CONCEPTS OF PURIFICATION AND PURIFIER OPERATION

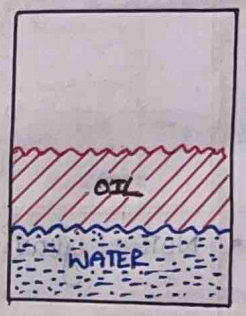
- **PURIFICATION:**

- "Process of separation (or removal) of 2 immiscible liquids (oil and water) (or impurities, contaminants from a liquid"

Importance of Purification: Prevents the damage of following
a) Liner
b) Fuel Injector
c) Piston ring & Exhaust Valve.

- **METHODS OF SEPARATION:**

(i) GRAVITATIONAL SEPARATION: Earlier Method



- A tank filled with oil-water mixture results in settling of water due to its higher density under gravity.

The separating force, as given by stoke's Law

i.e., Separating force $\propto \frac{\pi}{6} D^3 \times (\rho_w - \rho_o) g$

Here: D: Diameter of water droplet
ρ_w: density of water
ρ_o: density of oil
g: gravitational force (acceleration due to gravity)

Factors affecting separating force

a) Separation Temperature:

- When oil-Water Mixture is heated (heated), it is evident that density of water drops slowly than that of oil.
- Due to this, density difference increases.

i.e., $(\rho_w - \rho_o)$ = Increases

As separating force, $SF \propto \frac{\pi}{6} D^3 (\rho_w - \rho_o) g$

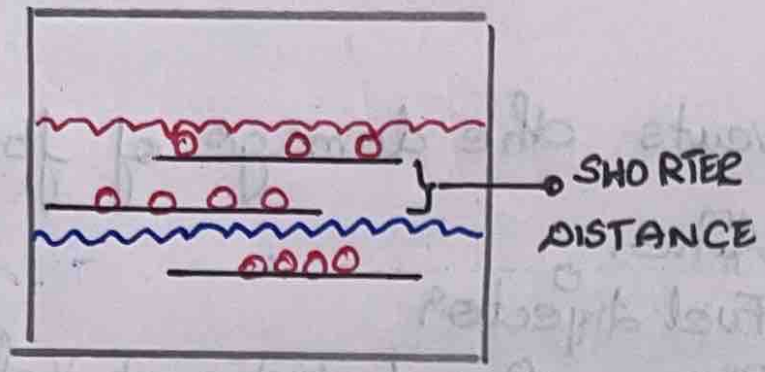
$\Rightarrow$ Separation is faster

b) Also, viscosity of oil & water drops
i.e., Viscous oil floats

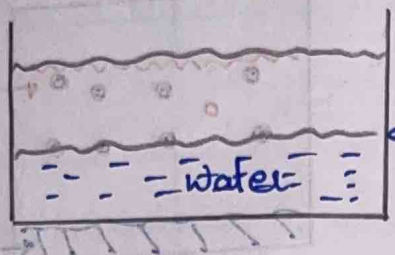
b) Surface area :

Suppose horizontal plates are placed in the (purifier) tank from the figure,

the oil droplets will have shorter distance to travel



"The line where water & oil separate" : Interface.

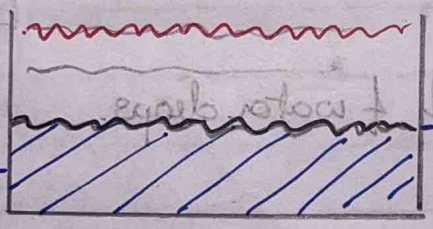


- Disadvantages: a) Longer time
b) Gravitation force isn't sufficient, hence, SF has to be increased. Centrifugal force is used.

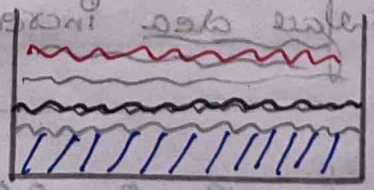
$\therefore$ S.F $\propto \frac{\pi}{6} D^3 (\rho_w - \rho_o) \times r\omega^2$; where $r\omega^2$ = Centrifugal force

NOTE: Settling tank is employed in modern day purification system
↳ Improves efficiency of purifier.

- We have to maintain the interface.



a) Water keeps being removed and if it is removed at a faster rate, oil comes down → seal breakage.



b) If water is removed slowly, water will be carried with oil

- NOTE: Gravitational separation is a time consuming process when engine is in operation, we require large quantity of oil which is pure and gravitational separation can't cope up. In this case, we need to increase the separation force so as to improve the rate of purification, and also the quality of purification so as to meeth the quality & requirements of the Engine system

Therefore, gravitational force is replaced by centrifugal force.

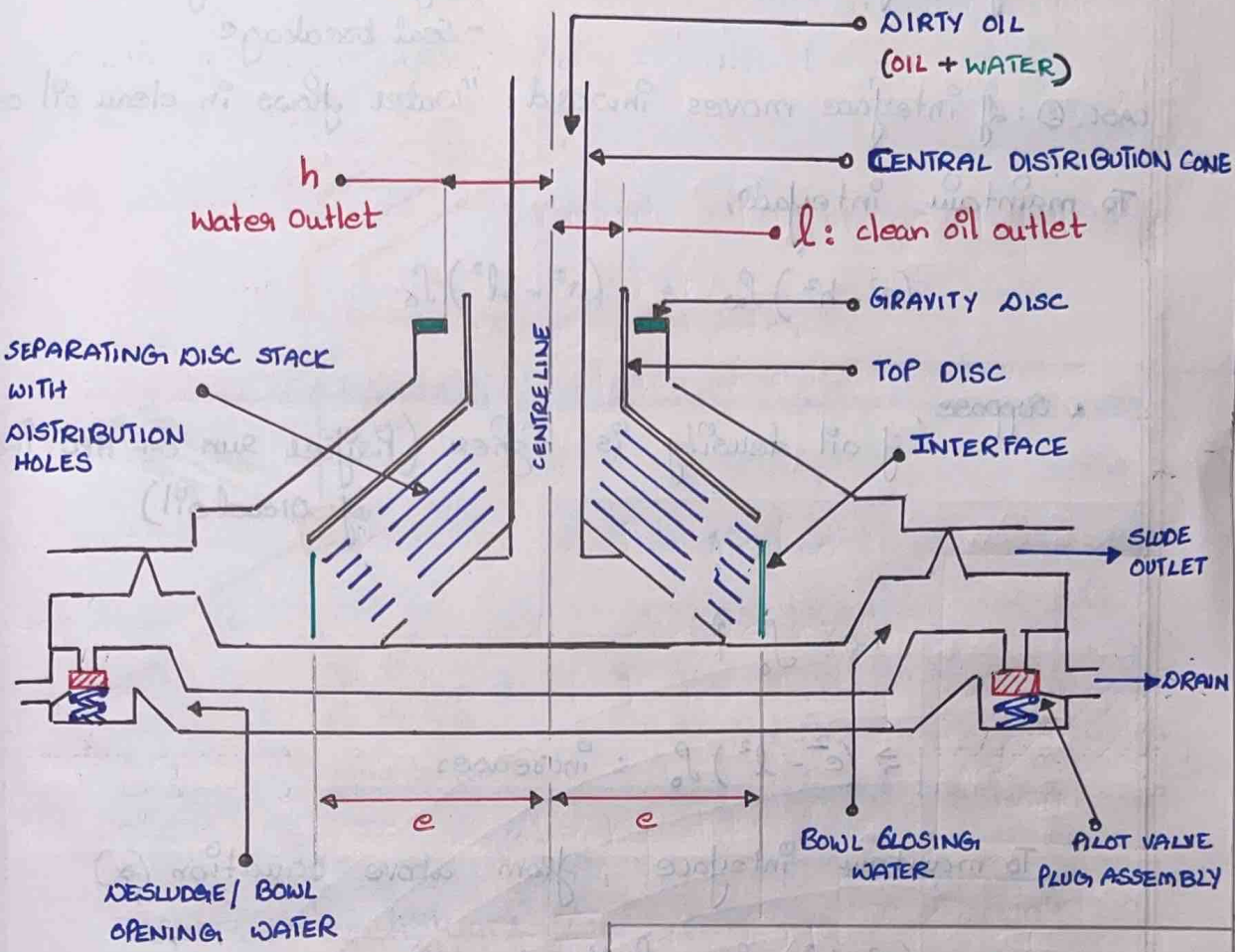
Then, separating force for a purifier $\propto \frac{\pi}{6} D^3 (\rho_w - \rho_o) \times (r\omega^2)$

where; $r\omega^2$ = Centrifugal force

CAUSE OF INTERFACE:

"Created by 2 liquids of different specific gravity"

CONCEPT OF OPERATION OF A PURIFIER



e: Distance of interface from centre line of purifier
h: water outlet
l: oil (clean) outlet.

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DESCRIPTION:

- Dirty oil enters the central distribution cone, the oil gets carried towards bowl periphery by the centrifugal force
- It then passes through the disc stack, where the "Actual separation takes place. Discs increase efficiency of Purifier by increasing surface area i.e., 150 - 160 discs, 0.5 - 0.6mm apart
- The oil mixture enters the gap between discs.
- Here 2 forces act on each solid (sludge) & liquid particles
  a) Throughput force acting upwards due to oil feed
  b) centrifugal force acting towards periphery ($\rho_{sludge} > \rho_w > \rho_{oil}$)

Dense particles (sludge > water) move outwards & oil towards centre.

"Interface should be maintained at the periphery of the separator disc stacks and inside the periphery of Top Disc"

CASE ①: If interface moves outward: "Overflow": Oil carry over in water
- Seal breakage

CASE ②: If interface moves inward: "Water flows in clean oil outlet"

To maintain interface,

$$(e^2 - h^2)\rho_w = (e^2 - l^2)\rho_o$$

* Suppose, if oil density is higher (Purifier run on HFO instead of Diesel oil)

i.e. $\rho_o \uparrow$

$\Rightarrow (e^2 - l^2)\rho_o$: increases

To maintain interface, from above equation (*)

$(e^2 - h^2)\rho_w$ shall also increase.

$\Rightarrow$ the only variable is "h".

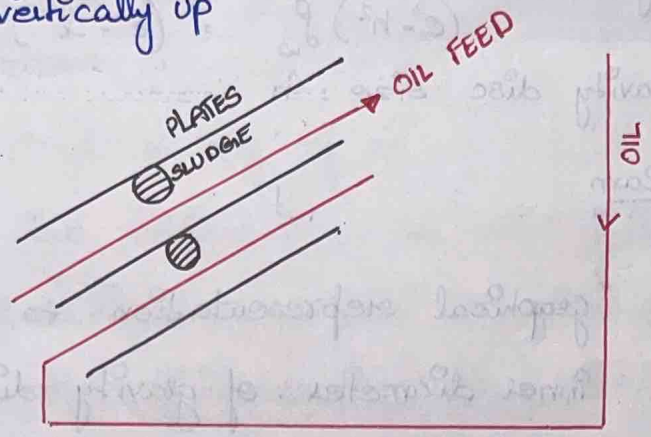
$\therefore$ when 'h' is decreased, $(e^2 - h^2)\rho_w$ increases

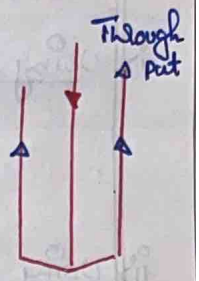
so as to meet LHS = RHS

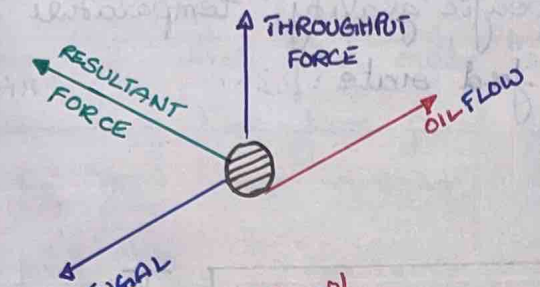
$\therefore$ **Gravity Disc Size $\propto \frac{1}{\text{Oil Density}}$**

HOW SEPARATION TAKES PLACE?

- As oil enters from top it provides the through-put force acting vertically up

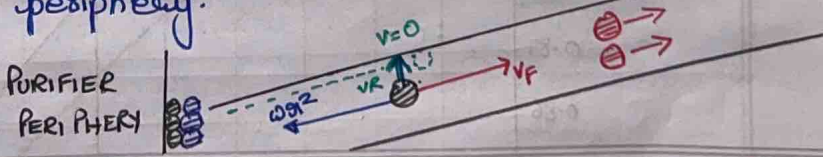






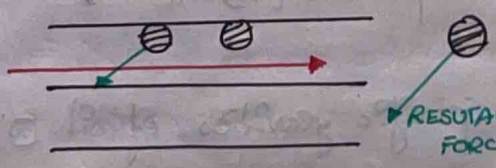
oil
sludge
water

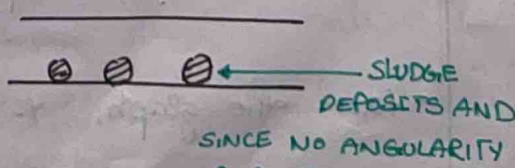
* After passing through the central distribution cone, the oil-mixture enters the separating disc channels.
* Here both solid (sludge) & liquid (oil + water) particles are subjected to 2 forces
* the particles are lifted upwards due to oil stream and also centrifugal force acts on the particles towards periphery.
* A resultant force develops, which causes the particles to strike the plate surface and loses its momentum and due to the angularity of plates, dense particles slide towards periphery.



Q: Why separating plates are at an angle & not horizontal?

A: If there were horizontal plates: there would be





SINCE NO ANGULARITY OF PLATES, NO SLIDING OF SLUDGE TO PERIPHERY

"Leads to choking of plates"

⇒ Purifier shut down

- HOW TO DETERMINE THE SIZE OF GRAVITY DISC:

i) Using the formula:

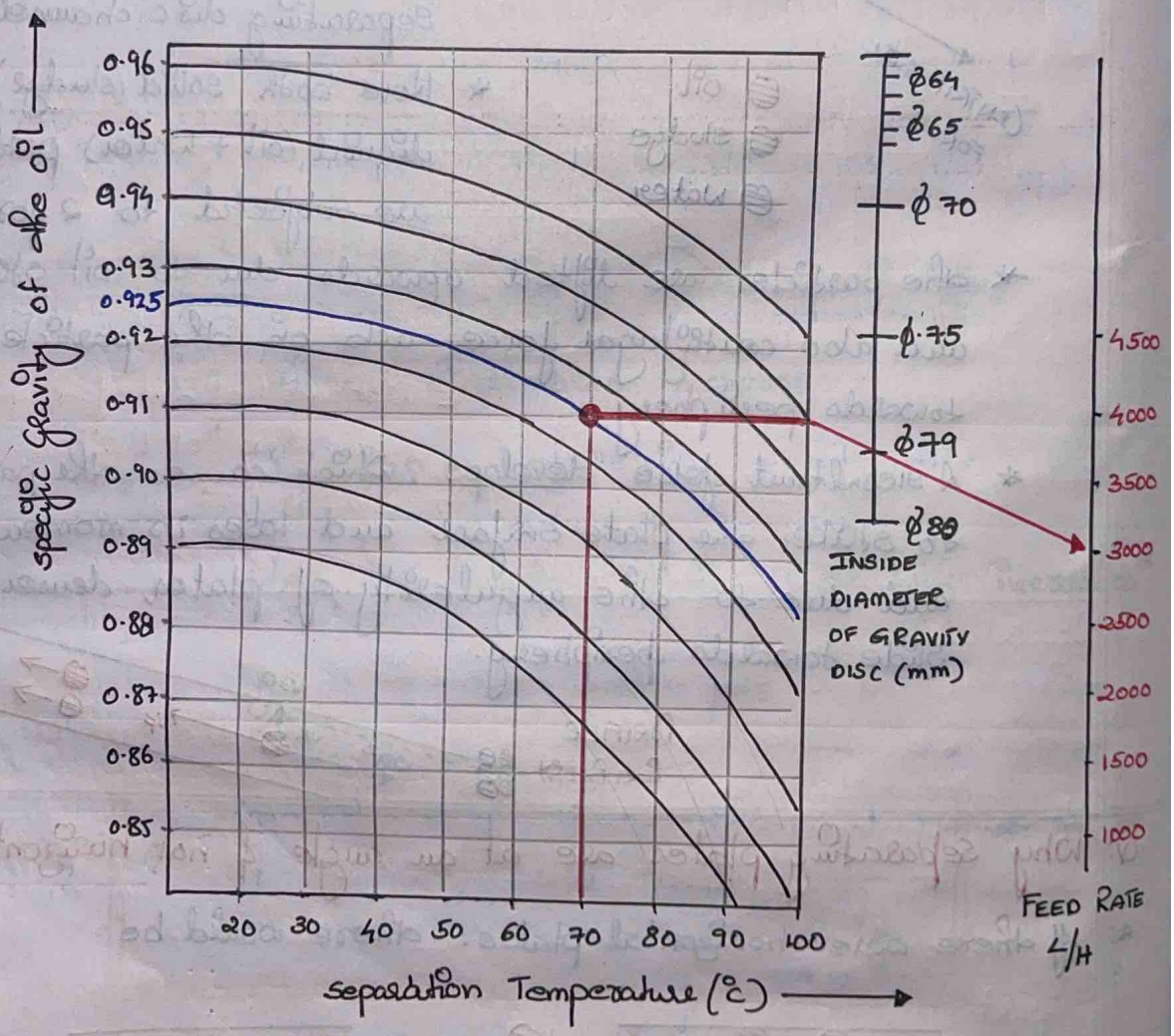
$$(e^2 - h^2)\rho_w = (e^2 - l^2)\rho_o$$

gravity disc size : h

ii) Using Nomogram

NOMOGRAM: "graphical representation to determine the inner diameter of gravity disc using factors such as specific gravity, temperature of separation, feed rate".

Description



- from the graph, Y-axis: Specific gravities of oil @ 15°C (BDN)

X-Axis

- As separting temperature increases, specific gravity falls

as represented by the downward heading curves

Now, to understand the concept of selecting gravity disc size using nomogram:

Consider specific gravity of oil 0.925 @ 15°C.

Now draw the vertical line to the falling curve of 0.925 at the separating temperature say: 70°C (Point of intersection: x)

- From this point of intersection, draw the horizontal line to the end of the chart. (Point y)
- Suppose the feed rate is 3000 litre/hour
  Draw a line from point 'y' to the feed rate scale
- This line will indicate the size of gravity disc at point 'z'. i.e, ≅ 79 mm

iii) TRIAL AND ERROR METHOD: If no NOMOGRAM is available, this method is used.

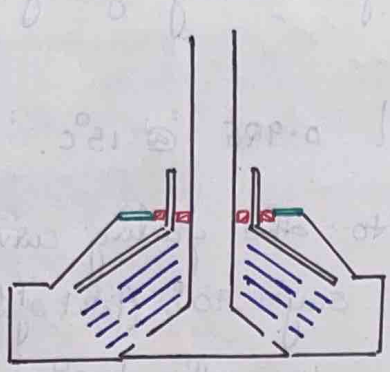
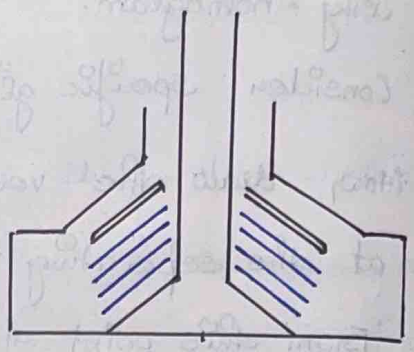
CASE I: If there are 2 gravity discs of different sizes (100 and 85, but actual is 90 mm)

a) Use of Higher size gravity Disc: (100 mm)
- oil overflow in water outlet as interface shifts outwards
- Reduce backpressure (on oil outlet) ⇒ interface shifts inwards until oil stops overflowing.

b) Use of Lower size gravity Disc: (85 mm)
- Interface shifts inwards and water flows in clear oil outlet
- Increase Back pressure to shift interface outward until water overflows with oil
- Reduce back pressure to stop oil overflow

CASE II: When there's no right gravity disc.
⇒ Maintain interface by throttling Back Pressure

DIFFERENCE BETWEEN PURIFIER AND CLARIFIER:

PURIFIER	CLARIFIER
	
i) Used to separate 2 immiscible liquids	ii) Used to separate solids from liquids
iii) Has 1 inlet : Dirty oil 2 outlets: clean oil & water	iii) Has 1 inlet : Dirty oil 1 outlet : Clean oil
iv) Top disc with neck so as to provide for a 2nd outlet for water	iv) No neck on top disc (sometimes No disc top)
v) Separating Disc stacks have distribution have holes	v) No distribution holes
vi) Requires gravity Disc	vi) No gravity Disc
vii) 2 Pairing Discs on - clean oil outlet - water outlet	vii) One Pairing disc
viii) Requires Sealing Water	viii) No Sealing Water required

PAIRING DISC: Acts like a centripetal pump
- Works on centripetal force (unlike centrifugal force)
- It remains stationary, while oil/water cuts from sides and discharge
- It takes oil & water from the purifier bowl and transfers it to attached gear pump inlet driven
- Converts KE into PE

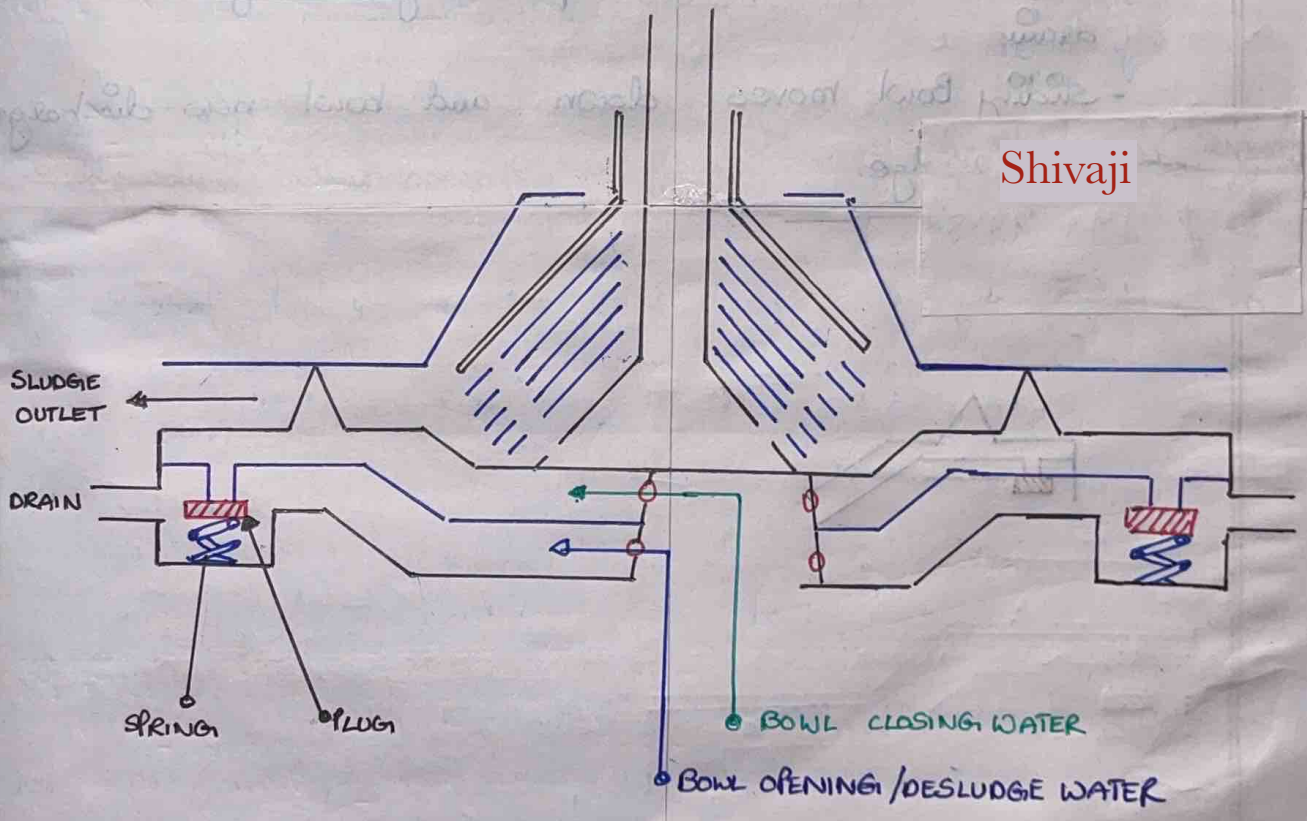
SEALING WATER:

- An arrangement provided only on Purifier to soften or condition the sludge and also to form the initial interface upon starting.

CONVERSION OF PURIFIER TO CLARIFIER:

- Replace disc stakes with the ones that have no holes
- If discs with no holes are not available, replace the last disc with no hole disc.
- Remove gravity disc and place a neck push (bush) of lowest size gravity disc
- Replace Top disc with neckless top disc
- Shut sealing water

DESLUDGE MECHANISM:



* When Purifier is running : Operating / closing water is supplied under the sliding bowl and this water due to centrifugal force lifts & closes the bowl by hydraulic pressure

- Bowl closing water is low pressure water from operating tank and won't drain due to teflon plug under spring force

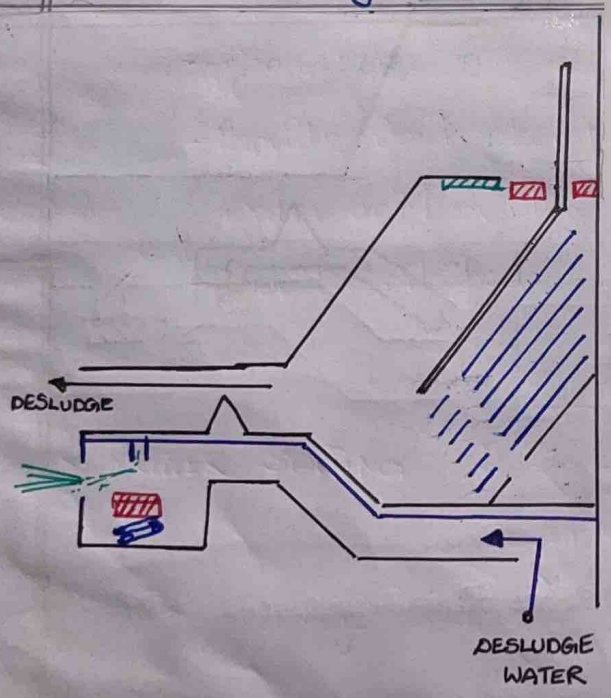
When sludge is formed at the bowl periphery, it has to be removed

MANUAL DE-SLUDGE PROCEDURE

- Stop oil feed
- Provide sealing water (until) water is seen at
  ⇒ It is a "conditional water" that softens the sludge

→ Shut operating water (Bowl closing water)
→ open Desludge (Bowl opening water) : "opening water"

- Desludge water is high pressure water from the hydrophore tank.
- It will overcome the spring pressure & move the plug downwards and operating / closing water will drain
- sliding Bowl moves down and bowl now discharges the sludge.



When desludge happens, there's a characteristic noise and Ampere increases: "which indicates desludge happens appropriately"

* Ampere Increases: "whole weight of the bowl is on the shaft which was otherwise held by the hydraulic pressure of the closing water"

- After desludge, provide operating water only after a time interval of stopping desludge water (to allow it to drain)
- Provide sealing water (until overflow at water outlet) & then shut it
- Provide feed to resume Purifying operation.

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* STARTING PROCEDURE FOR A PURIFIER:

i) Set up lines for Purifier feed Pump and ensure the 3 way recirculation valve in shut condition "Recirculation"

ii) start Purifier feed Pump and carry out heating sufficiently in fore-heaters and run in recirculation

iii) Purifier Checks: a) check gear case lube oil level
b) Ensure brakes are not applied. and free rotation of bowl

iv) Start Purifier : Monitor Amperes & Vibration
- Purifier was stopped in desludge condition. "Bowl is open"
- Upon starting, as bowl weight is entirely on the shaft (which would otherwise be held by Bowl closing water and running inertia), the Amperage will be very high (to overcome initial inertia)
- As purifier bowl attains certain speed, running inertia takes over and Amperage drops gradually. It indicates that "Bowl Speed is Acheived"

v) Provide Bowl closing water to close the bowl

vi) Provide sealing water (This is to create an interface) until overflow at water outlet and then shut it

vii) Provide oil feed "Filling". 3 Way valve opens to feed oil

"Purifier is in operation"

Check for Amperage, Vibrations & Noise, Back pressure developed

* PROCEDURE FOR DESLUDGE

- After 2-4 hours of Purifier operation or as recommended by the manufacturer, Desludge operation to be performed
- Stop the oil feed %.
- Provide sealing Water (to condition & soften the sludge)
- shut operating Water : Closing Water
- Open Desludge / Bowl - Opening Water

"Bowl opens with a characteristic Noise" & also Ampergage Increases

- This is due to the weight of the bowl body which now acts on the shaft, (as it would have been held by operating / Bowl closing water by hydraulic pressure)

* AFTER DESLUDGE :

* TO PUT IT BACK IN USE:

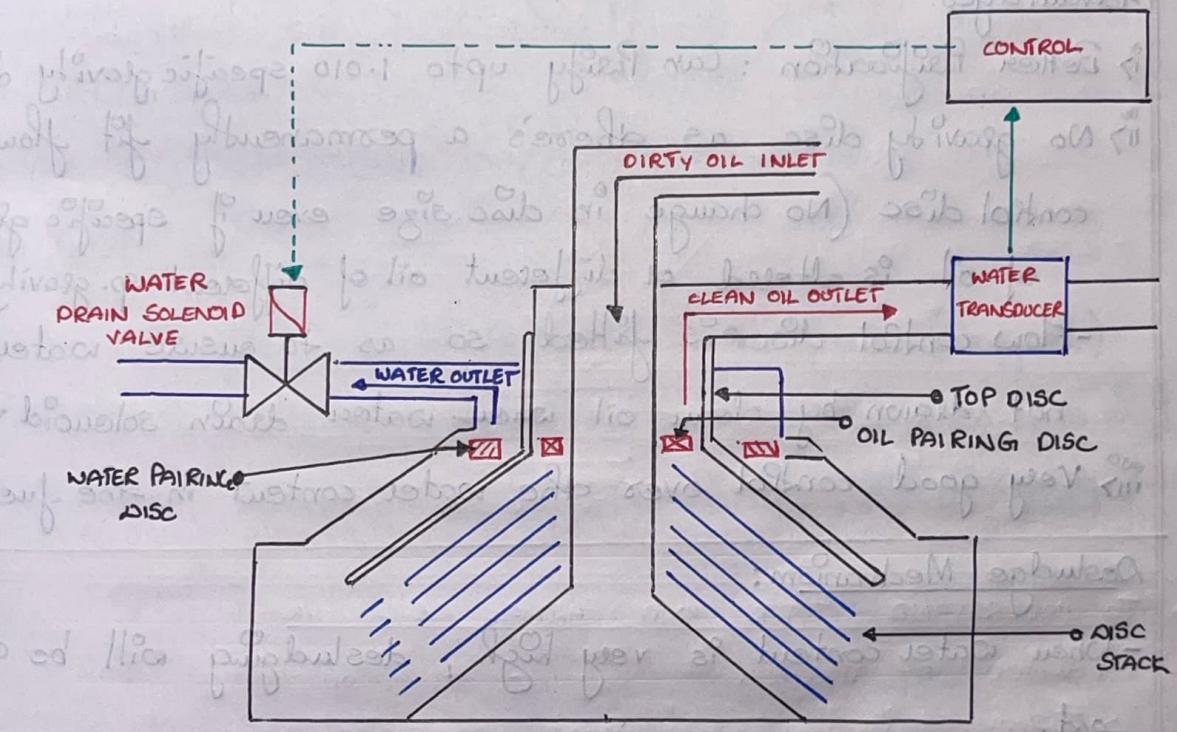
- Stop Desludge water
- After some time (to allow desludge water to drain)
- Provide Bowl closing water and the provide sealing water until overflow and then shut it.
- Provide oil feed.

* PURIFIER STOPPING: It is feasible and in good practise to desludge the purifier prior to stopping.

"Always desludge Purifier prior stopping.

Earlier, there were the use of Purifier and clarifier in series to maximum efficiency of Purification
Purifier used to remove water and then the oil was cleared off of sludge
Now, the amount of sludge is dominantly higher as a content than the content of water in the fuel/oil.
The importance of clarifier became significantly higher
Alfa

ALCAP : ALFA - LAVAL CLARIFIER AND PURIFIER: FOPX



System Description : For a FOPX ALCAP:

* Under normal operation or at starting, water drain valve will be shut. There's one inlet & one outlet (No sealing water is given)
"It acts as a clarifier"
* As operation takes place, water & sludge get accumulated at the periphery of the bowl.
* As the water gets accumulated at a higher rate, water gets carried over with oil as it separates through the

the disc stack and passes with oil to the oil outlet.

- the clean oil outlet continuously monitors the content of water using a transducer.
- the water transducer works on the principle of change in capacitance due to difference in dielectric of oil and water. (Dielectric of oil : 2-4 & water : 80)
- when a certain limit for water content is reached, the water transducer will activate the water drain valve to open to remove water; thereby acts as a "Purifier"

Advantages:

i) Better Purification : Can Purify upto 1.010 specific gravity oil.

ii) No gravity disc as there's a permanently fit flow control disc (No change in disc size even if specific gravity of oil is altered or different oil of different sp. gravity
- Flow control disc is fitted so as to ensure water is not drawn by clean oil when water drain solenoid valve

iii) Very good control over the water content in the fuel

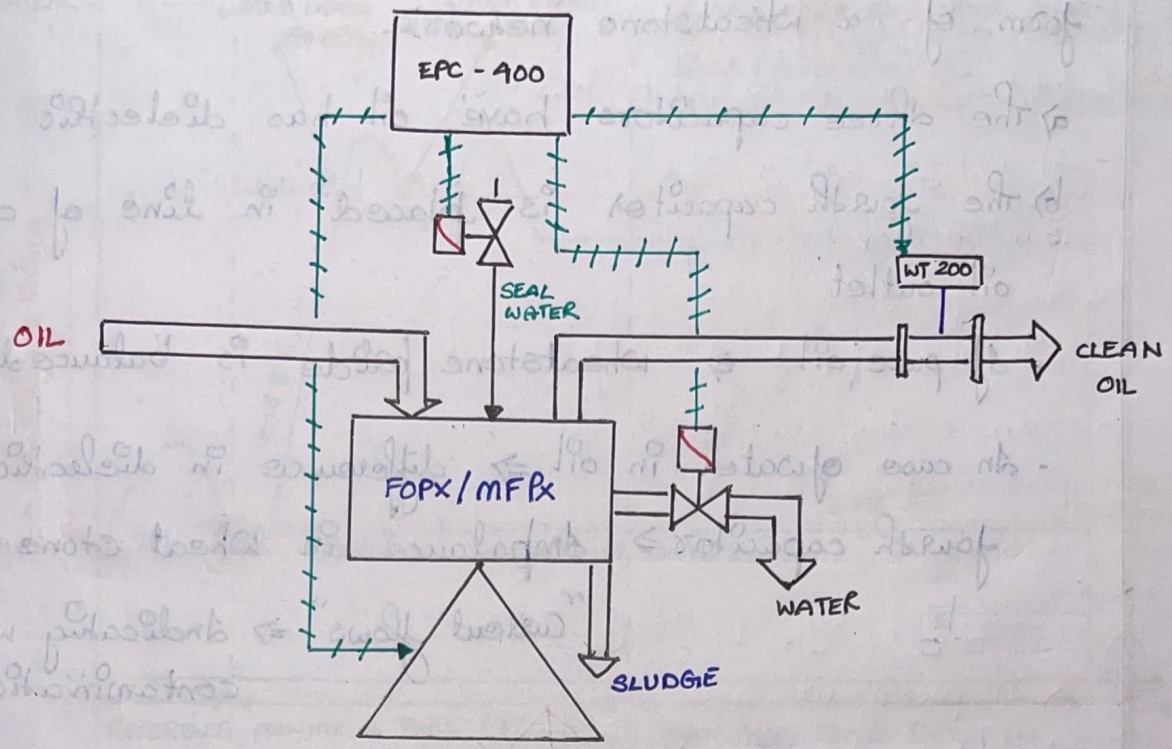
Desludge Mechanism:

- when water content is very high, desludging will be carried out.
- there are 2 types of desludging:

a) Partial Desludging:

- "oil feed" is not stopped:
  - the water transducer sends a signal to provide sealing water to condition the sludge (soften)
  - Desludge water is provided (bowl opening water) is provided for a shorter interval (as rpm 5000-6000), it will result in a partial Desludge and bowl closes immediately

FOPX ALCAP



b) Total Desludging:

- "oil feed" or throughput is stopped. (stopped)
- Now, Displacement water is given. Closing water is shut
- Now, Desludge water will be provided (Bowl) opening water
- Here, the bowl is open for a longer interval.
- Desludge water is shut and Bowl closing water is supplied
- After desludge, replacement water will be added and then oil feed will be started
- Purifier runs on normal operation

- WATER TRANSDUCER (WT 200) PRINCIPLE:

Dielectric of oil : 2 to 4

Dielectric of Water: 80

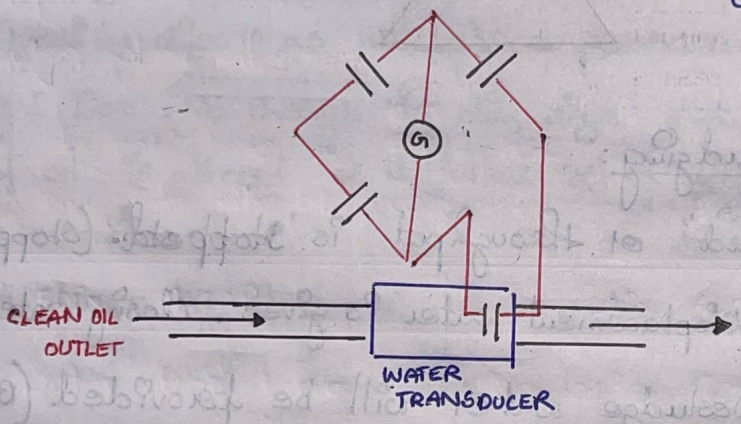
* The dielectric constant of oil contaminated with water is higher when water content of the oil increases.

the water transducer has a capacitive bank in the form of a wheatstone network.

a) the three capacitors have oil has dielectric

b) the fourth capacitor is placed in line of clean oil outlet

- if pure oil ⇒ wheatstone bride is balanced
- In case of water in oil ⇒ difference in dielectric of fourth capacitor ⇒ Imbalance in wheat stone network "current flows" ⇒ indicating water contamination.



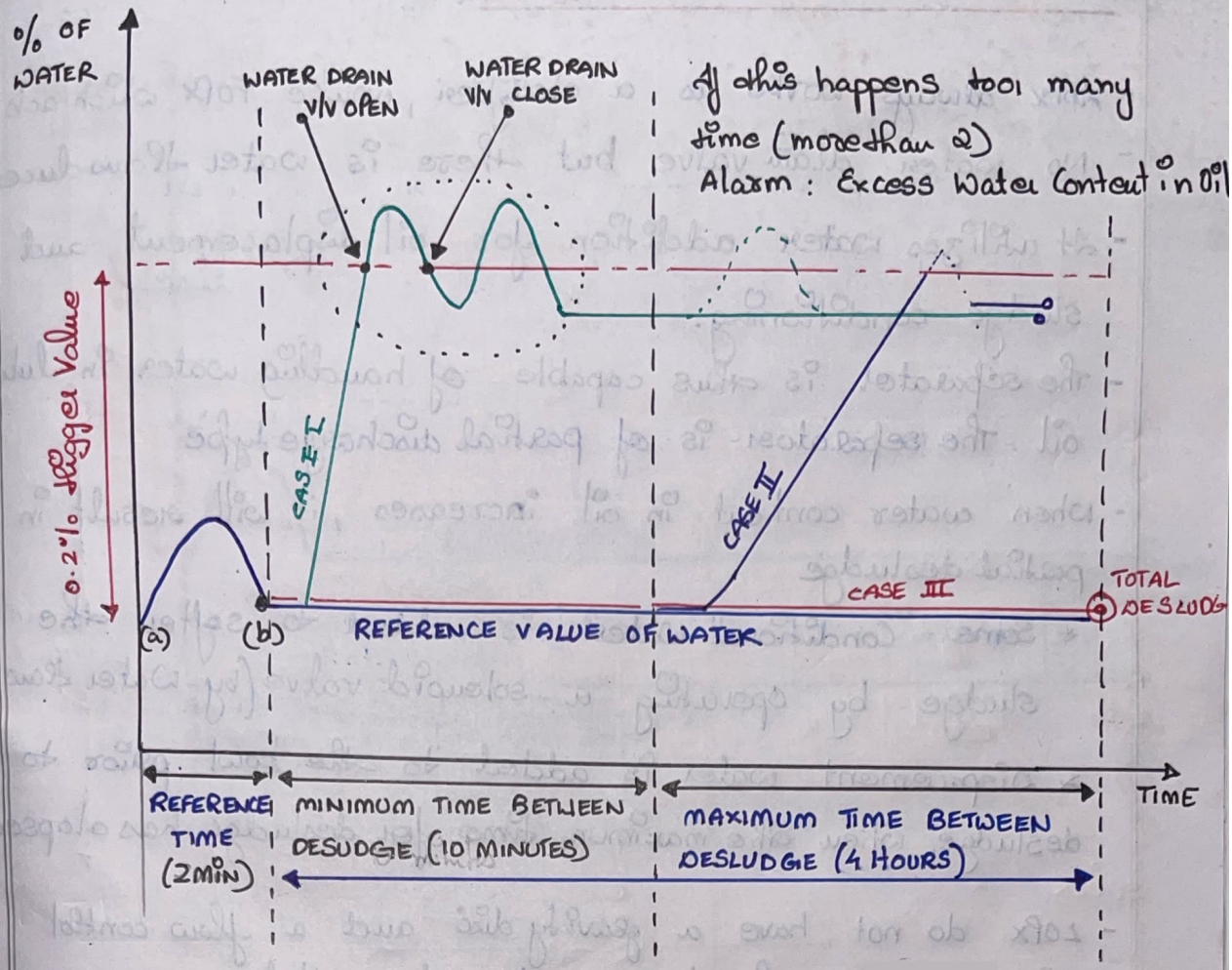
- TO UNDERSTAND TOTAL AND PARTIAL DESLUDGING:

condition of Purifier:

→ Total desludge has just completed:

- Takes time to stabilises
- water content increases initially from (a) to (b) and then stabilizes ⇒ "Reference Value"
- Now, purifier is perfectly clean condition

* Reference value changes every time purifier desludges



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CASE I: : Water level decreases b/w minimum time of desludge and reference time ; i.e, before minimum time for desludge:

- Water drain valve opens
- If drain valves opens frequently → Partial Desludges

CASE II: : If Water level increases (content) after minimum time for desludge & before maximum time for desludge

- Partial desludge happens (prior total desludge)
- when max time is reached : "Total desludge)

CASE III: : If water content remains below until maximum time for desludge "Total Desludge"

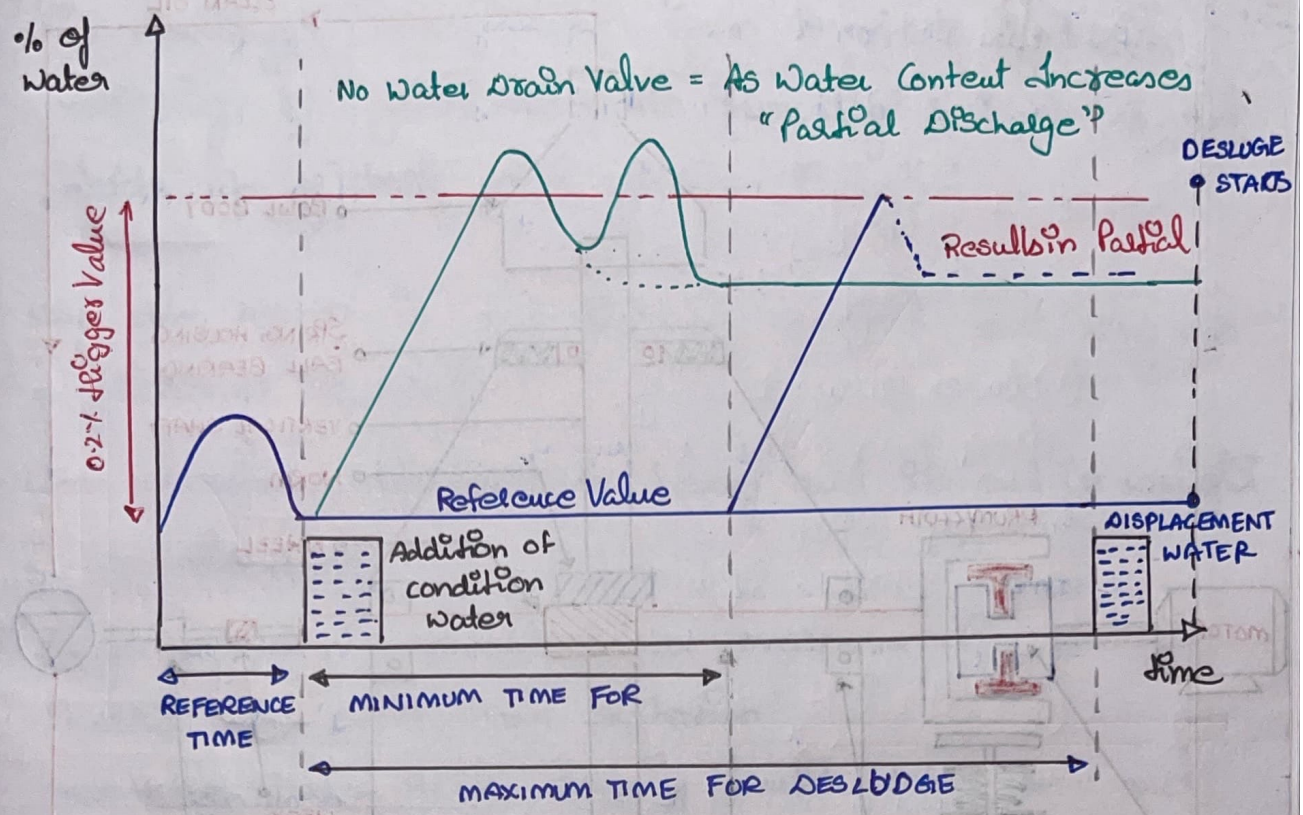
- **DIFFERENCE BETWEEN FOPX AND LOPX :**

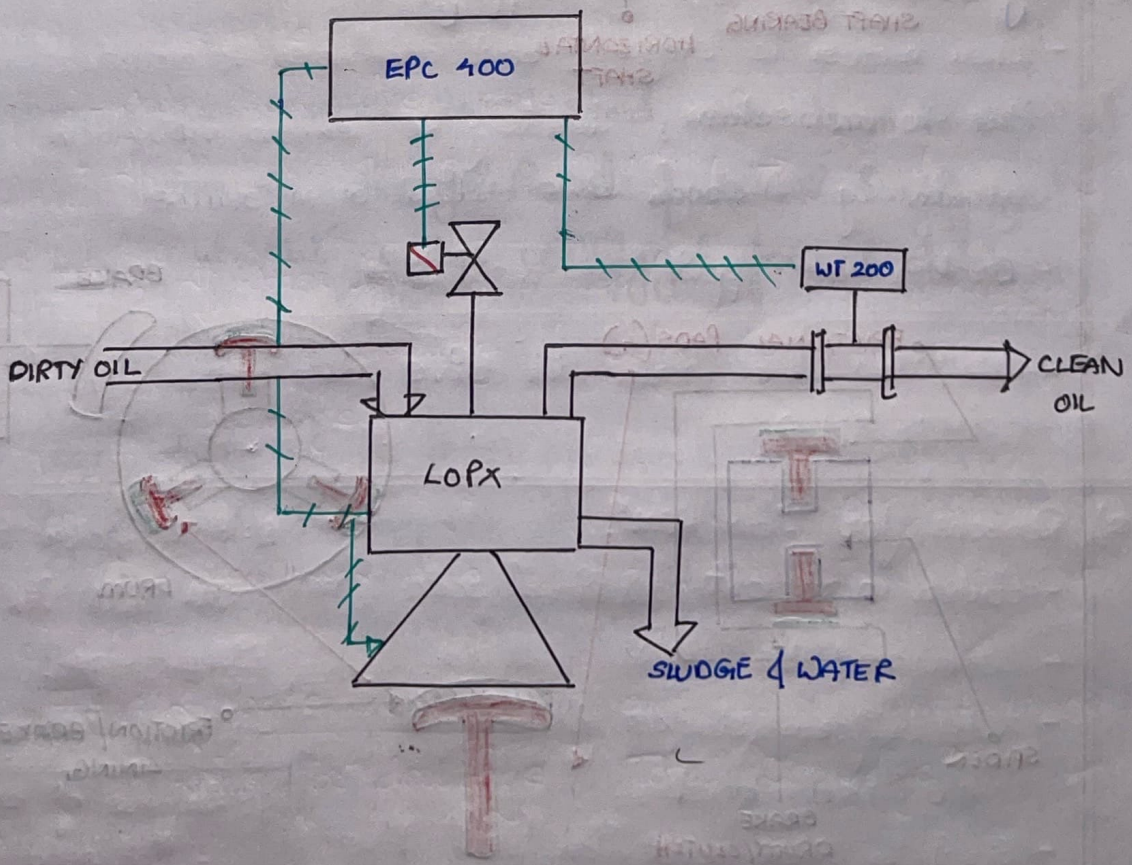
- LOPX always works as a clarifier, unlike FOPX which acts as both
- No water drain valve but there is water transducer
- It utilizes water addition for oil displacement and sludge conditioning.
- The separator is thus capable of handling water in lube oil. The separator is of partial discharge type
- When water content in oil increases, it will result in partial desludge
  - * Some "Conditional water" is added to soften the sludge by operating a solenoid valve (by water transducer)
  - * Dispacement water is added to the bowl prior to desludge, when the maximum time for desludge has elapsed
- LOPX do not have a gravity disc and a flow control disc owing to the absence of water outlet.

FOPX - ALCAP	LOPX ALCAP
- Has water drain valve	- No water Drain valve
- No gravity Disc	- No gravity Disc
- Has flow control disc permanently fit	- No permanent flow control disc
- Acts as Purifier & clarifier Partial & Total desludge	- Partial type separator desludge Predominantly a clarifier

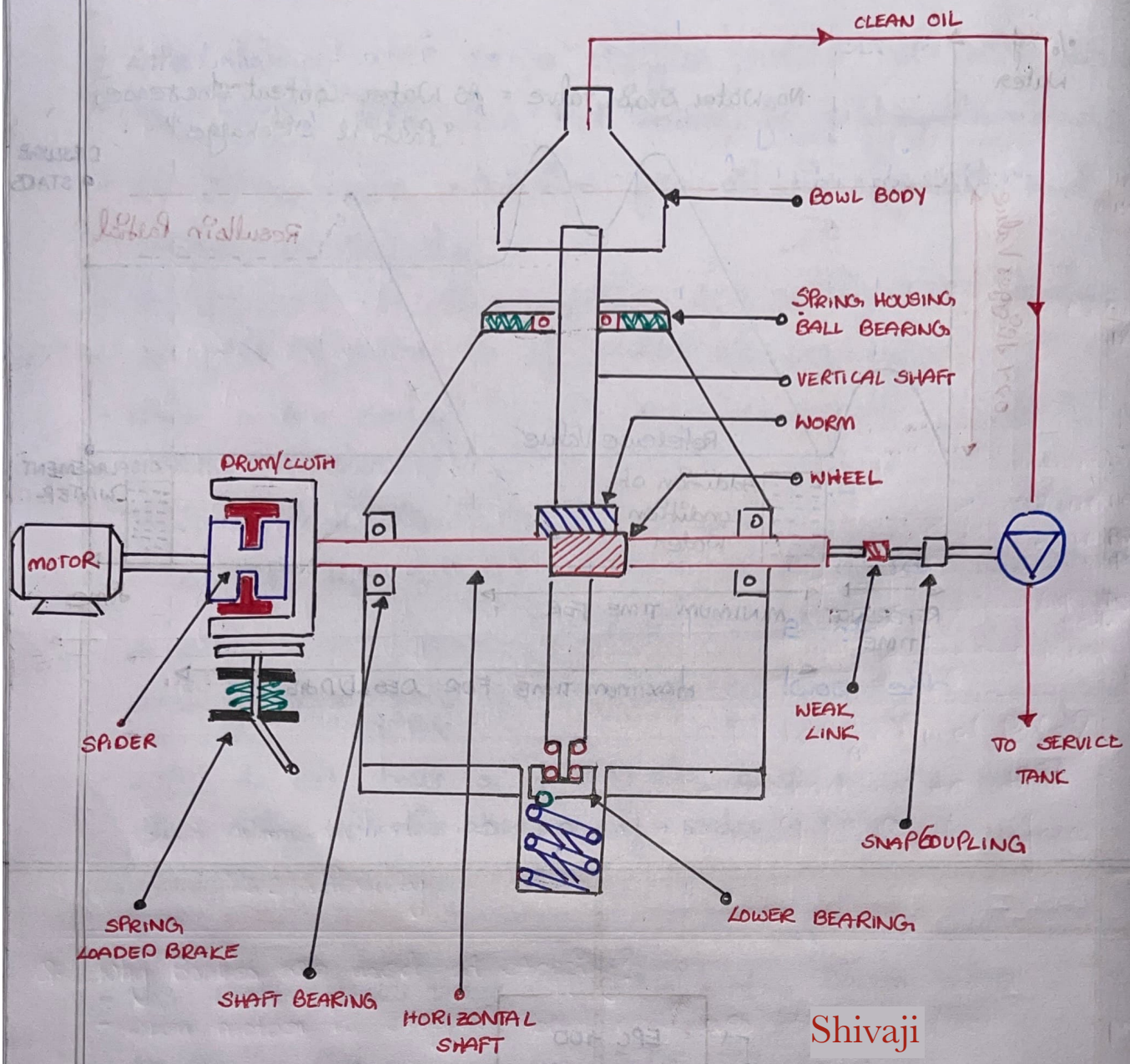
- **ADVANTAGES OF ALCAP : Over Conventional separators:**

  a) Less maintenance
  b) Optimum function & separation efficiency
  c) Greater flexibity of operating medium
  d) Low cost
  e) Simple operation


% of Water
No Water Drain Valve = As Water Content Increases "Partial Discharge"
DESLUDGE STARTS
Results in Partial
0.2% Trigger Value
Reference Value
Addition of condition water
DISPLACEMENT WATER
Time
REFERENCE TIME
MINIMUM TIME FOR
MAXIMUM TIME FOR DESLUDGE


EPC 400
WT 200
DIRTY OIL
CLEAN OIL
LOPX
SLUDGE & WATER

DRIVE MECHANISM OF PURIFIER:



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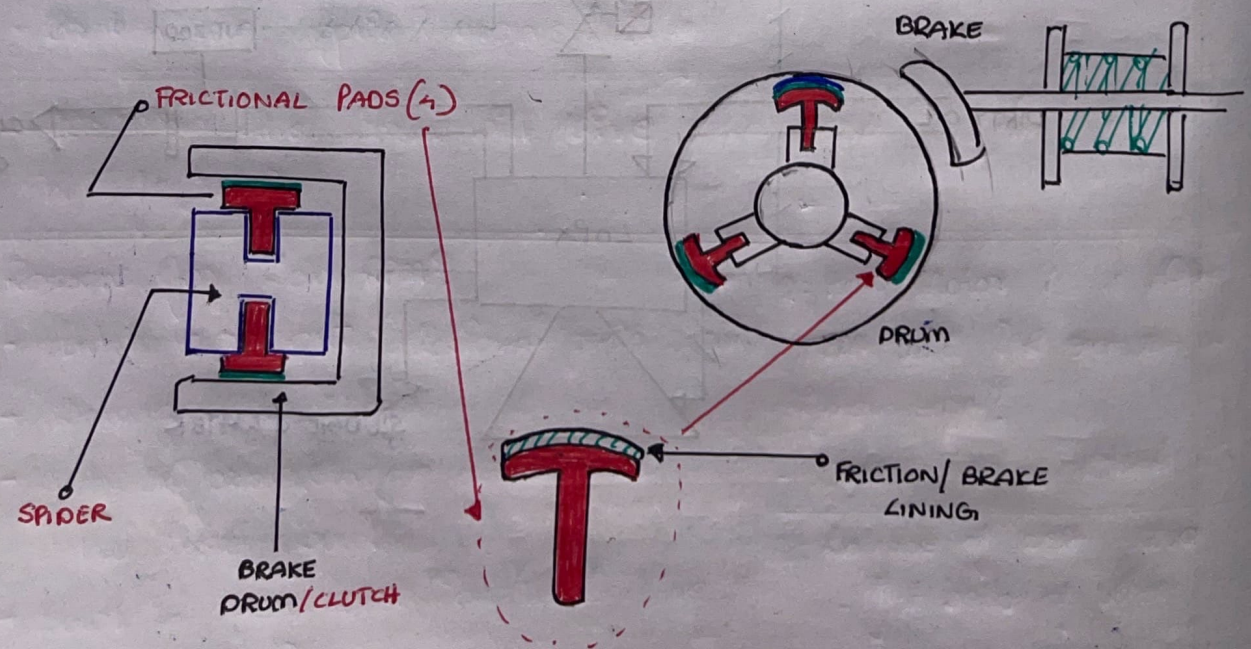


COMPONENTS AND THEIR VITAL ROLES:

* The centrifugal clutch/brake drum houses a spider consisting of frictional pads (usually 4 in number and made up of steel with friction lining)

Q: * Why the Motor is not directly coupled and why use a frictional clutch?

- Upon starting, the bowl is heavy and its entire weight is on the shaft.
- Large torque is required to overcome the starting inertia to start bowl rotation
- Once the bowl starts, running inertia takes over and less power/torque is consumed.
- A clutch is therefore used to prevent overloading of the motor at the time of starting as it ensures gradual loading.

* Operation: When motor is started, the drum is rotated due to the frictional pads that fly radially outward under centrifugal force & clutch on to the drum.

* There are two shafts interconnected by a Pinion gear

a) Vertical shaft: Supports the bowl

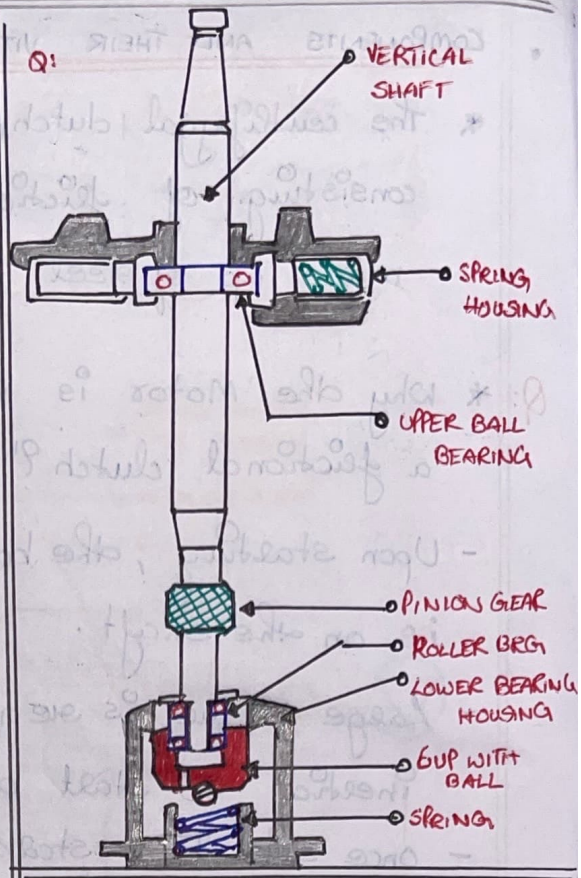
- 2 Bearings: ① Upper Bearings
  = Ball bearings in a spring housing to reduce blinelling effect of bearings and to dampen horizontal vibration (Radial Vibration)

② Lower Bearings

-The lower set of Bearings have 2 bearings ⓐ upper Roller bearings
⇒ take slight amount of misalignment & support shaft

ⓑ Lower thrust bearing (Deep grooved Ball bearing)
- In a cup which has a ball that is on a spring to dampen 'vertical Vibration' (vertical shaft rotates
⇓
Inner recess of bearing rotates
Outer recess stationary)

Load transmitted to cup as it is stationary

Q: 

Q: Polished frictional Pads?
- Use hacksaw to attain rough/ frictional surface.

Q: Why Brakes are used at stopping?
- When motor is stopped, bowl continues to rotate (5000-6000 rpm) due to momentum, leading to excess vibration as it passes gradually through the critical rpm range.
- Brakes are applied momentarily
- Also, now the worm will drive the worm wheel (which is not feasible)

Q) Reasons for Low RPM?
- clutch worn out (frictional pads worn)
- Damaged bearings
- Non-uniform sludge discharged
Unbalanced bowl
- Bowl in open condition (ineffective bowl closing)

Q: How Motor is at higher RPM and PFR rotates at higher rpm?
- Worm & worm Wheel ratio

Q: In case of belt drive:
- flat belts of different size
- different size pulley

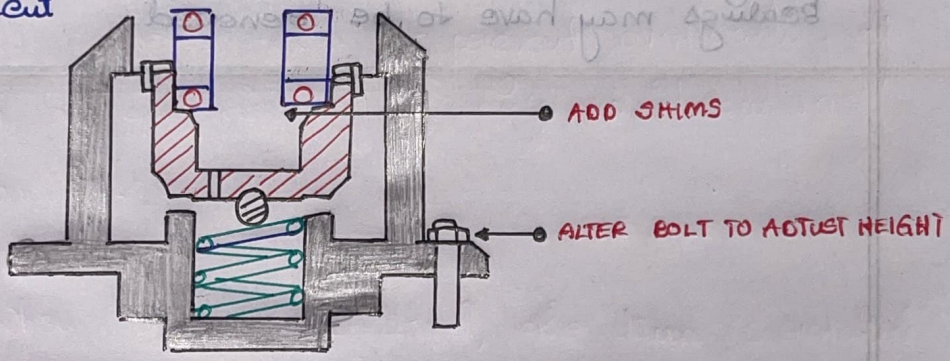
SIGNIFICANCE OF BOWL HEIGHT AND ITS MEASUREMENT PROCEDURE

If the bowl height is not appropriate
- affects Purification and Purifier overflows
- Vibration
- Desludge mechanism is affected (alignment of Nozzle and rings of passage)

The main reason for alteration of bowl height: "Bearings worn down"

METHODS TO ADJUST THE HEIGHT

- Addition of shims between the lower thrust bearing and cup
- Adjust the bolt provided in the lower bearing housing which lifts up the spring carrier > lift cup > lift bearings "Heigh adjustment"

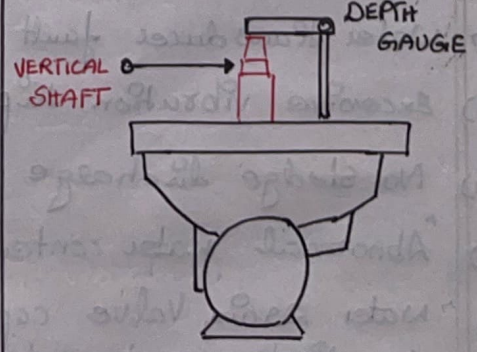


MEASUREMENT OF BOWL HEIGHT

2 methods:

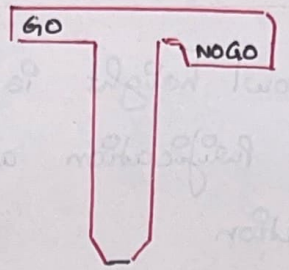
(1) USE DEPTH GAUGE:
- After removal of Purifier Cover and the bowl
- Measure the height between the top of the shaft and the purifier frame (cover of upper bearing)
- Compare the measurements to permissible limits as specified in manual

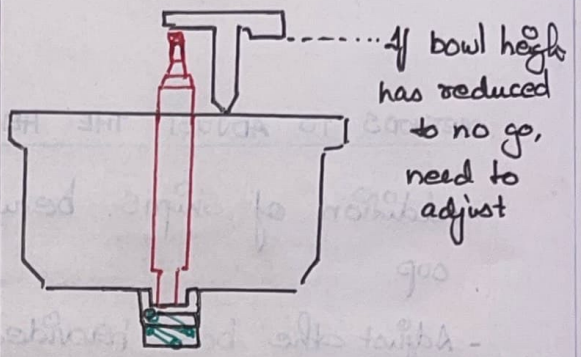
Diagram:



(2) USE OF TEMPLATE:

- Use of a template (GO- NOGO gauge)
- Provide by the manufacturer
- If the bowl shaft height is within the "GO" & "NO-GO" gauge, then the height is considered to be satisfactory and can be adjusted
- If the bowl, has under-gone shaft a deterioration of height under NO-GO, the shaft will be significantly lower and bearings may have to be renewed.





Q REASONS FOR PURIFIER OVERFLOW:

* Alteration in bowl height due to worn out bearings
* Temperature of oil is high → shift in interface
* faulty gravity disc size
* Issue with desludge Mechanisms: O-Rings, Nozzle don't align
* Bowl sealing ineffective

• SAFETIES AND ALARMS

i) Brakes
ii) Emergency stop
iii) Low oil flow alarm
iv) High/low oil temperature
v) Water transducer fault : Alarm
vi) Excessive vibration trip
vii) No sludge discharge alarm
viii) "Abnormal water content in oil" in oil outlet of water transducer
ix) Water drain valve capacity insufficient
x) No displacement water
xi) Power failure alarm
xii) Pre-heater fault