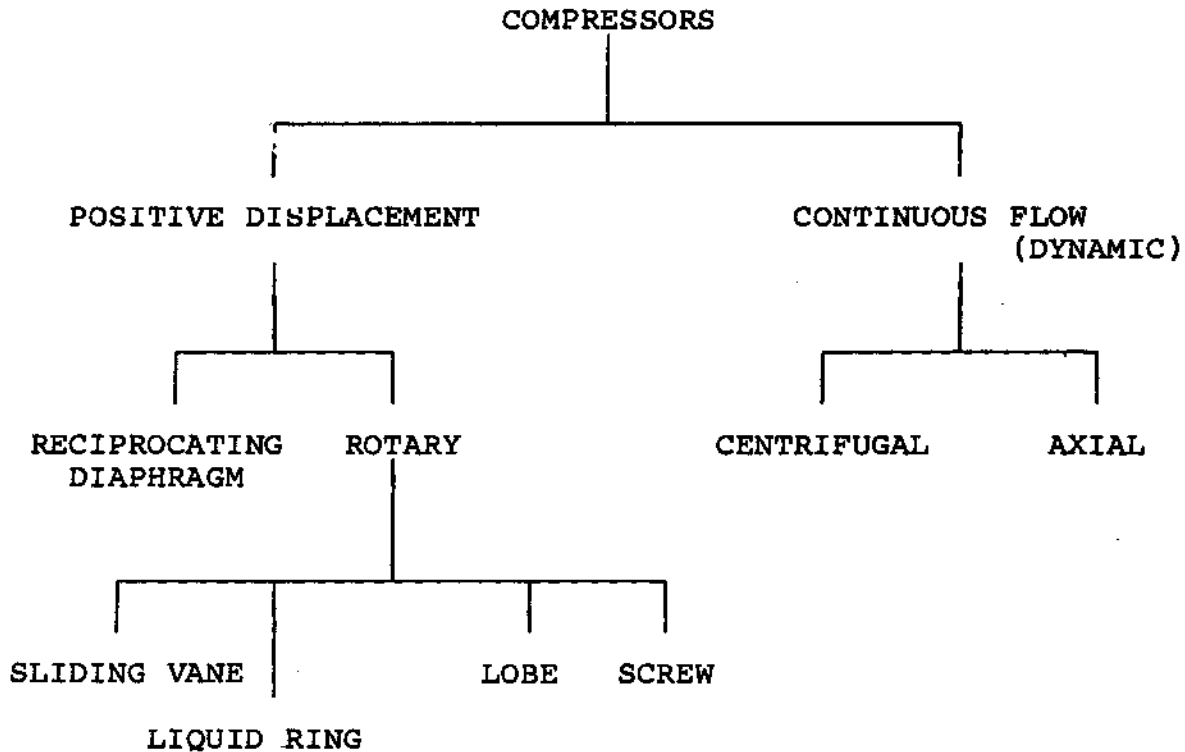
COMPRESSORS

TYPES

A large variety of compressors of different sizes, shapes and designs are available from a number of manufacturers. However, all compressors can be very simply classified as being either a:

1. Dynamic.
2. Positive Displacement.

Within each major type, there are further subdivisions as shown in Table 2.

Table 2

As you probably noticed, the classification scheme in Table 2 indicates a similarity between pumps and compressors. In fact, there is little difference between the principle of operation of pumps and compressors. A comparison of the two basic types of compressors with respect to flow, pressures and efficiencies could have been a comparison of the two main types of pumps.

Table 3

<u>TYPE</u>	<u>FLOW RATE</u>	<u>PRESSURE</u>	<u>EFFICIENCY</u>
Axial	Highest	Lowest	Intermediate
Centrifugal	Intermediate	Intermediate	Lowest
Positive Displacement	Lowest	Highest	Highest

} Dynamic

## DYNAMIC COMPRESSORS

### Principle of Operation

The principle of operation of the two dynamic compressors, centrifugal and axial, is basically the same. Two steps are involved:

1. A rapidly rotating element accelerates the gas as it passes through the machine. Centrifugal compressors use impellers which axial compressors use blades to accelerate the gas.
2. Compression of the gas occurs as velocity of the gas is converted into pressure by stationary elements. Centrifugal compressors employ a diffuser section and axial compressors use stationary blades.

The main difference which exists between the two is direction of air flow through the compressor. As indicated in Figure 1, centrifugal units have radial flow which axial units, Figure 2 have air flow parallel to shaft.

### Applications

In NGS, centrifugal compressors are used in the larger air conditioning units. Although selection factors are many, in comparison with reciprocating units:

1. maintenance and failure rates are lower.
2. smaller, less expensive foundations are required.
3. they offer continuous, smooth, larger flows.

Axial units, on the other hand, are used in gas turbines of the standby generators at Pickering and Bruce because of the higher flow requirements. In comparison with centrifugal units, they are:

1. smaller,
2. lighter weight,
3. and require smaller foundations.

As the pressure rise per stage is lower with the axial units than centrifugal units, axial compressors have more stages for a given total pressure rise.

Unfortunately, both units suffer from a common operational problem - surge. By definition, surge arises when capacity is reduced to a point when insufficient pressure is

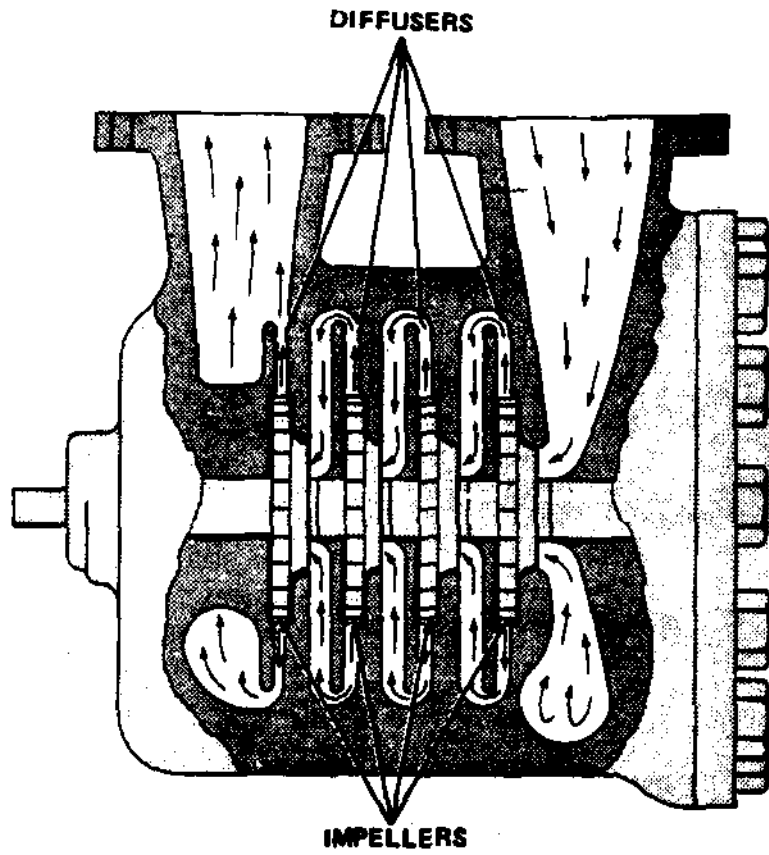


Figure 1

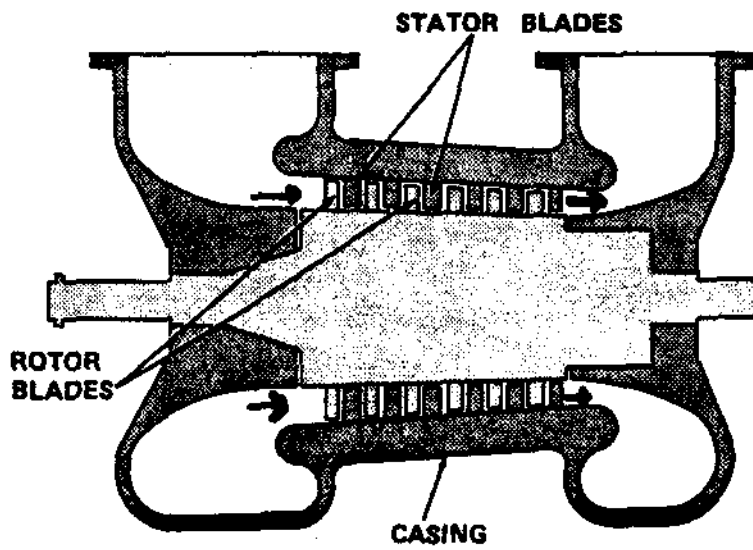


Figure 2

generated to maintain flow. Under this circumstance, a momentary reversal of flow within the compressor occurs. However, as soon as flow reverses, system discharge pressure drops and compressor assumes normal flow. These momentary pulsations are apt to be magnified in the discharge and result in excessive temperature rise, vibration, noise and excessive stress in the compressor.

### POSITIVE DISPLACEMENT

As mentioned previously, the second class of compressor is the positive displacement type. The five basic types that belong in this class are:

1. (a) Reciprocating.  
(b) Diaphragm.
2. Rotary (i) sliding vane  
(ii) multiple lobe  
(iii) liquid ring

### Principle of Operation

All positive displacement compressors have the same principle of operation. In each, a prime mover causes a reduction in volume of air which in turn initiates an increase in pressure.

### RECIPROCATING COMPRESSOR

Of all compressor types, the reciprocating compressors are the most widely used, available in a wide range of sizes and shapes.

### Characteristics

#### Advantages

1. Efficiency - as described previously in Table 1, they are the most efficient machines for most applications. With appropriate capacity controls, piston units can also maintain their efficiency at partial loads.
2. Type of Gas Handled - they can be built to handle any commercial gas (provided corrosion problems are solved).
3. Lubrication - cylinders can be either lubricated or non-lubricated.
4. Pressures - high discharge pressures are obtainable.

Disadvantages

1. Vibrations - because these units suffer from large inertia forces which tend to shake the units, large, costly foundations are required.
2. Pulsating Flow - if pulsating flow is a problem, units must be supplied with pulsation dampeners (accumulators).

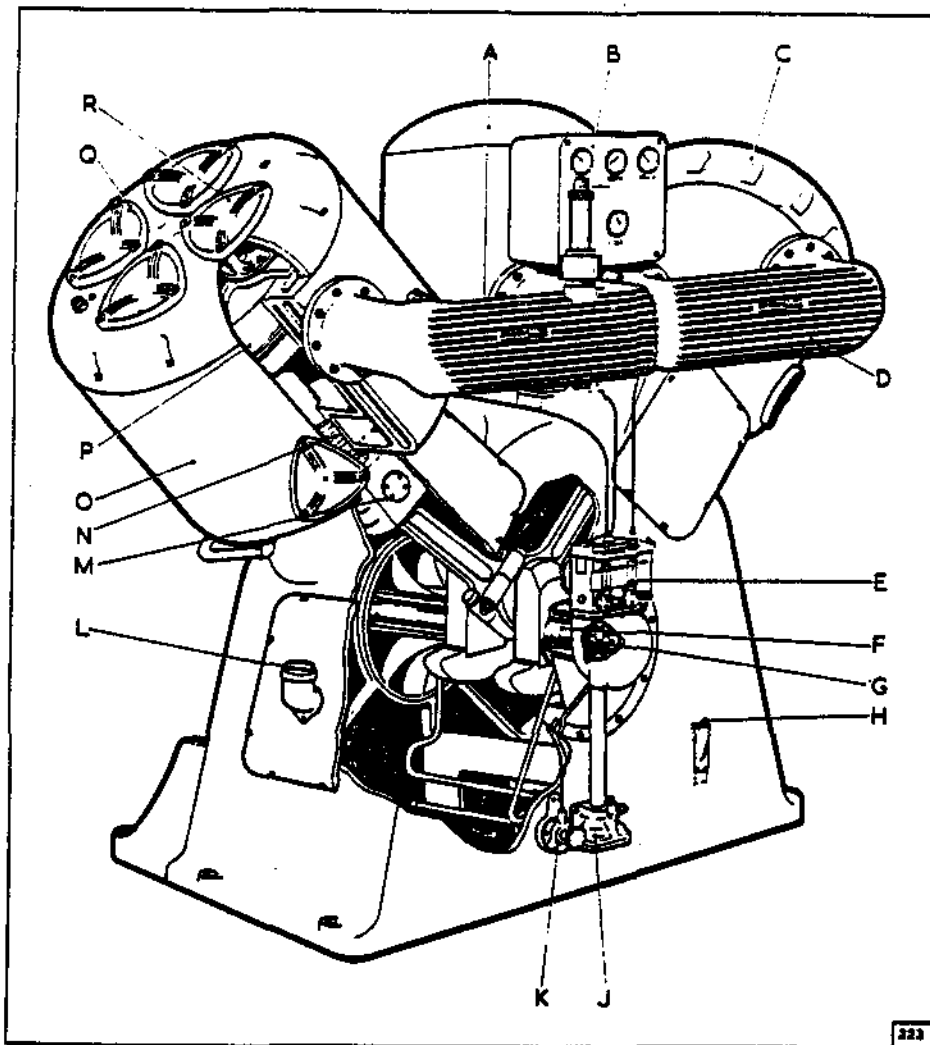
Description

Although these units appear complex on initial inspection, they can be simply described as positive displacement machines in which the compressing and displacing element is a piston having a reciprocating motion within a cylinder.

Figure 3 shows a schematic of a typical reciprocating compressor. For this example, a Broomwade model has been chosen to highlight the main components. Although models vary from station to station, components vary little.

This particular type is a two-stage, V-inclined, double acting, intercooled, reciprocating compressor. An explanation of each term follows:

1. Two-stages - or two separate cylinders are used when it is necessary to have two steps of compression. Multi-staging a compressor reduces power consumption but also becomes necessary if conditions go beyond the capabilities of a single stage compressor to handle high discharge temperatures and stresses.
2. Double-acting - describes a unit which is capable of compression on both sides of a piston.
3. V-inclined - each cylinder is 45° from the vertical.
4. Inter-cooling - describes a process of cooling air leaving the first stage before entering the second stage to:
  - (a) reduce the temperature of air.
  - (b) reduce volume of air to be compressed in the succeeding stage.
  - (c) save power.
 usually, the intercooler is a tube-in-shell water cooled heat exchanger.
5. Reciprocating Piston - is self-explanatory. Depending upon the system in which the compressor is used, the cylinder can be either lubricated or non-lubricated type employing carbon or teflon split rings.



Ref.	Part No.	Description	No. Off
A	C10190/213	Intercooler Sub-Assembly	1
B	C10190/474	Instrument Panel Assembly	1
C	C10190/471	H.P. Cylinder	1
D	C10190/132	Air Pipe - Intercooler to H.P. Cylinder	1
*E	A1413/727	Kirkham Two Feed Mechanical Lubricator	1
F	C10190/190	Crankshaft (N.C.I.)	1
G	C10190/178	Driven Gear (Pump Drive)	1
H	C10190/110	Dipstick	1
J	C10190/212	Oil Pump Sub-Assembly	1
K	A1413/481	Oil Filter	1
L	C10190/182	Oil Filler Cap Top	1
M	C10190/35	Crosshead	2
N	C10190/224	L.P. Gland Assembly	1
O	C10190/52	L.P. Cylinder	1
P	C10190/209	L.P. Piston Sub-Assembly	1
Q	C10190/199	L.P. Suction Valve Assembly	4
R	C10190/200	L.P. Delivery Valve Assembly	4

Figure 3

## Diaphragm Compressors

Diaphragm compressors can be considered a special type of reciprocating compressor. In both cases, an oscillating prime mover physically displaces air. The diaphragm compressor would, of course, employ a diaphragm as a prime mover.

Although not as common as reciprocating piston compressors, diaphragm units offer a number of favourable characteristics.

### Characteristics

1. In diaphragm units, the gas to be delivered is only in contact with the metal diaphragm. The gas is therefore compressed in a state of purity and without any lubricant.
2. There is no leakage of gas into the atmosphere.
3. Because the diaphragm separates the gas completely from the oil, the compressor operates without any packed gland; this enables the compressor to operate with the least amount of power.

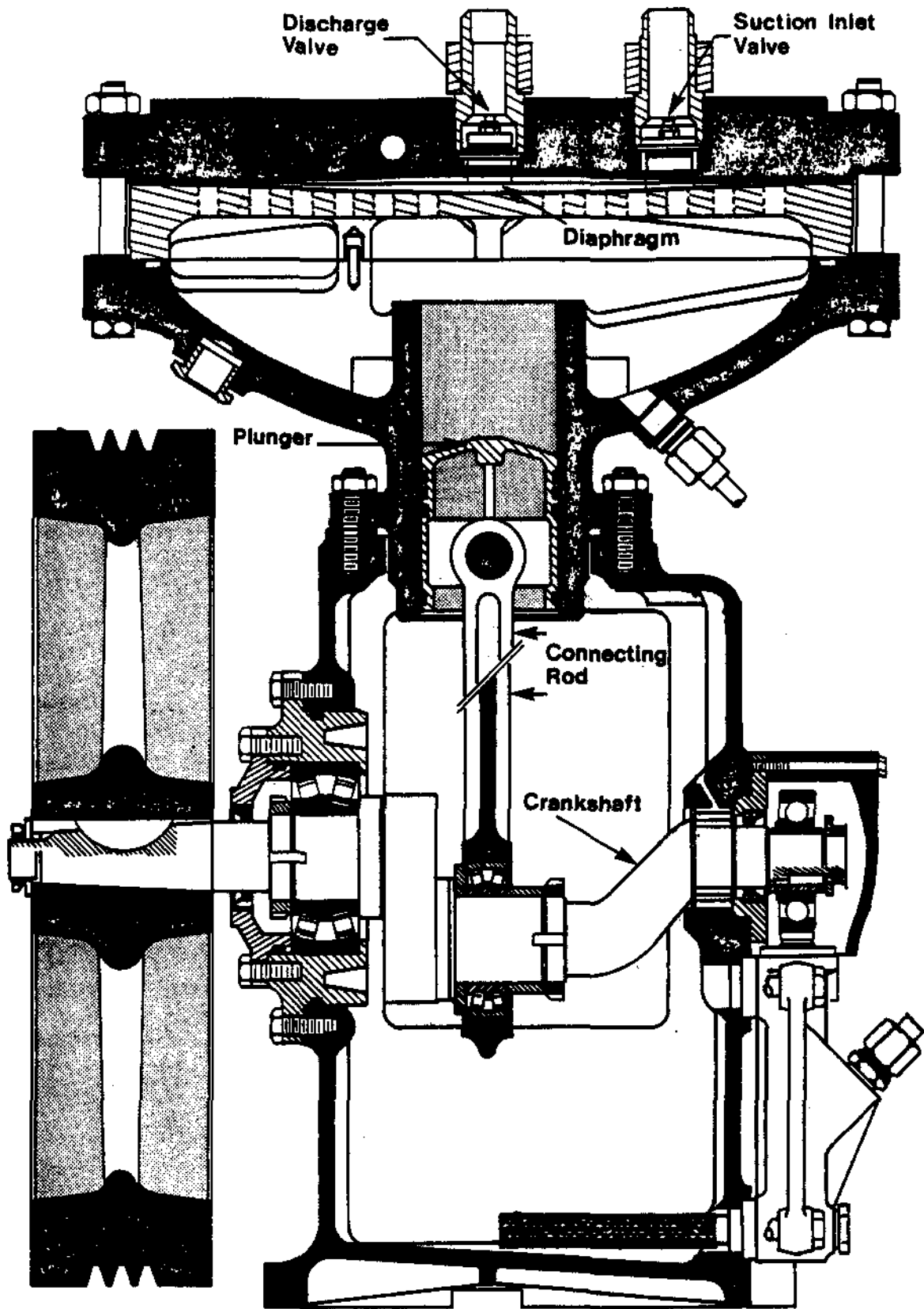
### Description

These compressors shown in Figure 4 consist of two cylindrical plates hollowed out. Between the two plates, a flexible metallic diaphragm is gripped and held in position by bolts.

The lower plate is perforated to allow transfer of oil from the cylinder of the pump; the other plate carries suction and discharge valves.

A piston acts on the oil, with which the cylinder of the pump is filled and thus impacts motion to the diaphragm. This forces the diaphragm to contact the plate carrying suction and discharge valves to discharge compressed gas.





DIAPHRAGM COMPRESSOR

LIQUID RING COMPRESSOR

The liquid ring compressor uses a rotor with multiple forward turned blades turning about a central cone containing inlet and discharge ports driving a ring of liquid around the inside of an elliptical casing. As outline in Figure 5, a certain amount of liquid is trapped between adjacent blades and as the rotor turns, the liquid face moves in and out of this space due to casing shape. This creates a liquid piston.

CharacterisitcsAdvantages

1. Non-Pulsating Air Flow
2. Oil-Free Air - lubrication is required only in the bearings external to the casing. The liquid acts as a coating, lubricating and sealing medium.

Disadvanges

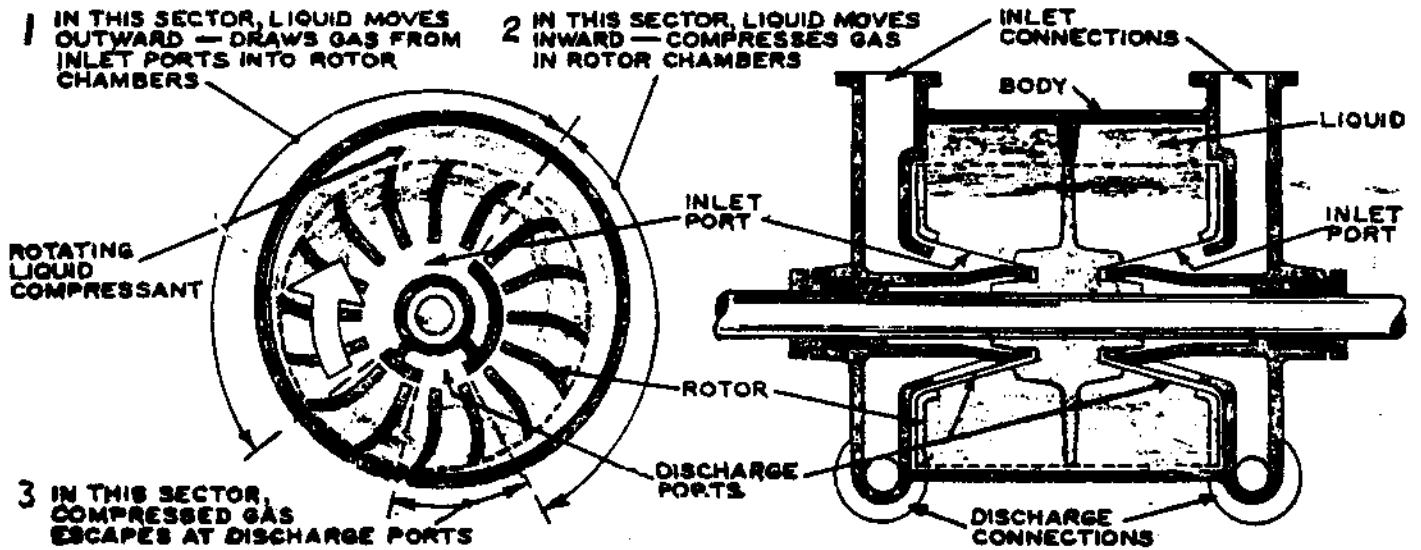
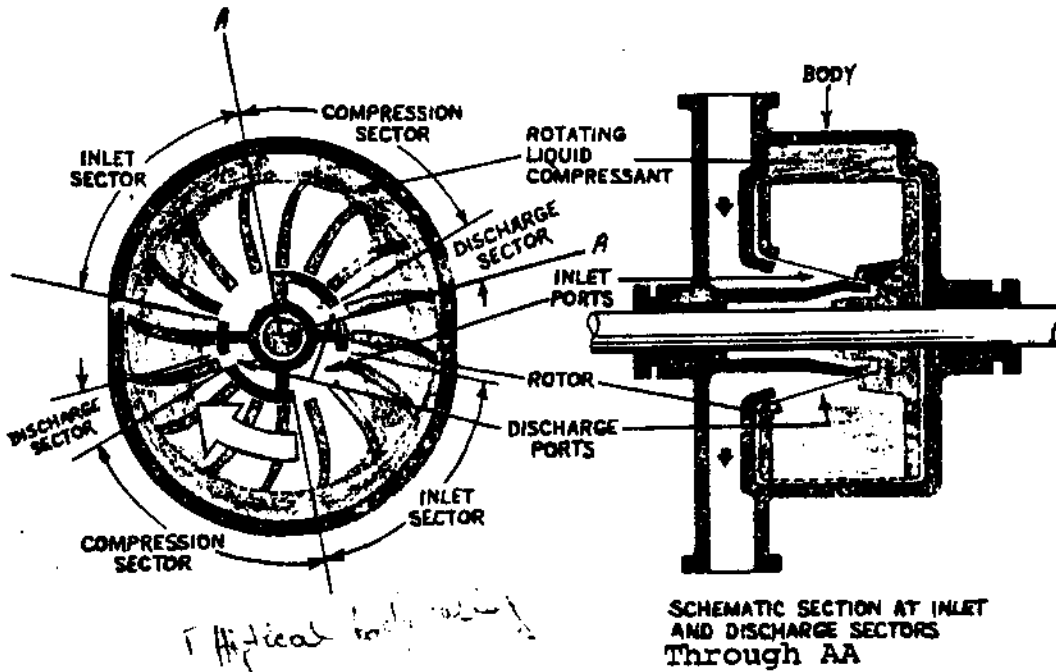
1. Excess Moisture - because the water is a sealant, the air produced becomes water saturated. This therefore demands a separator or drier be used.

SCREW COMPRESSORS

Helical or screw compressors are rotary, positive displacement machines in which two intermeshing rotors compress and discharge air. A description of the principle of operation is detailed in 430.10-6 and no further comment will be made.

A necessary component of a functioning screw unit is the external timing gears. Timing gears are used to transmit torque from driver to driven rotor and offer a number of advantages:

- (a) Oil Free Air - since contact is external, the compression chamber is oil free. It should be noted however, that there are some screw compressors which do not have internal lubrication.
- (b) Little Wear - results because of the small clearance space maintained between the two rotors.
- (c) Little Maintenance - a result of little wear.



*High speed rotor  
Part of rotor...*

Figure 5

However, the disadvantage of their design are:

1. Low Discharge Pressures - because of leakage.
2. Lower Efficiency - as a result of recirculation of Air.

To maintain the clearances, the screw compressor must operate under certain limitations as follows:

1. Discharge Temperature - are limited to prevent excessive distortion of casing and rotors with consequent change in clearance.
2. Temperature Rise Across the Unit - to prevent excessive relative distortion of rotors.
3. Pressure Differential - limited for the same reason as temperature rise.

#### SLIDING VANE COMPRESSOR

Because sliding vane compressors are not used on any main air system in NGS, there will be only a brief description.

This rotary machine has as its basic element a cylindrical casing with rotor and head assembly. The general arrangement appears in Figure 6.

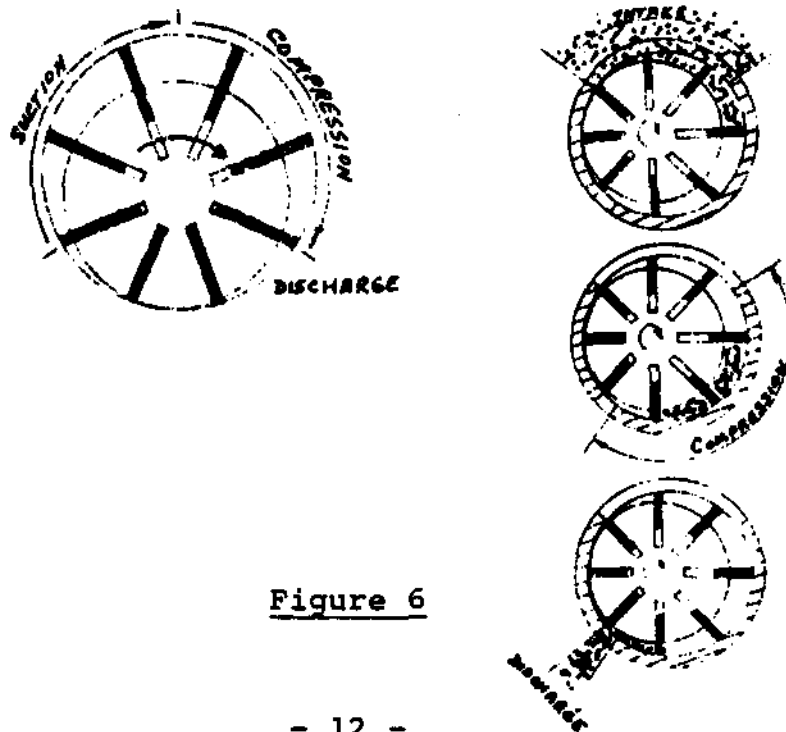


Figure 6

Compression takes place when the pocket volume decreases as the rotor turns.

With this type of compressor, it is important to maintain a lubricating film between vane and casing. The film not only reduces the wear but also acts as a sealant. Air entering the compressor should be clean to prevent any film disruption.

ASSIGNMENT

1. Name the four types of air moving devices. Describe how they are classified.
2. Compare the two main types of compressors with respect to flow rate, pressure and efficiency.
3. What advantages do centrifugal compressors have in comparison with reciprocating units?
4. What is one application of an axial compressor? Why has it been selected for this use?
5. Describe the problem of surge.
6. Discuss characteristics of reciprocating compressors.
7. Name the desirable characteristics of a diaphragm compressor.
8. Draw a typical reciprocating piston unit and explain the function of each main component.
9. Name two advantages of using a liquid ring compressor.
10. In the field, what screw compressor limitations should be monitored?

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