Atlas Copco

What is a Compressor?

– A Compressor is a Mechanical Device which sucks in air or a gas at a lower pressure and delivers it at a higher pressure .

How do we measure the performance of a compressor?

– The performance of a compressor is measured by following parameters

Capacity in volume per unit time referred as Free Air Delivery(FAD) . Free air delivery is the volume of air per unit time measured at discharge referred to suction conditions of temperature and pressure

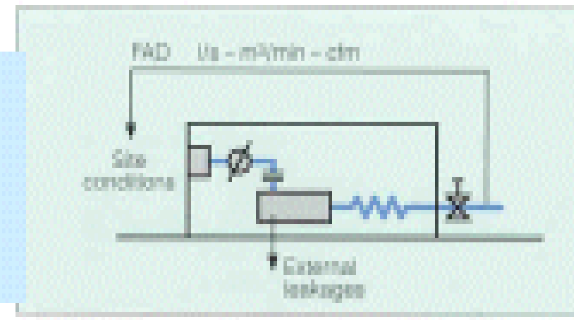
The units of FAD are :-

cum/min,l/s,cum/hr,cfm etc.

But is this enough

No!

Screw Measurement ISO 1217



free air delivery referred to site conditions

When ever FAD is mentioned the suction temperature and pressure should be clearly mentioned . Otherwise same compressor can be rated differently at different suction temperature and pressure .

Remember we always measure FAD under ISO condition and clearly mention it in our catalogues

Pressure :-

This is the pressure of air delivered by a compressor at the discharge . Pressure can be measured as Kg/Sq cm, psi etc

There are many units of pressure measurement. Some of these and their equivalents are listed below.
1 bar = 100000 N/m2
1 bar = 100 kPa
1 bar = 14.50 psi
1 bar = 10197 kgf/m2

When we refer to Pressure we should clearly understand the difference between the Absolute Pressure and Gauge Pressure .

Any reference to stated Power should clearly refer to the Pressure at which it is measured.

Pressure Ratio

– The Pressure Ratio is the relation between absolute pressure on the inlet and outlet sides

Accordingly , a machine that draws in air at Atmospheric pressure and compresses it to 7 bar over pressure works with a pressure ratio of (7+1)/1=8

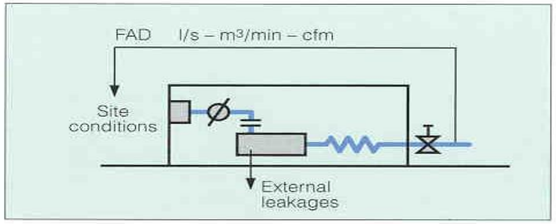
DIFFERENT STANDARDS OF MEASUREMENT

ISO 1217

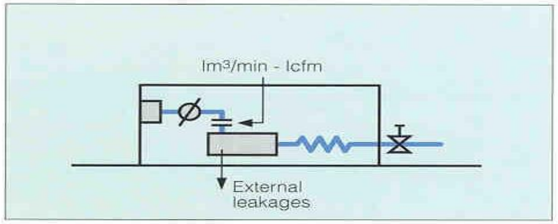
BS 1571

Apples with apples...

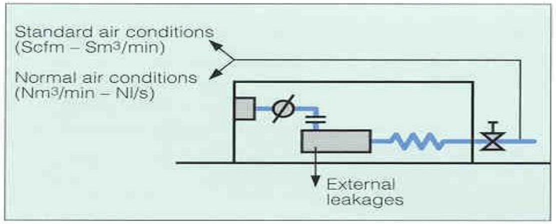
- Compare **capacity** rating with the same capacity rating:
  F.A.D. - Nl/s - Nm^3/min - Acfm - Scfm - Sm^3/min - Icfm - Im^3/min



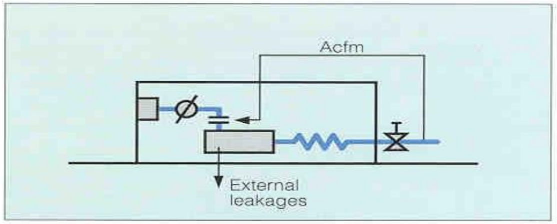
free air delivery referred to site conditions



inlet flow referred to compressor element inlet conditions



free air delivery referred to Normal (dry) or Standard air conditions



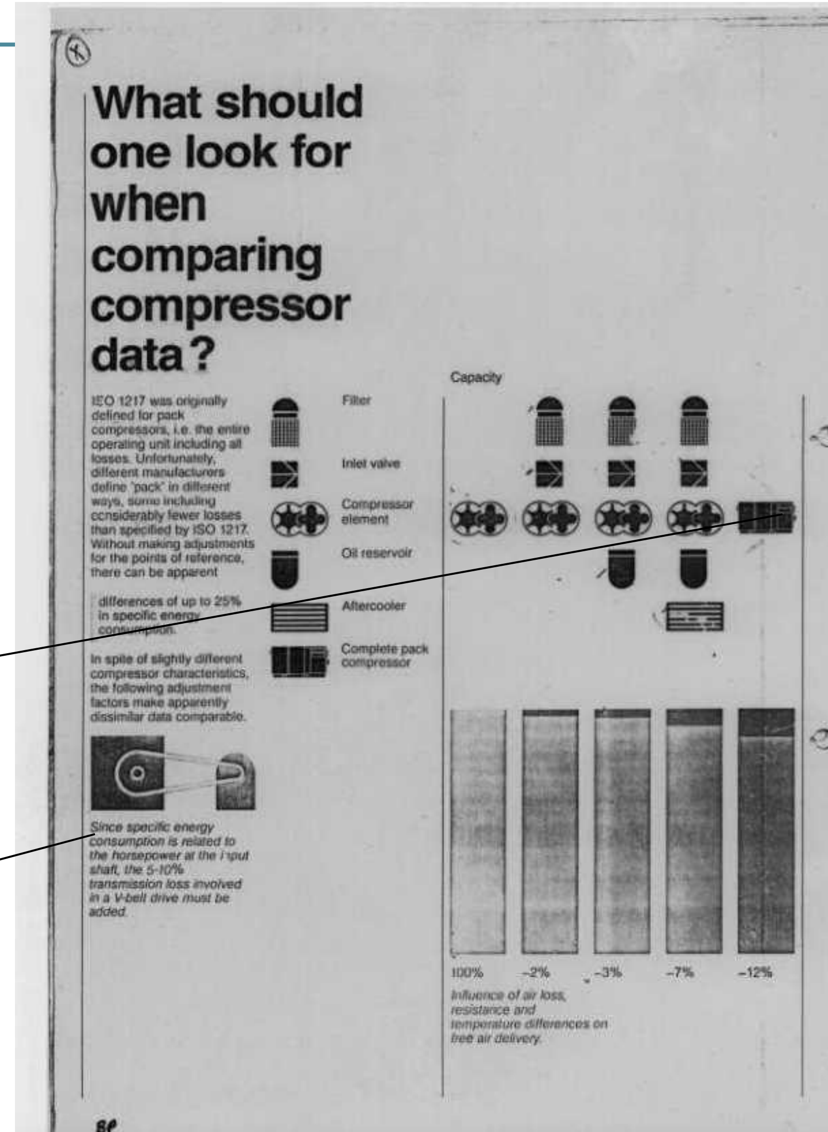
actual flow referred to compressor element inlet conditions

- The **working pressure** on the gauge is measured at the discharge valve. This is the pressure supplied to your system.
- The motor selection is based on true shaftpower figures; no extra safety margins for hidden **power consumption** must be added.

Performance testing as per ISO1217

Measurement at outlet of Pack

Belt drive results in 5-6% power loss



What should one look for when comparing compressor data?

IEO 1217 was originally defined for pack compressors, i.e. the entire operating unit including all losses. Unfortunately, different manufacturers define 'pack' in different ways, some including considerably fewer losses than specified by ISO 1217. Without making adjustments for the points of reference, there can be apparent

differences of up to 25% in specific energy consumption.

In spite of slightly different compressor characteristics, the following adjustment factors make apparently dissimilar data comparable.

Since specific energy consumption is related to the horsepower at the input shaft, the 5-10% transmission loss involved in a V-belt drive must be added.

Influence of air loss, resistance and temperature differences on free air delivery.

8P

PERFORMANCE TESTING OF RECIPS

Pressure in Kg/Cm2g	Discharge Air	9.0	9.0
	Inter Stage	2.55	2.55
	Oil Pump	2.5	2.5
Manometric Head in mm of Water	Across Nozzle (H)	810	798
	Downstream side (h1)	182	170
	At Suction Filter(h2)	10	10
Temperature in oC	At intake (T1)	25.6	28
	At Nozzle (Tn)	23.5	27.2
	Discharge Air	99.6	99
	Crankcase Oil	48	51
Speed in RPM	Compressor Shaft	656	657
Free Air Delivery in CFM.	At actual Speed	126.09	125.46
	At rated Speed	124.94	124.12
	with Alt. correction	125.69	124.87
Motor in-put Power	Current in Amperes	41.5	42 (PF=0.82)
	Voltage in Volts	430	432
	Power in KW	26.3	25.7
Compressor Shaft Input Power in KW	At rated speed of 650 RPM	22.28	21.74

Air Temperature in oC		L.P.Cylinder	Intercooler	H.P.Cylinder
	Inlet	25.6, 28	102, 103	26, 27.3
	Outlet	102, 103	26, 27.3	99.6, 99
Cooling Water Temperature in oC	Inlet	–	24, 26	–
	Outlet	–	–	28, 30

* Compressor No-Load Power 25 A, 430 V, 8 KW.
* Considered Transmission Efficiency 95% and Motor Efficiency 90%
* Barometric Pressure P1 = 713 mm of Hg
* Cooling water flow during test was 175 LPM. * Nozzle used: 1" Dia.

* Formula as per B.S.1571 Part II

$$\text{F.A.D.} = Q \text{ in Lit./sec.} = \frac{K \times T1}{P2} \times \text{Sq.Rt.}\left[\frac{H \times (P1-(h1/13.6))}{Tn}\right]$$

K=3.248 for 1"*
=7.377 for 1.5"
=20.516 for 2.5"
=52.429 for 4" dia.Nozzle.

P2=P1-(h2/13.6),T1&Tn in oK,1 M3/MIN = 35.315 CFM = 16.667 Lit./Sec.

TESTING AS PER BS 1571

- Discharge pressure and temperature is measured before after cooler
- Motor power is corrected for only for speed but not for altitude
- Transmission loss of 5 % is extra
- Pressure drop across air filter is measured

DIFFERENT STANDARDS OF MEASUREMENT

– From test report of BS 1571 following is the effect

Power consumption goes up by 5% due to belt loss

Power consumption goes up by 3 % due to altitude correction.

Why

Barometric pressure = 710 mm of Hg column

At 760 mm i.e sea level .285 .285

Power will go up by the ratio p2/p1(p3/p1 -1)/(p2/p1-1)

For measuring FAD at compressor inlet instead of before air filter FAD is shown to be increased by1.3 %

DIFFERENT STANDARDS OF MEASUREMENT… Cont

Pressure drop in after cooler and check valve is around 0.4 bar. Considering a normal 8 % rise for very 1bar rise in discharge pressure this will result in a rise of 4 %

As a result total effect is 14 % on specific power

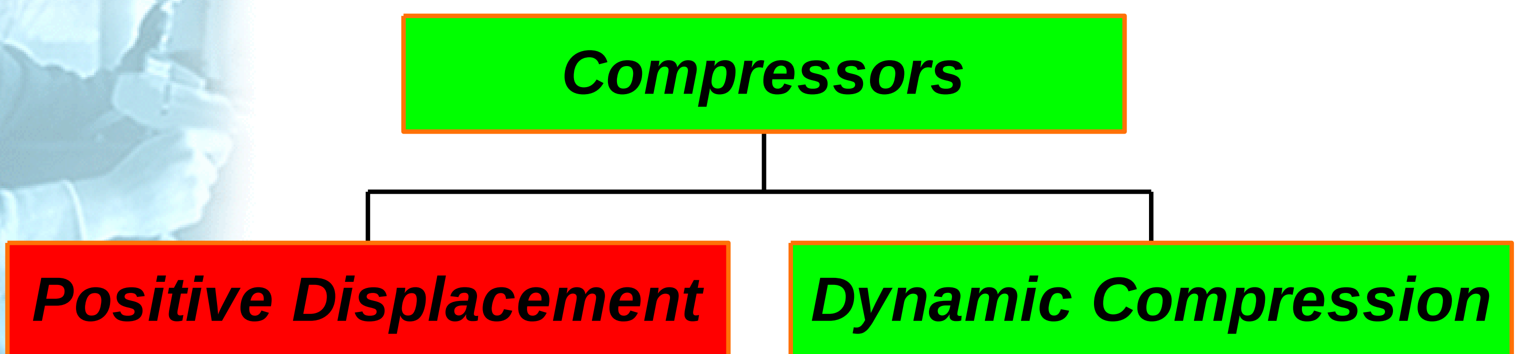
All these are not applicable for ISO 1217

Thus to have apple to apple comparison between ISO 1217 and Bs 1571 INCREASE SPECIFIC POWER BY 14 %

What are different working principles of compressors ?

Compressors are classified into two types based on the working principle

Two



What is a positive displacement compressor ?

Positive displacement principle

Reducing the volume of a gas increases its pressure

DYNAMIC COMPRESSOR

– Dynamic Principle

Velocity (Kinetic Energy)
1/2 mv 2
converted to pressure

Work done in a Positive Displacement Compressor

Compression work with isothermic compression becomes:

$$W = p_1 \times V_1 \times \ln(p_2/p_1)$$

Compression work with isentropic compression becomes:

$$W = \frac{\kappa}{\kappa - 1} \times (p_2V_2 - p_1V_1)$$

W = compression work (J)

p_1 = initial pressure (Pa)

V_1 = initial volume (m^3)

p_2 = final pressure (Pa)

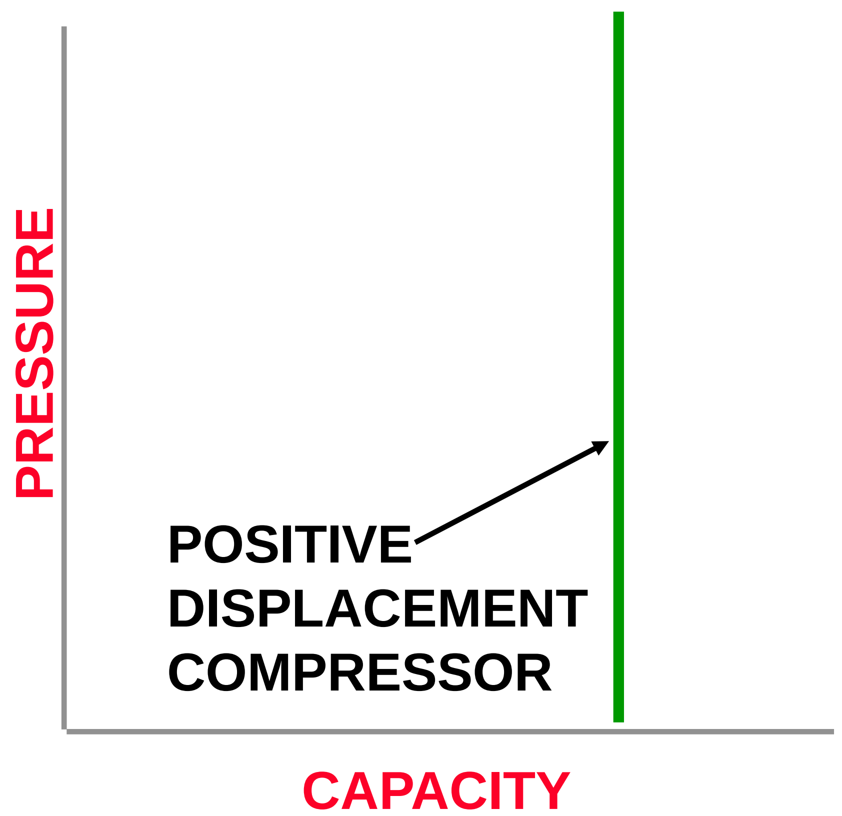
κ = isentropic exponent in most cases x $\kappa \approx 1,3 - 1,4$ applies.

POSITIVE DISPLACEMENT COMPRESSORS ARE :-

1. THERMODYNAMICALLY STABLE AND POWER SAVING
2. THE PERFORMANCE REMAINS UNAFFECTED BY THE CHANGE IN THE AMBIENT CONDITIONS
3. CAPACITY REMAINS SAME AT DIFFERENT OPERATING PRESSURES
4. SCREW ,SCROLLAND PISTON COMPRESSORS FALL IN THIS CATEGORY
5. THEY ARE IDEALLY SUITED FOR CAPAICTIES UPTO 4000 CFM AND PRESSURES UPTO 13 BAR

COMPRESSOR CHARACTERISTICS-POSITIVEDISPLACEMENT COMPRESSOR

Performance curves



DYNAMIC COMPRESSOR :-

•Dynamic Compressors are Thermodynamically Unstable . The Performance Changes with the Change in Ambient Temperature.

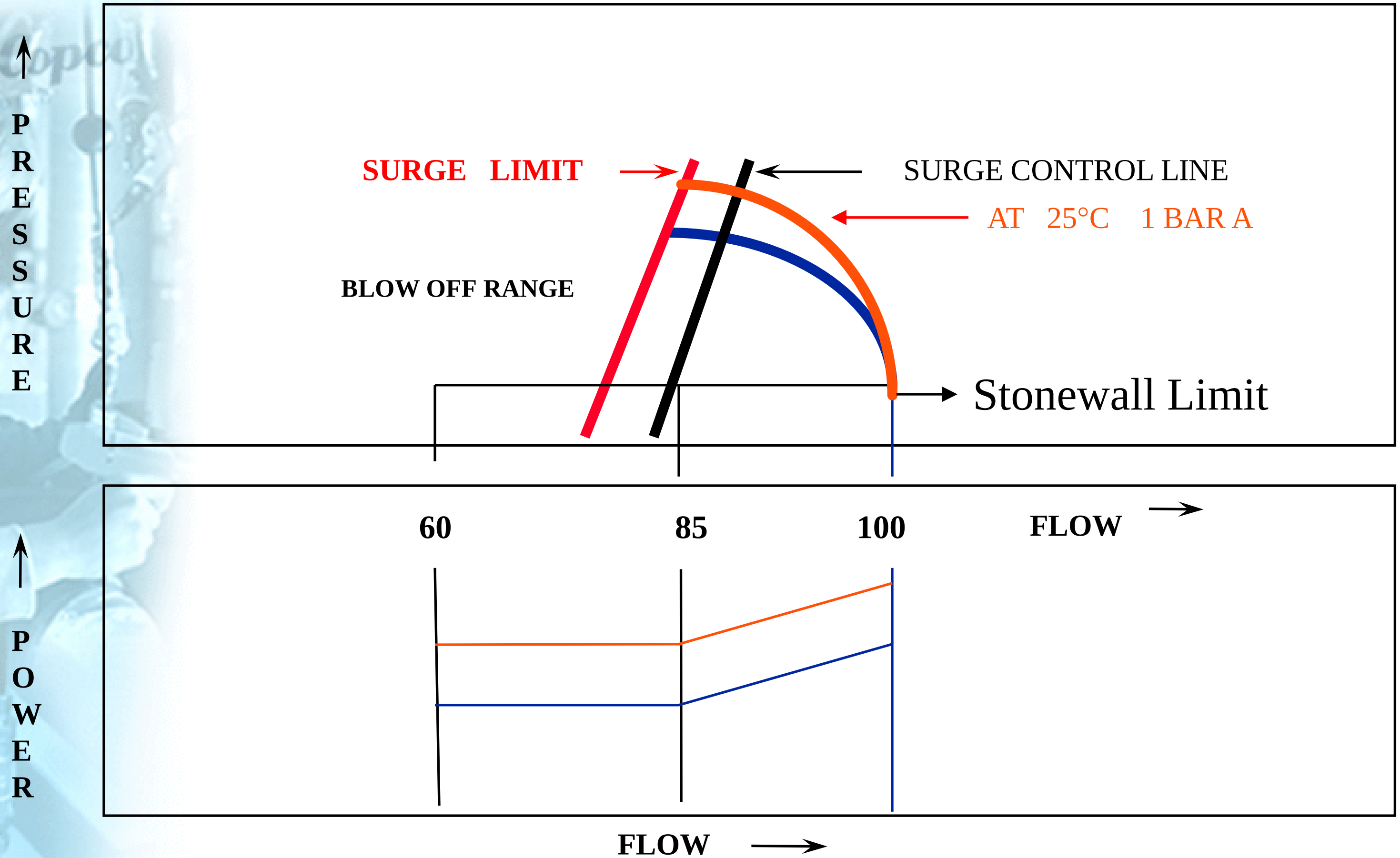
•The Capacity Band is Limited Between Surge and Stonewall.

•Centrifugal Compressors fall into this category.

•These compressors are suitable for base load operation with very high flows beyond 4000 cfm and the detailed discussion on these is outside the scope of this presentation .

Any enquiry on these compressors should be immediately forwarded to AC representative

Dynamic Compressor - Characteristics

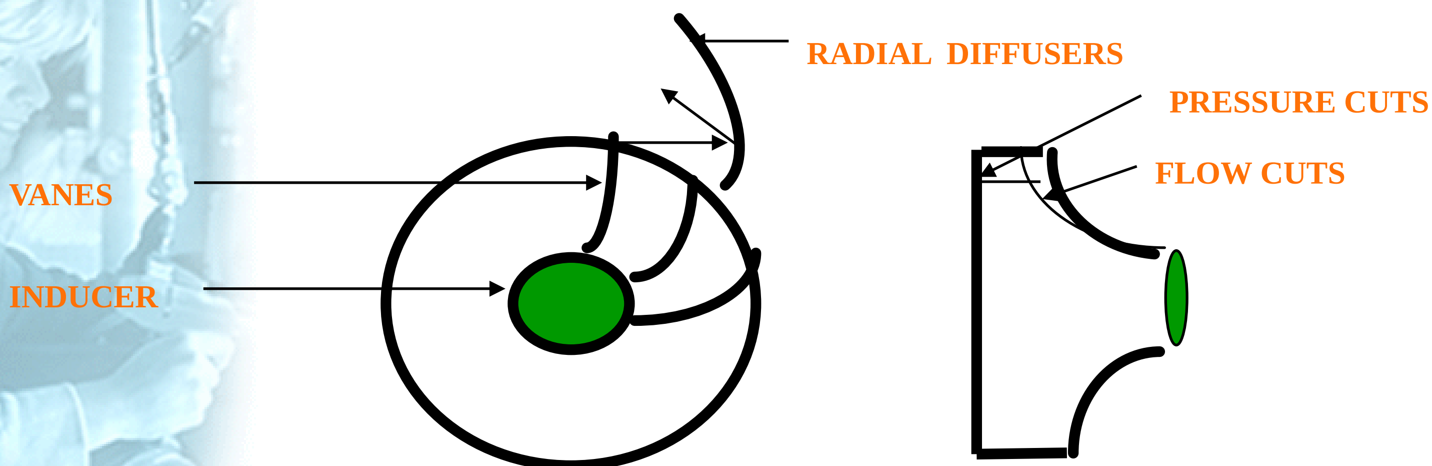


DYNAMIC COMPRESSOR

– Dynamic Principle

Velocity (Kinetic Energy) 1/2 mv 2 converted to pressure

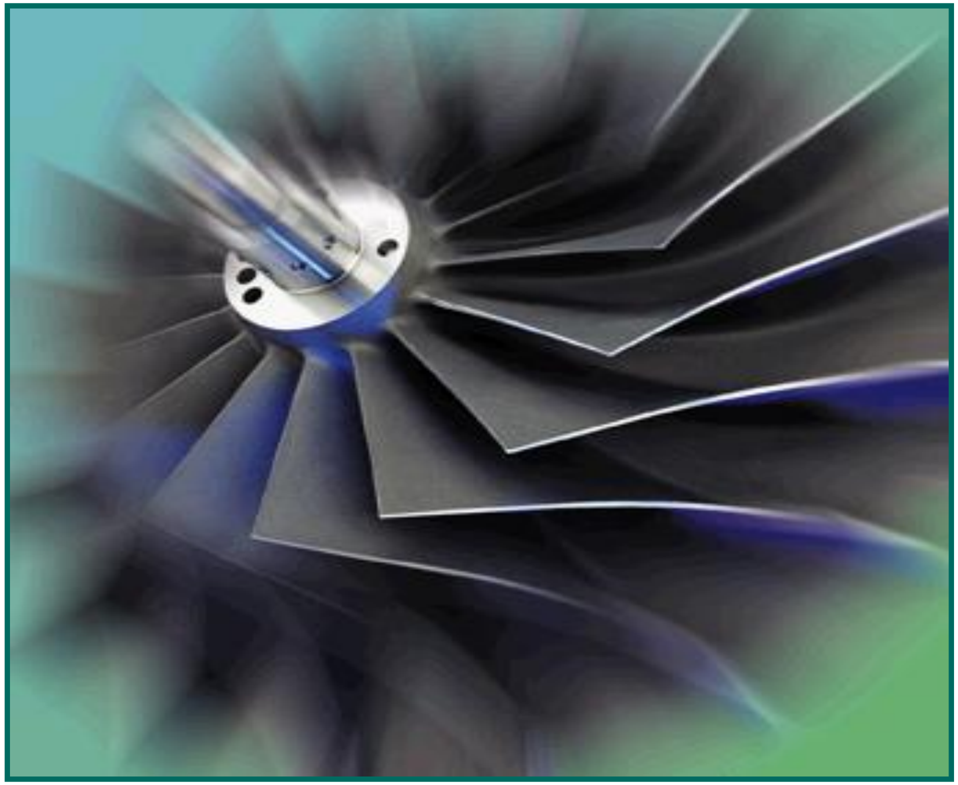
CENTRIFUGAL COMPRESSORS



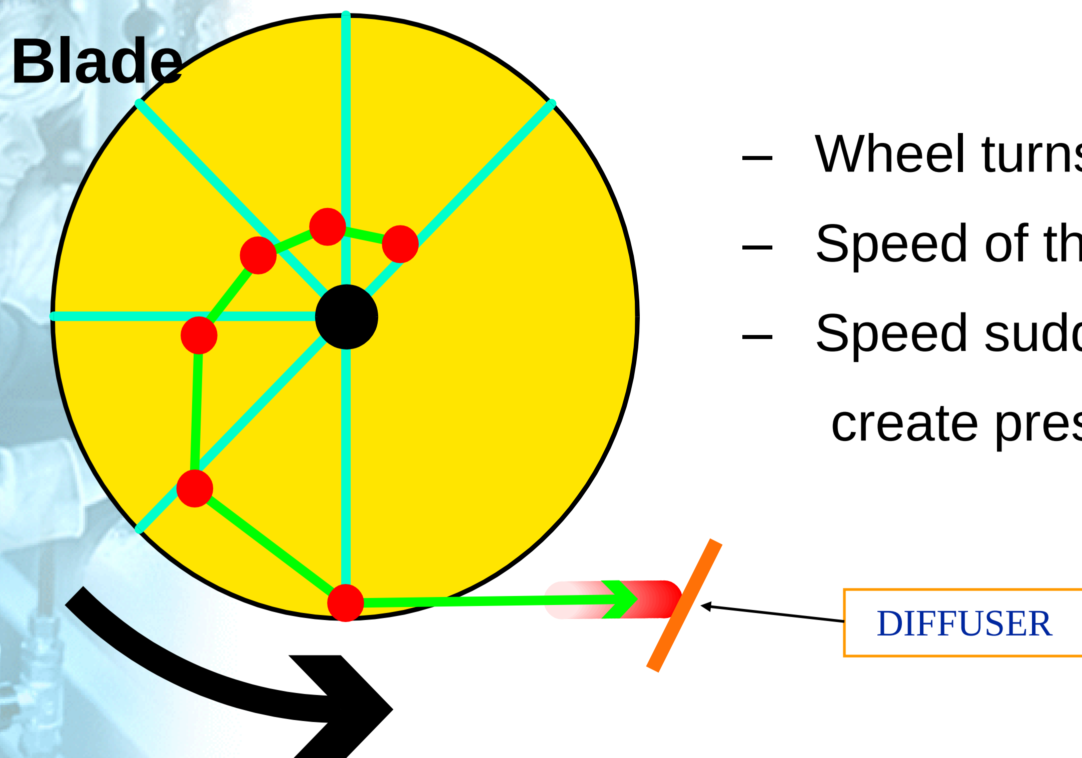
PRESSURE INCREASE FOLLOWS THE PRINCIPLE OF BERNOULLI

$$\Delta P \Rightarrow \Delta V^2$$

A CENTRIFUGAL IMPELLER

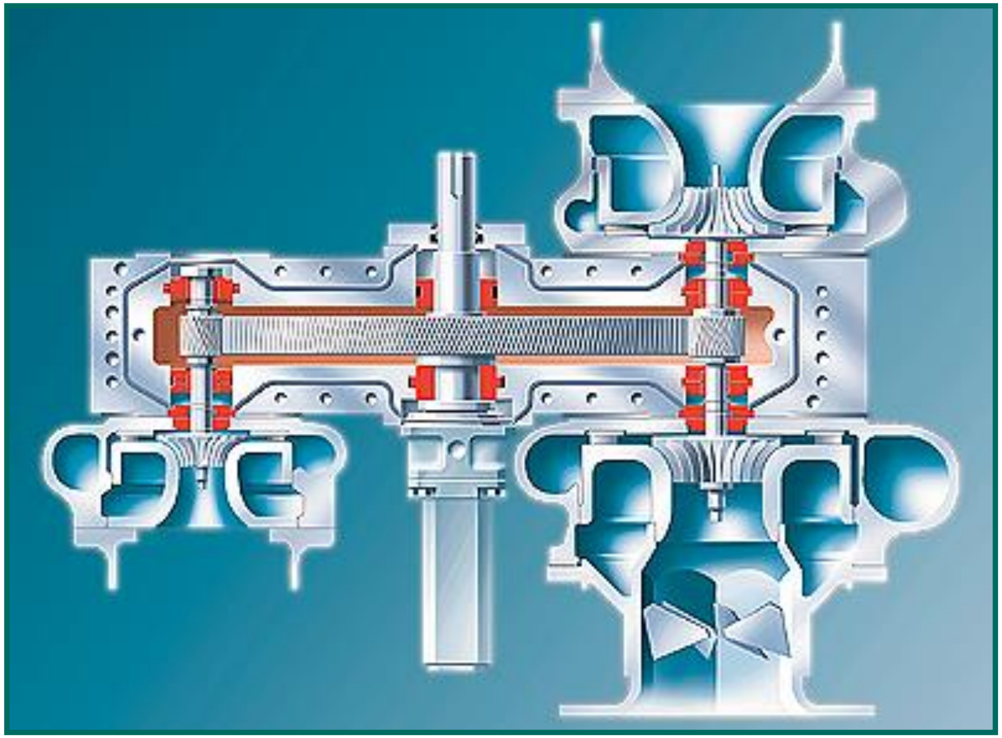


WORKING PRINCIPLE



- Wheel turns
- Speed of the ball increases
- Speed suddenly reduced to create pressure increase

CENTRIFUGAL COMPRESSOR GENERAL ARRANGEMENT



Classification of Positive Displacement Compressors

Two

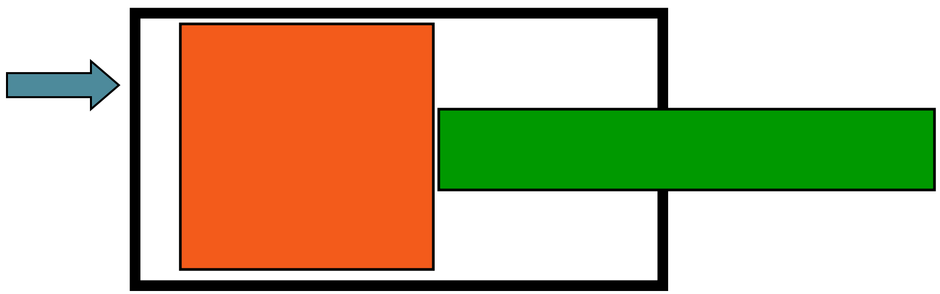
- **Positive Displacement Compressors**
  - **Screw**
  - **Reciprocating**

Piston compressor

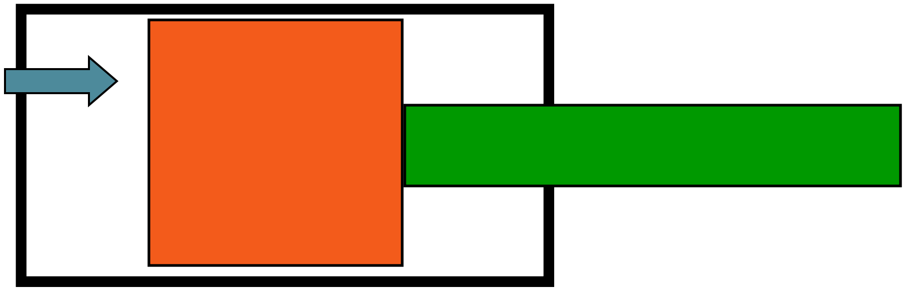
On a piston compressor air is drawn into a compression chamber ,which is closed from the inlet.Thereafter the volume of the chamber decreases and air is compressed . When the pressure has reached the same level as the pressure in the outlet manifold ,the valve is opened and the air is discharged at a constant pressure under continued reduction of the compression chamber volume

Piston Working Principle.exe

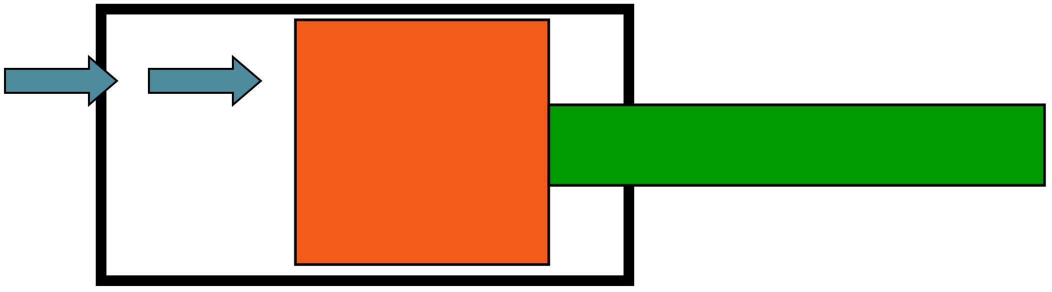
PISTON COMPRESSORS



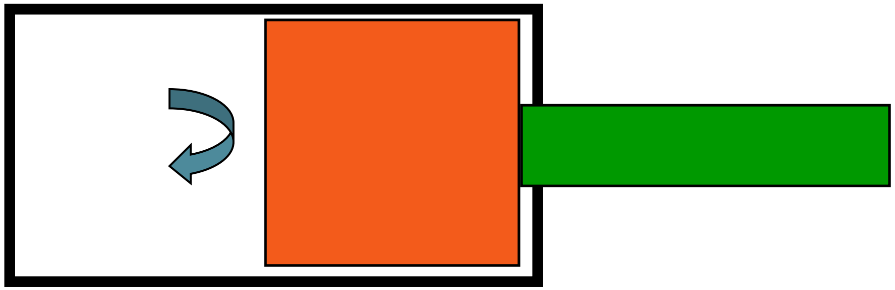
PISTON COMPRESSORS



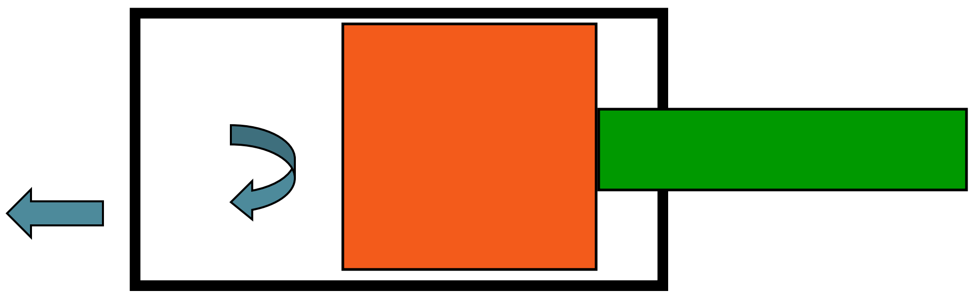
PISTON COMPRESSORS



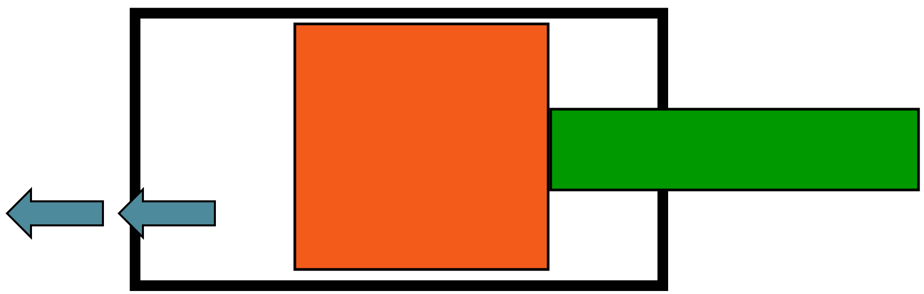
PISTON COMPRESSORS



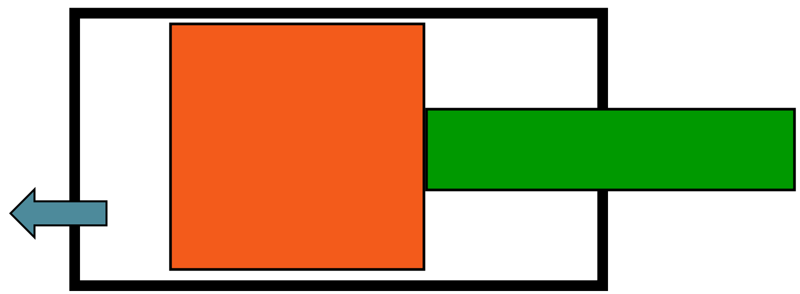
PISTON COMPRESSORS



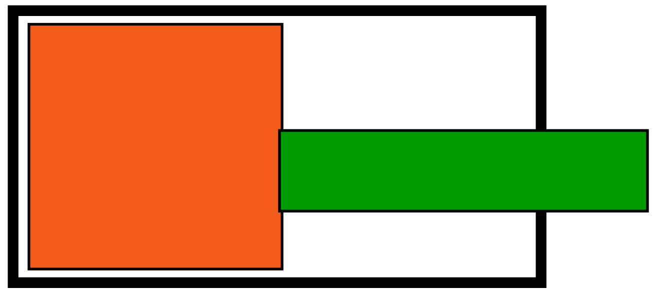
PISTON COMPRESSORS



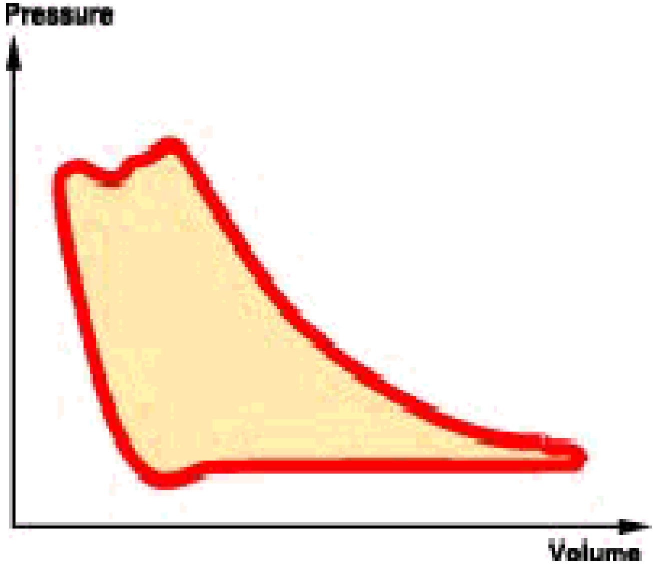
PISTON COMPRESSORS



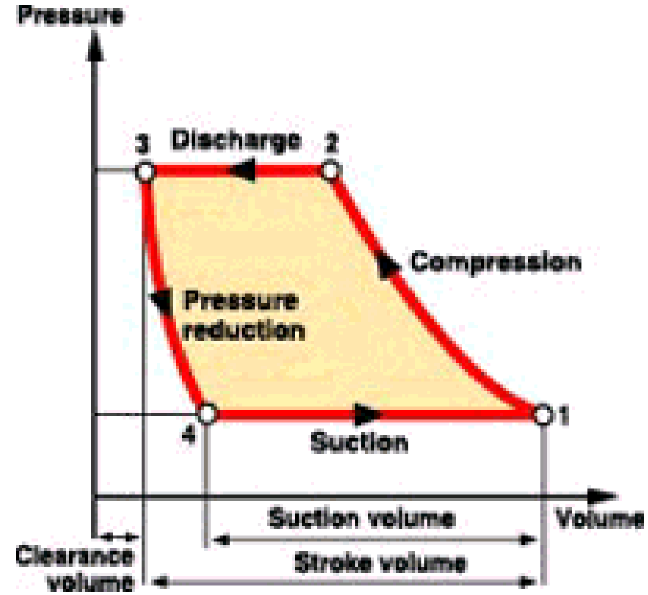
PISTON COMPRESSORS



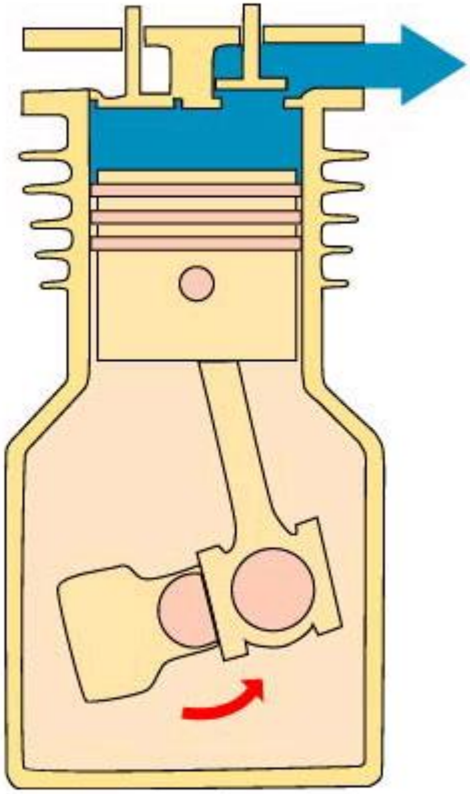
PV Diagram/ Work Done on a Piston Compressor



This is how the actual p/V diagram can appear for a piston compressor.
The pressure drop on the inlet side and the overpressure on the discharge side are minimised primarily by giving the compressor sufficient valve area.

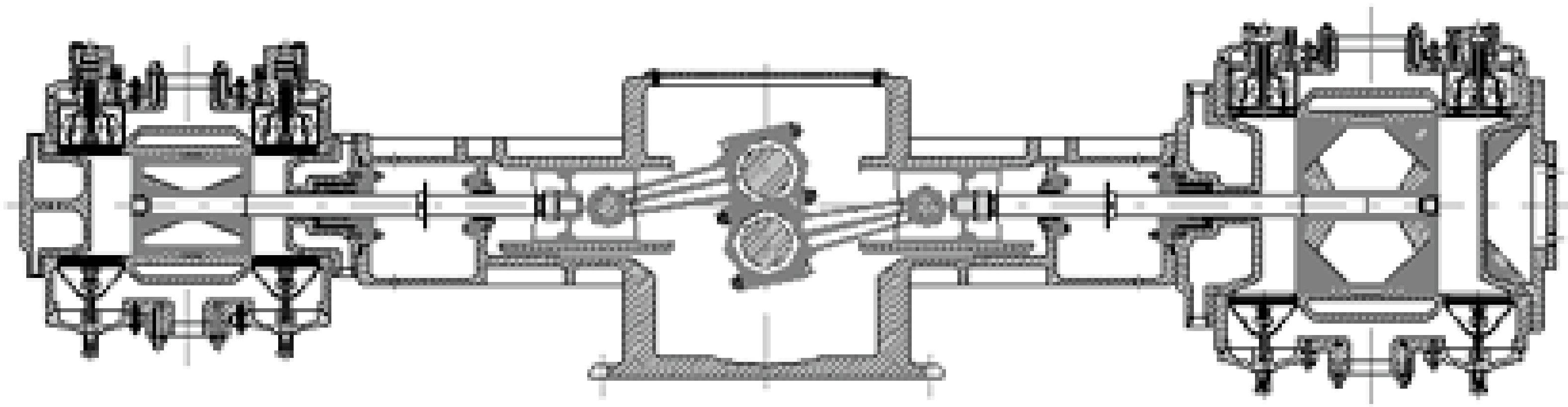


This is how a piston compressor works in theroy with self-acting valves.
The p/V diagram shows the theoritical process, without losses with complete filling and emptying of the cylinder.



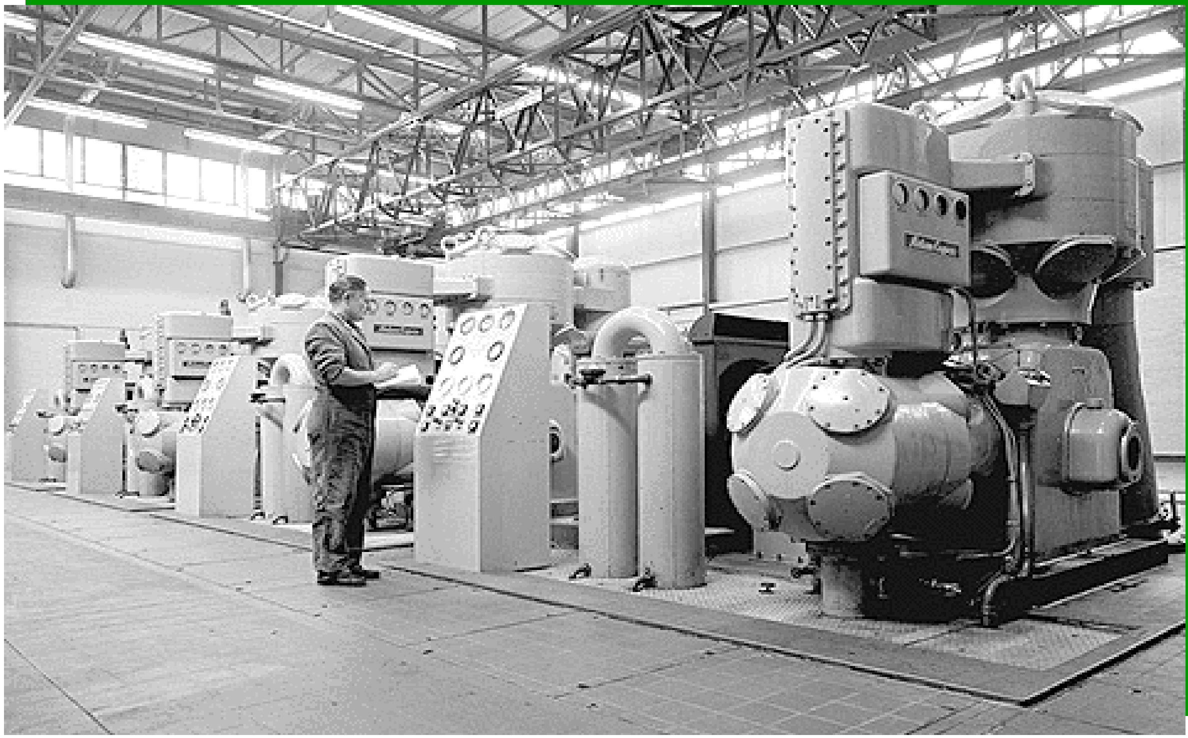
Single stage, single acting piston compressor

A` tank mounted piston compressor

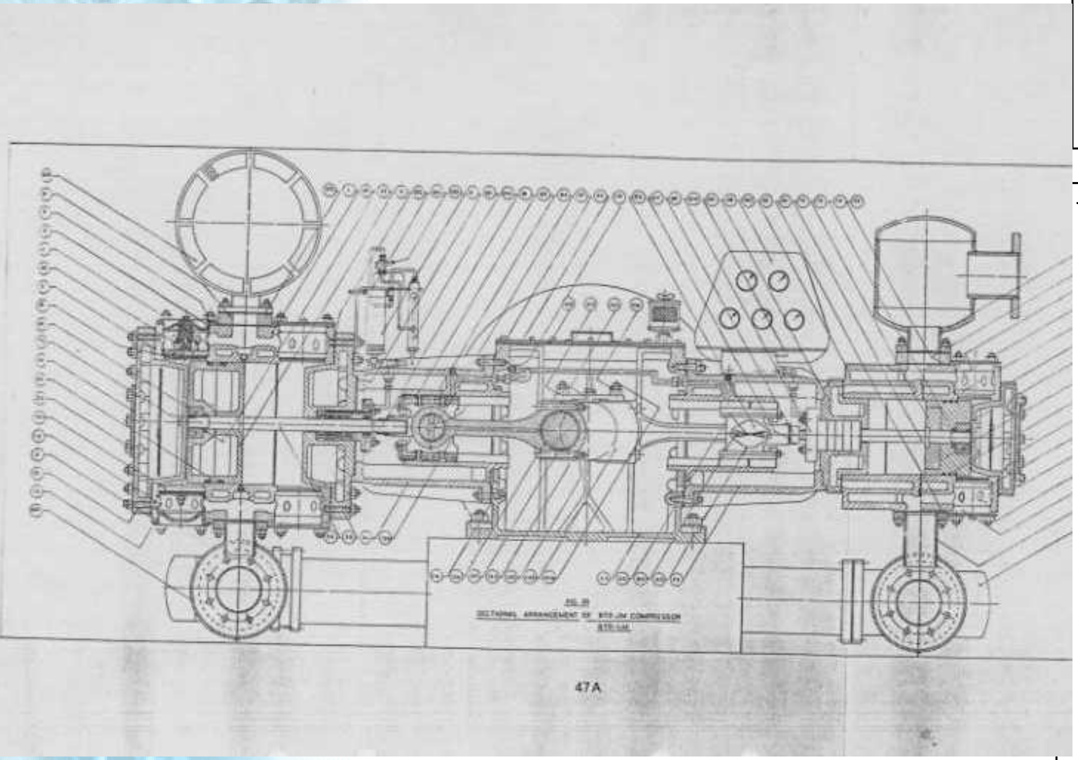


A Horizontally Double Acting Piston Compressor

Large Vertical Reciprocating Compressors



RECIPROCATING COMPRESSORS



STRENGTH

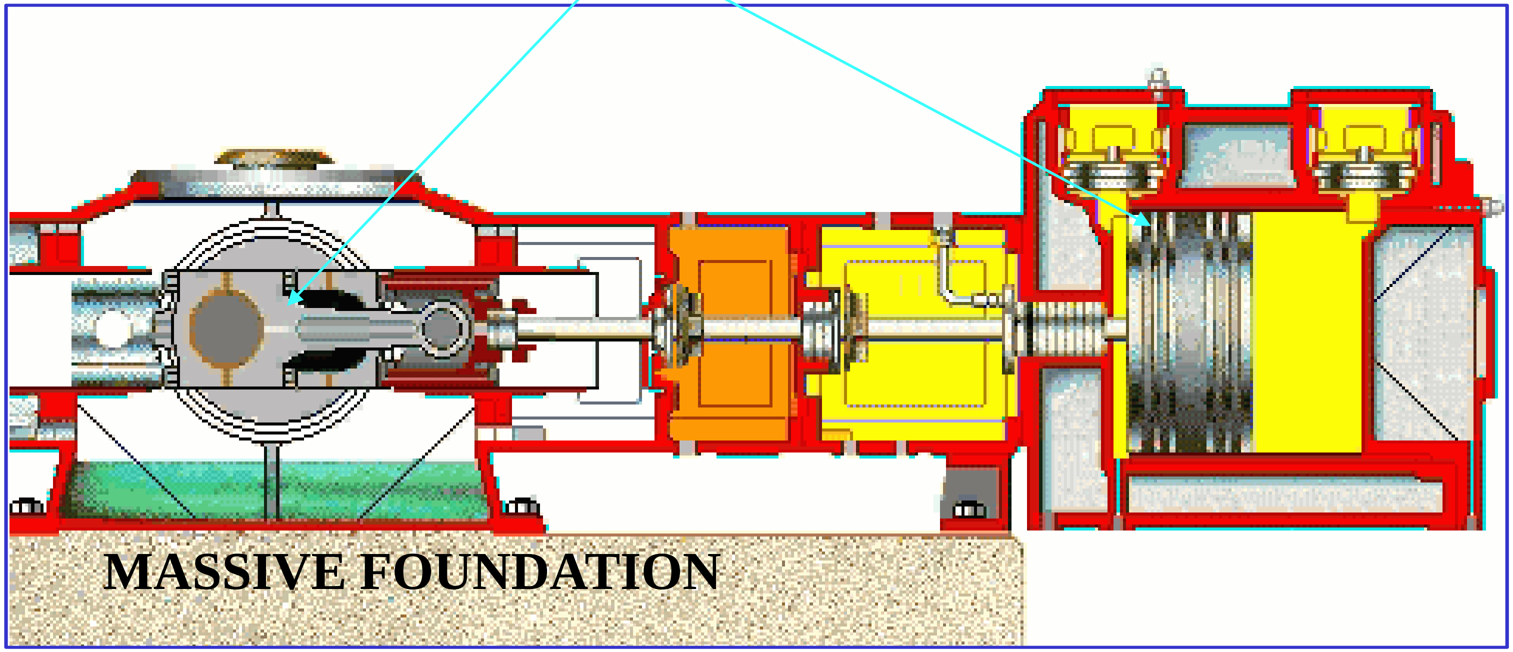
- LOW INITIAL PRICE
- OLD, TRADITIONAL TECHNOLOGY HENCE EASY ACCEPTANCE

WEAKNESS

- **WATER-COOLED**
- **NEEDS HEAVY FOUNDATION**
- **LOT OF SITE WORK**
- **HIGH MAINTENANCE**
- **MANY MOVING PARTS**
- **HIGH DOWN TIME**
- **HIGH RUNNING COST – MORE MAINTENANCE, MORE POWER**

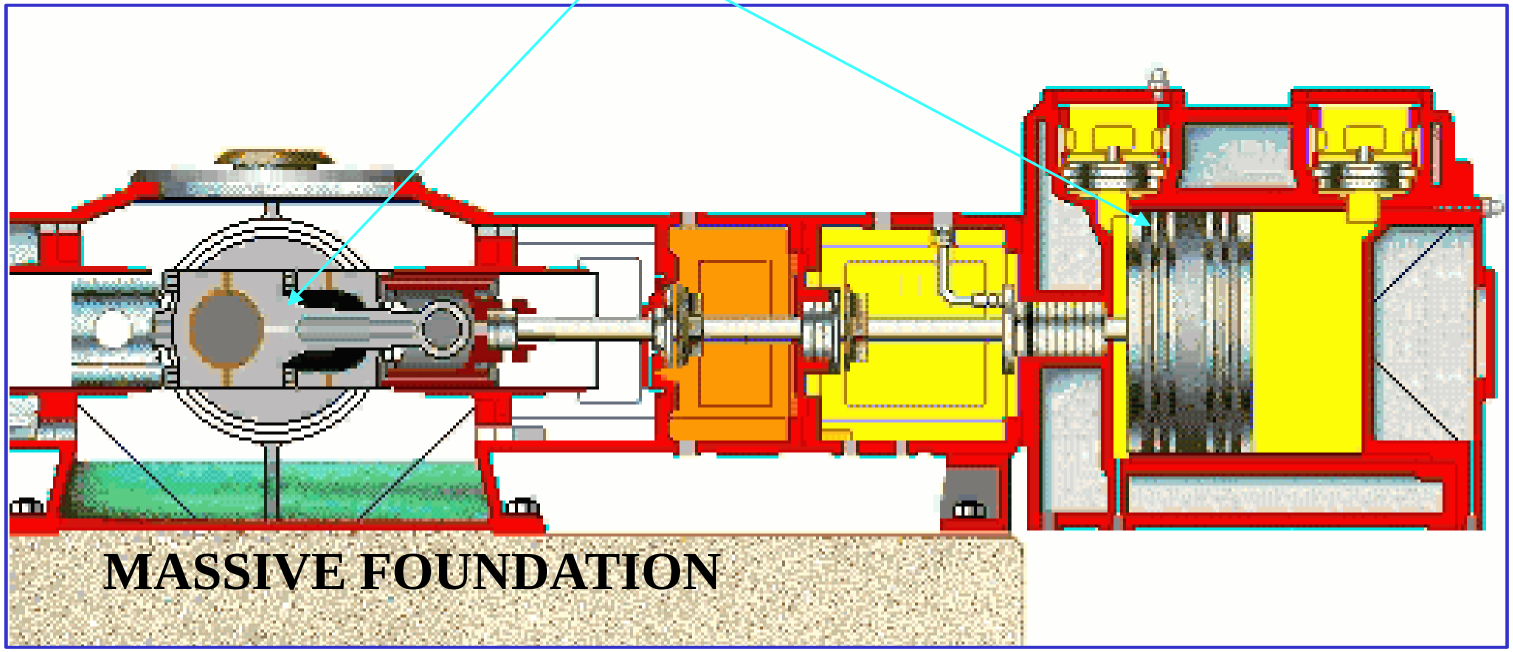
MAINTENANCE

More moving parts - More Maintenance



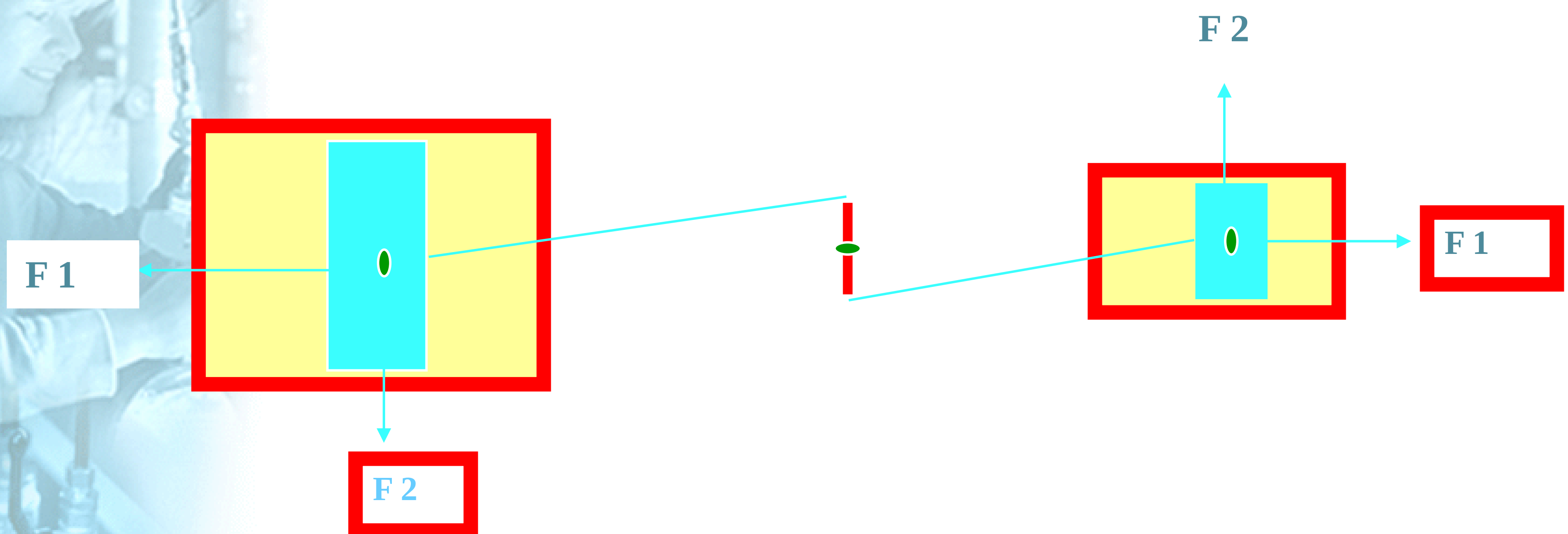
MAINTENANCE

More moving parts - More Maintenance



A Two Stage Double Acting Reciprocating Compressors Have Close to 99 Moving Components

Pistons Require Very Heavy Foundations.

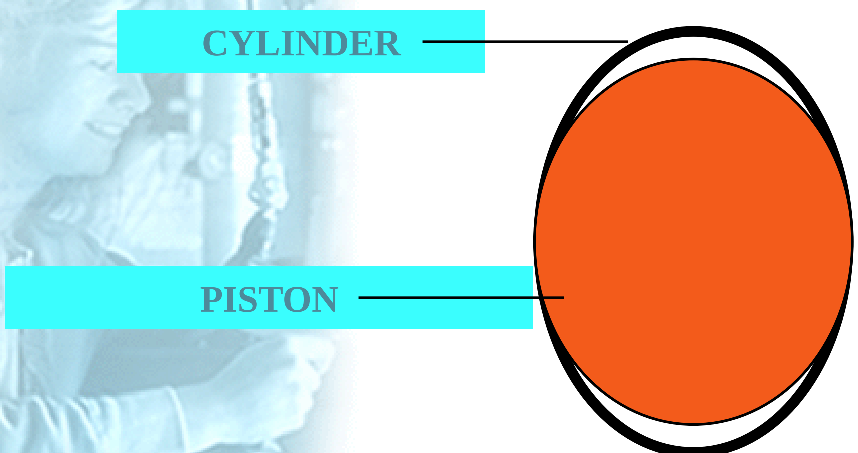


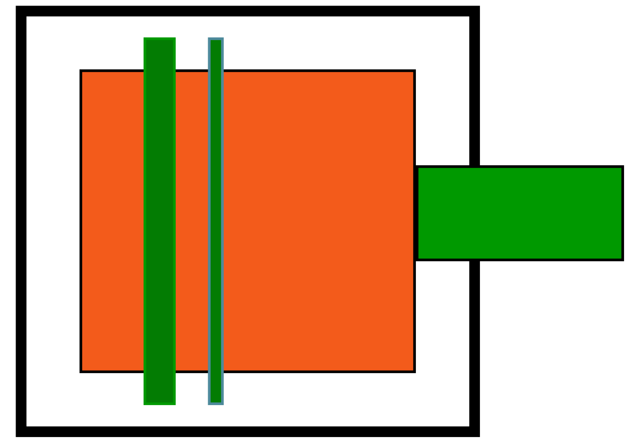
1. HORIZONTAL FORCES F1 BALANCE OUT

2. UNBALANCED VERTICAL FORCES CAUSE CYLINDER OVALITY,ACTING ALONG WITH THE PISTON WEIGHT AND ALSO AN UNBALANCED COUPLE NECESSITATING HEAVY FOUNDATIONS.

POWER COMPARISON-DERATION

PISTON COMPRESSORS





CYLINDER OVALITY PREVENTS RESUMPTION OF CAPACITY TO ORIGINAL LEVEL LEADING TO CONTINUED AI LEAKAGE

There is a 3 to 5 % Deration in capacity every year !!!

WEAR ITEMS
A COMPARISON

PISTON	SCREW
VEE BELTS (6)	2 GEARS
CRANKSHAFTS	6 BEARINGS
MAIN BEARINGS (4)	2 ROTORS
BIG END BEARINGS (4)	
CONNECTING RODS (4)	
SMALL END BEARINGS (4)	
CROSS HEADS (4)	
WIPER RINGS (4 SETS)	
PISTONS (4)	
PISTON RINGS (16)	
CYLINDERS (4)	
40 VALVES (SUCTION/DELIVERY)	
TOTAL 99 WEAR ITEMS	TOTAL 10 WEAR ITEMS

WEAR ALONG WITH OVALITY CAUSES A CAPACITY DERATION OF3-5% PER YEAR.

HIGH NUMBER OF PARTS INCREASES DOWN TIME AND MANPOWER OUTLAY

GENESIS OF SCREW COMPRESSORS

- IN THE 1930S COMPRESSED AIR AND GAS USERS HAD 2 MAIN OPTIONS :
- PISTONS AND CENTRIFUGALS

* PISTONS WERE POSITIVE DISPLACEMENT M/CS & WERE :

– THERMODYNAMICALLY STABLE AND POWER SAVING
– SUITABLE TO HANDLE DIRTY GASES
– REQUIRED EXPENSIVE INSTALLATION AND FOUNDATIONS
– MAINTENANCE INTENSIVE - EXPENSIVE/HIGH DOWNTIME
– CAPACITY FELL OVER A PERIOD OF TIME/WITH USE

– CENTRIFUGALS WERE LESS MAINTENANCE INTENSIVE BUT :

– REQUIRED EXPENSIVE INSTALLATION AND FOUNDATIONS
– WERE THERMODYNAMICALLY UNSTABLE
– OPERATING BAND WAS LIMITED
– SENSITIVE TO DUST AND UNSUITABLE FOR DIRTY GASES
– CAPACITY FELL EVEN WITH A FEW MICRON DUST BUILDUP

GENESIS OF SCREW COMPRESSORS II

PROFESSOR LYSHOLM OF THE ROYAL SWEDISH INSTITUTE OF SCIENCE DOING RESEARCH ON COMPRESSORS SET ABOUT FINDING AN IDEAL SYSTEM ON THE FOLLOWING HYPOTHESIS

- TO OVERCOME WEAKNESSES OF THE PISTONS HIS DREAM MACHINE HAD TO BE ROTARY IN NATURE WITH NO METAL TO METAL CONTACT
- AT THE SAME TIME, TO OVERCOME DISADVANTAGES OF CENTRIFUGALS IT HAD TO BE A POSITIVE DISPLACEMENT MACHINE

THUS WAS BORN THE IDEA OF THE ROTARY SCREW WHICH COMBINED THERMODYNAMIC AND OPERATIONAL STABILITY AND LOW PARTS CONSUMPTION BECAUSE OF VERY LOW MAINTENANCE

WITH UNPARALLELED RELIABILITY

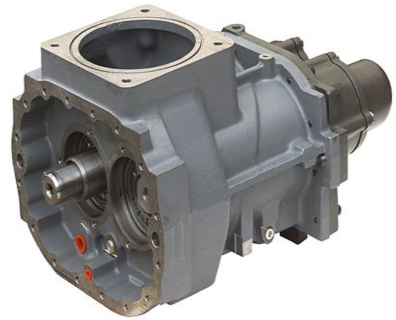
GENESIS OF SCREW COMPRESSORS III

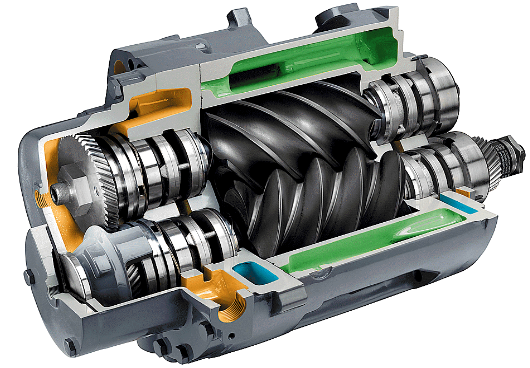
- ATLAS COPCO DREW ON THIS BASIC IDEA AND AFTER INTENSIVE RESEARCH , COMMERCIALLY INTRODUCED THE U SERIES OF SCREW COMPRESSORS IN 1957. MANY OF THESE MACHINES ARE STILL OPERATING THE WORLD OVER

- IN THE 1970S THE ATLAS COPCO RESEARCH CENTRE "THE CERAC INSTITUTE" IN GENEVA DESIGNED AND PATENTED A REVOLUTIONARY ASSYMETRIC SCREW PROFILE WHICH IS CURRENTLY USED IN THE G AND Z SERIES MACHINES

- IN THE WORLD TODAY 9 OUT OF 10 MACHINES PRODUCED AND SOLD IN THEIR RANGE ARE ROTARY SCREW COMPRERSSORS

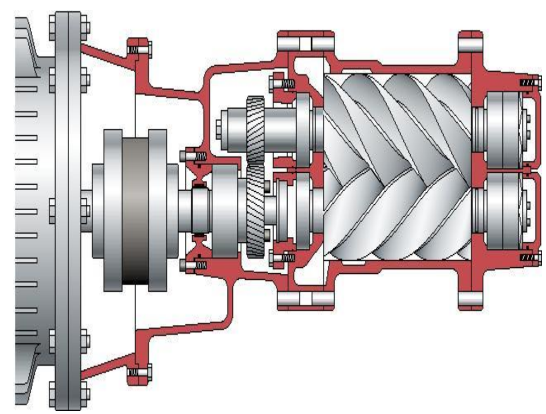
Screw Compressor



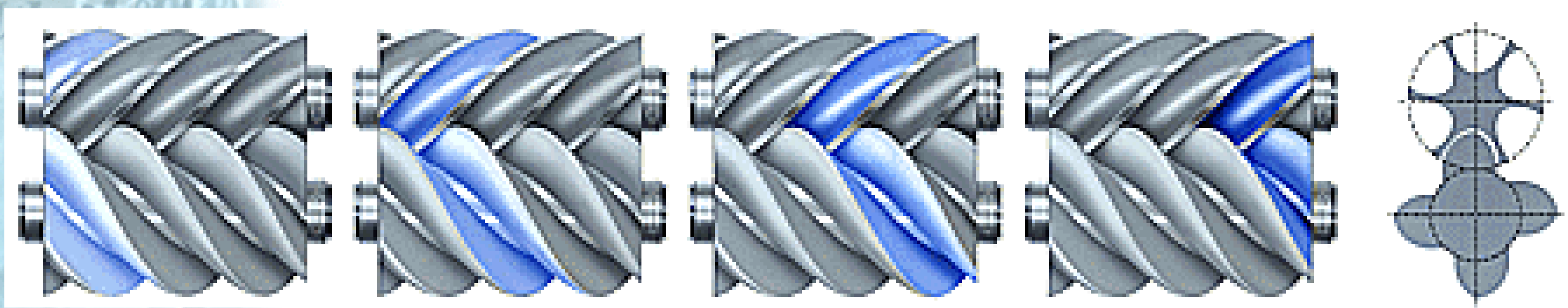


A Screw Compressor is a Rotary Positive Displacement Compressor.

It is noiseless,does not require any foundations,is maintenance free,energy efficient and delivers pulsation free air .

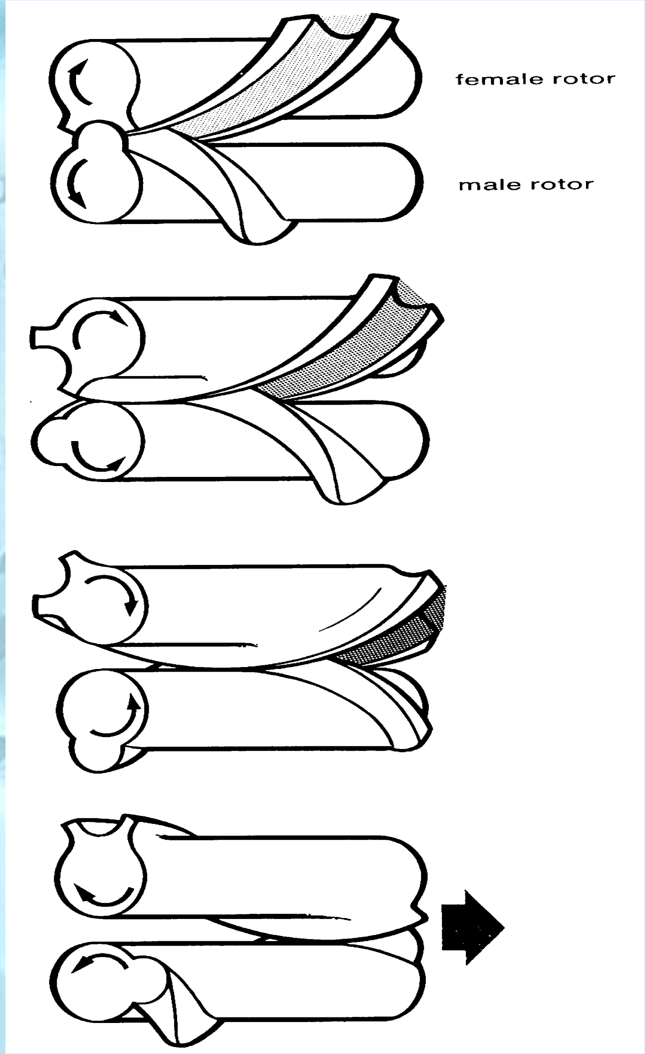


Screw compressor



The screw compressor consists of male and female rotors which move towards each other while the volume between them and the housing progressively decreases

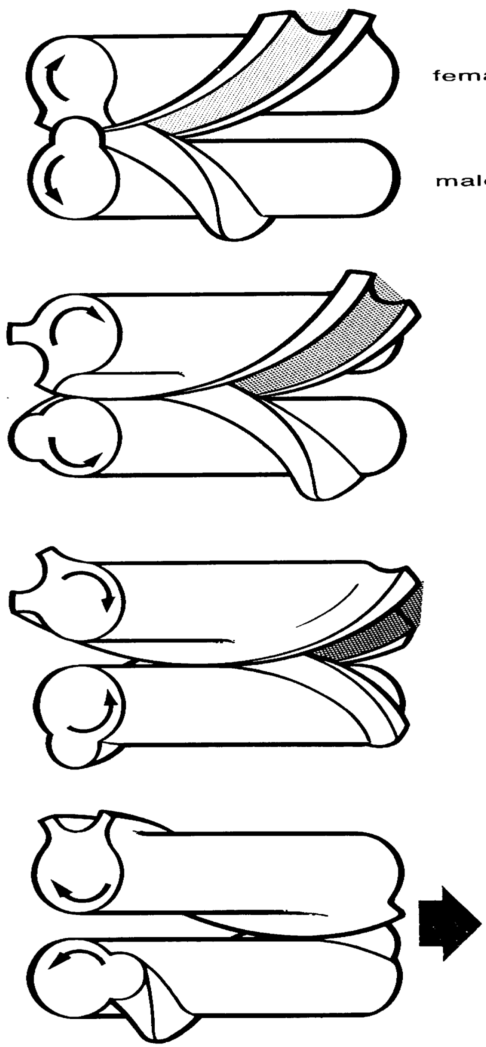
WORKING PRINCIPLES



The Positive Displacement Principle As Applies To Screw

The volume of the air or gas is progressively reduced along the length of the screw,causing a pressure increase.

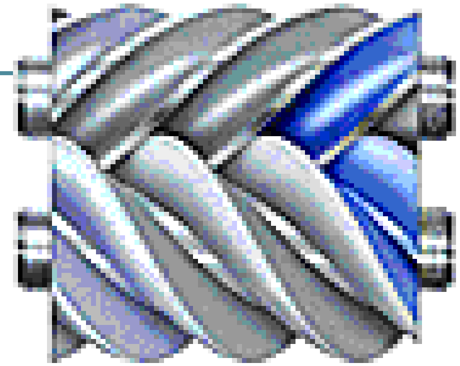
WORKING PRINCIPLES



The Positive Displacement Principle As Applies To Screw

The volume of the air or gas is progressively reduced along the length of the screw,causing a pressure increase.

Screw Compressor



Built in Pressure Ratio :-

Each screw element has a built in pressure ratio which depends upon its length,the pitch of the screw and the form of the discharge port.

To attain the best efficiency ,the pressure ratio must be adapted to the required working pressure.

Atlas Copco GA Oil Injected Screw Compressors Z Oil Free Screw Compressors

- FOUNDATIONLESS INSTALLATION
- READY TO USE – NO SITE WORK
- LESS MOVING PARTS LIKE
- CONSEQUENTLY LESS MAINTENANCE , LOWEST DOWN TIME & HIGH AVAILABILITY.
- AVAILABLE IN AIR-COOLED VERSION
- POWER SAVING – DIRECT DRIVE

Compressor Control

Most industrial processes require a varying amount of air

The changes in air demand can be due to:

•Extent of plant utilization

-Time of the day or the day of the week

-Degree of maturity of the process

•Large consumers of air with intermittent demands (Forging hammers,Presses,etc)

•Mass dependent processes such as air separation

•Or simply because the air demand is over-estimated

The compressor therefore requires a control system to regulate the air generation of the compressor in direct relation to the demand

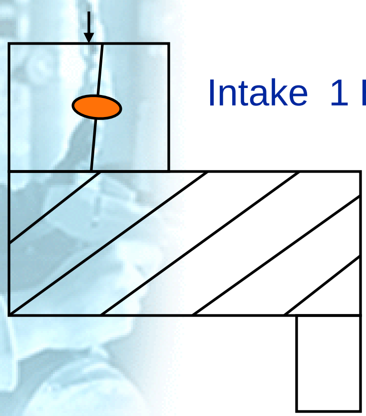
TYPICAL AIR DEMAND PATTERNS

Screw Compressor Controls-Modulation Control

In a modulation control a butterfly valve regulates the intake

Full load

- Butterfly valve is fully open with full flow of air
- Compressor operates at the built-in pressure ratio



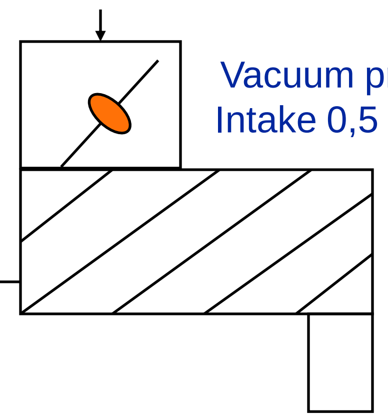
Intake 1 Bar A

Outlet 8 Bar A

Pressure ratio = 8

Part load

- Restriction at the inlet (Vacuum)
- Outlet pressure remains the same(air net pressure)



Vacuum prevails
Intake 0,5 bar A *

Outlet 8 Bar A

SCREW ELEMENT

Pressure ratio = 16 Higher than the BIPR,hence inefficient at part loads

* Figures are used for concept demonstration only

Screw Compressor Controls
Load-no load regulation

•In a load-no load control the machine runs either fully loaded or unloaded

•In the loaded condition,the intake valve is fully open and hence the machine operates at the BIPR

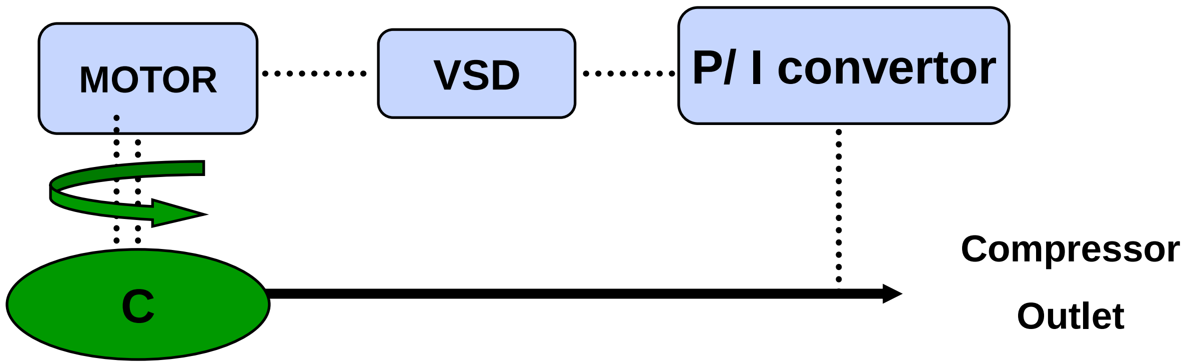
•In the unloaded condition,the intake valve is fully closed and the element is isolated from the Air-net.

•Hence part load power comes down dramatically and the machine operates efficiently even at part loads

Screw Compressor Controls
Variable speed drives

In a variable speed control the speed of the machine is continuously adjusted in line with the demand

Schematic:



•P to I convertor senses pressure and generates a proportional 4-20 mA signal

•This current signal is used by the VSD to alter the frequency to the electric motor

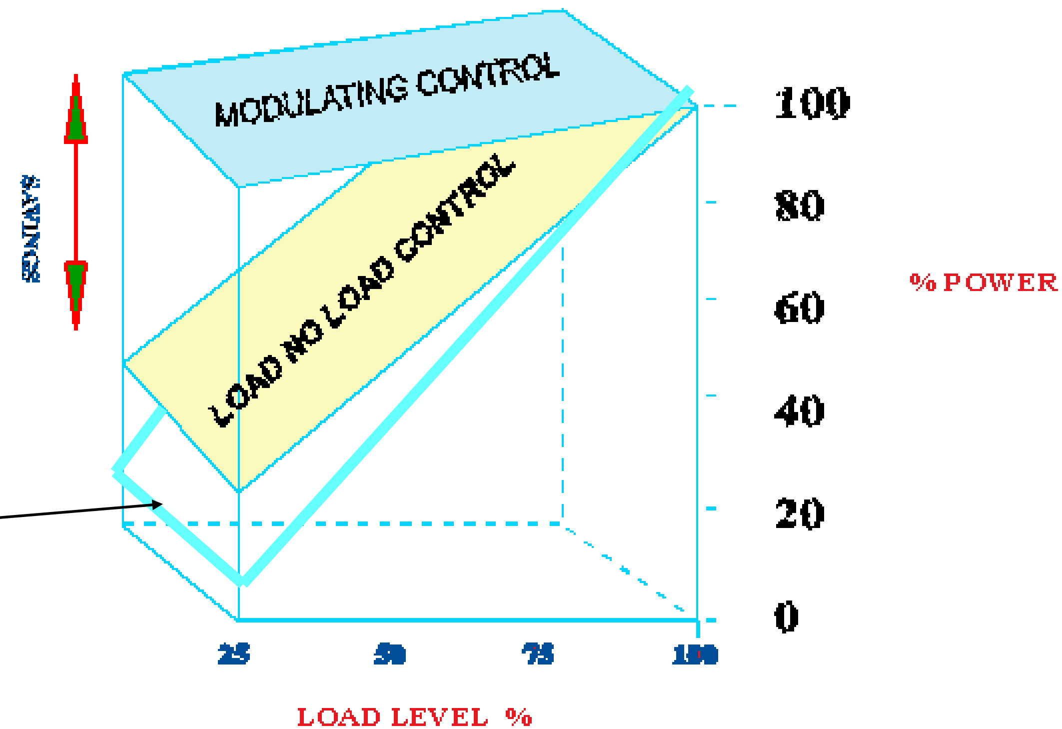
•The electric motor speed varies as a function of the frequency

•Variable speed drives constitutes the most efficient compressor control

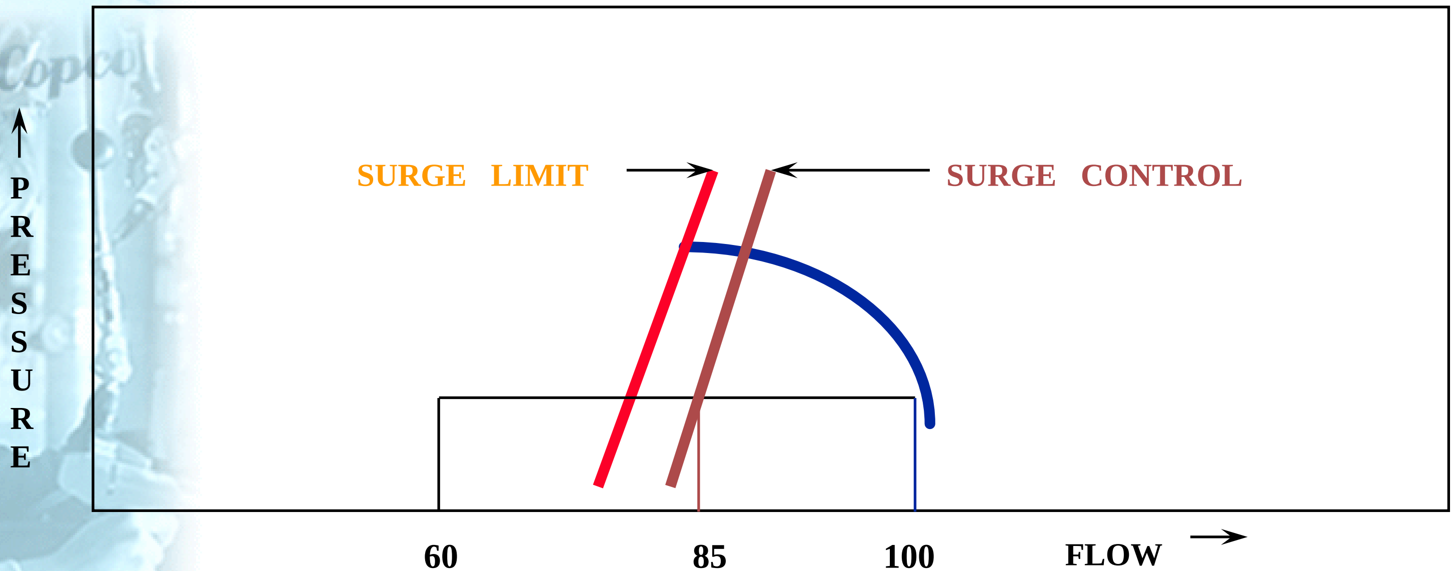
Screw Compressor Controls
A Comparison

COMPARISON OF REGULATION SYSTEMS

VARIABLE SPEED CONTROL



Dynamic Compressor Control



DEMAND FALLS BELOW SURGE CONTROL

DEMAND IS ABOVE SURGE CONTROL

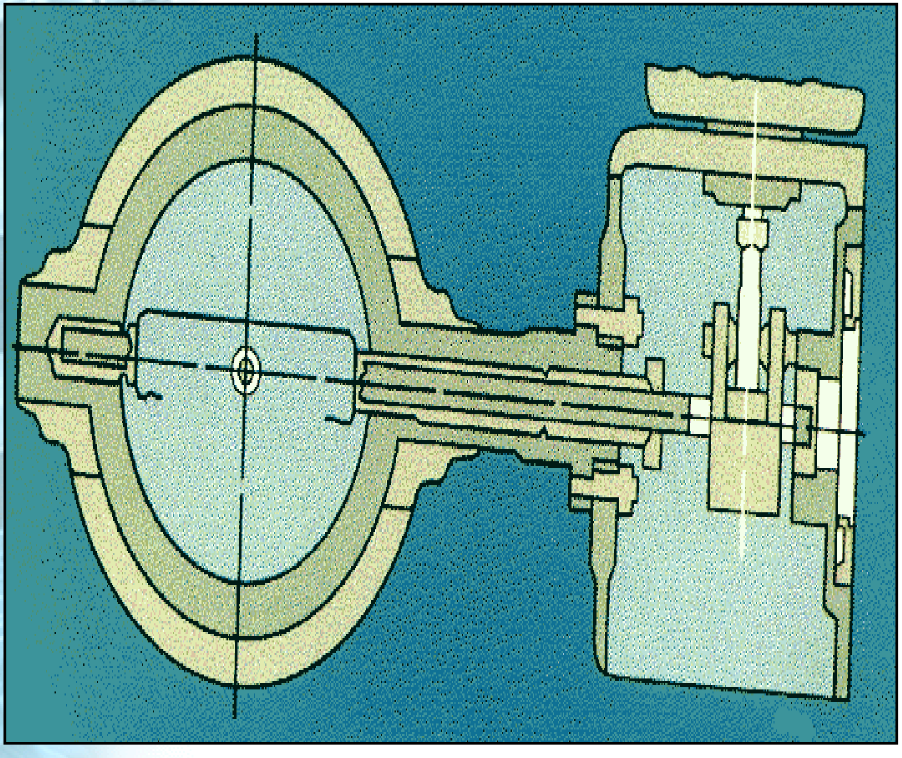
2 SCENARIOS:

- CONTROL ABOVE SURGE CONTROL
- CONTROL BELOW SURGE CONTROL

Dynamic Compressor Controls

Control above surge control line

Inlet Throttle Valve

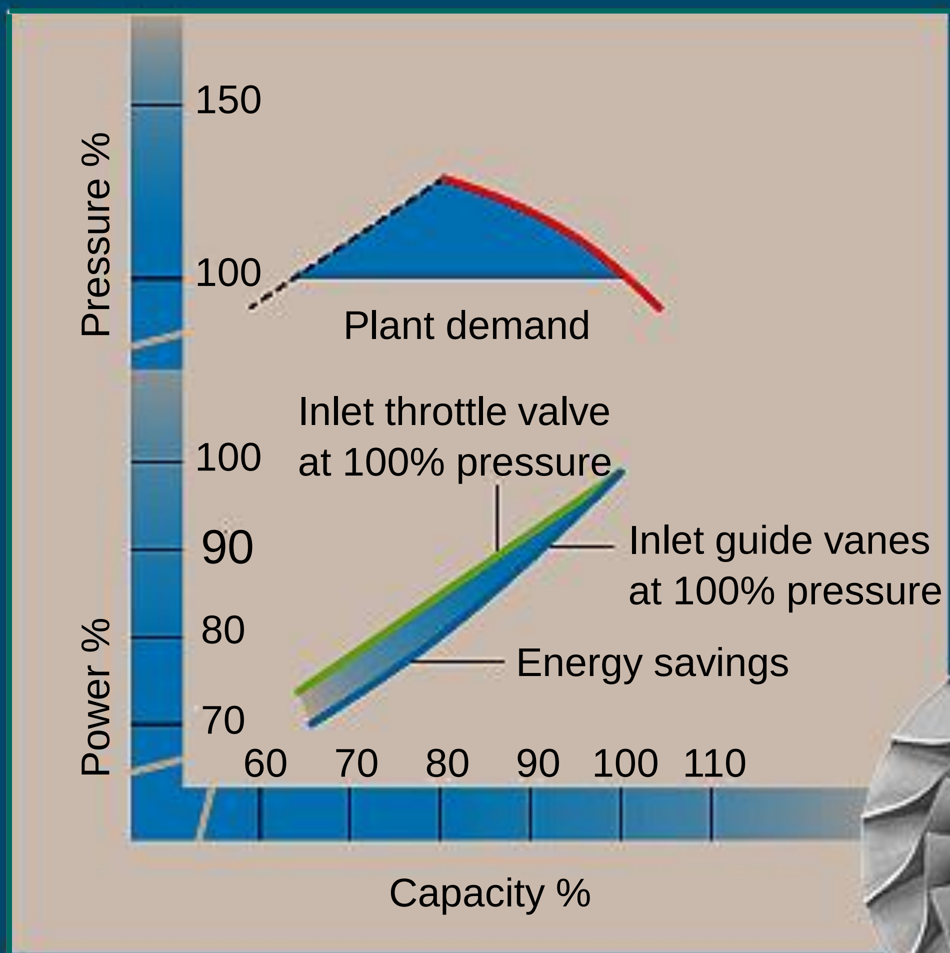


Inlet Guide Vane

OIL-FREE AIR COMPRESSORS

ZH-series

Efficient centrifugal compressors

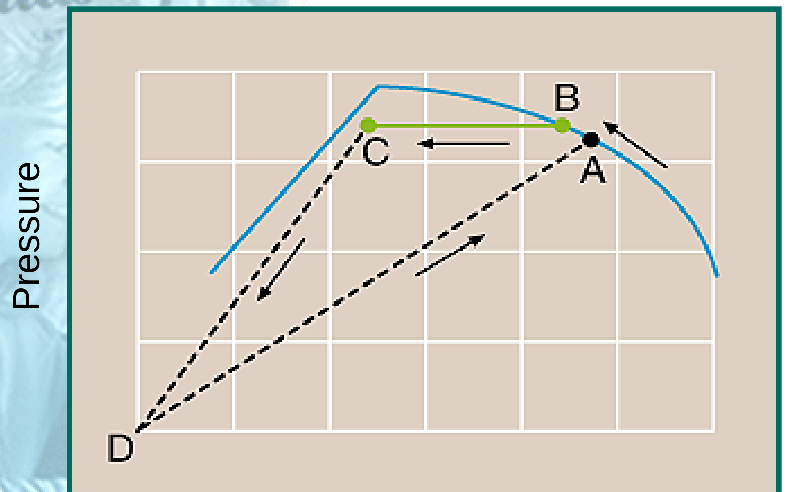


Adjustable inlet guide vanes provide a pre whirl to the air or gas,smoothly controlling capacity without any turbulence unlike the throttle valve

9%energy savings at part load

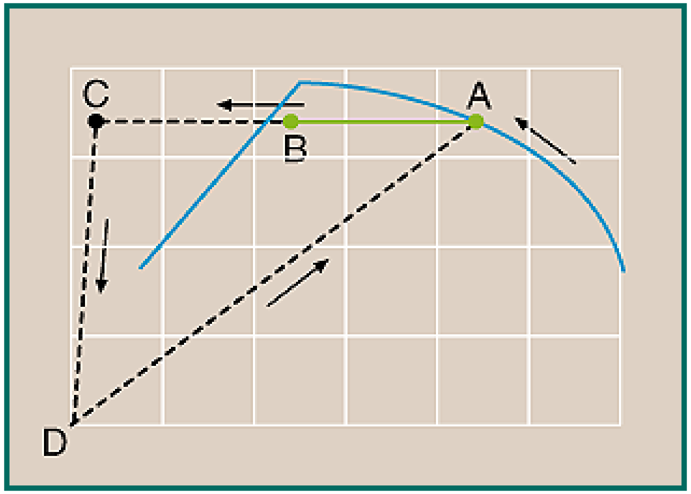
Dynamic Compressor Controls
Control below Surge control line

Auto Dual control



Volume flow

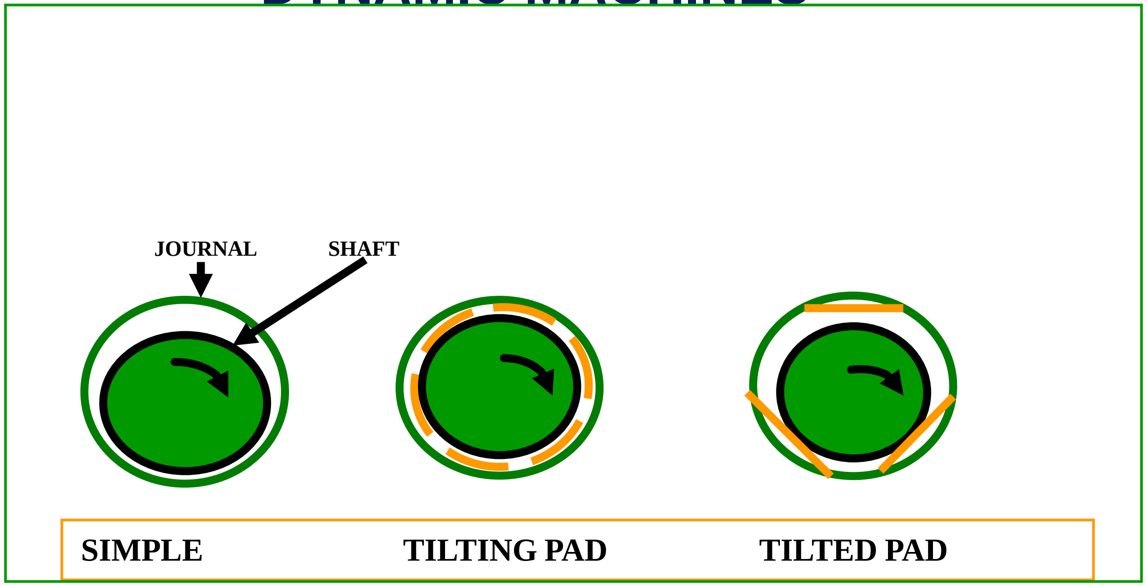
Modulated Blow-Off Control



Re-loading time is long,calling for huge stored capacities to protect the process

Entails blow-off at partial loads,thus wasting energy

BEARING CONFIGURATIONS
DYNAMIC MACHINES



•Turbo machines operate above critical speeds and hence need sleeve bearings,which support the rotating shaft on an oil film.Starting and stopping,frequent load changes and vibrations cause thinning of the oil film (Film Dispersion)

•Hence Loading Unloading cycles have to be strictly controlled and spaced out for effective protection of the compressor.

THE FLEXIPAD BEARINGS

Tilting pad or flexi pad bearings offer better dampening characteristics as compared to the fixed geometry bearings

THE NUMBER OF STAGES IS DEDUCED AS FOLLOWS :

- With17-4 PH SS as impeller material,the max.tip speed is 450 m/s
- When using 45 Deg impellers,this is attained at a PR of 2,1 per stage.
- Hence a 2 stage machine should not run beyond 3,4 bar.
- And a 3 stage can achieve upto 8,2 bar upto the safe limits.
- Exceeding maximum tip speeds entail serious risks of impeller breakage