AIR COMPRESSORS : Theory, Principles, Operation & Maintenance

- Compressed air is required for many purposes on board includes: Engine starting, Control Air & Service Air (cleaning, chipping, spring air for Exhaust Valve.
- Air is compressed by an Air Compressor and the pressurised air is stored in an air bottle.

- **Methods of Compression**: 2 Methods of Air Compression

a) **Iso thermal Compression**: PV = Constant

- As piston moves upwards, the reciprocating energy is converted to pressure energy
  The heat energy generated during this process is called "Heat of Compression" (All heat is transferred to cylinder liner wall)

∴ If temperature at the beginning of compression is equal to temperature at the end of compression, it is said to be a "Isothermal compression Process"

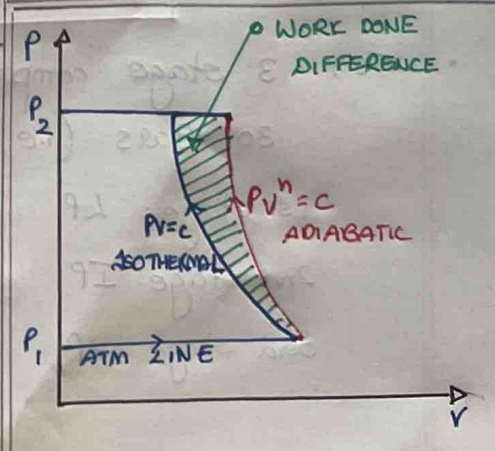
b) **Adiabatic Compression**: PV^n = Constant, $n = 1.4$

- Heat of compression is retained as in Internal Comb. Engines.

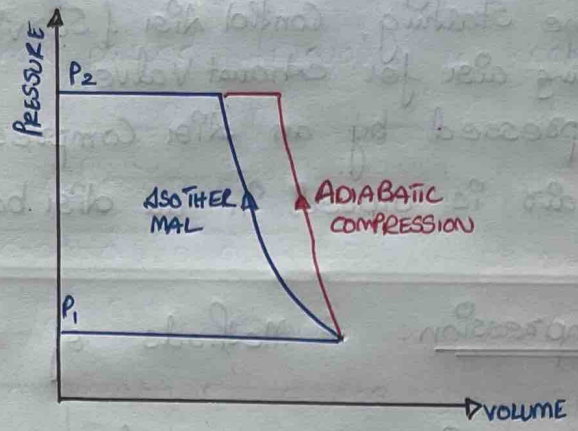
∴ Temperature at End of Compression >> Temperature at Beginning of Compression

- NOTE : Work done for a Isothermal Process is least (Area under PV curve)
  However, it is very difficult to achieve an Isothermal process and hence we arrive at a "Polytropic Process"

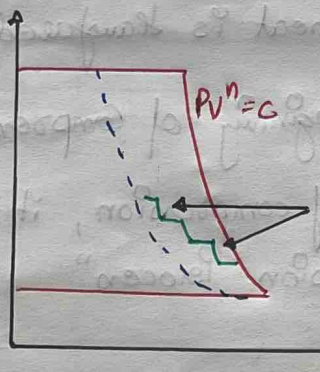
∴ Air Compressors work on a Polytropic Compression ($PV^n = C$, $n = 1.3$)



- NOTE: In Air Compressors: Adiabatic Process is Converted to Isothermal Work done during Adiabatic compression is significantly higher as indicated in the graph / P-V graph.

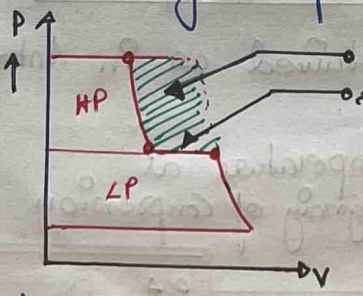


To obtain compression as close to isothermal nature, air is compressed and cooled and this is done in alternate stages i.e., in number of stages of coolers.
- Practicality & complexity becomes tedious & stringent.



Multiple Stages of coolers & compression
* Theoretically possible

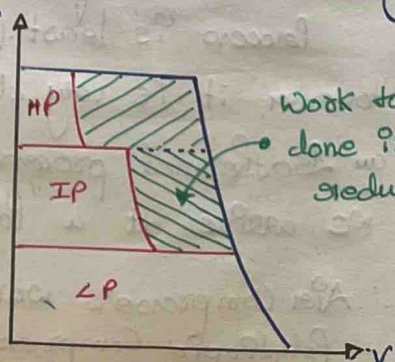
i.e., why 2 or 3 stage Compressors are used.



Work done to be is reduced
Intercooler / cooling
* 2 stage Air Compressors are used : 30 BAR

- NOTE: 3 stage compressors are used to obtain air beyond 30 Bars (i.e., ≅ 40 BARS)

1st stage: LP
2nd stage: IP
3rd stage: HP



Work to be done is reduced.

Basic theory of air compressors

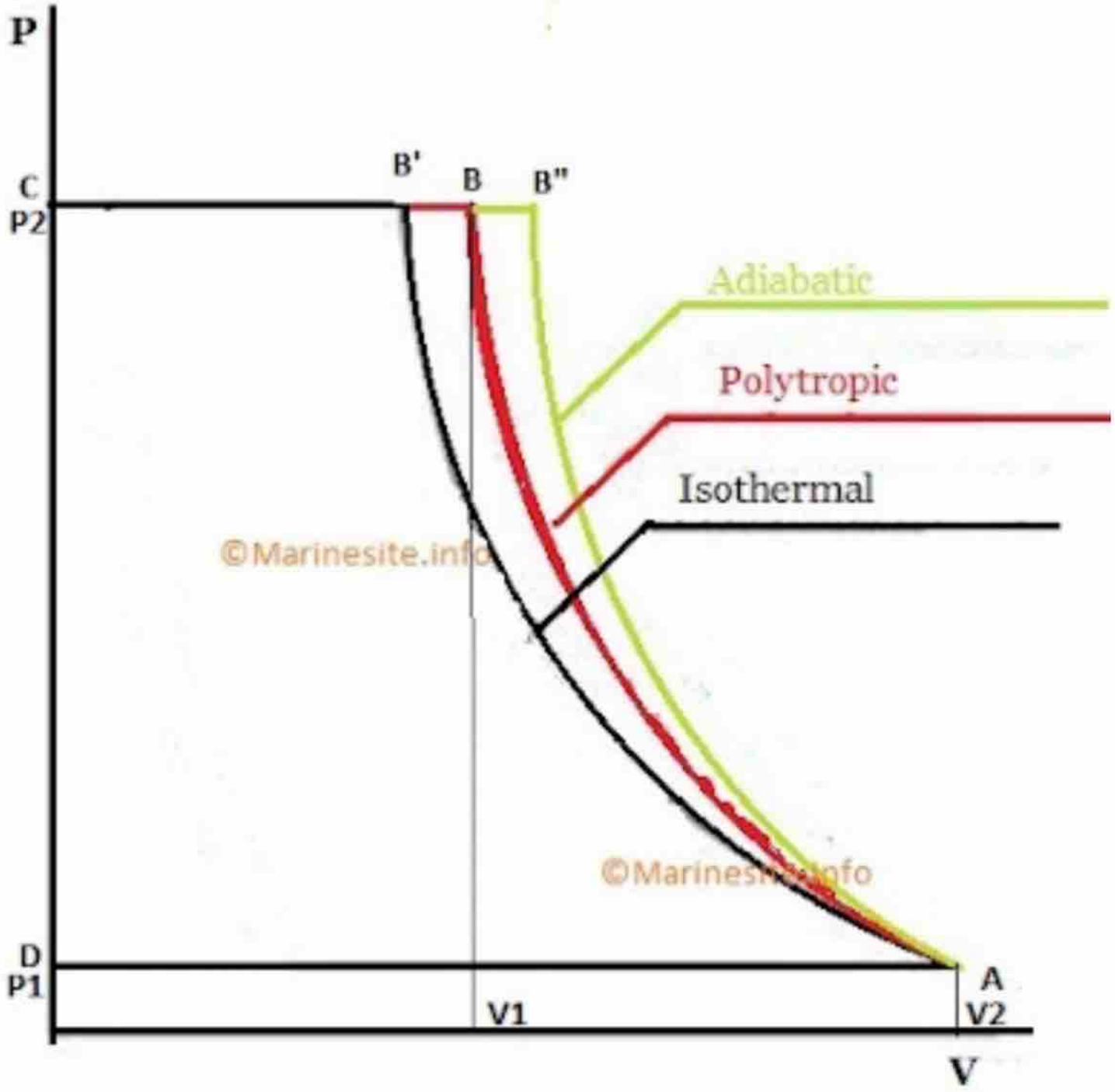
When the piston moves from BDC to TDC air gets compressed, as a result, pressure increases and therefore volume decreases. The work done to compress the air is converted to heat energy in the air so that, the air temperature is increased.

During compression, if all the heat generated is taken by cylinder wall then it is called **Isothermal compression**. Here, further temperature rise is avoided and the compression is taking place at constant temperature. The relationship between the pressure and volume would follow Boyles law (PV =C)

If there is no heat transfer from the compressed air, then all the work done during compression would appear as stored heat energy. This is known as the **Adiabatic compression** and the relationship between pressure and volume would be $PV^{\gamma} = C$ ($\gamma = 1.4$ for air)

The actual compression process in an air compressor is between the isothermal and the adiabatic and is referred to as **Polytropic compression**. The relationship between the pressure and the volume is $Pv^{n} = C$, where n is a value of about 1.25 - 1.35.

PV Diagram With Explanation



D-A: Intake

Assume there is no bumping clearance, initial volume when the piston at the top is zero. Thus as the piston moves from top to bottom, a volume of air V2 is drawn into the compressor from the atmosphere with pressure P1. The temperature of air is T1.

A-B: Compression

As the piston moves up, the air is compressed Polytropically ($PV^n = C$). The pressure of air increases from P1 to P2. The volume decreases from V2 to V1. The temperature increases from T1 to T2.

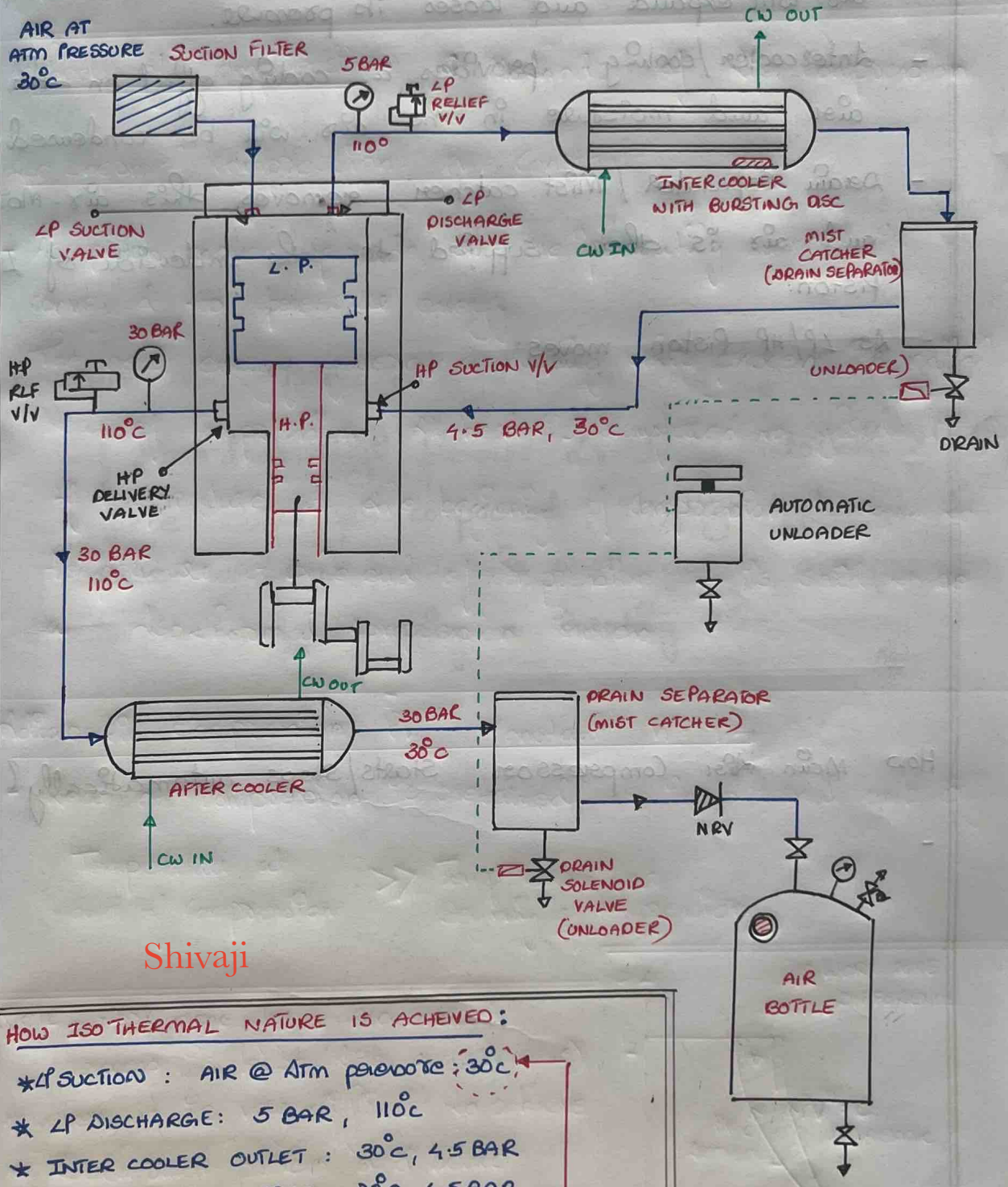
B-C: Delivery

The compressed air at the pressure P2, volume V2 and temperature T2 is delivered out of the compressor to the air receiver.

ADVANTAGES OF MULTI STAGING AND USING COOLERS:

- Volumetric Efficiency of Compressor
- Life of Compressor Valves is increased
- Improved quality of air
- Less Carbon Deposit ⇒ Increased time between overhauls
- Reduces work required

SINGLE - THROW 2-STAGE TANDEM COMPRESSOR



HOW ISOTHERMAL NATURE IS ACHIEVED:

* LP SUCTION : AIR @ Atm pressure ; 30°C
* LP DISCHARGE: 5 BAR, 110°C
* INTER COOLER OUTLET : 30°C, 4.5 BAR
* HP SUCTION: 5BAR : 30°C, 4.5 BAR
* HP DISCHARGE: 30 BAR, 110°C
* AFTER-COOLER OUTLET: 30 BAR : 30°C

SYSTEM DESCRIPTION:

- When LP piston goes down, Air gets sucked
- When piston moves up, LP suction valve closes and LP Discharge valves open. (Due to air pressure) (Also, HP Suction Open)
- Air is then passed through a cooler "Intercooler"
- Air passes through the tubes: so as to maintain the pressure. Otherwise, if air passes through the shell, air will expand and looses its pressure.
- Intercooler / cooling provides a cooling effect on the air and moisture in the air will be condensed.
- Drain Separator / Mist catcher removes this air-Moisture and air is then supplied to the underside of LP Piston. (Works like a cyclone Separator removing oil & water)
- As LP/HP Piston moves, the 4-5 Bar air gets compressed and is then transferred after the opening of HP delivery valve at approximately 110°C & 30 Bar.
- This air passes through the after cooler, where they pass through the tubes and are cooled. Moisture gets condensed and this is drained via Mist Catcher
- Air then enters the Air bottle through NRV and when Air bottle pressure reaches 30 Bar, pressure switch stop compressor

Q: How Main Air Compressor Starts/stops automatically?

Ans Due to pressure switches. that utilize air lines to monitor.

- The pressure switches have a diaphragm (or element)
- When the Air bottle is at maximum pressure, it distorts the diaphragm in the switches in such a way that its movement will break the contact inside the switch and power stops flowing to compressor's Motor Circuit supply
- Constant air pressure @ specific volume keeps diaphragm deformed
- When air pressure reduces below an enough value, diaphragm revert back to their initial position. Contacts touch and thus initiating Power supply.

Air compressor pressure switches use air lines to monitor pressurised air as it moves to and from your air tank. All pressure switches have some element that reacts when pressure is applied to it. The most common device is a diaphragm that will physically compress when exposed to this air.

Air pressure in your compressor tank will increase and eventually build up enough backwards pressure — also called cut-out pressure — to change the shape of this diaphragm. Deformation here will cause movement in the pressure switch.

When your air compressor pressure switch's diaphragm is deformed enough, its movement will break contact inside the switch so that power stops flowing to the compressor's motor circuit, stopping the compressor from further pressurising the air in your tank.

Constant air pressure at a specific volume will keep the diaphragm deformed. When the air pressure in your tank drops far enough, the diaphragm will revert back to its normal shape. Once this pressure — called cut-in pressure — lightens to a certain level, an internal operator within the diaphragm will deform in an opposite manner. This movement closes the circuit and starts the motor back up again.

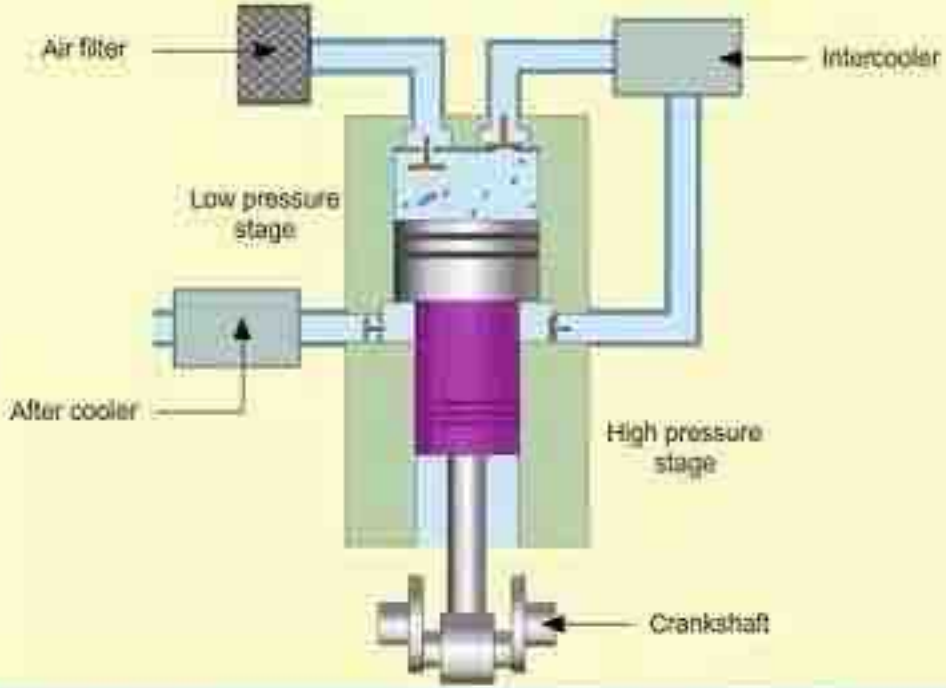
Your air compressor pressure switch continues this dance as long as your machinery is using compressed air. The cycle is broken when the unit is no longer powered externally or when there is an issue. Leaks at any point in your compressor's pressure switch and nearby casing can stop your work and cause major problems.

LP relief Valves: Set at a pressure not more than 10% of the working pressure.

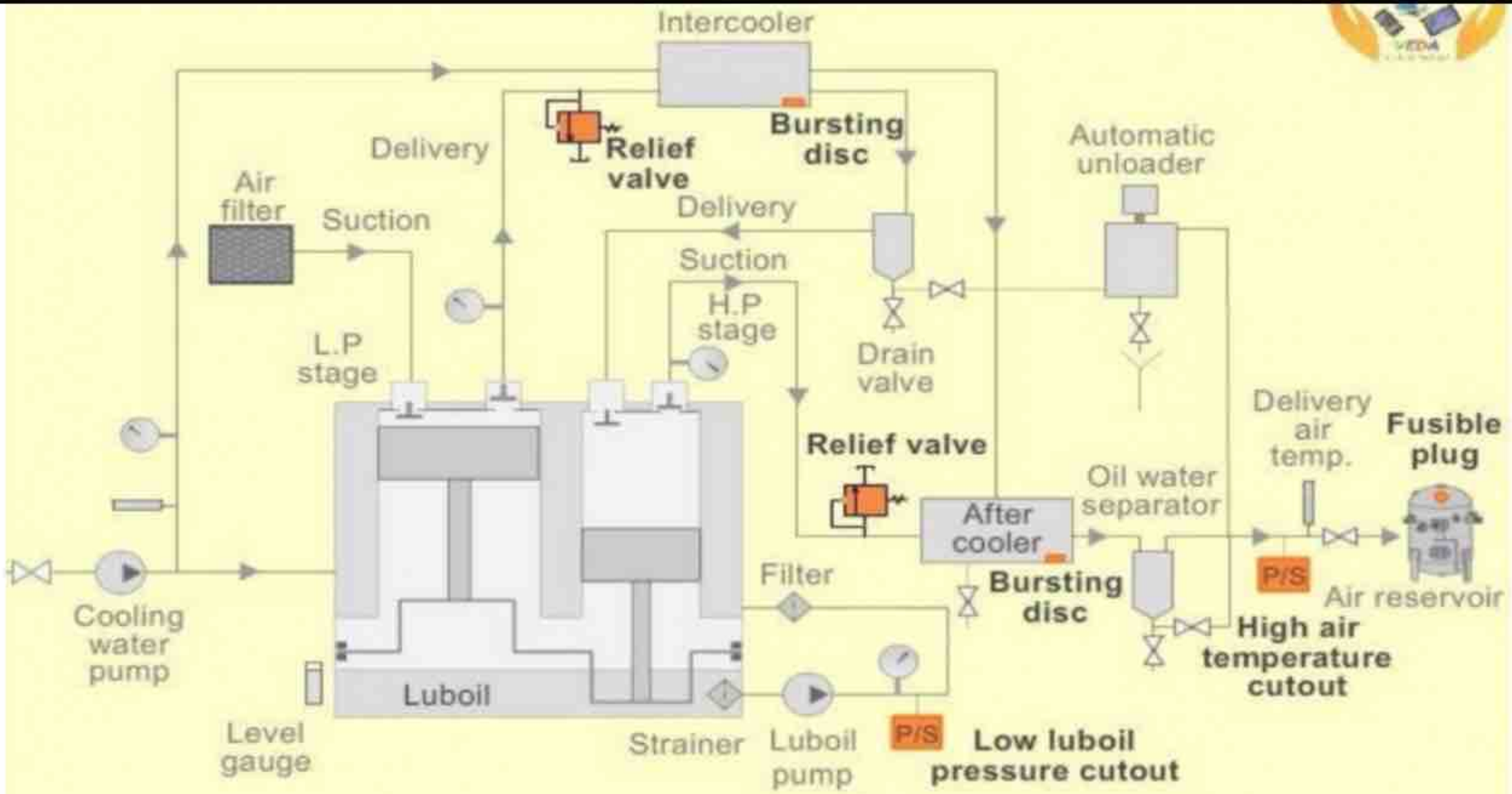
The above illustration is of a single throw (Same Crankthrow has 2 units) Tandem Compressor.

- NOTE: Multithrow type Compressors are also predominantly in use (2 units LP & HP are on separate crankthrows as shown)

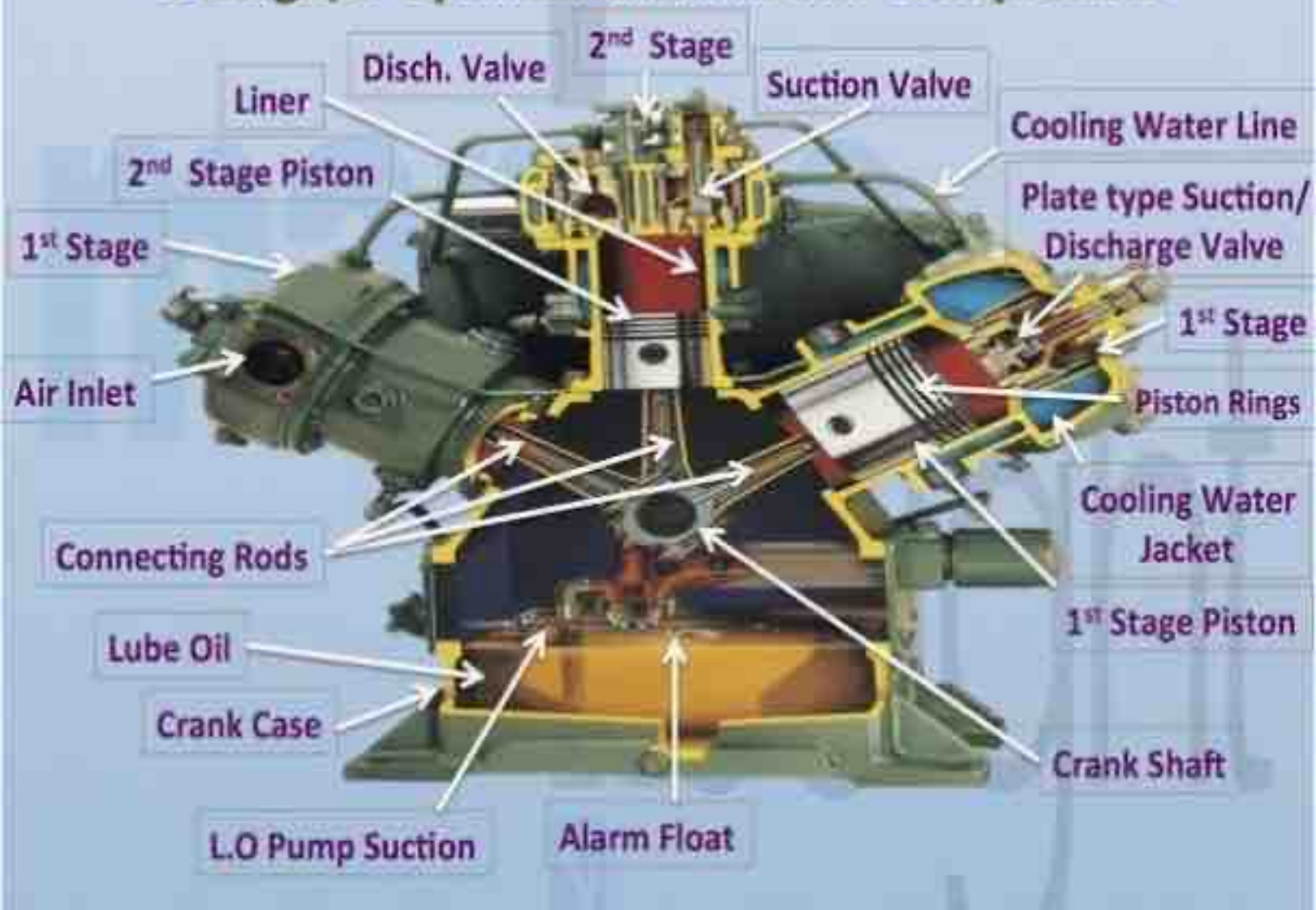
Double acting



In this arrangement, the low pressure first stage piston is at the top and the high pressure piston is at the bottom.


Intercooler
Bursting disc
Relief valve
Delivery
Air filter
Suction
Delivery
Suction
H.P stage
L.P stage
Drain valve
Automatic unloader
Relief valve
Delivery air temp.
Fusible plug
Oil water separator
After cooler
Bursting disc
P/S
Air reservoir
High air temperature cutout
Filter
Cooling water pump
Luboil
Level gauge
Strainer
Luboil pump
P/S
Low luboil pressure cutout

2 stage/3 Cylinder Marine Air Compressor



SAFETIES ON AN AIR COMPRESSOR:

i) **RELIEF VALVE:** To provide protection & prevent overpressurisation of the line/system. (after each stage)
- set at 10% above working pressure)

ii) **BURSTING DISC:** Fitted on the water side of the cooler

- If tubes leak, high pressure air leaks into the shell and since water gets compressed, its high hydraulic pressure would rupture the shell due to over pressure. This is prevented by using a Bursting Disc. which itself ruptures and safely discharges the pressure preventing damage of the shell/casing of cooler and also injury to any personnel in the vicinity is prevented.

iii) **LOW LUBE OIL PRESSURE CUT OUT**

iv) **HIGH AIR DELIVERY TEMPERATURE** (In some, fusible plug)

v) **MOTOR OVERLOAD TRIP**

vi) **FUSIBLE PLUG ON AIR BOTTLE**

- NOTE: Bursting Disc is mostly on Intercooler, However, the after cooler may also be fit with a bursting tube. Although, since its a common water circuit, Bursting Disc is only fitted inside an intercooler.

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i.e., if tubes of HP/Aftr cooler tubes leak, same cooling water circuit gets pressurised and Bursting Disc in Intercooler will burst first (if fit with Bursting Disc in aftercooler also, making no legible/ credible reason to fit the aftr cooler with a bursting Disc.

i.e., a) Intercooler inlet air pressure is 5 Bar and the Bursting Disc May be set at 5 Bar (water side)

b) Also, if Aftr cooler is fit with bursting disc, since the air from HP delivery valve is at 25 - 30 Bar and hence, Bursting disc will also be set @ 25 - 30 Bar

- When tubes in aftr cooler leak, as the water cooling circuit is common, the bursting disc in Intercooler will first rupture.

TO UNDERSTAND THIS CONCEPT:

Q: How to identify / know that tubes are leaking:

Ans Stop compressor. As cooling water flow is kept open, manually open the drain valve of mist catcher

"Continuous flow of water from drain ⇒ Tubes are leaking

Q: How to determine which tubes are leaking? Action

- Remove end covers
- Connect oil/hydraulic pump & carry pressure test
- Any leak is observed in the tube.
- Plug the tube

- DISADVANTAGE OF BURSTING DISCS:
  - Ruptured bursting disc have to be replaced prior further operation and it is a tedious task to replace & maintain spares. i.e., why some coolers are fit with relief valves.

Q: During Manoeuvering, if Bursting disc ruptures, what actions will you take?

- Stop the compressor
- Drain the cooler. Open end covers. (If water shortage, connect hose where bursting disc has bursted and then transfer water to Expansion tank).
- Plug the tube (Hydraulic Testing)
- Replace with new bursting disc.
- Assemble back

- NOTE: Never make a burstic disc on board.
  - Bursting Discs are made up of Copper Alloys and are provided by the manufacturer

- NOTE: Never use any other material to make a bursting disc other than the one provided by the Manufacturer
  - As if other materials are used, they might not work and hence damaged cooler

- PURPOSE OF UNLOADER: "Drain Unloader is mostly used"
  - Used to reduce starting torque at the time of starting This is achieved by keeping the drain solenoid valves open at the time of starting (characteristic noise) thereby unloading the compressor and reducing the starting torque on compressor motor.
  - These solenoid valves also operate at time of stopping
  - When compressor is in stopped condition, the drain solenoid valves are open.
  - Also, they are operated in between the long running of the compressors, as ships operate at tropical climates, large water vapour may be present & if not blown off by drain valves, it may mix up with crankcase oil

- NOTE: When compressor is in stopped condition, its drain solenoid valves are open.

∴ A NRV is provided between the Air bottle and Air compressor so as to not allow air from air bottle to leak through the solenoid valves (as filling valves of air bottle remain open during Automatic operation of MAC)

* If Solenoid Valve shows air, ⇒ NRV leaks or has a hole. (Air bottle pressure decreases.

- NOTE II: Suppose we compress from atmospheric pressure to 30 BAR

→ First stage Discharge Pressure:

- Absolute Pressure = $\sqrt{\frac{(30)+(1)}{(0)+(1)}} = \sqrt{31}$ (AIR BOTTLE / ATM)

then, Gauge Pressure = $\sqrt{31} - 1$

Note: we add '1' as atmospheric pressure is very low ≅ 0 and dividing by zero is not possible (1 is error)

→ Second stage Discharge Pressure

Absolute: $\sqrt{31} \times \sqrt{31} = 31$

Gauge: $31 - 1 = 30$

In case of 3-stage, 3rd stage: 40 Bar Pressure

then: 1st stage Discharge: Absolute: $\sqrt[3]{\frac{40+1}{0+1}} = \sqrt[3]{41}$

Gauge: $\sqrt[3]{41} - 1$

2nd stage Discharge: Absolute: $\sqrt[3]{41} \times \sqrt[3]{41}$

Gauge: $\left(\sqrt[3]{41} \times \sqrt[3]{41}\right) - 1$

3rd stage Discharge Pressure: Absolute: $\sqrt[3]{41} \times \sqrt[3]{41} \times \sqrt[3]{41}$

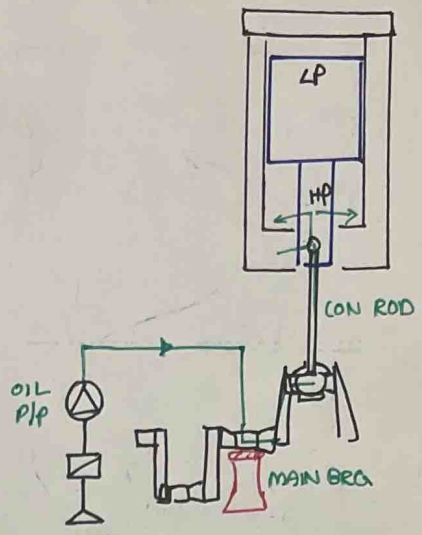
$= 41$ Bar

Gauge: $41 - 1 = 40$ Bar

How Lubrication is achieved:

i) For HP Piston:

- Oil pump supplied from c/c to Main Brg.
- from Main Bearing, to drilled passages on crank web & pin to bottom end bearing
- from bottom end bearing, through con Rod to gudgeon pin & liner

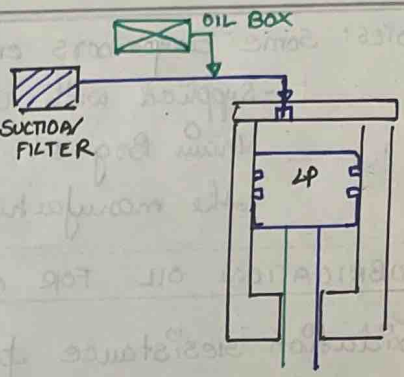


ii) For LP Piston:

- Various Methods:

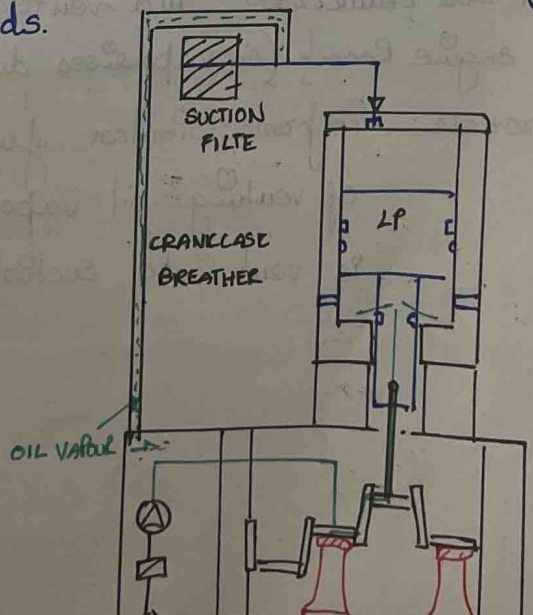
Method I: Drip Lubrication

- Oil Box/Pot on Suction Line
- When air gets sucked, oil is sucked dropwise into LP stage as shown

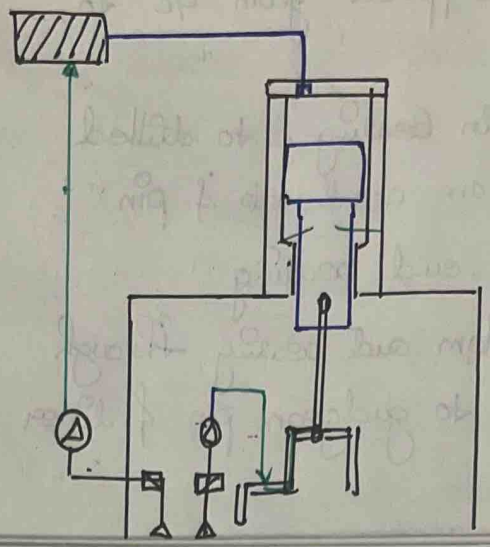


Method II: Through Crankcase breather pipe (Best Configuration)

- the crankcase breather vent pipe is attached to the suction side of the suction line as shown.
- Oil vapours from Crankcase are sucked during suction (LP piston moving downwards. along with air



Method III: Separate Pump supplying oil dropwise to suction filter



- NOTES: Some compressors employ quills on the liners of 1st stage - supplied with c/c oil either by main oil p/p supplying main brg or a separate oil pump, as designed by the manufacturer.

- LUBRICATION OIL FOR AIR COMPRESSOR : PO 100 Synthetic Oil.

1) Oxidation resistance properties.
   - oil shall have high resistance to oxidation. (otherwise oil forms carbon deposits and (since large air & high temperature) oxidise.
2) Demulsifying Nature: oil shall not form emulsion with water.
3) High flash point

- PURPOSE OF CRANKCASE BREATHER:

In Main Engine, Auxiliary Engines: Oil vapours formed in the crankcase due to high temperature are removed from the crankcase and vented out to the atmosphere {or engine Room} (oil vaporises due to BRGs running hot)

In Air Compressors: Performs similar function, but, instead of venting oil vapour to surrounding, it is vent into suction side.

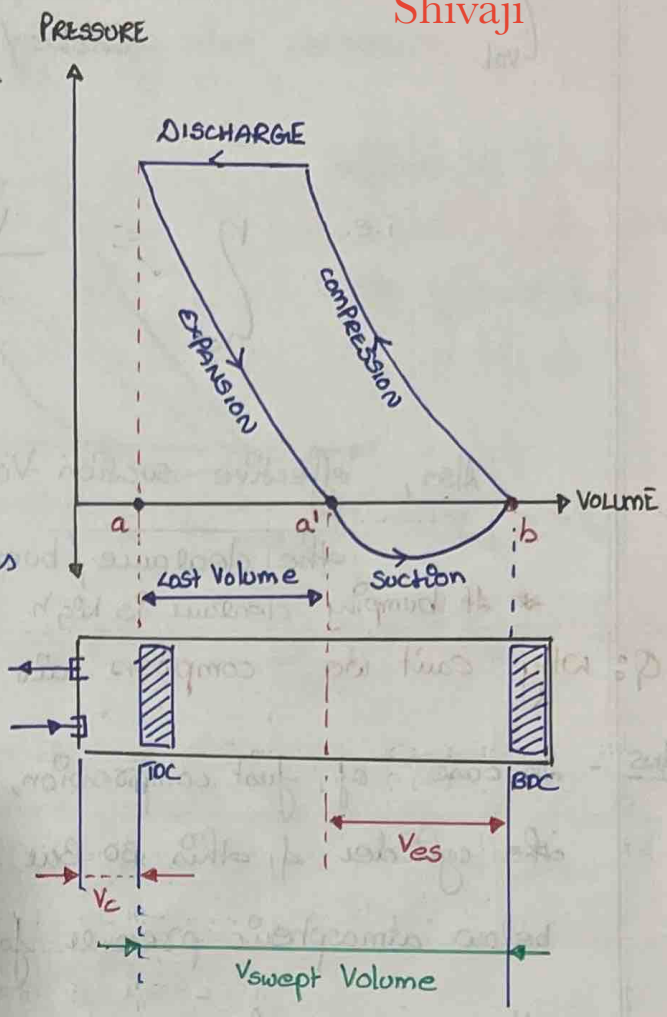
VOLUMETRIC EFFICIENCY:

To understand Volumetric efficiency, we shall discuss:

- clearance volume is provided so as to prevent the piston from banging on to the cylinder head. Also known as "Bumping clearance"

Clearance Volume = "V_c"

consider a scenario where an initial/ first Compression has occured.



- Air will be trapped at the clearance space which is at High Pressure
- As piston starts moving towards BDC, theoretically Suction valve must have opened at Point 'a'
- This doesn't happen as the air at high presure trapped inside prevents entry of fresh air at atmospheric presure
- When the piston further moves towards BDC, the air inside expands until its presure drops below atmospheric pressure at point 'a' : where suction valve opens
- Suction valve closes at b.

∴ Theoretically: Volume of air drawn in = V_{swept}

Practical: Volume of air Actually drawn

∴ V_{swept} − Lost Volume

= $V_{effective\ suction}$

= V_{es}

$$\therefore \eta_{vol} = \frac{\text{Actual Volume of air entering the cylinder}}{\text{stroke / swept volume}}$$

$$\text{i.e., } \eta_{vol} = \frac{V_{es}}{V_s}$$

Also, effective suction Volume : V_{es} is dependent on the clearance / bumping clearance.

* If bumping clearance is high, V_{es} is less $\Rightarrow \eta_{vol}$ is low

Q: Why can't we compress air to 30 Bar in a single stage?

Ans - In case of just compression, 30 Bar air is trapped inside the cylinder & this 30 Bar air has to undergo expansion below atmospheric pressure for fresh air to enter

- It may expand near to BDC or not expand at all

Thus V_{es} is very low

$\Rightarrow \eta_{vol}$ is less

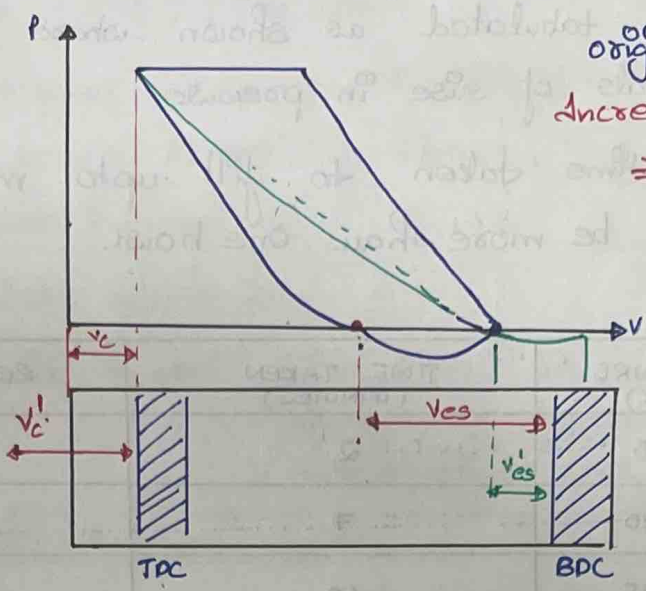
This is why, we limit compression in single stage to 5-7 Bar

- Also, High pressure rise in single stage $\Rightarrow$ High temperature thermal stresses on valves, piston & its rings etc
- Large engine components
- Torque & balancing problems (More torque on Motor)

If Bumping clearance increases, V_{es} decreases and as

$$\eta_{vol} = \frac{V_{es}}{V_s}$$, efficiency also decreases

i.e;



original: V_c & V_{es}

Increased Bumping clear
$\Rightarrow V_c'$ and V_{es}'

$V_{es} >> V_{es}'$

$\Rightarrow \eta_{vol} >> \eta_{vol}'$

- As Bumping clearance increases → More air trapped
  - More time for this air to expand allowing fresh air later $\Rightarrow$ Lower effective suction volume "V_{es}'"

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* SOLAS REQUIREMENT FOR AIR COMPRESSORS:

- A minimum of 2 or more Air Compressors
- Sufficient capacity to charge Air receivers in 1 hour from atmospheric air pressure to maximum rated pressure
- One emergency Air compressor & Receiver for Dead Ship Condition.
- Air receivers : At least 2 air receivers of sufficient capacity to provide
  - 6 starts (Non-Reversible Engines
  - 12 starts (Reversible Engines: Alternate AHD & ASF)

- **TEST FOR VOLUMETRIC EFFICIENCY :**

(a) **AT THE TIME OF DELIVERY:**

- One compressor is operated to run and fill one Air bottle.
- A chart is tabulated as shown where the time is noted for intervals of rise in pressure.
- The total time taken to fill upto maximum pressure should not be more than one hour.

PRESSURE (BAR)	TIME TAKEN (MINUTES)	REMARKS
0 - 5	2	
5 - 10	7	
10 - 15	10	
15 - 20	12	
20 - 25	18	
25 - 30	20	

TOTAL TIME $\leq$ 1 hour (60 minutes)

(b) **EVERY SIX MONTHS:**

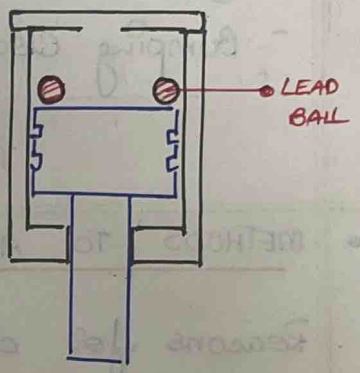
- Drain one Air bottle and run a compressor to fill the drained bottle
- If time taken to fill maximum pressure, exceeds 1 hour, it fails the volumetric efficiency test

- **FACTORS AFFECTING VOLUMETRIC EFFICIENCY:**
  - Leaky valves & dirty valves
  - Blowpast due to faulty piston rings
  - Inefficient Cooling water / Dirty cooler
  - Increase in clearance volume, i.e., Bumping clearance due to Bearing wear down, or thick gaskets.
  - High air temperature at inlet.
  - High Cooling Water temperature.
  - Throttling of air intake:- Dirty / clogged Suction filter
    - Insufficient suction v/v lift
    - Suction valve spring stong.

- **METHODS TO CHECK BUMPING CLEARANCE:**

(i) **LEAD BALL METHOD:**

- Remove valve from cylinder head
- Place lead balls on top of piston
- Turn the piston to TDC
- Lead balls get compressed between cylinder head & piston.
- Remove the ball and measure its thickness ⇒ "Bumping Clearance"
- Bumping Clearance is about 5% of stroke volume.

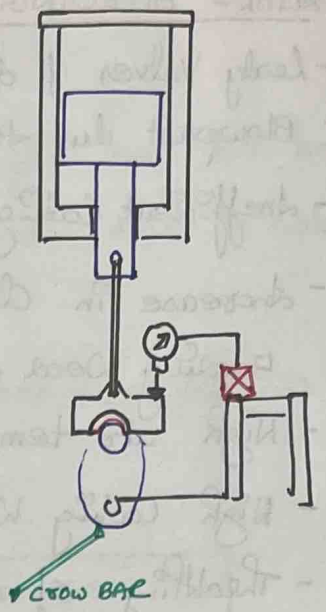


The Lead Ball used shall be of 2 times the actual/initial bumping clearance.

i.e., if bomping clearance allowed = 2 mm
Use lead ball of 4 mm diameter (ie, 2 x 2mm)

(2) DIAL GAUGE WITH MAGNETIC BLOCK:

- Take unit to BDC
- Remove bottom end bearing keep
- Place Magnetic block on Crank Web
- And dial gauge on top keep
- Lift the bottom end using crowbar
- the Dial guage reads the bumping clearance.



(3) DEPTH GAUGE METHOD

- Some compressors have a provision to directly insert a depth gauge.
- Cylinder head and valves need not be removed
- Bumping Clearance : Reading - thickness of cylinder and the thickness of gasket.

- METHODS TO ADJUST BUMPING CLEARANCE

Reasons for change in Bumping Clearance:

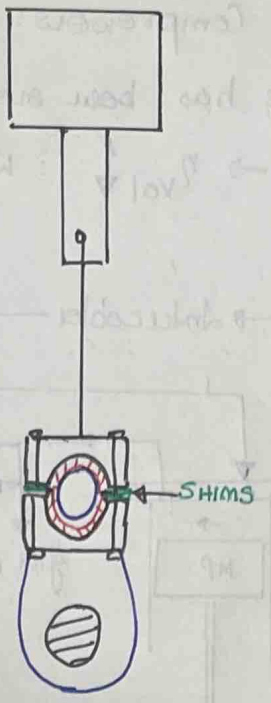
a) Due to wear down of either of the bearings: (Main Brg, Bottom End Brg, Gudgeon Brg)

b) Thicker cylinder head gasket.

To rectify: ① "Renew Bearings" %

② Add shims if it is a Marine Palm type Con Rod.

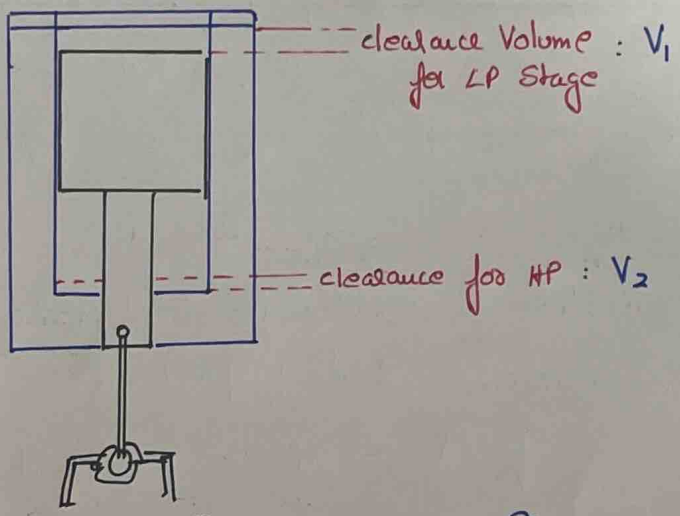
- NOTE: Addition of shims will only adjust bearing clearance as only bottom shell will be displaced.



* Addition of shims will alter bearing clearance
* It doesnot affect the vertical position of the Piston i.e, Bumping clearance is not altered

"ONLY SOLUTION IS TO RENEW WORN BEARINGS"

- Why changing of bearings is the best method?



* In case of Bearing Wear down, Piston tandem moves down

V_1 Increases

V_2 Decreases

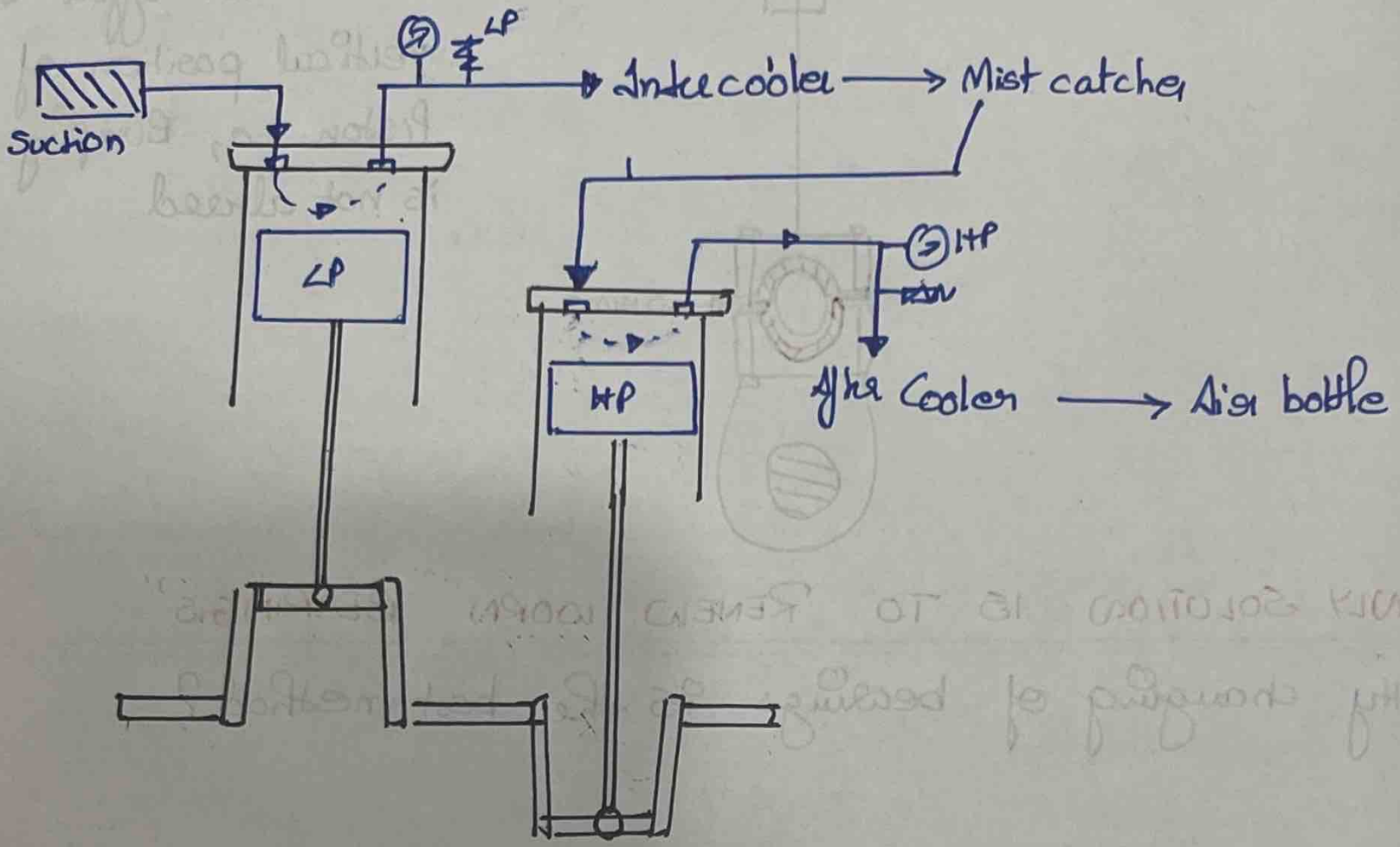
When Bearings are renewed, Both V_1 & V_2 are automatically adjusted back to normal.

- NOTE: If LP is adjusted using thinner gasket → It will give more air, but HP won't take air as its η_{vol} efficiency is low
  ⇒ " LP Relief V/V lifts"
  this is the reason why, both clearances V_1 & V_2 are to adjusted

In case of Multistage Compressors: Adjust Both Clearances

- If LP stage clearance has been rectified: η_{vol} ↑ : more air delivered

But HP isn't altered → η_{vol} ↓ : Won't admit air. " LP Relief Valve left



COMPONENTS:

VALVE SEAT : 0.4% Carbon steel hardened & Polished

VALVE : Nickel steel, chromium steel plate, Vanadium steel

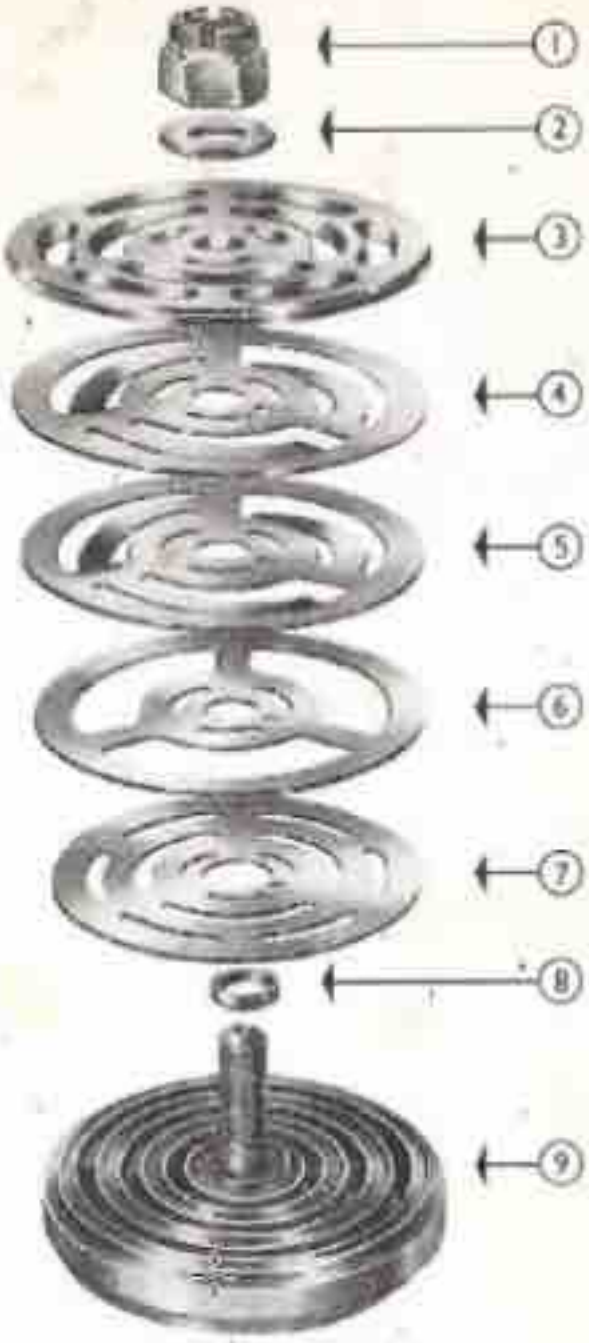
SPRING: Hardened & ground & then polished to mirror finish
Hardened steel

- The Suction and delivery valves are usually of the same type, the only differences being in the spring load and the lift
- These are plate type of valves : Lighter, open & close fast. No throttling effect.

Unlike other machineries such as generators, Engines, which have mushroom valves.

- The seat is usually made up of 0.4% Carbon steel machined all over (Due to high finish, losses are minimal)
- Ports are tapered with inlet edges rounded off and passages are finely finished
- Multiple ports - large effective area which allows a low lift
- The faces of the seat have a mirror finish and hence, air tightness for prolonged periods are ensured
- A pin on the seat prevents rotation of parts
- Distance piece sets the lift of the valve (8)

(9): Seat with Pin
(8): Distance Piece
(7): valve Plate
(6): Backing / Support plate / Cushion Plate
(5) & (4): Springs
(3) Valve Cover Plate
(2) Washer
(1) Nut & Access for Locking Pin



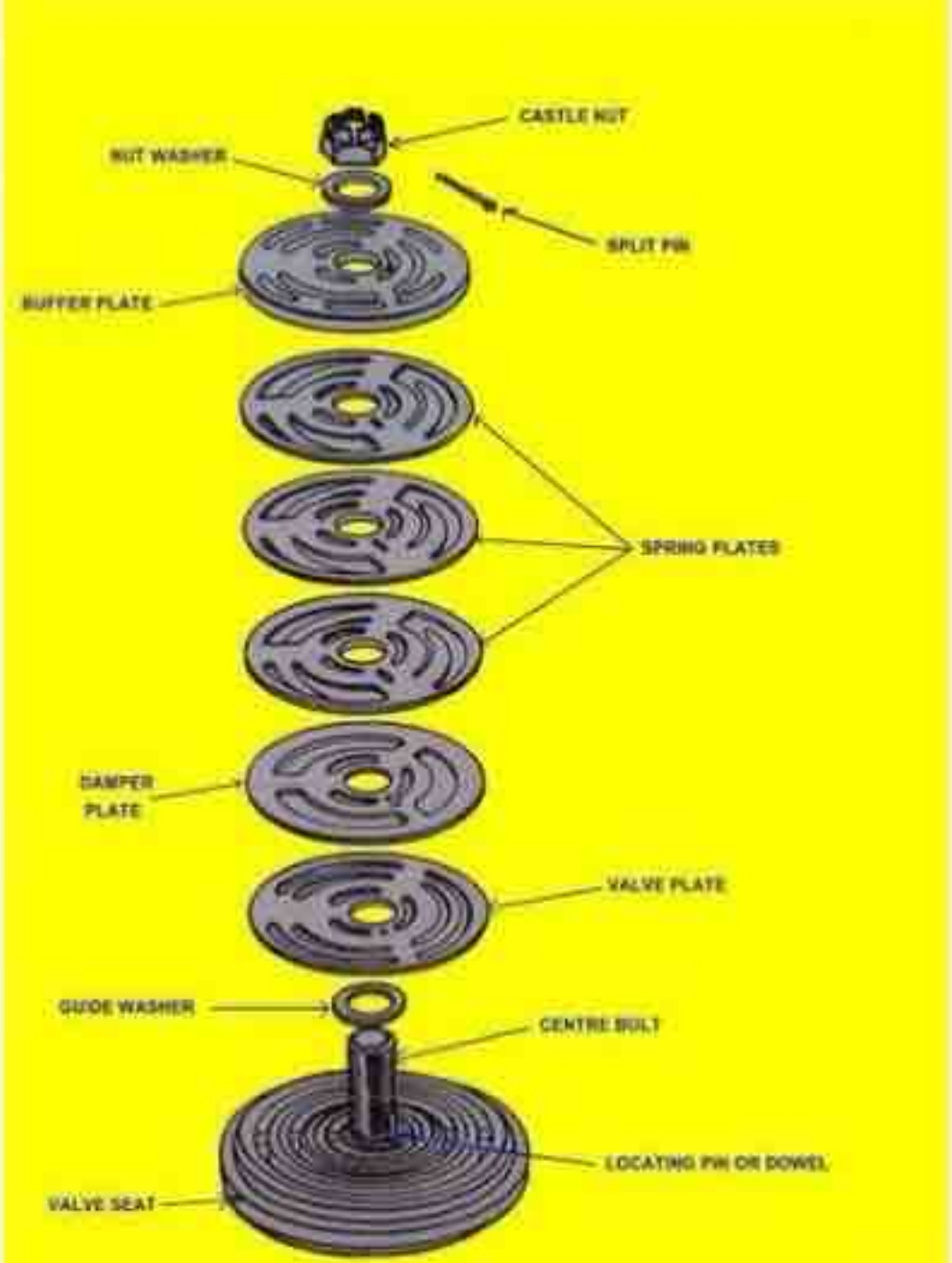
No. H16.—AIR COMPRESSOR VALVES.

1, Nut.
2, Washer.
3, Valve cover plate.
4, Spring.
5, Spring.
6, Cushion plate.
7, Valve.
8, Distance piece.
9, Valve seat.

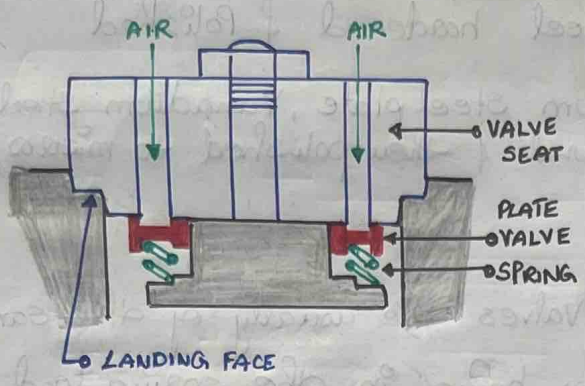
[The author is indebted to the Metallic Valve Co. Ltd. for the illustration.]

AIR COMPRESSION SUCTION AND DELIVERY VALVES

One of the most important parts of an air compressor, as regards efficiency, is undoubtedly the valves. Any care taken with these parts during manufacture will be repaid during the whole life of the valve. Small savings, such as those made by polishing the ports, reducing the weight or the effective lift of the valve, decreasing the lost time to open the valve at the beginning of the suction stroke or to close it at the end of the delivery stroke, or by increasing the time between overhauls are the points to be aimed at during the design and manufacturing periods. The suction and delivery valves are usually of the same type, the only differences being in the spring load and the lift. It is therefore necessary, during cleaning, that the valves be treated as units, the various parts assembled exactly as before they were dismantled. The spares also should be clearly marked "SUCTION" and "DELIVERY" and used only for that purpose. No. H16 illustrates a modern type of valve designed specially for high and medium speed air compressors. The seat (9) is usually made from 0·4 per cent. carbon steel, machined all over from a solid blank. Owing to the high finish, minimum losses are secured. The tapered ports with the inlet edges well rounded off and the passages finely finished, so assisting to reduce losses, are milled from the solid blank. The multiple ports give a large effective area which allows a low lift being used. The faces on the seat, where the valve bears, are narrow and have a mirror finish; by these means air tightness over a long period is assured. A pin can be seen in the seat; this prevents the various parts from rotating, and must never be left out when assembling. The distance piece (8) sets the lift of the valve and therefore the free escape area. The valve (7) is usually made from high-grade steel plate, rolled and cross-rolled, to prevent unidirectional grain flow. The steel used may be nickel steel, chrome vanadium steel, or stainless steel. In order to keep the weight down to a minimum, ports are trepanned or milled through the plate and the burred edges carefully removed. Particular care is taken to leave no nicks or scratches; these might cause a concentration of stresses and lead to a broken valve. The plate is now heat-treated to obtain hardness of between 300 and 400 Brinell. The valve is now ground to a mirror finish on both faces. The sharp edges are then carefully finished to small, very smooth, radii. The cushion plate (6), spring plates (5) and (4), also the cover plate (3), are all made from steel. The grade and quality of the steel used for each part is carefully chosen to suit the duties required from it. The machining process for each is almost the same; the ports or apertures are either trepanned or milled through the plates, which are then ground on both faces, all sharp edges carefully removed, leaving a small smooth radius on all edges. The plates are now heat-treated, if necessary, and in the case of the springs (5) and (4) the tongue is set to the correct deflection, so giving the exact pressure required. The cushion plate (6) effectively reduces the impact forces of opening. The spring (4), similar to (5), bears on the ribs on (7). The valve plate has therefore three points of applied pressure distributed equidistantly. This method ensures the valve being seated firmly, promptly, and gently without rebound or leakage. When all parts are assembled on the stud, in the correct positions, the valve cover plate (3), the washer (2), and the nut (1) are put on, screwed up tight, and locked by a split pin.

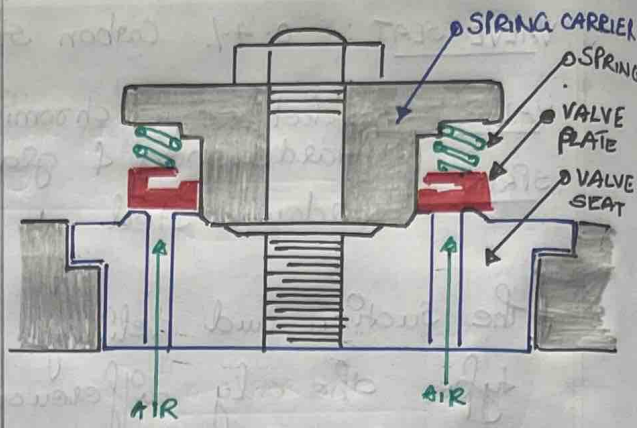

CASTLE NUT
NUT WASHER
SPLIT PIN
BUFFER PLATE
SPRING PLATES
DAMPER PLATE
VALVE PLATE
GUIDE WASHER
CENTRE BOLT
LOCATING PIN OR DOWEL
VALVE SEAT

SUCTION VALVE



* As piston moves down, vacuum inside over comes spring pressure and valves move downward to open and allow intake of air through suction filter

DELIVERY VALVE



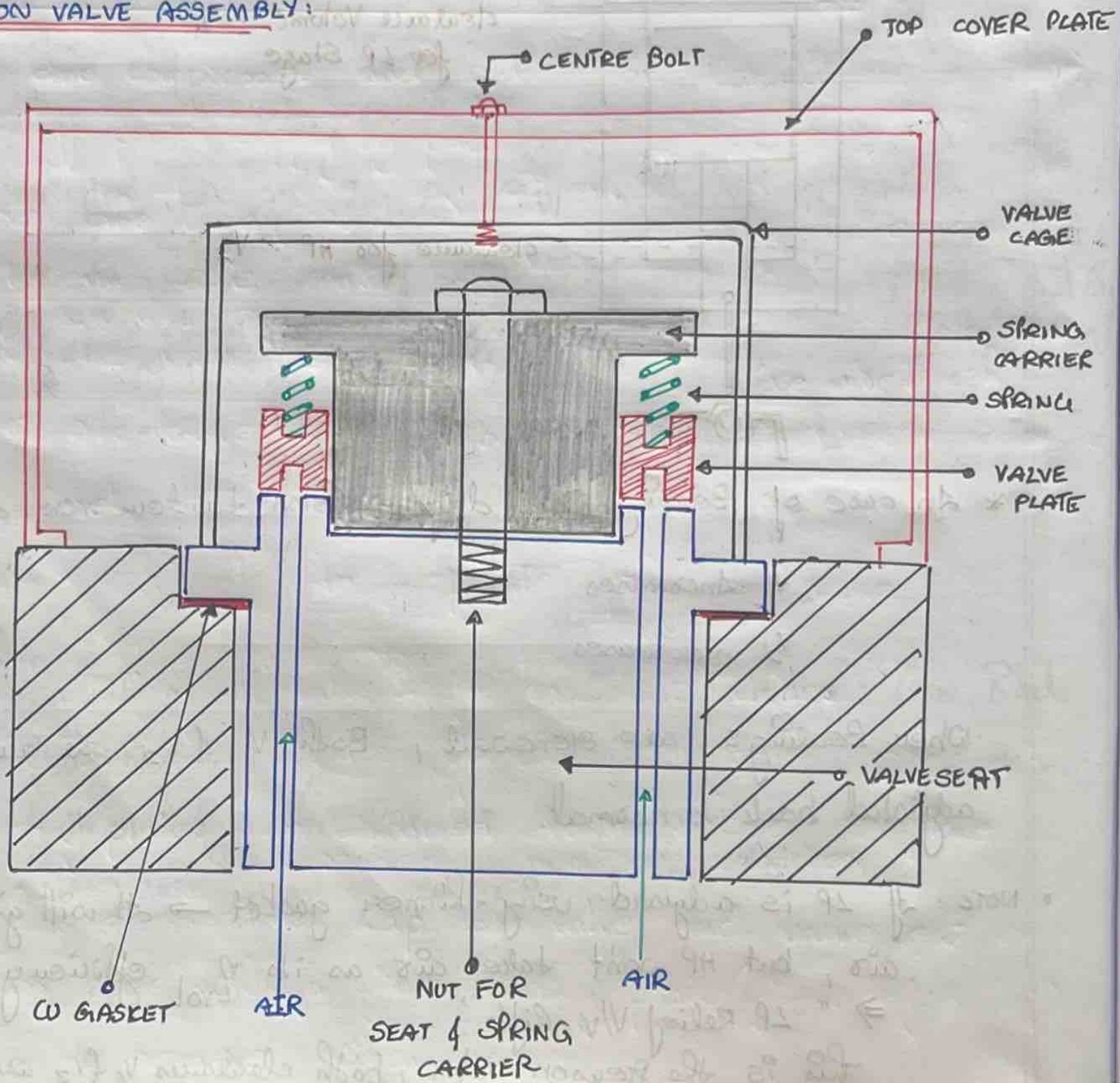
*As piston moves up, air pressure overcomes the spring pressure and lift up the valve plates as shown

- NOTE: Suction Valves are usually larger than delivery valves.
  - they cannot be interchanged as their landings are different
  - the valve plates can be placed upside down.

- OVERHAULING AIR COMPRESSOR PLATE TYPE VALVES:

- stop the compressor and put it on Manual (Not on STBY)
- shut off power supply by putting off the breaker
- Remove the Cage (cast Iron) after removing plate cover. by loosening the centre bolt.
- Remove the valve using plier.
- clean the valve off of carbon deposits (use wire brush) and then wash in diesel.
- Remove seat nut to separate spring and valve.
- checks:
  a) Condition of Valve Seat: for cracks, scratches
  b) condition of Plates: for cracks, scratches, corrosion, bending
  - If plates are thinned down, twisted : replace corroded & numerous scratches
  c) In case of scratches, Lap the valve and valve seat on a glass plate with a fine grinding paste (figure of 8 Lap) wash to remove grinding paste

SUCTION VALVE ASSEMBLY:



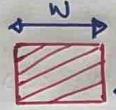
- Plates can be placed upside down
- Blow through the faces to remove any lapping paste with air

Box Back: - Place plate, Place spring & spring carrier and then tighten with nut. "Valve assembly"
- Place it upside down: Use a rod/screw driver and check the operation of the valve: Seats are pressed & then released → seat rests back due to spring
"Plates to easily move" ⇒ "Movement of plate against spring"
- Carry out Leak test: Put water (or diesel) in air passages (when valve is upside down)
- Do not use Lube oil
- Wait for 10-15 minutes to observe for leaks

- Prior placing the valve in the seat pocket, place the copper gasket after annealing and apply copa-slip. Then apply valve, valve cage & cover

- NOTE: As Air compressors deal with only fresh air, the wear down of components are comparitively minimal
- Overhauls of compressor, for the above reason are after long intervals: ~~20~~0000 hours - 30,000 hours
- Rarely any wear on Piston, rings and liner

a) Piston checks: Piston ring width, clearances (Axial, Radial)



- Condition: Wear, broken, Grooded
- Loss in elasticity
- Check scrapper rings

b) Suction filter: If partially choked, it will create vaccum at the time of suction. ⇒ Compression Ratio is too high
⇒ LP stage temperature is very high: "Leads to Explosion, "dirty"

c) Clean oil filters that is inside the crankcase

d) Change Crankcase oil : 1000 - 1500 hours (As per PMS)

d) check cutouts : L.O. Low pressure trip, High air temperature

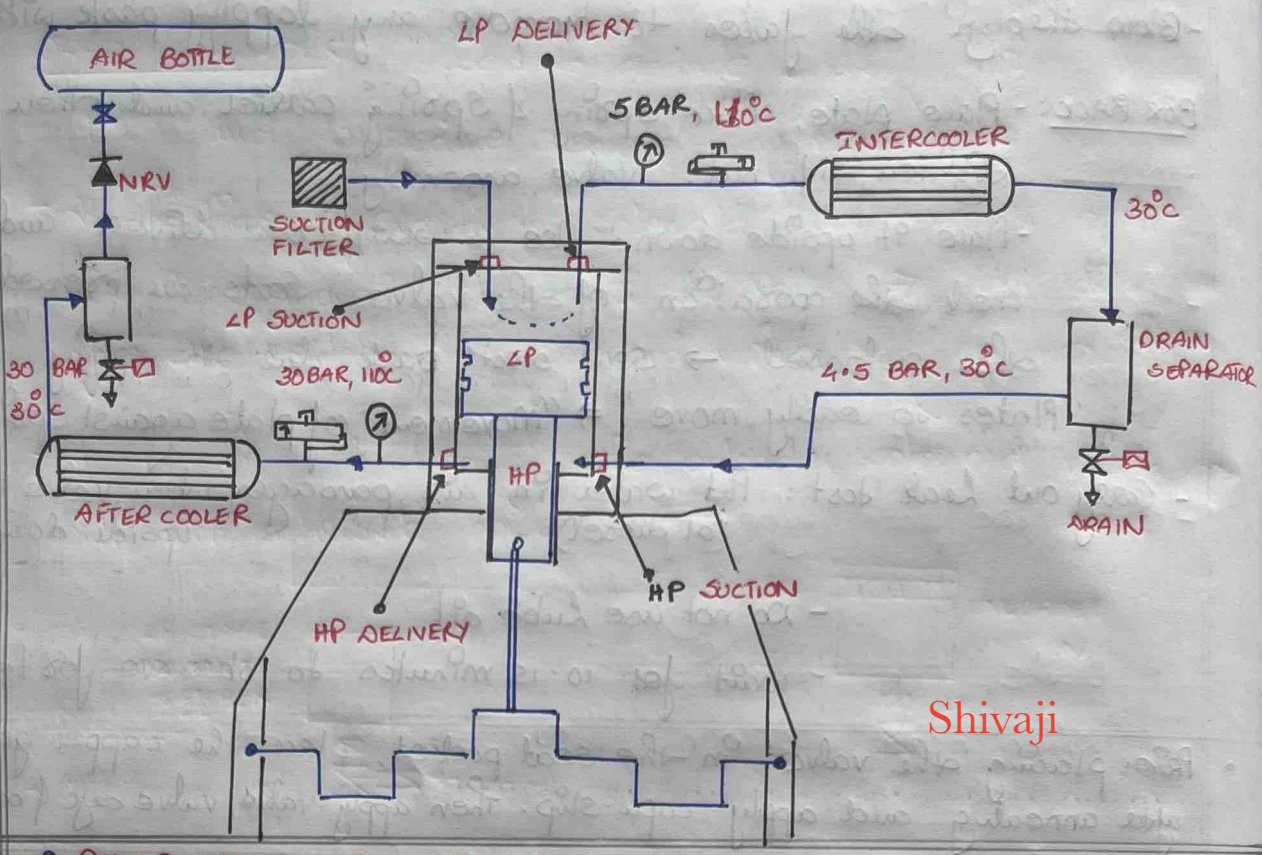
f) Valves to be checked. Lapped if necessary on glass plate

g) check condition of Unloader and clean filters due to carbon deposit : 250 hours

h) Valve Overhaul : 250 hours : Cleaned, Lapped

i) Coolers to be cleaned (tubes have deposit): 250 hours

HOW TO CHECK THE CONDITION OF VALVES AND THEIR OPERATION:



(1) LP RELIEF VALVE IS LIFTING: "Relief Valve set at 10% above work pr

* HP suction valve is leaking (25 Bar air flows in a return pat
* HP delivery valve is leaking (High pressure air enters in HP stage → High pressure in the stage and hence, 5 Bar air from LP delivery will not enter and pressurise the line
* Tubes may be chocked in intercooler

- RELIEF VALVE PRESSURE TESTING: To be done once in 6 months.
  - Workshop → Hydraulically testing.

% OPERATION CHECK OF SUCTION AND DELIVERY VALVES:

- Compressor to be ensure in stop condition
- Place hand on suction filter
- Turn Engine and when piston is turned from TDC to BDC, Vacuum must be felt on Hand.

⇒ "LP discharge/delivery Valve is intact"

- otherwise, if it was leaky, air would enter from discharge side and vacuum will not be felt

⇒ "LP Suction Valve is Intact"

- When further turned, as piston moves from BDC to TDC, no air shall be felt on the hand, which would indicate leaky valve, otherwise. If pressure is felt on hand, valve suction is leaky. (Less air in LP stage, compressor runs longer as air is get continuously leading.

⇒ "HP Delivery Valve is Intact"

- Remove NR valve.
- Air from air bottle will flow back
- HP piston to be at TDC.
- Remove HP Suction Valve.

- Compressor runs longer
- LP & HP delivery pressure drops

- If HP delivery valve leaks, air will be felt at Suction Valve passage/pocket

(2) HP RELIEF VALVE LIFTING:

* NR Valve defective

- REASONS FOR HIGH DELIVERY AIR TEMPERATURE

* Inefficient cooling water
* Chocked of the cooler tubes

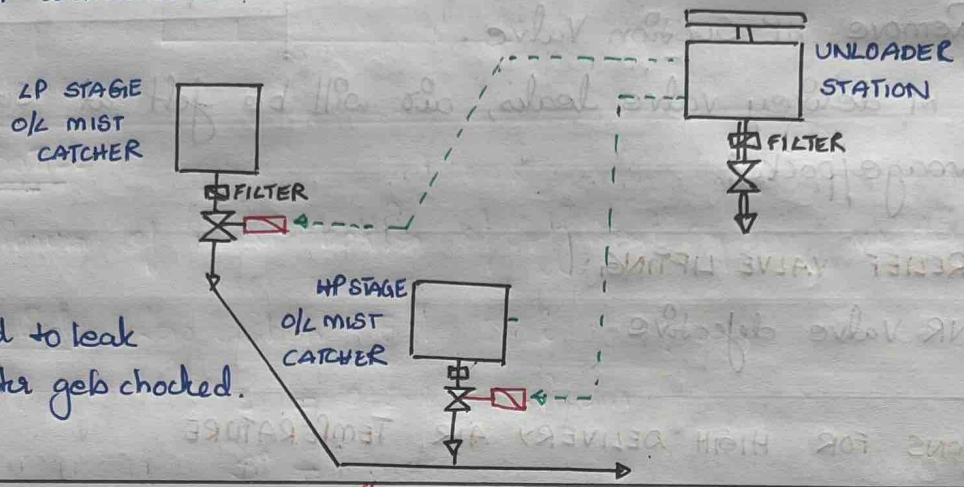
- REASONS FOR LONG RUNNING OF COMPRESSOR:

* Leaky suction valves
* Defective Unloader drain valves
* Dirty/clogged Air filter
* Defective/Worn piston rings : Blow past
* Air bottle drain valves are open
* Drop in η_{vol} due to increase in bumping clearance
* Faulty pressure switches

• TYPES OF UNLOADERS IN AIR COMPRESSOR

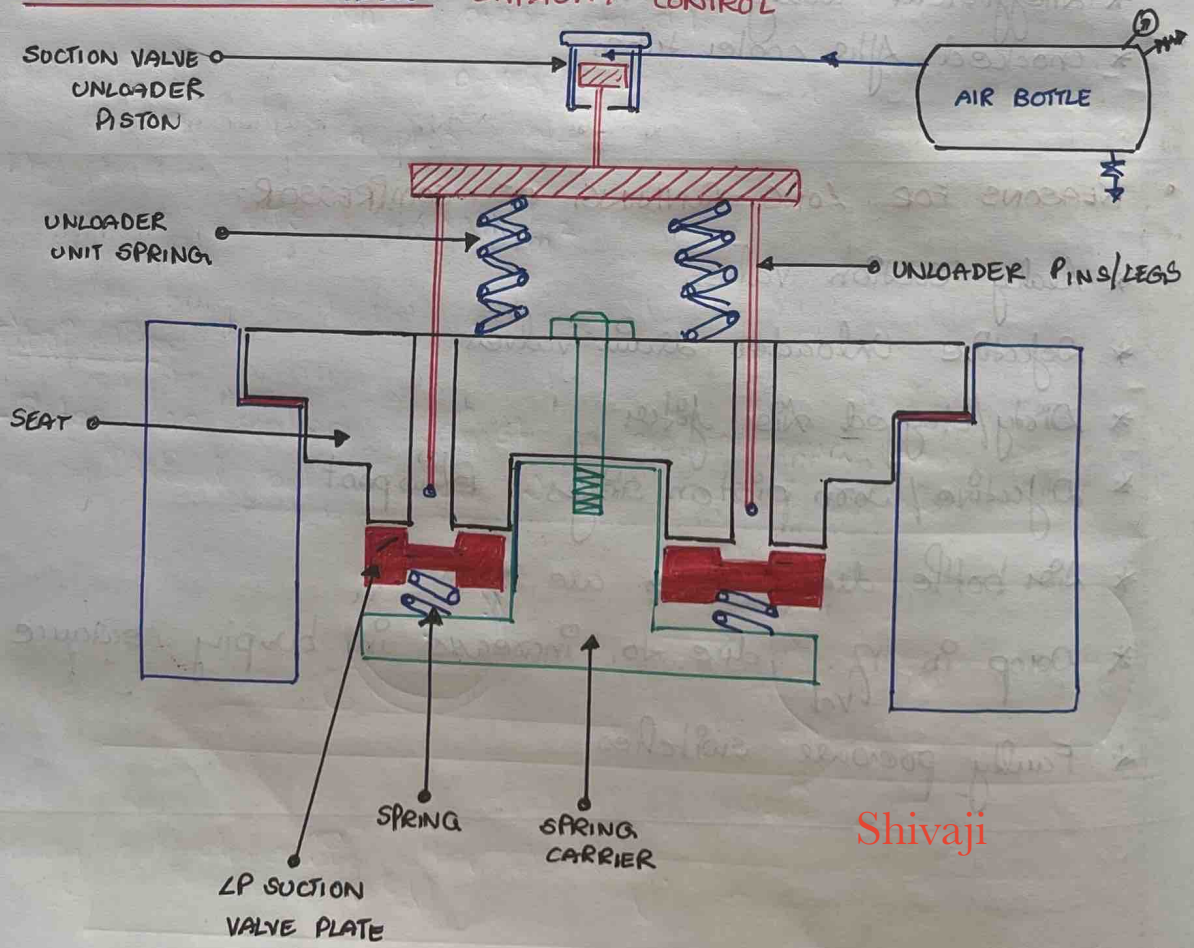
(1) **DRAIN UNLOADER:** "Used to reduce starting torque on the motor and to reduce/remove any moisture"

- At the time of starting, solenoid drain valves open and air is removed "characteristic Noise" ⇒ "Unloading" After the certain time, solenoid valves shut & compression starts
- At the time of stopping, the unloader solenoid valves open with a characteristic noise

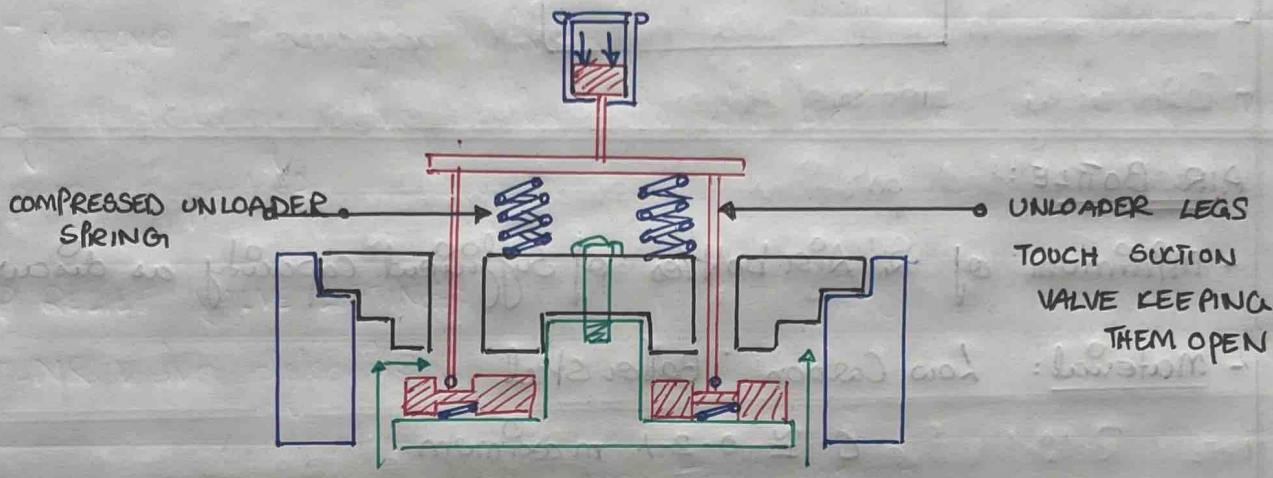


* Tend to leak as filter gets chocked.

(2) **SUCTION VALVE UNLOADER:** "CAPACITY CONTROL"



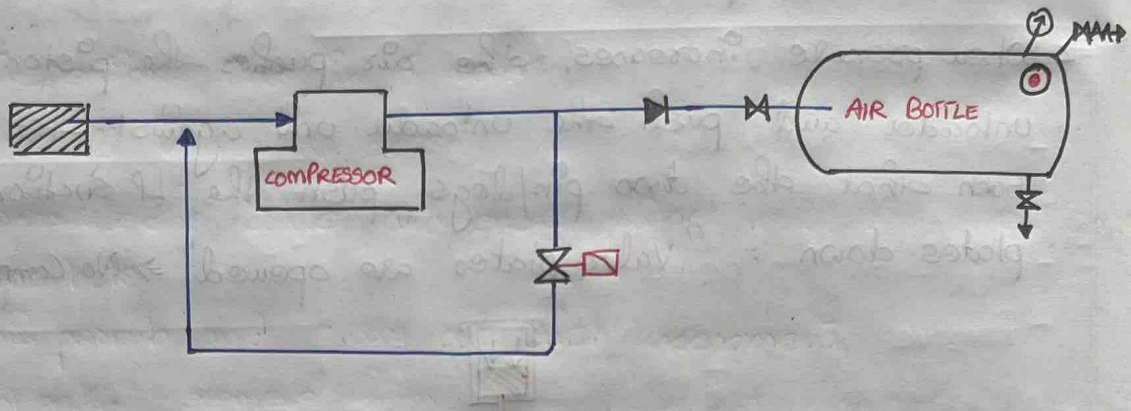
- This type of compressor unloader is used in low pressure compressors where continuous air is used (fluctuations in air demand) (Deck air compressors)
- When Air bottle pressure is low, spring pushes the unloader unit upwards.
- When pressure increases, the air pushes the piston of the unloader and push the unloader unit against the spring such that the two pin/legs push the LP suction valve plates down : "Valve plates are opened" ⇒ No Compression



Example: Deck air compressor running continuously
- 7 chipping Machines were being operated
- 2 chipping Machines stopped
  - Air pressure increases and now acts on the unloader piston and will keep the valves open so no further compression takes place
  - If again another chipping machine is started, unloader spring compression decreases as the unloader piston receives less air due to drop in bottle pressure, thus closing the suction valves as legs move up and loading the compressor

3) BYPASS UNLOADER:

- Air upon discharged to the air bottle and upon overpressising, air is discharged back to the suction side



- AIR BOTTLE:

- Minimum of 2 Air bottles of sufficient capacity as discussed

- Material: Low Carbon Boiler steel

C ≅ 0.2-% maximum

Si = 0.35%

Mn = 0.05-% to 0.1-%

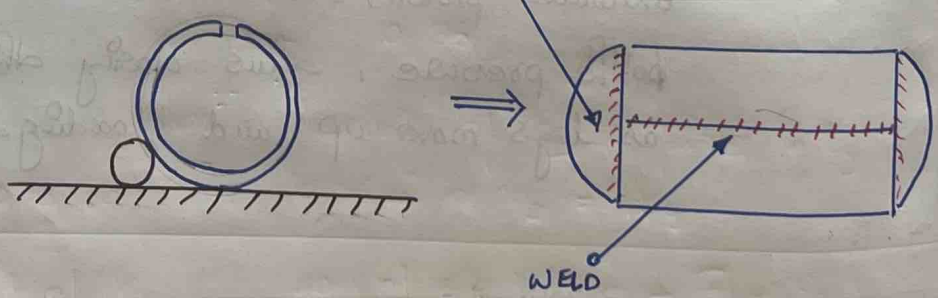
S = 0.05-%

P, Phosphor : 0.05

UTS : 460 MN/m^2

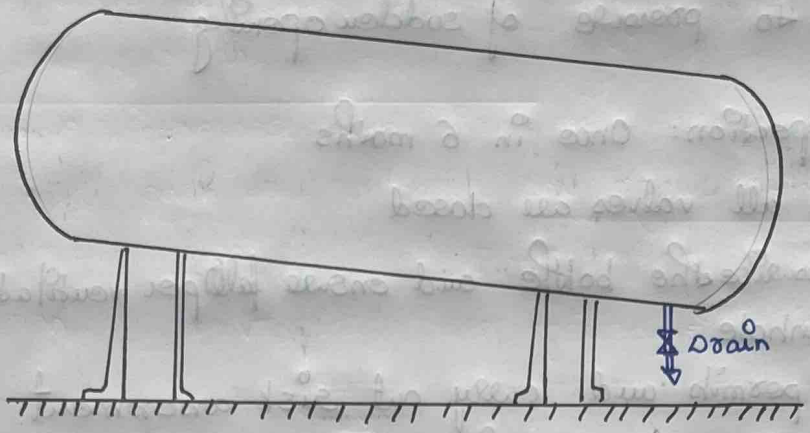
Fabrication:

- Plates are rolled against a roller and then welded for a cylindrical configuration. "Dished Ends" are also welded



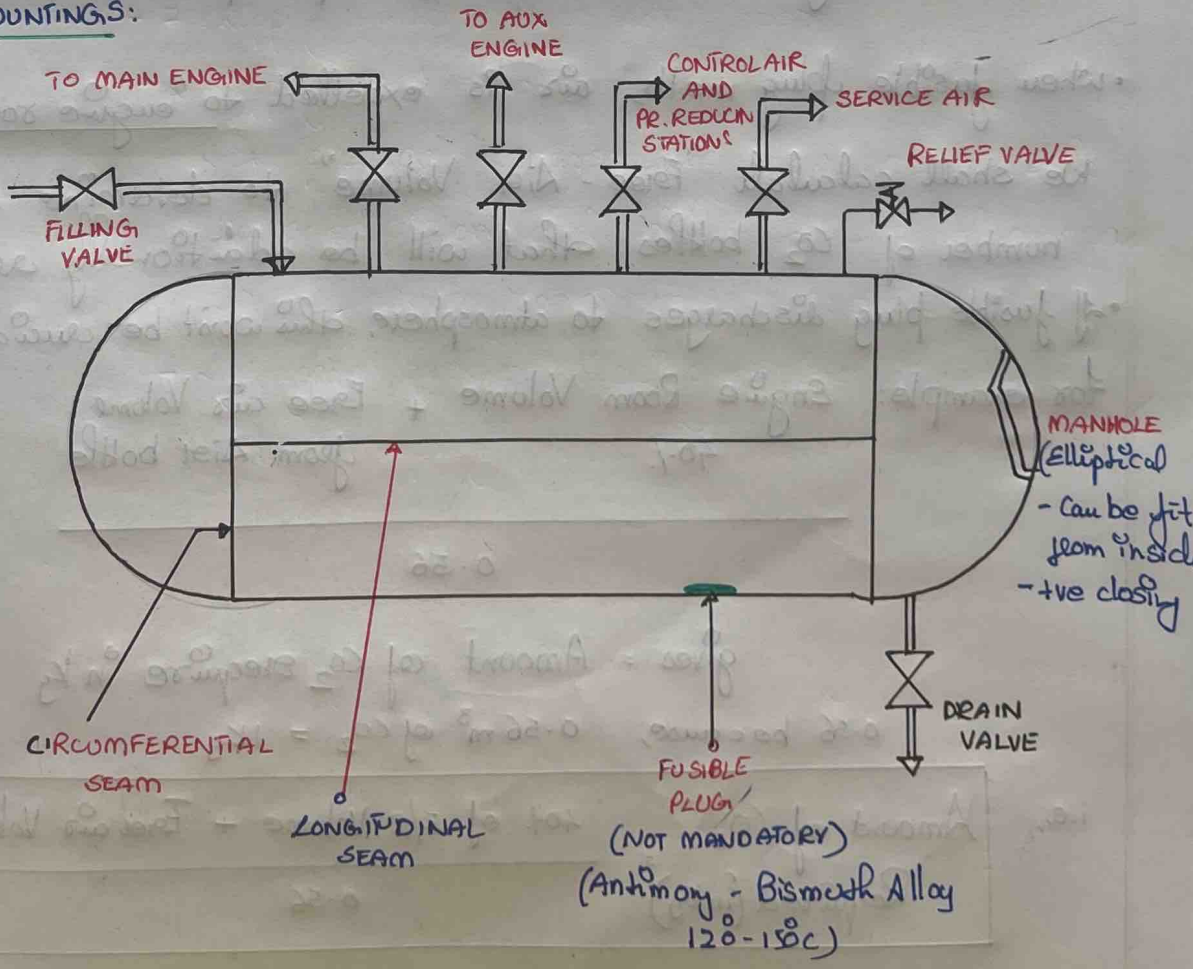
- Carry out Annealing after Welding.

- Air bottles to be fitted slightly tapered so as to have an arrangement for condensate draining.



- Air bottles internal surfaces are subjected to corrosion due to presence of air, water and oil vapours. To protect from effects of corrosion, they are internally coated with "clear COPAL Varnish"

MOUNTINGS:



- All valves are SDNR and slow opening due to their fine threading on valve spindle.
  Gradual opening allows prevention of rupture of pipelines due to pressure of sudden opening

For inspection: Once in 6 months
- Ensure all valves are closed
- Depressurise the bottle and ensure proper ventilation after removing of manhole
- Obtain permits and carry out risk assessment
- Preferably, remove shoes so as to not damage the coating
- check welded portions, internal coating and other checks for corrosion & pitting

NOTE: Relief Valve : works on principle of pressure rise
Fusible plug : works on principle of temperature rise

- When fusible plug melts, air is expelled to "engine room"
  We shall calculate "Free - Air Volume" to determine the number of CO_2 bottles that will be additionally required
- If fusible plug discharges to atmosphere, this won't be crucial.

for example: $\frac{\text{Engine Room Volume} + \text{Free air Volume}}{0.56}$
40% from Air bottle

gives = Amount of CO_2 require in kg

0.56 because, $0.56\ m^3$ of CO_2 = 1Kg

i.e., $\text{Amount of } CO_2 \text{ Required (in Kg)} = \frac{40\% \text{ of E/R Volume} + \text{Free air Volume}}{0.56}$

Nowadays, fusible plugs are not required.

If the air bottle relief valve can be isolated from the air bottle, then only a fusible plug is required.

To calculate free air volume:

* free air volume: When air from air bottle is released, the volume that it occupies is "free air volume"

Suppose Air bottle pressure $\Rightarrow$ "30 Bar" = P_1

then, $P_1 V_1 = P_2 V_2$

$\Rightarrow (30+1) V_1 = (0+1) V_2$

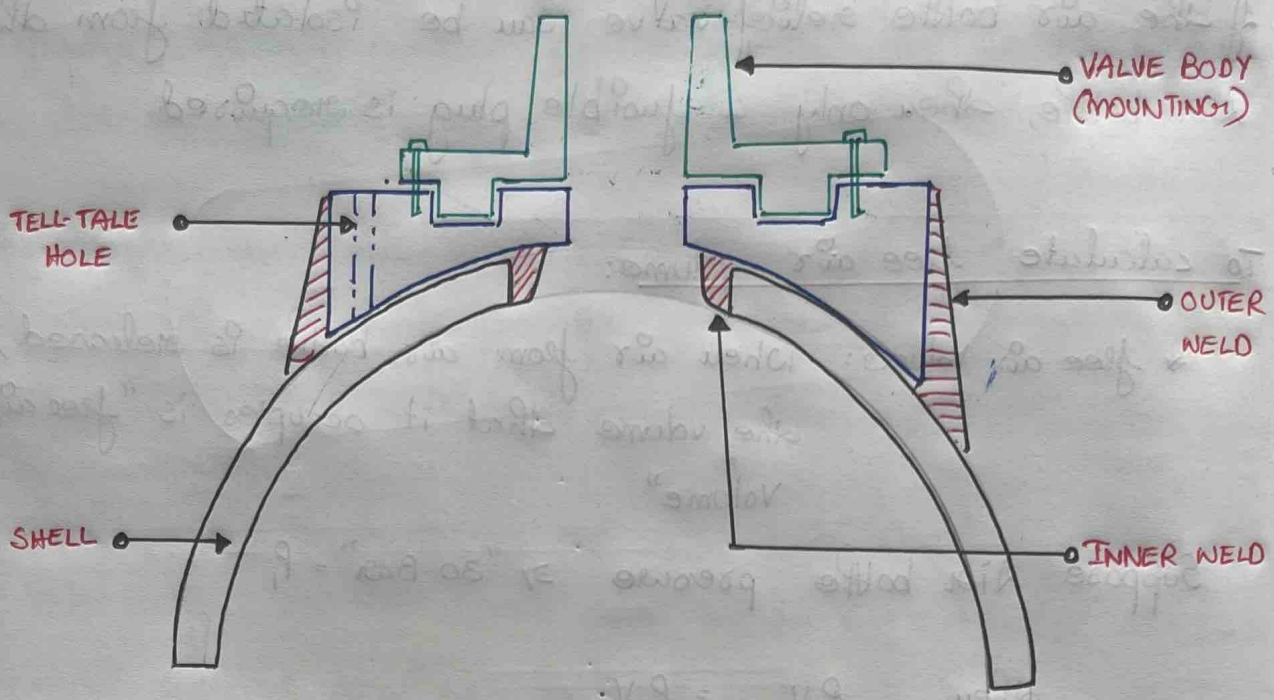
$\Rightarrow V_2 = 31 V_1$

i.e., free air Vdume will expand & occupy 31 times the Vdume of air bottle.

- EMERGENCY AIR BOTTLE : first start arrangement
  - Sufficient capacity with an air compressor to be capable of providing 3 consecutive kicks of generator Engine
  - for inspection, since small $\Rightarrow$ Cannot enter

  Hence, pressure testing is done. (2 times the working pressure)

HOW MOUNTINGS ARE FIT:



Description:

- When the shell is cut for a mounting/fitting, it becomes weak.
- A compensating ring is therefore attached and welded from inside & outside as shown
  The compensating ring has a tell-tale hole
- The outer weld can be inspected from outside
- Inner weld cannot be inspected from outside.
  If it cracks, high pressure air will be seen flowing through tell-tale hole indicating "Crack in the weld"

* Air bottle pressure test is carried out during manufacturing
* Only Air bottle inspection is carried out. (6 months)