Basic Principles

- Boyle's law → Pressure Volume law $V \propto 1/P$ – Temp & mass constant
  $PV = C$

- Charle's law → Temperature Volume law $V \propto T$ – const. pressure
  $V/T = C$

- Gay-Lussac's law → Pressure Temperature law $P \propto T$ – const. volume.
  $P/T = C$.

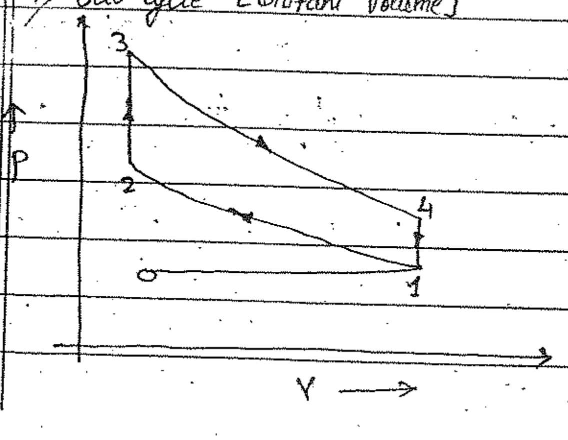
- Ideal Gas law → $PV = nRT$
  n ↗ no. of moles. R ↖ universal gas constant (0.0821 L-atm/mol-K.)

- Isothermal → Temp. constant.
  Adiabatic → heat constant.
  Isobaric → Pressure constant.
  Isochoric → Volume constant.
  Polytropic → pV^n = constant. where n - polytropic index & $n<0$ to $n = \propto$
  when $n=0$ → isobaric. ; $n=1$ → isothermal ; $n=\gamma$ → isentropic ;
  $n=\infty$ → isochoric.

- Engines :- (1) Internal Combustion [IC engines] – (a) Spark ignition ~ petrol or gas eng
  (b) Compression ignition ~ diesel.
  (2) External Combustion – steam engines.

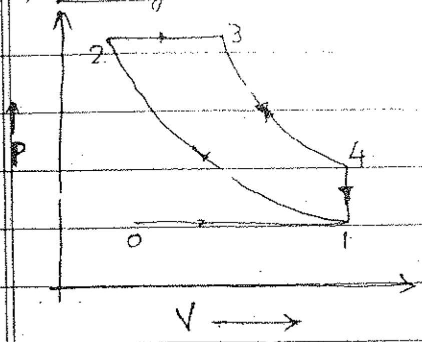
Cycles

1) Otto cycle [Constant Volume] ~ SI engines & high speed engines.



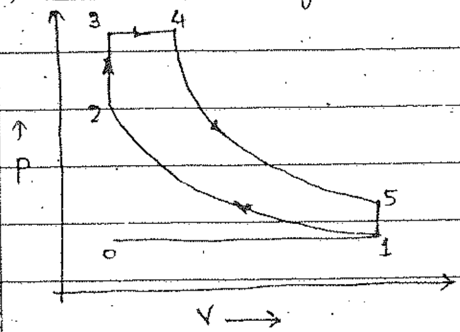
0-1 → air in at const. pressure.
1-2 → isentropic & adiabatic compression of air
$V\downarrow$ & $P\uparrow$.
2-3 → const. volume heat transfer. from external source while piston at TDC. This represents → ignition of fuel-air mix.
3-4 → isentropic expansion.
4-1 → constant volume exhaust out.
1-0 → exhaust released at const. pressure.

2) Diesel Cycle [Constant Pressure] ~ CI engines.



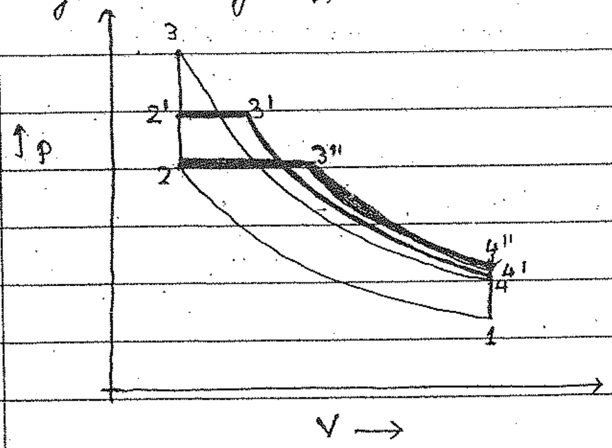
0-1 ~ air intake at const. pr.
1-2 ~ isentropic compression of air
2-3 ~ heat / fuel addition at const pr.
3-4 ~ isentropic expansion.
4~1 ~ constant vol^m exh. out.

3) Dual combustion Cycle. ~ most modern CI engines ~ Marine Engine.



1-2 ~ isentropic compression
2-3 ~ heat addition at const. vol^m
3-4 ~ heat addition at const pressure.
4-5 ~ isentropic expansion
4-1 ~ const vol^m exh. out.

- why dual cycle ??



1-2-3-4-1 ⟶ otto cycle.
1-2-3''-4''1 ⟶ diesel cycle.
1-2-2'-3'-4'1 ⟶ dual cycle

otto cycle → highest economy as ~~regards~~ to fuel consumption as it rejects minimum heat but max pressure is ~~max~~ high.

Diesel cycle → least economy in fuel consumption ~~&~~ but ~~least~~ max^n pr. is low.

Dual cycle → falls b/w the two cycle. i.e fuel consumption is not very high as well as peak pressure is within limits.

- **Compression Ratio** $= \dfrac{\text{Vol}^m \text{ of air at the start of compression stroke}}{\text{Vol}^m \text{ of air at the end of compression stroke}}$

for CI engine ~ 12.5 to 13.5

for life boat engine ~ 18 to 20 (so that engine can start even at −15 °C within 2 mins).

Comp. ratio of ME cannot exceed a certain limit. b coz if it is increased, peak pressure ↑, temp ↑, Thermal stresses ↑, Load on bearing ↑, Weight & cost of engine will ↑.

Upper limit of comp. ratio is determined by :- ~~st~~ strength of cylinder, bearings and other parts.

Lower limit of comp. ratio can be determined by considering good startability from cold condition.

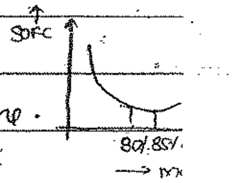
* Boost of the m.e.p in the cylinder by not increasing the max^m pressure is possible by ‹i› Reducing compression Ratio /

‹ii› Simultaneously ↑ the charge air pressure at cylinder intake

- **Scavenge Efficiency** $= \dfrac{\text{qty of air drawn in cylinder}}{\text{total volume of cylinder / vol}^m \text{ at beginning of comp.}}$

- **Specific fuel oil Consumption (SFOC).**

↳ fuel consumption in grams for unit power in unit time.



Unit :- gm / kw ~~/~~ hr.

BSFOC ~ brake SFOC → calculated with brake power.

ISFOC ~ Indicated SFOC → calculated with indicated power.

BSFOC > ISFOC.

$$\text{SFOC} = \frac{\text{fuel oil consumed in lts per hr} \times \text{Sp. gravity} \times 1000}{\text{power in KW per hr.}}$$

~~Corrected fuel~~ Sp. gravity

1000 ← convert ~~grams to kg.~~ Kg to g.

$$\boxed{\begin{aligned} \text{SFOC} &= \frac{\text{mass of fuel} \times 1000 \ (\text{kg to g})}{\text{power in KW / hr}} \\ \text{mass} &= \text{Sp. gravity} \times \text{vol}^m \text{ in lts.} \end{aligned}}$$

~~Sp. gravity = Sp. gravity at 15 °C × [1 − α t.~~

Sp. gravity at 15 °C × [R (temp @ flowmeter − 15

R ← 0.00065 for HFO.

- Fuel Air Ratio — theoritical — 14.5 kg / kg fuel.
  Actual — 29-44 kg / kg fuel.

- Power

Work done by piston in a working cycle = $P \times V$

mean pressure over the cycle in N/m2

piston displacement in m3.

$$\text{Power} = \frac{P \times V \times N}{C}$$

no. of revolutions persec.

stroke/cycle ratio.

for 2 stroke $C = 1$ & 4 stroke $C = 2$.

cylinder bore dia in mtrs.

Now, $V = \frac{\pi d^2}{4} \times L = \cancel{B}\ A \times L$

length in mtrs.

$\therefore$ Power = $P \times L \times A \times N$ kW.

(i) Brake Power — power output of the drive ~~end~~ shaft of an engine without the power loss caused by gears, transmission, friction etc. [Also called pure / useful / true power]

useful power at output shaft

(ii) Indicated Power — theoretical maxm output power of engine.

power produced in the cylinder.

BP < IP. due to losses.

IP = BP + f.p.

★ Mechanical efficiency $\eta_{mech} = \frac{B.P}{I.P.}$

★ Mean effective pressure (m.e.p) — it is that theoretical constant pr. which may be assumed to act on the piston during its power stroke.

E W E R R A T I N G S

- Maximum Continuous Rating [MCR] :- max^m continuous output at which the engine can run safely & continuously.

- Continuous Service Rating [CSR] :- it is the output at continuous service speed.

- Overload Rating :- extent of overload above MCR that can be safely exerted on the engine for a short period. [10% overload for 1 hr]

- Astern output :- max^m output in going astern.

- Stroke Bore Ratio.

3 factors :- (i) in-cylinder heat transfer – ↑ s to b ratio, ↓ surface area exposed to combustion chamber gasses → leads to reduced in cylinder heat transfer, ↑ energy transfer to crankshaft and ↑ $\eta\%$.

*(More time for compression so cheaper fuel.)

*(But ~~high~~ height of engine will increase.)

(ii) Cylinder scavenging – ↑ s to b ratio, ↑ in the distance the fresh air has to travel b/w inlet port & exhaust. ↑ scavenge efficiency, ↓ pumping work

(iii) Engine friction – ↓ in s to b ratio, ↑ bearing friction because the ~~as~~ larger piston area transfers larger force to crankshaft bea

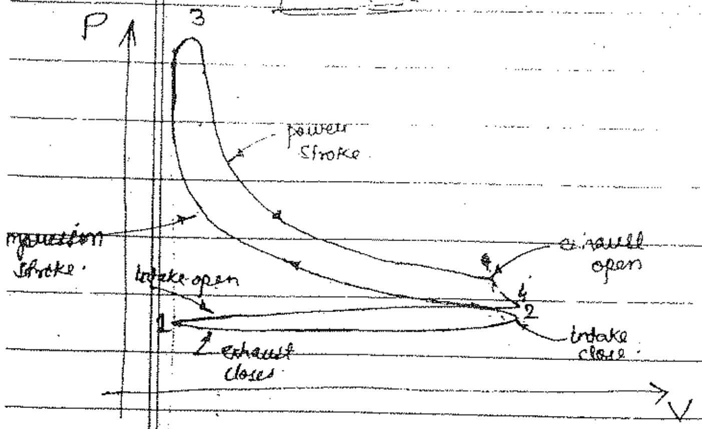
☆ If 'd' bore dia is ↑, size of engine ↑, stresses on liner $\left(\frac{pd}{2t}\right)$ ↑. So counter this thickness should be ↑, thus engine becomes large & heavy Moreover sealing becomes difficult.

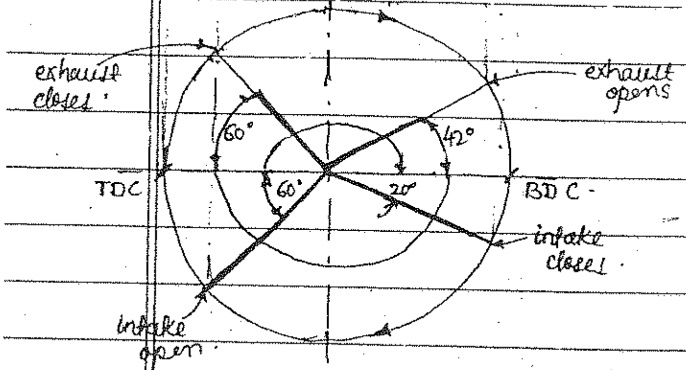
∴ Longer stroke is better → ↓ speed, ↑ time for fuel burning, ↑ efficiency.

dia of prop. blade ← superlong – 3.8 to 4.2 : 1

ultralong → 4.2 : 1

4 STROKE



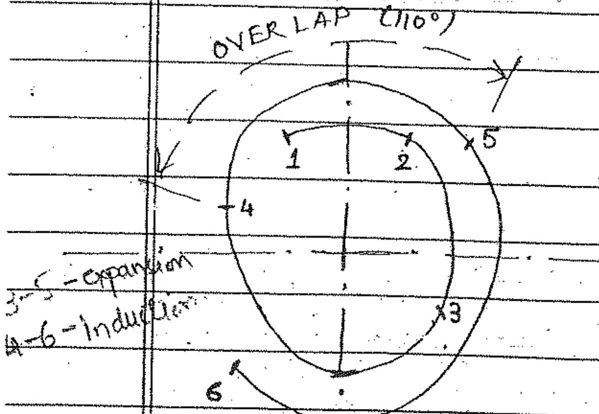


1-2 : induction stroke.

2-3 : Compression stroke.

3-4 : Expansion stroke.

4-1 : exhaust stroke.



1 - fuel injection start [10-15° before TDC]

2 - " stop [10-15° after TDC]

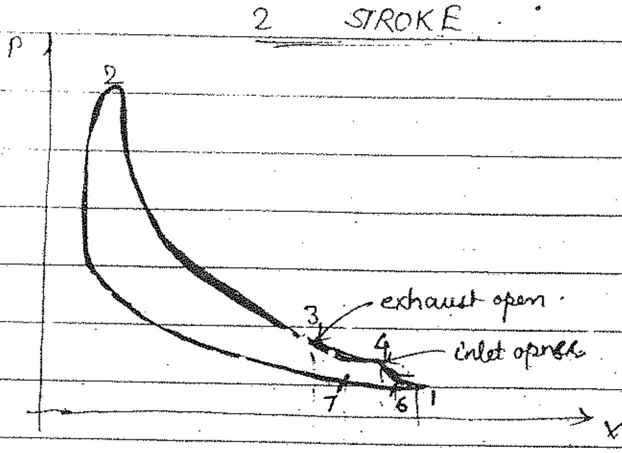
3 - exhaust v/v opens [60° before BDC]

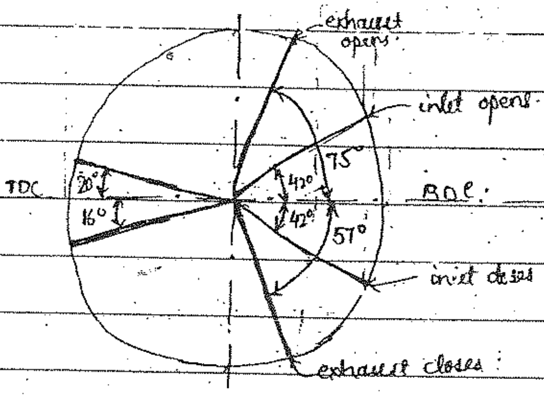
4 - intake v/v open [70° before' after BDC]

5 - exhaust v/v close [40° after BDC]

6 - intake v/v close [30° after BDC]

2 STROKE



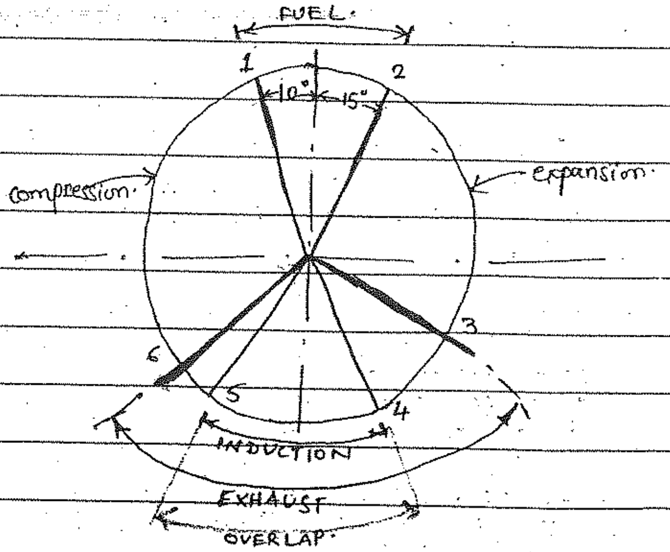


4-1-6 ~ Induction.

1-2 ~ compression

2-3 ~ expansion.

3-1-7 ~ exhaust.



1 - fuel injection start (10-15° Before TDC]

2 - " stop (" after TDC]

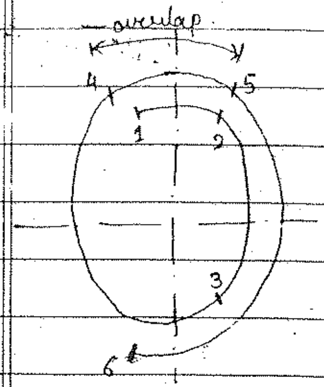
3 - exhaust v/v opens (120° after TDC)

4 - inlet ~~port~~ opens (50° before BDC)

5 - inlet port closes (60° after BDC)

6 - exhaust v/v closes (55° after BDC)

☆ 4 stroke natural aspirated engine :- (Eg:- Life boat engines)



1 - fuel injection starts (10° before BDC)
2 - " " stops (variable)
3 - exhaust v/v opens (30° before BDC)
4 - intake v/v " (20° before TDC)
5 - Exh v/v closes (20° after TDC)
6 - intake v/v closes (20° after BDC)

- Blowdown effect — most of the gases in the cylinder are blown down ou when exhaust v/v opens by its own energy (i.e. when pressure exists in the cylinder). This is blowdown effect. [Piston does little work to drive out gas

- VEC ~ Variable Exhaust Closing
  ↑ load → early ~~opening~~ close of exh v/v → more air → ↑ comp.

INDICATOR DIAGRAM

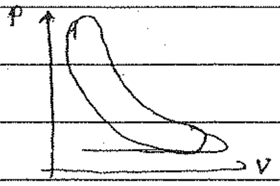
- diagrame indicating pressure & relative position of piston in the cylinder simultane

Purpose :- (i) determine engine output (Indicated)
(ii) determine combustion pressure [Pmax] & Compression pressure [Pcomp]
(iii) Evaluate combustion process.
(iv) Evaluate exhaust and scavenging conditions.

→ How to take indicator diagram?
- check condition of spring.
- lubricate the necessary parts.
- fix paper firmly over the drum.
- Open indicator cock & blow through 2 to 3 times.
- Draw atmospheric pressure line, hook the cord to indicator drive, open indicator cock & take power diagram.

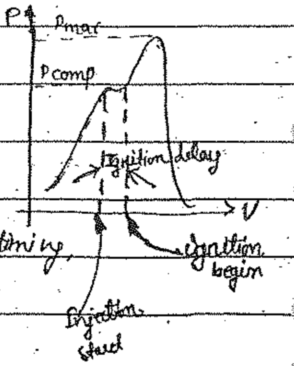
→ Types of indicator diagram
1) Power card.
2) Draw card
3) Compression card.
4) Light Spring diagram.

Power card - to calculate indicated power.
also shows peak pressure.
[In phase with piston movement, with fuel on]

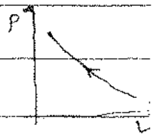


area under the diagram can be calculated using planimeter or Simpson's Rule.

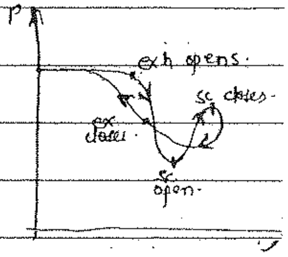
Draw Card - It shows Pcomp & Pmax (more accurately)
also shows ignition delay period.
- to evaluate injection, ignition delay, fuel quality, combustion, loss of compression, expansion process, fuel p/p timing, and after burning.
[90° out of phase with piston movement, with fuel on]



☆ No indicator card in 4 stroke, piston touches TDC twice in 1 cycle. The only peak pressure and compression pressure is taken.



Compression Card :- to know compression pressure of cylinder & cylinder tightness
[In phase & fuel cut off]



Light spring diagram :- determine pr. variation in cylinder during exhaust & scavenging periods.
- shows choke exhaust ports / V/V's
- loss of scavenge air.

[In phase, using light spring, with fuel on]

Early Combustion

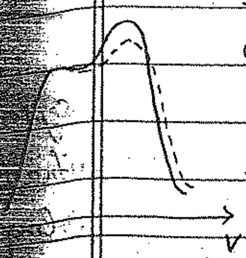
Effects :- Very ↑ Pmax, low exh temp, ↑ Power, ↑ $\eta_{thermal}$, heavy shock load to bearings, ↑ engine knocking, Ignition before TDC, ↓ SFOC.

Causes :- Overheated piston, cetane no. of fuel ↑, fuel p/p plunger set too ↑ (incorrect fuel p/p timing / wrong V.I.T setting), incorrect adjustment of fuel cam on camshaft, incorrect adjustment of fuel V/V spring pr.

Late Ignition.

Effects :- ↓ Pmax, ↑ exh temp., loss of power, ↓ $\eta_{thermal}$, ↓ $\eta_{scavenge}$, ↑ pulsation in exh manifold, Ignition after TDC, ↑ SFOC.

Caused :- Incorrect fuel timing / wrong VIT, faulty fuel V/V, Injection viscosity too low, lack of scavenge air, bad atomization, cetane no. of fuel ↓, worn out fuel pump, cam & roller, ↓ compressi leaky fuel pump delivery V/V or spill V/V.



It may cause :- exh V/V burning, turbocharger surging, fouling of exh system, uptake fires, ↑ cyl. temp. resulting in liner lubrication difficult.

After Burning

Symptoms & effects :- ↑ exh temp & ↑ exh pr., exh V/V burn, exh system fouling, T/C surging, uptake fires, ↑ temp within cylinder can cause deterioration in lubrication & possible damage to liner & piston rings piston crown burning, Smoky exhaust.

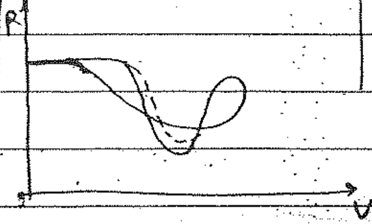
Causes :- incorrect fuel timing (slow or late combustion of fuel), faulty fuel injector, HFO temp too ↓, viscosity ↑, lack of scavenge air, poor compression, poor fuel quality.

Exhaust V/V opening

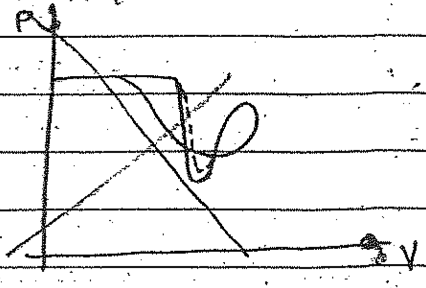
Early :- ↑ exh temp with risk of overheating & contamination. loss of power since pressure is released too soon.

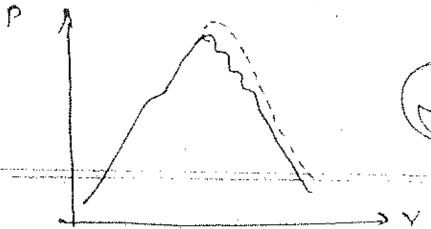
Late :- ↓ η scavenge by reducing blowdown. affects supply of energy to T/C.

Chock exhaust ports. /valves.

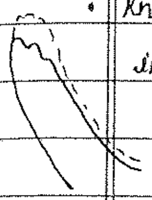
Symptoms.	Causes	Remedies.
• ↑ exh pr. with sooty smoke	• faulty fuel injection	• correct fuel timing
• ↑ mean temp. of working parts.	• lack of scavenge air.	• maintain scavenging system in good order.
	• excessive cyl lubrication	
• ↑ exh. temp.	• fouling of exh system	• Correct cyl. lubrication feed.
• ↓ Pmax, ↓ Pcomp, ↓ Power		• Clean exh. grid & T/C.
• Surging of T/C		

Chocked fuel V/V

Symptoms	Causes	Remedies
• ↓ engine power	• contamination of fuel with debris may choke the atomizer hole.	• change fuel V/V
• hammering of pipe b/w fuel p/p & injector.	• leaky injector allows hot gases to blow back into the injector	• clean whole fuel system. • Ensure correct purification. • Maintain correct cooling temp of fuel V/V.
• ↓ exh temp, - can be confirmed by indicator diagram power & draw card. - irregularities at peak of the diagram.	• overheating of injector nozzle may cause build up of carbon	



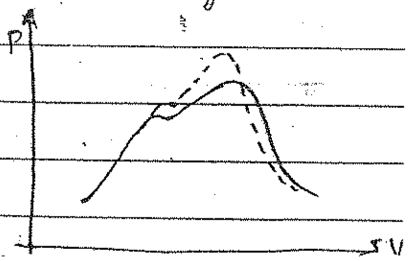
Leaky fuel injector



Symptoms	It may causes :—	Remedies
• ↓ power	i) afterburning	· Renew fuel v/v
• ↑ exh temp. with smoke	ii) choke injectors	· Check fuel purification system.
• knock or pr wave in fuel injection system	iii) fouling & loss efficiency of T/C	• FO system temp. & nozzle cooling temp must be maintain correctly.
	iv) Chocking exh ports.	

Leaky piston rings / worn liner.

Symptoms.	Causes	Remedies
• ↓ power	1) excessive liner wear.	• Renew liner if necessary.
• ↓ Pcom & Pmax.	2) lack of cyl. lubrication	• O'haul piston.
• ↑ exh temp with smoke.	3) worn, broken, stuck or poorly maintained pistonrings.	• Clean groove & gauge.
It may cause :—	4) Worn piston ring groove landing allowing rings to cant & jam	• Machine or fit new groove inserts
- blowpast of combustion gas.	5) Carbon jamming rings in grooves	• Renew piston rings.
- high rate of cyl. liner wear	6) T/C failure due to fouling	• Maintain correct cyl. lubrication.
- scavenge fire.	7) Blockages in exh gas system	
- piston seizure due to overheating.		



CETANE NUMBER ~ a measure of ignition quality of fuel.

↑ Cetane no., ↓ time b/w fuel injection & rapid combustion.

Range 30 – 45

↑ Cetane No.	↓ Cetane No.
shorter delay period	longer delay period.
early combustion	late combustion.
↑ power	↓ power
knocking	after burning.
	↑ exh temp & smoke.

ENGINE STRUCTURE

※ Bed Plate, Holding down bolt & chocks.

Bed plate - foundation of engine responsible for the strength & rigidity of other components of the engine.

Material - fabricated steel [stress releaved by annealing]

Forces acting - • Gas pressure • thermal stresses.
• Inertia forces of moving parts. • Hull deflection
• wt. of engine.

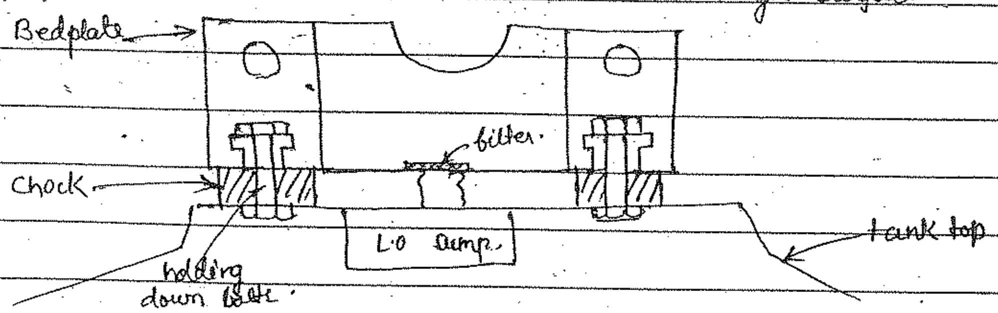
Chocks & holding down bolts - used to ~~connect~~ fix the bedplate and the tanktop.

Functions of chock :- (i) any variation in Tanktop will not affect the engine.
(ii) avoide misalignment of engine.
(iii) endchock absorbs vibration & thrust. [Reduce noise levels.]
(iv) side chocks absorb unbalanced forces due to rotational parts.

Materials :- (i) cast steel (ii) Epoxy resine ← used mostly.

Cast steel: Require expertise for installation & expensive.

Epoxy resine:
- cost effective.
- do not require any special measures.
- 100% contact even on rough surface.
- Non corrosive
- chemical resistance.



Fixing resin chocks :-

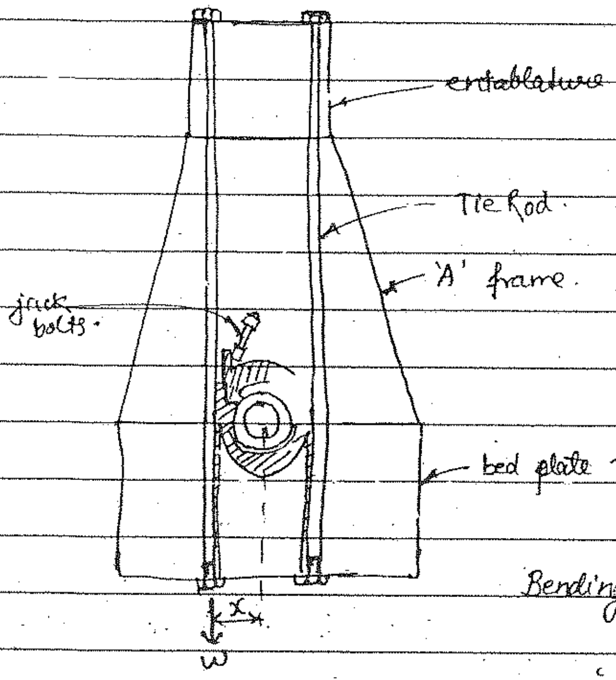
1) Clean the surface.
2) Prepare the chock mixture.
3) Prepare dye or dam for chock.
4) Fix holding down bolt & then pour resin mix around the inserted bolt. Note the temp of mix must not be less than 25°C.
5) Tighten the holding down bolt with hydraulic jack at required pressure.

Dry up time - 48hrs.

→ X. **"A" Frames** – They carry the crosshead guides & support entablature (cylinder block)

Material – fabricated steel.

→ X. **Tie Rods**



Bending moment = $W \times x$

Function :- Bind cyl. block, A frame & bed plate firmly.
Keep structure under compression ; Keep load on structure within admissible limits, prevent fretting b/w components ; transfer firing load to cover studs.

– subjected to large amount of stresses & bending moment ($W \times x$)
To reduce B.M, reduce 'x'. So tie rods should be as close as possible to ℄ of crankshaft.

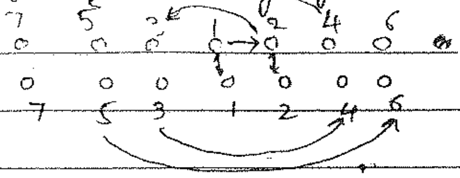
No. of tie rods = $(2n+2)$ where n = no. of units.
↑ if chain casing is provided.

Engine has become longer, so tie rods into 2 parts joined using a coupling.

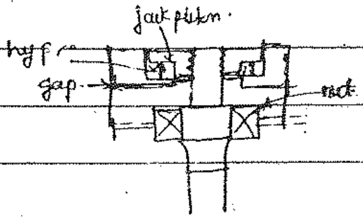
To prevent tie rods from vibrating in the tubes, pinching screws are provided.

Tie-Rod tightening :-

Sulzer → Starting from mid & going in steps towards aft & fwd alternately



MAN B&W → start from free end (fwd) and move towards power take off side with original pr. Then return to first pair & check at 90% of original pr. If found slack raise the pr to 100% & tightenen.



Procedure
- check c/shaft deflection.
- Remove clamping screw & thread protecting hood.
- clean contact faces of intermediate ring.
- Screw the jacks till it reachs the intermediate ring.
- Connect the jack to hydraulic HP p/p & vent the system.
- Operate the p/p until tension pr is reached & maintained.
- Use feeler gauge to check clearance b/w tie rods & intermediate rings. If clearance exists tighten the nuts using tommy bar.
- Check clearance again & then ~~disconnect~~ remove the connections.

Tie Rod Breakage :- can be identified by leakage of L.O from mating surface of diff. engine parts.

→ Reasons :- Scavenge fire.
Overtightening / overstressed
Slack
Pmax ↑

* Non critical part ~ no spare provided onboard usually.

Breake at neck

Remove broken part.
weld eyebolt at top.
lift tie rod out using eye bolt & crane.

Breake at bottom most neck

- Remove the broken part.
- Then follow the above procedure. [ist procedure]

Breaks at centre

1) Cut out one by one from bottom by gas cutting ~ lengthy process.

2) ◦ Fallen tie rod lifted by 2 chain blocks.
  ◦ Weld eye bolt to bottom of tie bolt.
  - Remove the nut at the bottom of tie rod as no tension exists.
  - Fix 5-6 wires at the bottom bringing it from top.
  - Bunch all wires together & lift it out with crane.

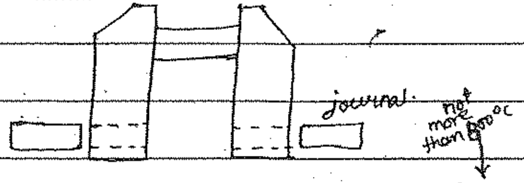
X. CRANK SHAFT - is a part of the engine that converts reciprocating linear piston motion into rotation.

Material :- low carbon steel [low alloy Mild Steel],
C - 0.3 %, Mn - 0.7 % [If C ↑, strength ↑ but brittleness also ↑]

Types :-

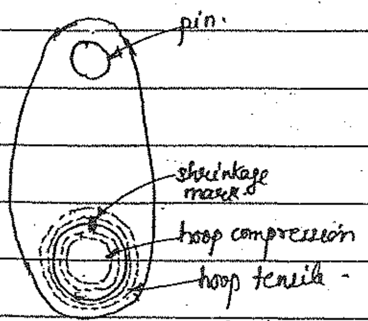
lighter.
Required in section.
continuous grain flow.

① Semi built :- most commonly used - large 2 stroke engine.



for crank pin & webs made (forged) as single piece
Journal is shrunk fit.
Size of journal is more than that of the holes in the web. One is healed to expand & other is cooled to contract. Then they are inserted so that that they can shrunk fit.

Shrink fit allowance $\frac{1}{520}$ to $\frac{1}{660}$ of diameter

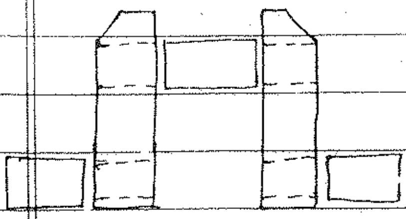


Transfer of torque is by Hoop's Compressive & Tensile stresses. Journal is under hoop compression & hole is under hoop tension.

Hoop's stresses transmit torque (τ) ∴ Stresses must be continuous. If torque exceeds hoop's stresses then slippage. Thus a reference shrinkage mark is provided.

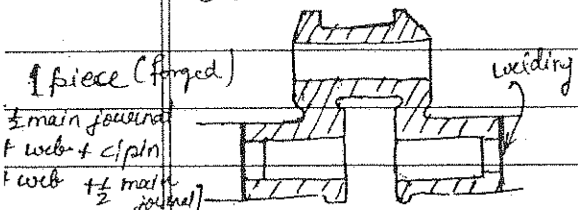
liquid on top of piston can cause , so slippage.
Hence slow turning & blow through is required.

② **Fully Built** built in 3 parts ie pin, web & journal. They are shrunk fitted. [c/shaft heavy & bigger]



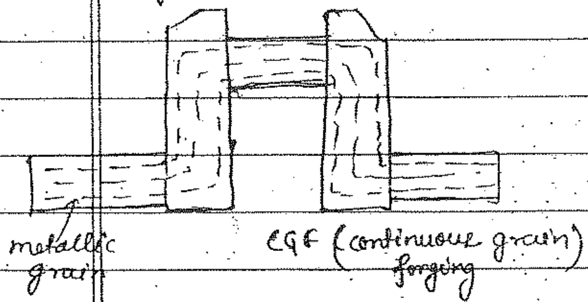
Heat webs upto 800°C & cool the pin & journal using liquid nitrogen & shrunk fit.
- easy to manufacture.
- ~~can be repaired in sections~~

③ **Welded** Journal & webs welded together using submerged arc welding. C/shaft gets extremely light. But in due course of time shaft becomes rigid & brake.
Not used nowa days.

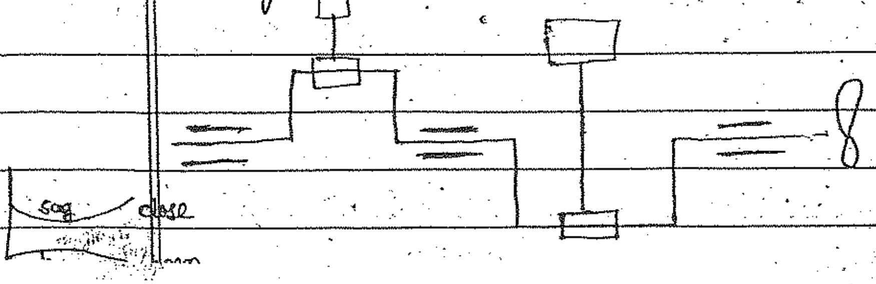


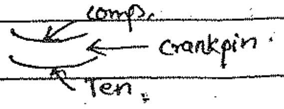
↳ easy to manufacture.
Repair in section.

④ **Forged** In 4-stroke / smaller engines // Air compressors.
Good fatigue strength.
expensive.



→ **Stresses on Crankshaft**
- Bending moment due to combustion load, static wt of piston & conrod.
  ↳ causing tension & compression stresses of shaft.
- Hoop tensile & comp. stresses b'coz of type of built
- Torsional stresses.
- Shear stress on journal, web, crankpin.
- Fatigue stresses.





Stresses ↑ due to misalignment.

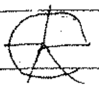
when to take :-
① 6000 - 8000 running hrs.
Ⓘ After foundation chock repair/renewal
Ⓘ Grounding / Docking / fire / Propeller bending or impounding with smthg.
Ⓘ m/E o'haul / renewal / removal
Ⓥ Damage on bearing brackets / ~~holding down bolts~~ / chock.

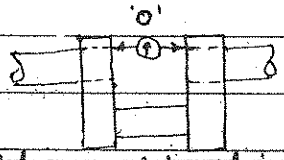
Crankshaft Deflection :- to check misalignment

Indications :- ↑ bearing temp ; damaged bearings

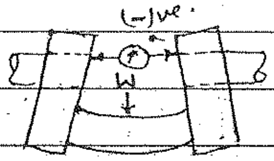
Reasons :-
① Worn out bearings
Ⓘ Distorted bedplate [grounding , collision]
Ⓘ Uneven loading
Ⓘ Keel blocks improperly laid in drydock.
Ⓥ Unbalanced engine (power unbalanced)
Ⓘ Overloaded units / engine.
Ⓘ Fuel cut off to particular unit
Ⓘ Material difference.
(ix) Loose tie rods, holding down bolts.

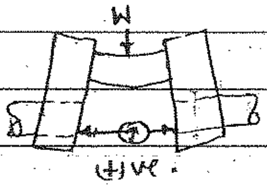
→ can lead to :-
① Bending of c/shaft.
Ⓘ fatigue failure owing to cyclic stresses.
Ⓘ Undue vibrations
Ⓘ Damage to bearings.





dial gauge at journal circumference diametrically opposite to crank pin.
[Normally a punch mark is provided]

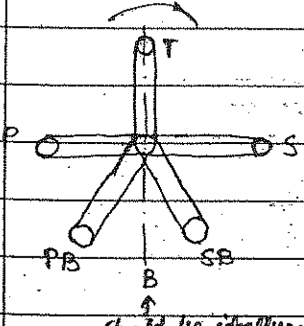




Condition :- (i) Calm weather. (ii) Stable trim.

Take propeller clearance

Steps :- ① Stop engine & allow to cool.
Ⓘ Open indicator cocks (b'coz air will compress & will wrong reading on turning the engine)
Ⓘ Stop L.O pump. Put Tag "Men" at work.
Ⓘ Engage turning gear (to avoid injury to personnel inside c/case as shaft may turn due to propeller turning b'coz of waves)
Ⓥ Open c/case & allow ventilation before entry.
Ⓘ Fix the dial gauge as shown in fig.
Ⓘ Turn c/shaft to position PB ; 30° ABDC and adjust dial gauge to '0'. [Do not touch the gauge until all readings taken]
Ⓘ Take reading at successive points i.e P, T, S & SB and record in a table.



Should be ideally zero.

(T-B) is the deflection. (P-S) should be '0' ideally - no horizontal deflection

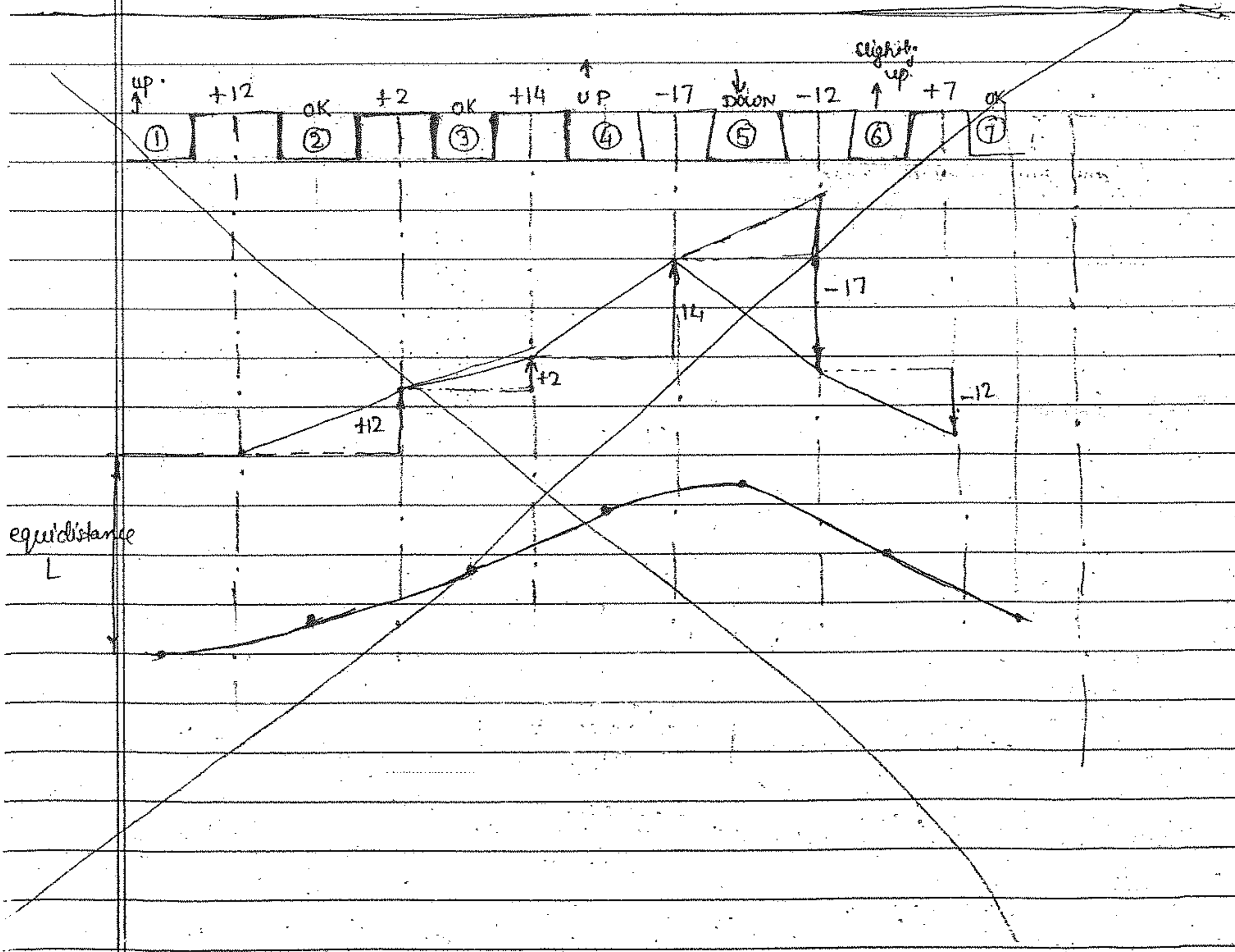
★ Tangential lift of turning gear has to be eased by ~~try~~ giving a small reverse kick. Else it will give a false reading. (↑ in last 3 units especially) - flywheel teeth

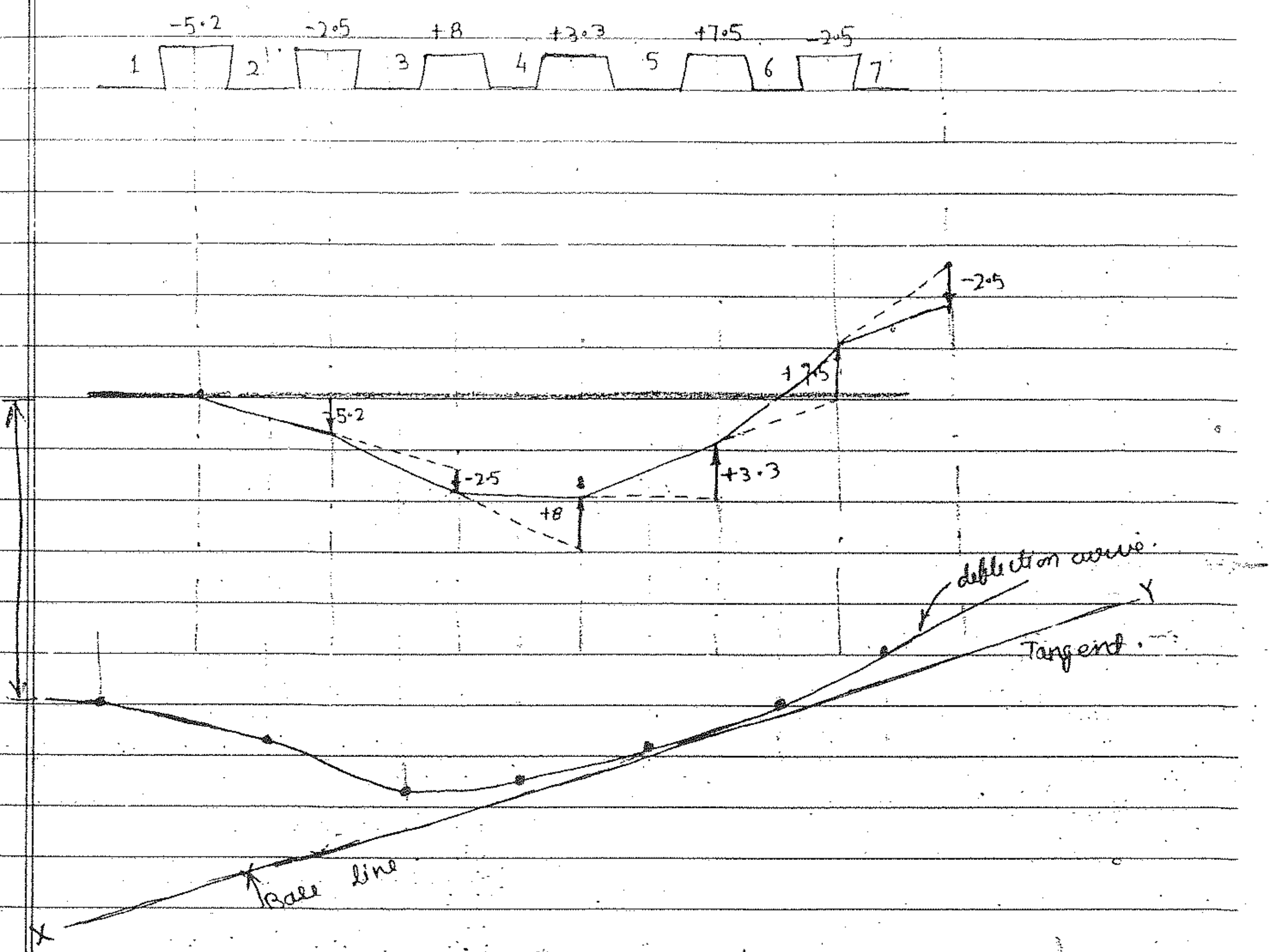
Table

	Position/Unit →	1	2	3	4
	PB				
	P				
	T				
	S				
	SB				
	$B = \frac{PB+SB}{2}$				
rtical	T-B				
horizontal	P-S				

Note:-

$(P+S) \simeq (T+B)$ - if the readings are taken correctly.

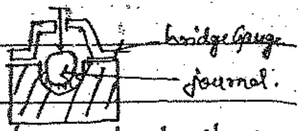




Unit 1 & 2 is two far away from base line. So it needs attention. Even If the values of vertical misalignment is within the limits as per the manufacturer's specification; the relative wear & tear might be sufficient to cause too much misalignment. Hence this is a method to double sure about the c/shaft being aligned properly.

* Feeler Gauge :- check the clearance b/w upper shell and the journal. If clearance is more then tie-rods may be loose or actual wear of the lower shell.

* Bridge Gauge :- gives bearing weardown reading. taken at various positions after every 90°. Reading should be equal at all position. If diff. then it indicates ovality.



If bridge gauge reading ↑ by 0.3 mm, open the bottom half of main bearing. Check

- Lead wire method → Put lead wire b/w bearings & tighten upto working torque. Remove & measure thickness.

- Remove shells & measure thickness by ball point micrometer.

* L.O inlet pipe connection can be removed & depth is measured ~~at~~ using depth gauge through this hole to ascertain bearing weardown.

→ Improvement in C/shaft design
① fillets are machined where ever change of cross-section occurs.
(ii) oil holes / key ways avoided.

→ ☒ CRANK CASE INSPECTION
Purpose:- (i) tightness of nuts & bolts, pipes & other fittings.
(ii) any sign of overheating of bearings.
(iii) metal particles.
(iv) flow of lub oil.
(v) signs of corrosion & cracks.
(vi) leakage of water, fuel oil through sealing rings, diaphragms.
Take bearing clearances and/or crankshaft deflection.
~~Op~~ ~~Propeller~~ Immobilization
Preparation:- (i) Engage turning gear.
(ii) Open C/case door (at least 30 mins after engine stop)
(iii) Allow ventilation.
(iv) Arrange for proper illumination
(v) Use proper PPE before entry.

Inspection
1. Colour of components — Dark layer of carbon ~ oil not properly purified.
~ lost detergency.
Localized dark — hot spots / overheating.
2. Look for broken pieces of metal or metallic dust.
3. Nuts ~ use hammer to check their firmly held.
& Bolt inspect locking wires, split pins.

4. Inspect lower end of tie rod under lowermost section of cross girder.
5. Corrosion & Rusting ~ moisture in crankcase.
6. Inspect crank web & look for slippage (check marking) & signs of cracks.
7. Condition of pipes.
8. Bearing clearances – main bearing & bottom end bearings.
9. cross head, cross head guide, cross head bearing & upper part of c/case.
10. clearance of cross head bearings ; also b/w cross head & guide.
11. Diaphragm ~ over heating.
12. Sump grating (may be chocked)
13. chain drive / gear train ~ condition of chain links, gear teeth.
14. Start L.O p/p for few minutes & turn the engine ~ observe oil flow to bearings ; piston cooling oil flow.
15. Sticky sediments – bacterial action.
Paint peeled off – oil is acidic.
16. Before closing c/case door inspect contact surface & clean them. Check condition of joint b/w door & frames.

X. CYLINDER LINER

Material :- Modular or spheroidal cast iron.

in form of graphite flakes → C – 3.5 %. (smooth sliding surface due to graphite content for improved lubrication)

Si – 1.5 %. (porous surface with retains oil as well as expose fresh surface in case of scuffing or scoring)

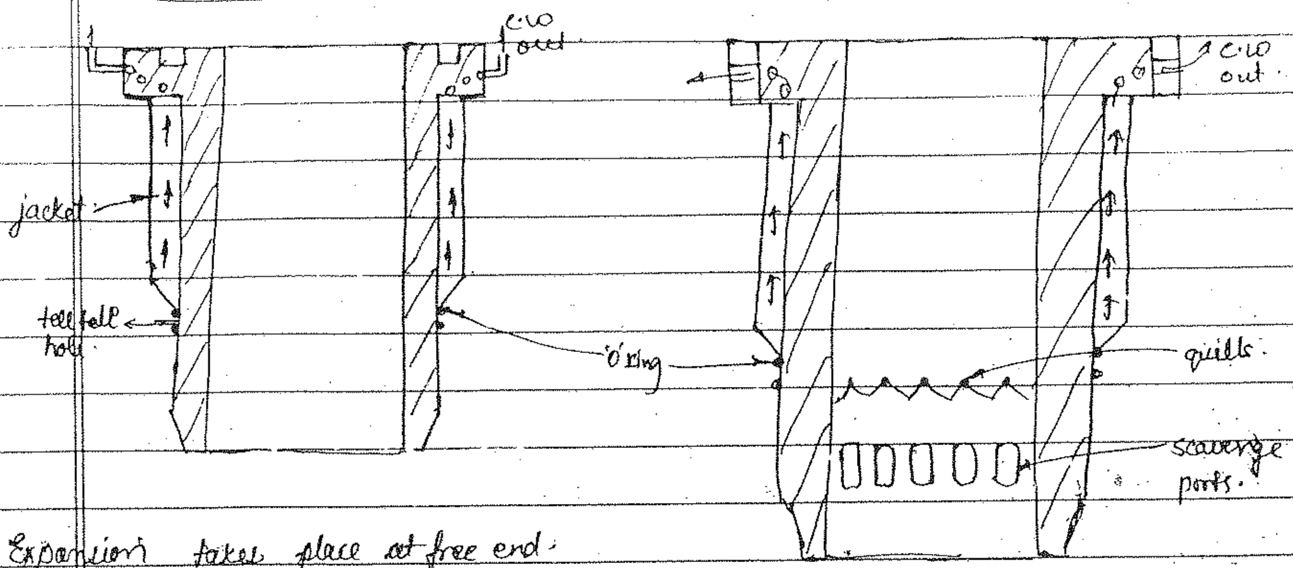
Mn – 0.7 %. (↑ toughness)

Vn – 0.2 %. (refines grains)

Ti – 0.1 %. (Improves strength)

- Usually sand cast (above 300 mm dia)
- Split type – to avoid distortion of bore shape due to non-uniform heat deformation.
in 2 stroke engine.
- Liners are press fitted into the respective bore of cylinder block.

4- Stroke liner. 2-Stroke liner.

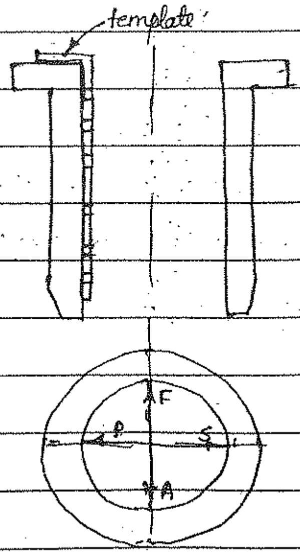


- Expansion takes place at free end.
- O' rings seal / case from leaking of water
- O'ring — Viton / Silicon Rubber.

In sulzer — quills passes through the water jackets [wet quills].

In MAN B&W → quills just above scavenge ports [dry quills]

✯ Liner Calibration



- Clean the liner properly.
- Use template to put marking on liner [P-S ; F-A]
- Check accuracy of measuring instrument.
- Take readings using inside micrometer.

✯ More readings taken at top bcz max wear is at top — combustion space (↑ temp, ↑ pressure, thermal stresses

Position	P-S	F-A	Ovality
1			
2			
3			
4			

$$\text{Wear down rate} = \frac{\text{Present Reading} - \text{Previous Reading}}{\text{Running hrs since last Reading}} \times 1000 \text{ hrs.}$$

Max^{m} weardown = 0.7 % of total liner dia. [0.03 - 0.06 mm / 1000 hr. ← 2S

Ovality = 0.02 to 0.03 mm max

0.013 - 0.025 mm/1000 hr. ← 4S

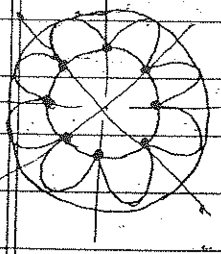
☆ When to Replace Liner :- (i) Liner wear down exceeds limits.
(ii) Excessive ovality.
(iii) Crack in liner.

☆ **Liner Wear.** → causes :- improper lubrication; poor fuel quality; improper cooling; scavenge air system fouled; improper liner & piston rings clearance; overloading; misaligned piston.

Corrosive Wear	Abrasive Wear ← Scoring	Contact Friction / Adhesive Wear [Scuffing]
• due to cold corrosion [Sulphur in F.O - SO_2 in gaseous state + water → H_2SO_4]	• due to hard particles of ash deposits & catalytic fines. ~ continuously cut, scratch & plough liner surface.	• due to Piston Ring friction on liner walls & inadequate lubrication. - causes fusion of metals at high temp — on separation causes tear on liner surface.
• Remedies :- (i) ↑ liner wall temp above due point of water acid mix. (ii) ↑ TBN content (iii) Low sulpur fuel.	• Remedies (i) Oil purification. (ii) Air filteration.	Remedies : (i) Proper cooling (ii) proper lubrication.

Consequences of liner wear :- (i) Blow past (ii) ↓ Pcom, ↓ Pmax, ↓ Beff, η↓ (iii) scavenge fire. (iv) Crase explosion (v) ↑ exh. temp. (vi) Black smoke. (vii) T/C surging (viii) liner crack (ix) piston ring break.

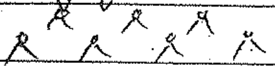
☆ **Clover Leafing** – uneven wear in the shape of a clover leaf on the liner surface



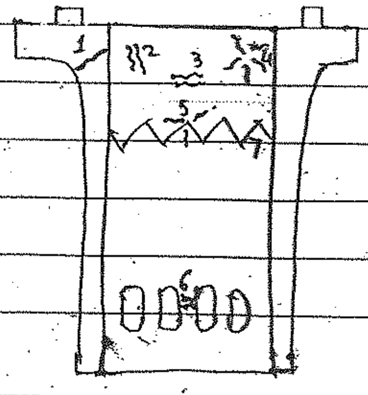
Reason :- uneven distribution of cylinder oil. High corrosive wear occurs on the liner surface between the oil injection points.

Remedies :- (i) Keep passages clean
(ii) Proper quantity & quality of oil.

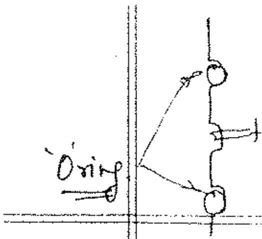
In Sulzer, 2 sets of quill



Effect :- In extreme cases, combustion gas blow-past takes plage or failure of liner can occur.



(1) cracks due to excessive, incorrect or uneven tightening of cyl. head studs.
(2) Poor liner support shows hoop stress cracks.
(3) Upper ring area prone to wear ridge circumferential cracks.
(4) Flame impingement region in the combustion space leads to star shaped cracks.
(5) J/W leaks at the L.O quill piping causing star shaped cracks.
(6) scavenge port area due to scavenge fire or overloaded engine operation.
(7) Clover leafing



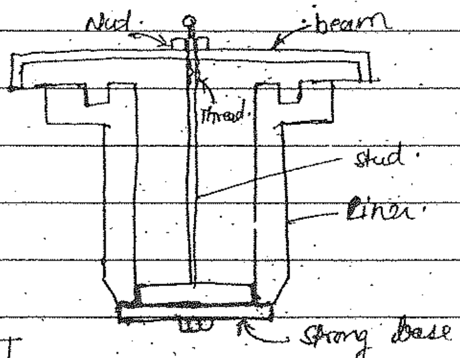
4stroke → (P-S) wear is more – side thrust is more b'coz no crosshead & piston rod.

2 stroke → (F-A) wear is more ~~due~~ b'coz – ship is always trim by aft.

★ **Liner crack** ① Improper cooling (JCW ~~wale~~ space scaled)
Ⅱ Thermal stresses
Ⅲ Engine / Unit overloaded.
Ⅳ Fuel injector holes too big / high penetration.
Ⅴ Engine started from cold.

Symptoms:– ⊙ White smoke ⊙ High peak pr.
⊙ Gas smell / black deposits in expansion tk.
⊙ loss of water ⊙ exh temp ↓ ⊙ Bubbling in exp tk.
⊙ JCW temp ↑ (of that unit).

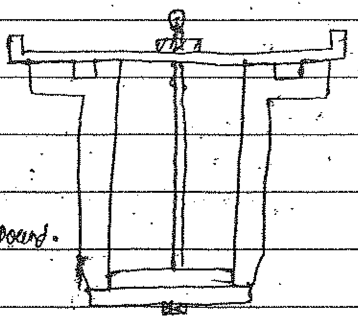
★ **Liner Removal** ~Jacking up.



- Shut the engine & isolate.
- Drain water.
- Remove cyl.head, piston.
- Remove liner as shown in fig.

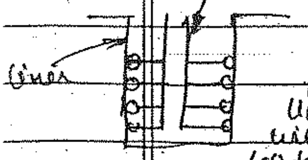
ROCKET TOOL

★ **Liner Assembly**



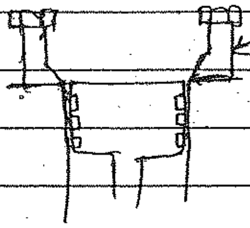
- Check the liner specifications.
- Clean the surface & calibrate.
- Clean liner landing surface.
- Put 'O' rings & remove twist. Apply silicon compound.
- Clean the jacket.
- Clean the 'O' ring mating surface on jacket.
- Fix liner in place. Ensure marking on liner & entablature coincide.

★ **Honing Tool**



used in case mirror finish in liner which will not allow L-O to form film.

★ **Holding down tool.**



to hold the liner while taking out piston.

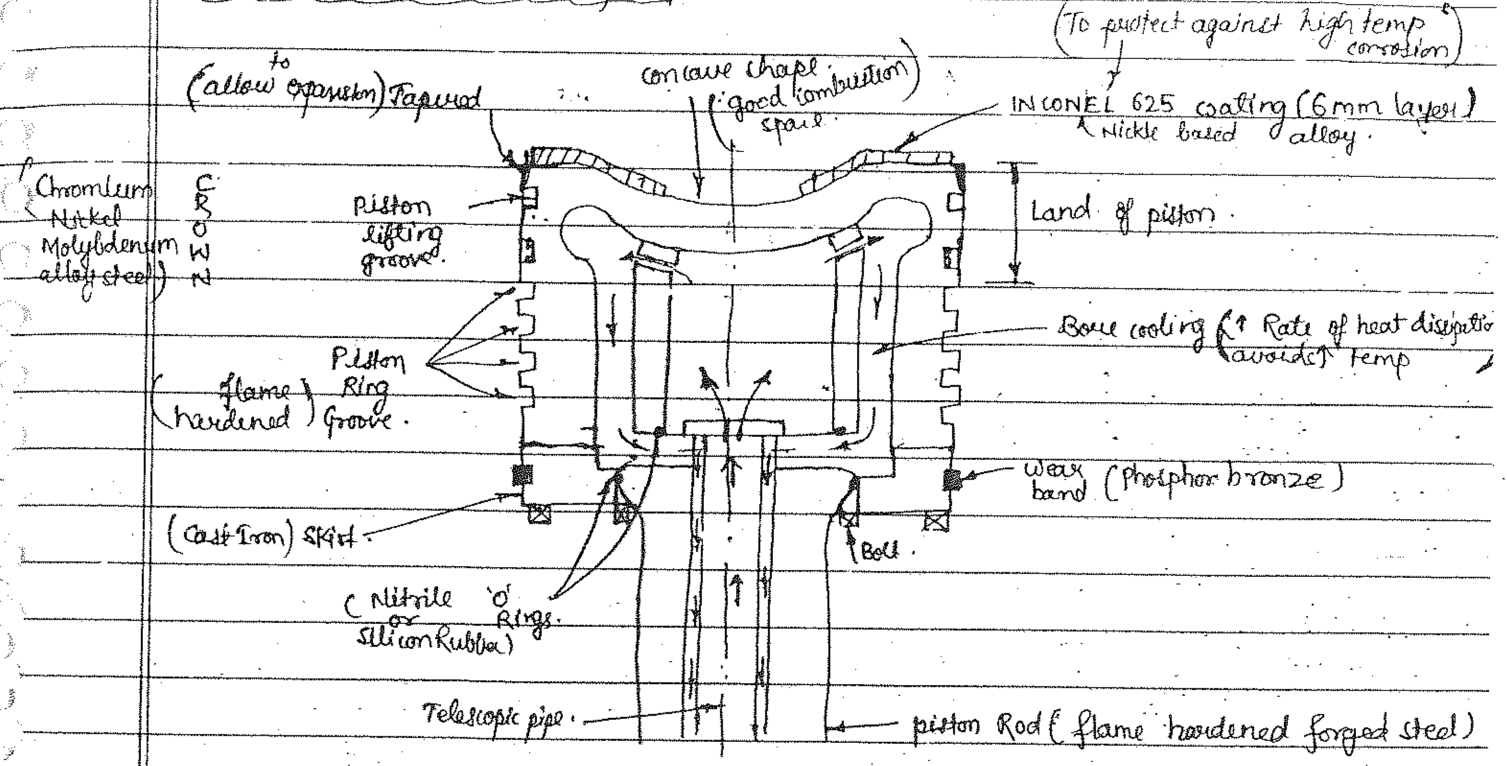
★ **Hot Corrosion** :– due to presence of V & Na in fuel.

$V + O_2 \xrightarrow[\text{catalyst}]{Na} V_2O_5$ ← very hard transparent coating.
Reduces Melting point of metal.

PISTON

- withstand thermal stresses during combustion
- ~~withstand mech stresses of combustion gas pressure & inertia forces~~

MAN B&W Oil cooled piston



we cannot Replace it

Wear band:- press fit in 3 or 4 segments. Have ↑ thermal coeff. of expansion. Expand faster & touch liner giving sealing effect during (I) Breaking in (to remove asperities b/w ring & liner (24-48 hrs)) and (II) Running in.

If there is slight misalignment b/w piston & liner ∴ then wear band touches the liner instead of piston. Being soft doesn't damage liner & takes in all misalignment.

Jet Shaker Effect

Oil cooled pistons employs a spray nozzle plate. A no. of spray nozzle direct the cooling oil into the blind bores of the crown at all crank angles.

At TDC → shaker cooling.

At BDC – jet cooling.

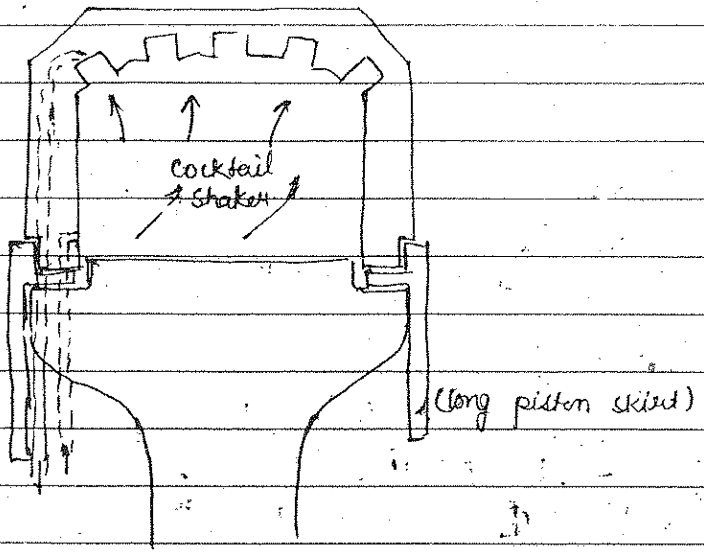
Cocktail Shaker Effect.

When piston moves then reserve oil splashes underneath the crown. This effect is cocktail effect.

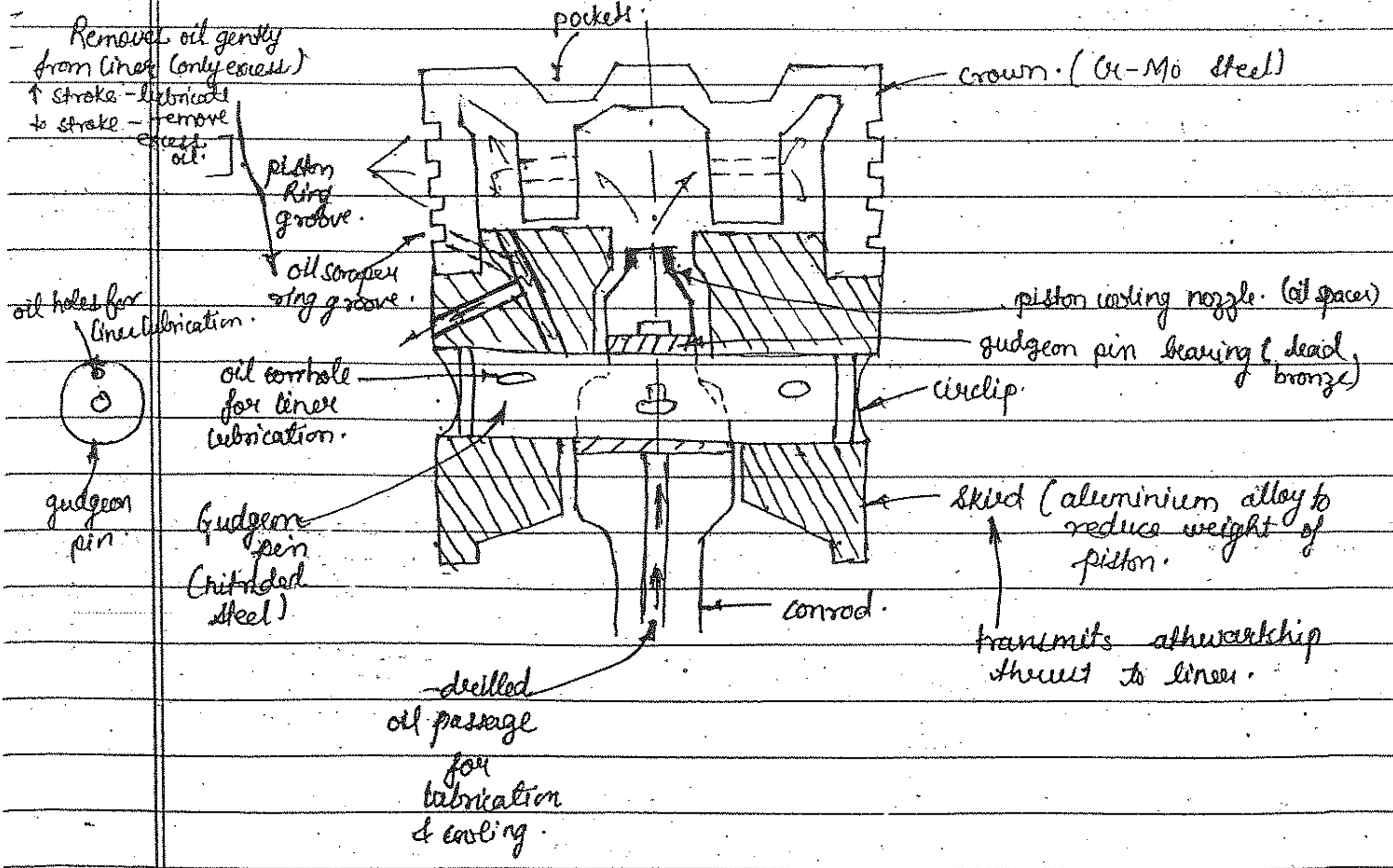
Advantages of oil cooled over water cooled :-

① Initial cost low
② No possibility of c'case contamination.
③ No scaling in cooling space.
④ lower stresses & temp.↓

(SULZER) water cooled piston – prone to thermal stress failure



4 - Stroke Engine Piston.

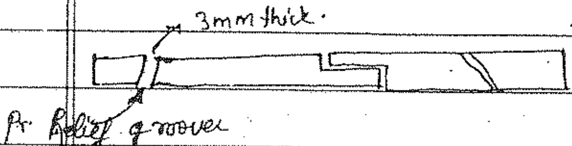


☆ Stresses on Piston.

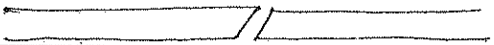
- Gas pressure acting downwards causes BM. Upper layer of piston subjected to compressive stresses. Inner layer of piston is subjected to tensile stresses. Shear stress on crown by gas pressure. Piston side walls subjected to compressive stresses by gas force.
- Thermal stresses.
- Fatigue stresses ~ due to cyclic loading.
- Effect of inertia force due to reciprocating masses.

☆ Piston Rings.

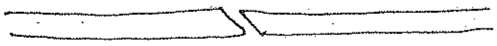
may be chrome plated (protect from combustion wear down)



Lap joint (1st Ring) very good sealing effect but less strength.

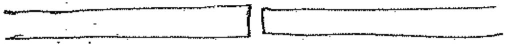


Bevel joint (2nd ring).



Angle cut (3rd Ring)

} Less leakage. Piston ring rotates in groove when ~~cracks~~ on bevel.



4th Ring (Butt joint) – very good strength but more leakage

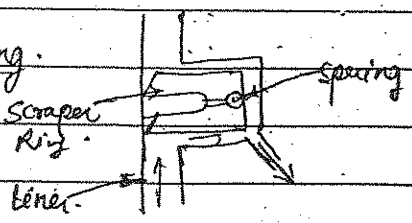
1st Ring → subjected to max pr. & temp. So provided with Controlled Pressure Relief (CPR) so i.e it has 6 controlled pr. relief grooves cut across the face. This ensures even pressure distribution & decrease thermal load to the 2nd ring as well as liner.

Chromium – Porous (retain oil) ; Aluminium – ↑ life [ALUCOAT].

Material :- Grey cast Iron (good wear & scuffing resistance)

Alloyed – C = 3.5% ; Si = 1.5% ; Mn = 0.7% ; Vn = 0.2% ; Ti = 0.1%

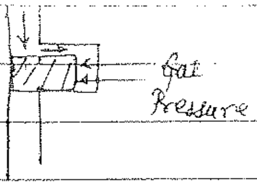
Scraper Ring.



•) No gas pr. to push it against liner as there is hole.
∴ Spring is provided for sealing.

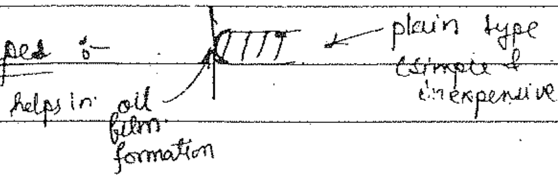
↓ Scraping oil ; ↑ spreading oil

Compression Ring: — to prevent blow-by · — transfer heat to liner
— seal combustion chamber



· Initial compression of ring puts a radial pr on the liner; further sealing is provided by the gas pressure itself entering the back clearance space b/w piston & ring.

Shapes :-



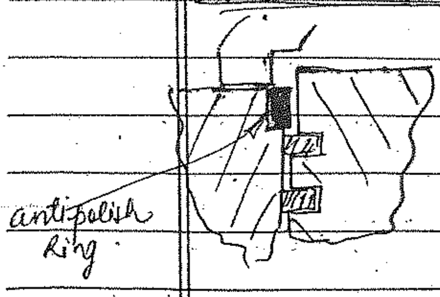
Life :- wear rate (0.1mm/1000 hrs) depends on

- (I) T/C fouling.
- (II) Poor clearances.
- (III) Poor fuel injection / fuel quality
- (IV) Poor lubrication.
- (V) Overload / excess pr. rise.
- (VI) Dirt accumulation in ring pack area.

~~Clearing piston Ring~~

Piston Cleaning Ring — embedded in the top edge of line just below cylinder head level. Purpose is to remove ~~combusti~~ excessive carboneous deposits at the top land portion of the combustion chamber wall.

Anti-Polish Ring: — Reduces polished effect of liner wall which is formed due to the hard deposits from combustion in contact with the liner.



Polishing unwanted — does not allow oil film to retain on the liner wall.
Also oil passes over the ring pack portion to combustion area where it is burned & wasted.

★ Piston Ring clearances

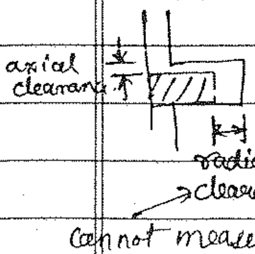
① **Axial clearance** – b/w piston Ring & groove in vertical direction

↳ essential so than gas pr can act on ring & sealing can be proper.

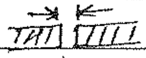
– measuresed using feeler gauge. /(ht of ~~ring~~ groove – ht of ring)

clearance ↑ = ring will hammer & break.

↓ = C deposit & ring seize.



② **Butt Clearance** – when Ring warms up, it expand & the 2 ends come closer.



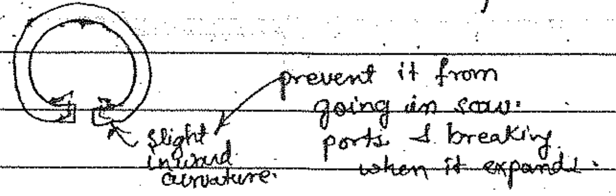
∴ Butt clearance ↑ = blow past. (ineffective sealing)

↓ – Radial pr. on liner & rapid weardown.

It ↑ with time ; ↓ in radial thickness, ↑ in butt clearance. Usually 15% wear of radial thickness – limit for butt clearance.

★ While taking clearance for new piston rings – take where min wear i.e bottom part of liner.

for old rings – at top of liner (max wear).



★ **Pr. Broken** :- ① Ovality of liner

(ii) Pmax ↑

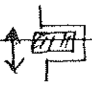
(iii) Too less / more groove clearance.

(iv) Insufficient cooling of piston.

★ Piston Ring failures.

① **Collapse** – inward push of ring against the piston body due to gas pr. against the running face of the ring.

Reasons – Reduce axial clearance ; poor ring & groove sealing ; ring not free to move in groove ; poor lubrication.



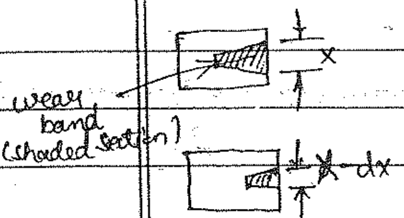
② Flutter – oscillation movement of piston ring along its own plane
↳ due to radially worn ring leading to a reduction in radial areas, or pounding of rings in groove when piston changes direction.

③ Wear – due to poor clearances, corrosion, abrasion, scuffing or improper lubrication

④ Jammed or sticking piston rings. – due to build up of carbon deposits or poor clearance.

⑤ Scuffing – overall damage on sliding surfaces, caused by the formation of local welds. These welds occur due to high local temp (800°C), which hardens the base metal; forming hardened ~~piston~~ particles at that point

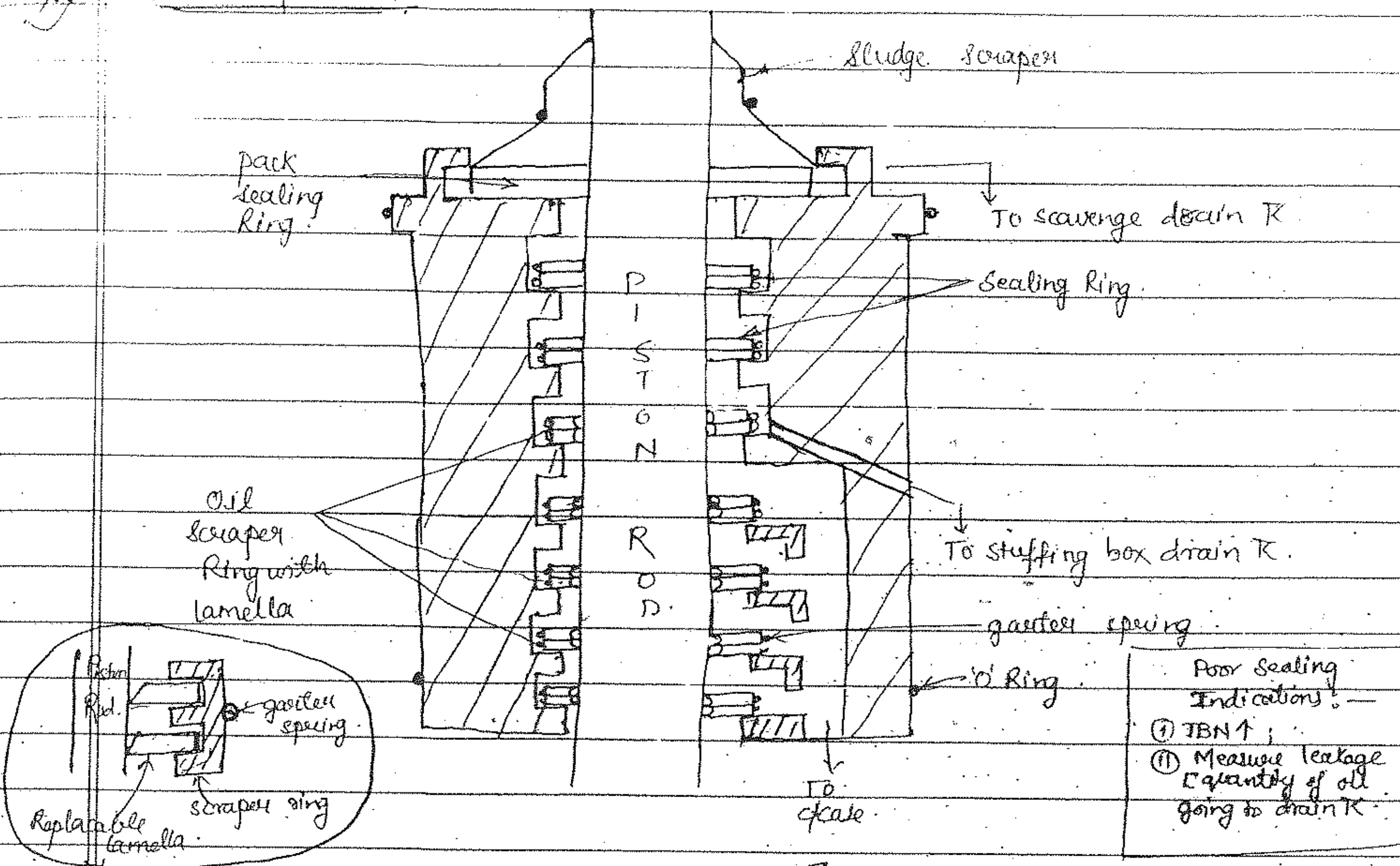
* SIPWA (Sulzer's Integrated Piston Wear Analysis)
– continuous online feedback measurement of piston Ring wear condition.



piston ring incorporated with wear-band. As wear down of piston takes place, a corresponding wear down of copper wear-band takes place. A sensor in the cylinder liner senses the wear & transmits this signal to an electronic unit which records & prints any wear down which can be used as pre-warning.

Beveled, Stepped, slotted

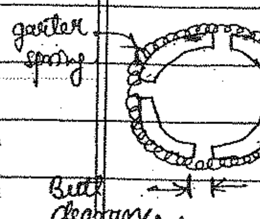
STUFFING BOX



Poor Sealing Indications :-
① TBN ↑ ;
⑪ Measure leakage [quantity of oil going to drain T.

- Seal b/w scavenge space & crankcase [i.e ① seals c/case oil entering into the scavenge space & scavenge deposits or cylinder oil entering c/case. ⑪ prevents air going to c/case]
- 3 parts :-

① Sludge Scraper Ring - 4 segmets ; brass ; held with garter spring ; Remove sludge ⎤ Scavenge drain T.
⑪ Sealing Ring - 1 set ; 4 segmets ; brass ; " ; Seals air from going into c/case.
⑪⑪ Oil scraper ring - 4-5 sets ; 3 segmets ; Cast Iron with lamellas ; scraps c/case oil back to c/case. [1st oil scraper ring scraps oil to stuffing box drain T ~ bcoz it contains mix of system & cyl. oil]



When butt clearance ↓, change the sealing rings. [Reduce to ½ the original]

✱ Poor sealing :- worn out rings, badly aligned joints, sticky rings, closed butt joints, weak spring, excessive axial clearance.

✱ Leads to → loss of c/case oil ; ↑ cost ; contamination of c/case & unburnt cyl oil.

CYLINDER HEAD

– cover cyl liner & block which seals the combustion chamber.

→ Materials :– Grey Cast Iron (good tensile strength &
Mo – Steel (elasticity & strength)

It houses, exhaust v/v, fuel injectors, starting air v/v, indicator cock & cooling water passages.

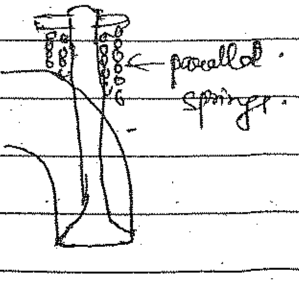
→ Stresses :– (I) Bending moment due to gas force.
(II) High compressive stresses.
(III) Thermal stresses.

→ Defects :– (I) Cracks due to thermal changes on the cooling water temp; sudden overloading or heating; uneven/incorrect studs tightness
(II) Distortion due to temp. variations.
(III) Cooling space fouling [Scale / sludge deposits]
(IV) Corrosion

VALVES

→ Reasons for fitting twin v/v's :–

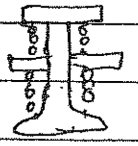
① 2 smaller v/v's gives large area than that of one big v/v for effective exhausting & scavenge.
② Bigger v/v's have higher bending moment; possibility of failure ↑.
③ Smaller v/v's easy to rotate.
④ Opening force for smaller v/v is less.
⑤ v/v bouncing is reduced; inertia force is ↓.
⑥ Better sealing & seating in small v/v's.



~~used~~ ~~to~~ employed to alter natural freq.

→ Advantage of parallel spring :– Less vibration bcoz vib. of one is cancelled by other [1 is right hand & other is left hand].

① breakage due to Resonance is less
② Increased safety factor

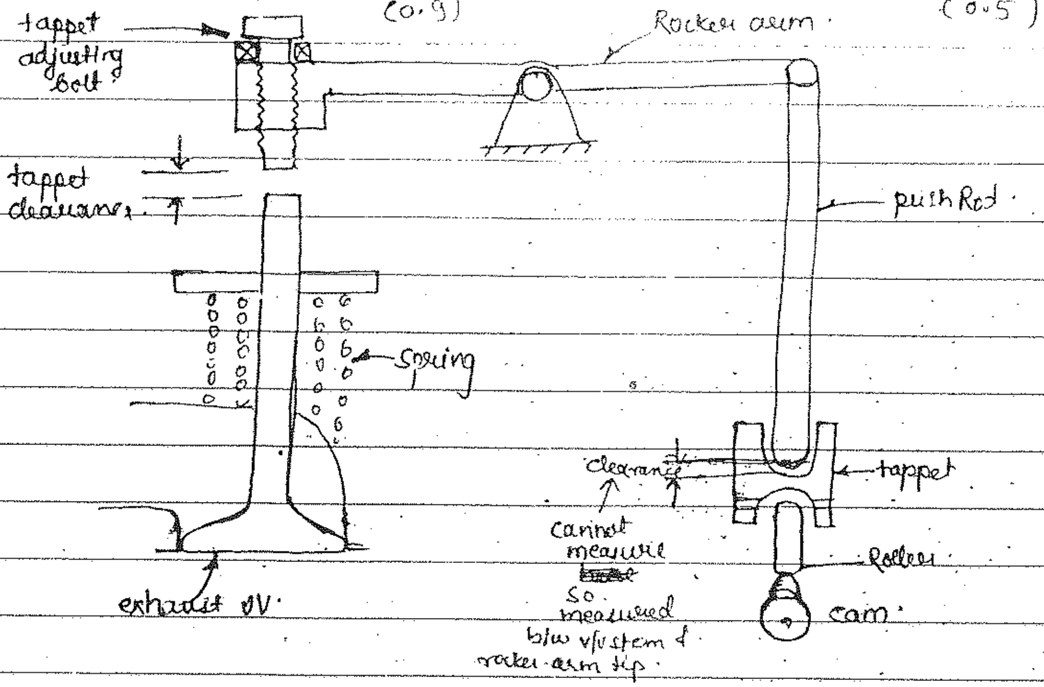


Series spring. – used in older engines for closing of each v/v as single spring would buckle.

① less buckling & bending stresses
② not used becoz of smaller design.

→ Tappet clearance :- to allow expansion of v/v spindle

usually exh v/v tappet clearance (0.9) > inlet v/v tappet clearance (0.5).



For measuring & adjusting tappet clearance :-

(I) Push rods should be free [i.e both inlet & exh v/v closed]
↳ This takes place when engine is at firing TDC ~ check marking on fly wheel.

(II) Open cam case cover & ensure that roller is on the base circle of the cam.

(III) Fuel pump have a sleeve marking. Top mark is beginning of injection & bottom is end of injection ~ check the beginning of injection.

★ To be taken when engine is warm.

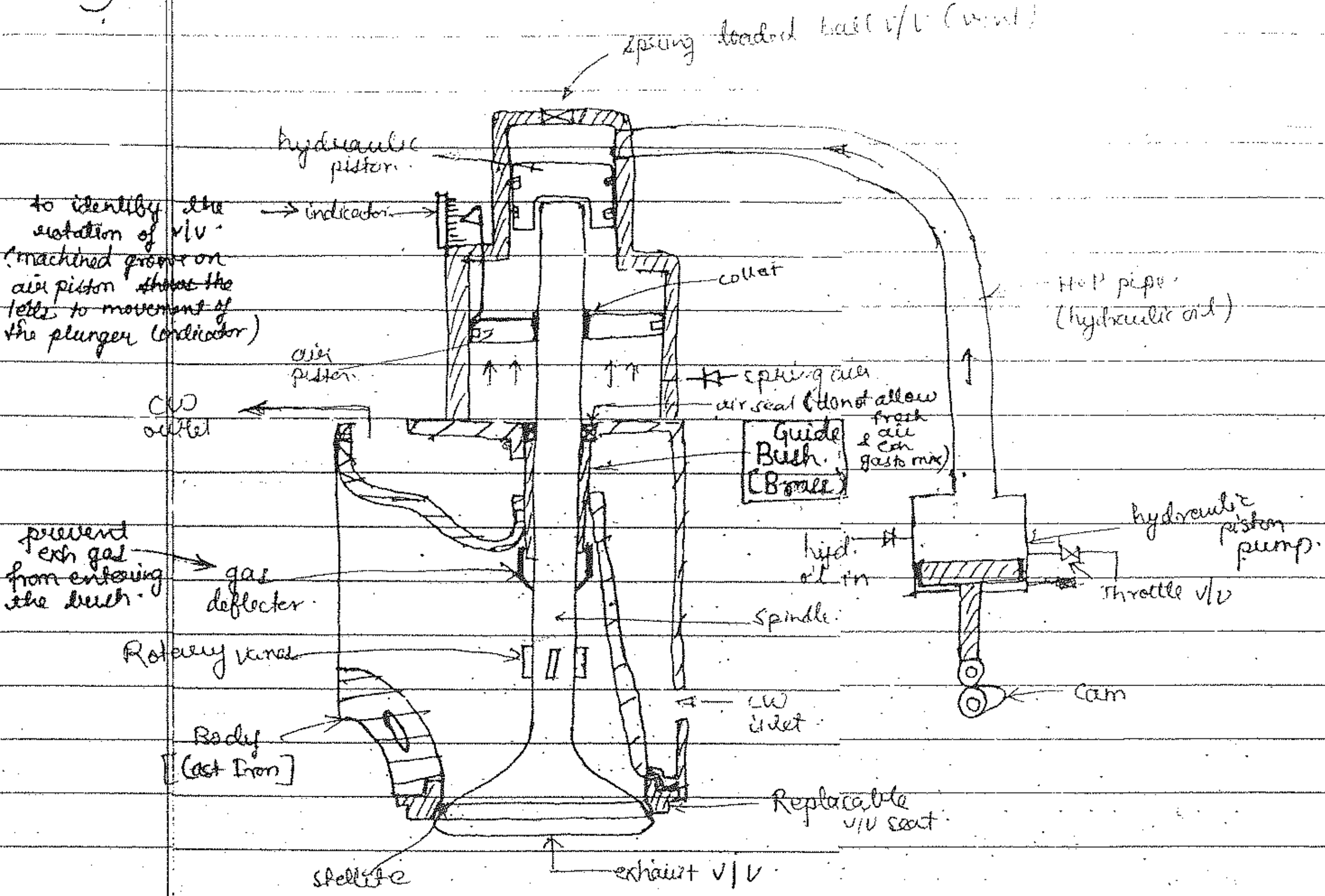
clearance more :- (I) inlet v/v opens late (blowdown ↓; loss of power; poor combustion)
↑
hammering of v/v stem
(II) exhaust v/v opens late (quality of air ↓; loss of power; smoky exhaust)

clearance less :- v/vs opens early [loss of compression; Pmax ↓, power ↓, v/v burning occurs]

★ Virtual Tappet (Main Engine) :- explained pg. 35

HVOC → High velocity Oxygen coating is the method of coating Cr on stem.

EXHAUST VALVE



<u>Material</u> :- Stellite [Co - 50% ; Cr - 20% , Mo - 18% , C - 2% , Tungsten - 10
↳ coating on the seat - superior hardness ; corrosion resistance , good surface finish & high temp strength.

Valve - nickel based alloy [C - 0.1% ; Fe - 0.1% , Cr - 15% ; Ti - 1% ; Al - 5% , Co - 20% , Mo - 4% , rest nickle]

Valve cage - cast iron.

V/V Guide - Pearlite Cast Iron.

Spindle - Nimonic ~~alloy~~ [Ni - based alloy)

Function :- ① Gas deflector - prevents exh gas from entering the bush.

② Valve Rotor indicator - Indicates the rotation of v/v.

uneven groove |||| → will go up at diff height everytime

Rotation of v/v → (i) less deposit on seat & sealing faces.
(ii) less corrosion & erosion.
(iii) Overheating of single spot reduced.
(iv) Temp of v/v seat & sealing faces reduced.

(iii) sealing air – from scavenge manifold – prevents the ~~gr~~ exhaust gases to come up & mix with the fresh air. Also supplied with L.O for cooling & lubrication of guide.

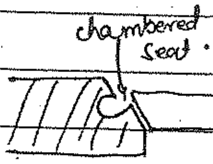
(iv) Throttle v/v – After sometime of operation the hydraulic oil will expand due to heat and will occupy more volume. Due to this the valve will remain open. ∴ Throttle v/v is provided. which has very small opening so that small amount of oil always leaves the p/p when exhaust v/v closes. If throttle v/v open too much, then v/v hits against the seat [This is virtual Tappet Clearance (so that v/v closes smoothly)]

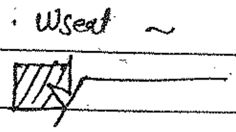
(v) Rotary vane – They turn the v/v when exh v/v opens due to high exhaust ~~temp~~ pressures. [No exh rotocap since no rocker arm - Ideally v/v should rotate during closing].

(vi) Working :– Hyd. pr is provided by the cam operated hyd. pump to the hydraulic piston of the hyd. actuator. L.O from the camshaft system is used to actuate the hydraulic actuator to open the exh. v/v by moving it downwards. Control air pr (7 bar) is supplied to air piston to use it as spring air, which closes the exh v/v when the pneumatic air force is greater than the hyd. oil force.

→ No rocker arm & push rod in 2 stroke.
(i) heavy – engine needs to overcome their inertia.
(ii) Sideway thrust – motion of rocker arm & piston rod produces side thrust on v/v spindle leading to damage of guide resulting in exh gas leaking up the spindle causing wear.
(iii) Springs – liable to break after sometime

→

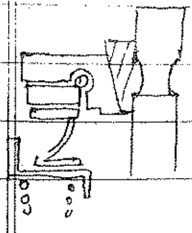


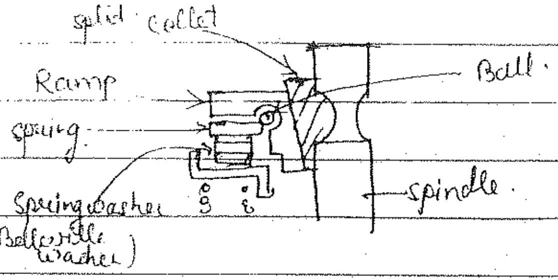


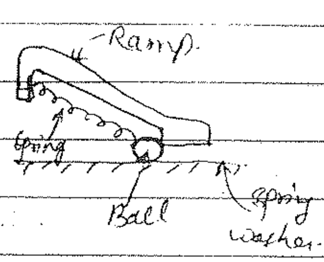
v/v & seat ground at diff. angle [1-2° at least] — to cover when the v/v expands & proper contact is made.

Inlet V/V	Exh V/V
→ marked (I)	→ marked (E)
→ Bigger (more air for scavenge)	→ smaller.
→ sitting angle - 120°	→ sitting angle is 90°
→ material - 41 Steel	→ material - Stellite.

★ Rotocap — 4 stroke exh v/v.





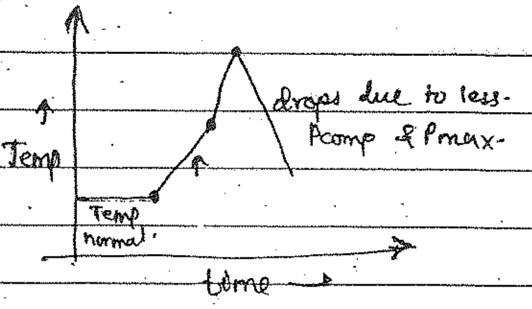


· Rotate when about to close.

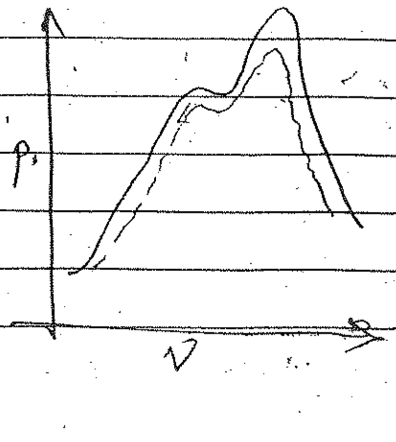
- In closed position, 'Belleville washer disc' is pushed against the body with slight force & disc spring is not diflected. When the v/v opens, the washer disc gets pused against the body with ~~to~~ higher force. This load is transferred to the balls, which ~~to~~ causes the balls to be pushed to the deeper recesses & induce rotation. Releasing of pressure when v/v closes, causes the balls & springs to return to the original position.

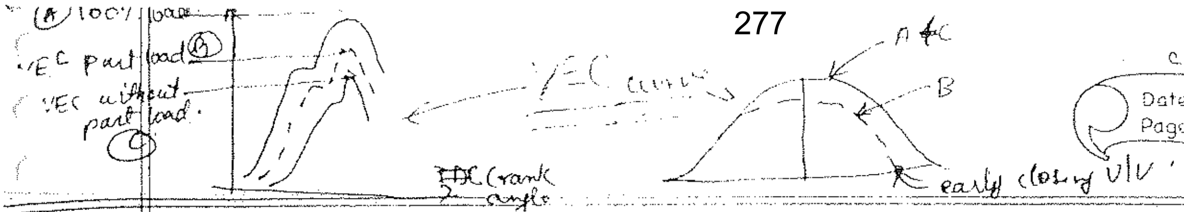
★ Exh. V/V leakage indication :—

⊙ Gradual increase in exh temp of that particular unit.
⊙ loss of Pcomp, Pmax & power.
⊙ Spark & Black smoke from funnel.
⊙ Ultimately unit will not fire.
⊙ T/C may surge.



Reasons:— (I) excessive grinding of v/v & seat.
(II) Stellite coating worn out.
(III) rotocap not functioning.
(IV) material isn't proper.
(V) if ~~bad~~ ↑ of all units !— bad quality fuel





→ Check v/v's timing :- A piece of paper is kept on spindle top. Engine is turned until paper gets tight on the place & cannot be withdrawn. This is angle of v/v opening. Continue turning until the paper can be withdrawn. This the angle of closing. [Note the angle on flywheel]
This angle changes only by weardown of cam & roller or shifting of cam/camshaft.
If timing is excessively out, cams have to be repositioned.

→ Variable exhaust closing [VEC] :- In latest engines especially in Sulzer engines, exh v/v closing time can be varied depending on load.

during 70-80% MCR load.

↑ Load, exh v/v closes early. As air pr will be more, it drives out exh gas fast. This also gives more compression.
Every 10° of early closing can cause an ↑ in 4 bar pr.
In VEC some hydraulic oil pr for opening is leaked off, when v/v is still open. This results in v/v closing slightly ~~early~~ when open. & the v/v fully closing earlier.

→ Hot corrosion :- ↑ temp corrosion. [above 550°C]
due to presence of Vanadium & Sodium in fuel oil.

$$V + O_2 \xrightarrow[\text{catalyst}]{Na} V_2O_5$$

V_2O_5 gets deposited on v/v structures. As it is highly corrosive it creates small grooves on the surface. When ↑ temp. gases impinges on it, wiredrawing occurs. Thus v/v leaks or breaks in course of time.

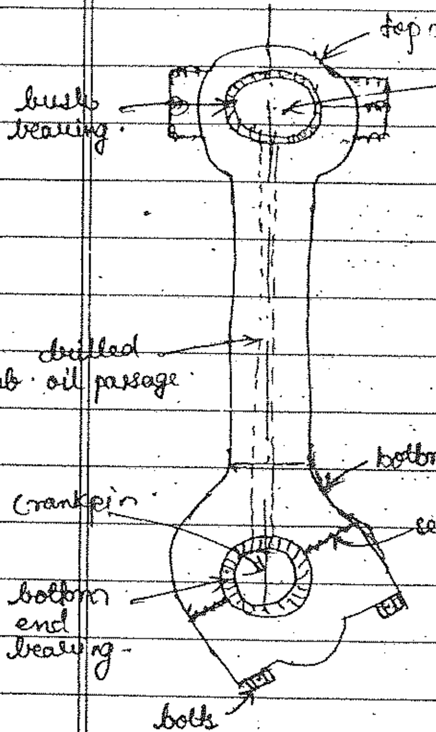
→ Cold corrosion :- bcoz of sulphur content in fuel. SO_2 when combined with water [moisture in air ; condensation due to low JW temp]. gives H_2SO_4 which leads to corrosion.
∴ low load operation of engine or excessive cooling is to be avoided.
To avoid excessive cooling, cooling water flow through exh. v/v is controlled by an orifice at the outlet.

★ Exh v/v failures :- ↑ temp corrosion; Erosion at seat area & sealing faces ; dents & scratches ; overheated spots (due to after burning, improper cooling) ; Spring failure
Reseating failure [tappet clearance, jamming of guide, distortion of spindle) ;
Mech. Impact loading (due to banging, hard deposits) :

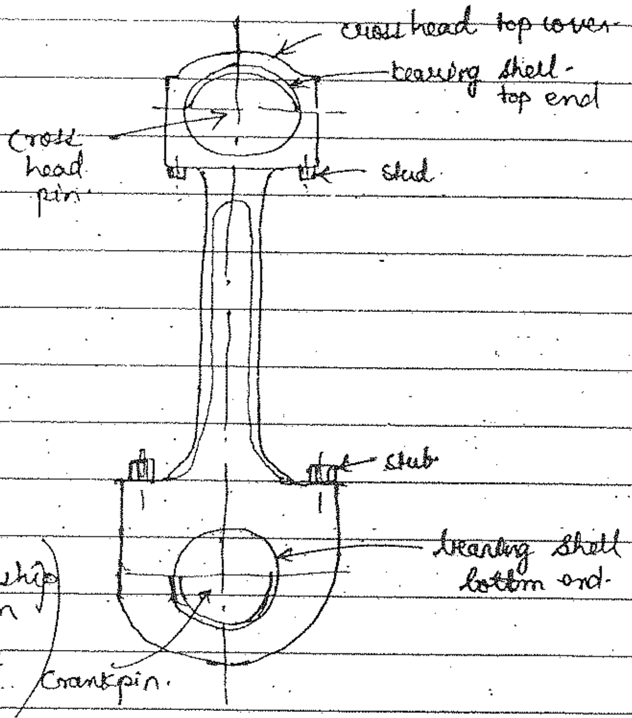
I section of Con Rod → ↑ Rigidity & reduces wt.

✓ **CON ROD** :- connects top end bearing (crosshead bearing in 2 stroke or gudgeon bearing (in 4 stroke) and the bottom end bearing (crankpin bearing) → purpose is to convert the reciprocating motion of the piston to rotary ~~motion~~ motion of C/shaft.

- most highly stressed component of a diesel engine. It is subjected to a high purely compressive force.



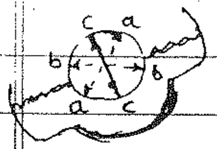
(to take athwartship thrust from con rod movement so that the bolts donot shear off.)



4-stroke	2-stroke
- only big end bearings split [usually in oblique shape direction to reduce the big-end width, lessen load on bolts & increase crankpin dia] - Top end may be bush type bearing.	- split type [2 halves for each small & big end bearings] - made up of I ~~..~~ forged high tensile material such as manganese steel or chromium alloy steel. - con rod ends are shaped to house x head bearing shell lower half & bottom end bearing shell upper half.

Checks on con Rod : ① Leccations – dye penetrant test for cracks.
Ⓘ ovality – $\frac{a+b}{2} - c$ ~ max 0.05 mm (inside micrometer)
Ⓘ straightness of con rod ~ put a thin rod inside the oil groove.

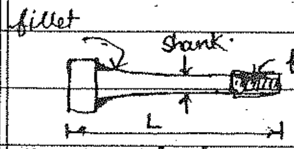
Measuring ovality :– measure aa, bb & cc using inside micrometer.

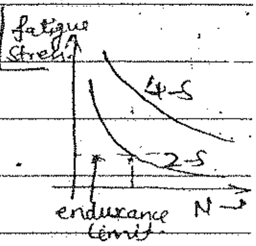


$$\text{ovality} = \frac{a+b}{2} - \boxed{c}$$ ← vertical

ovality is taken after tightressning con rod bolts but without keeping bearings in place.

Con Rod bolts :– max fatigue stresses in 4-S as ↑ force during comp & ↓ force during exh. [ie direction of load changes] · Endurance limit is ↓.
To check the bolts ~ hammer the bolts to hear solid sound.
~ check the lashing wire / locking plate / splitpin
~ measure length (L) when removed
~ Ensure proper & sequential tightening.





∴ Shank dia should be less than the threaded root part to ensure greater stresses act on the shank.

4-S bolts must be changed after certain running hrs (as per maker's)
2-S ~ loading in one direction. So less chances of failure.

Con Rod failures :– ① Buckling when starting engine if oil or water is present on top of the piston.
Ⓘ fatigue cracks or failures can occur in high stress con. areas.
Ⓘ Thin walled steel back shell bearings have more possibilities to fail rather than white metal bearings.

.%. Bearings :– ① to support the journal & prevent metal to metal contact by keeping the journal floating.
Ⓘ to transmit the load via lubricant.
Ⓘ reduce rotational friction

Material Requirements :– anti-friction resistant ; running-in & grinding-in ability ; non corrosive by lubricants ; should not scratch or score the journal ; build up adhesive oil films under boundary lubrication ; tensile & compressive strength ; fatigue resistance ; thermal conductivity ; ↑ Melting point ; ductility ; ↑ load carrying capacity

Bearing materials :-

1) white metal bearing.

Sn (Tin) - 88 % ~ soft matrix to allow small change in alignment b/w bearing & journal.

Sb (Antimony) - 8% ~ hard, wear resistant cubes to absorb & transmit load.

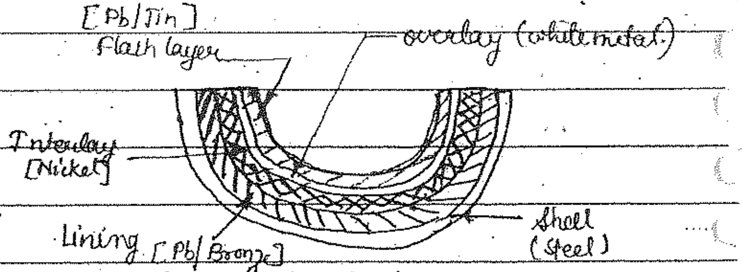
Cu - 4% ~ to segregate & hold antimony cubes in tin matrix.

Fatigue Resistance ↓ ; so they are replaced by
→ Tin Aluminium bearings [Sn - 40 %, Al - 60 %] ← ↑ fatigue Resis
→ Lead Bronze bearings [Cu, Zn, Sn & Pb] ← hard bearing used where very high load carrying capacity required
(Gudgeon pin Bearing) →

⊙ Quality of thin shell is better because of fine grain structure.
⊙ Its ~~[illegible]~~ temp ~~coo~~ is low.
⊙ have no lips & white metal is much thinner.

☆ Sn in white metal can oxidize giving a layer of SnO which forms a very hard & brittle layer on the bearing surface. This reduces the bearing clearance. SnO can break into fragments & can severely damage the pin [scoring].

2> Thin wall shell bearing



⊙ provided with lips allowing correct location of bearings.
⊙ temp is more than white metal bearing.

1st layer (Flash) :- • for corrosion (also acts as dry lubricant during installation.)
• 1 micron thickness
• Pb / Sn.
~ protect from outside atm & corrosion & wear during storage period only.

2nd layer (Overlay) :- • 20 micron thickness.
• white metal.
• soft & ductile coating to ensure good embedability & conformity b/w bearing sliding surface & pin surface geometry

3rd layer [Interlay] :- • reduces corrosion of white metal
• 5 micron thickness.
• Nickel

4th layer (Lining) :- • 1 mm thick ~ provides strength to bearing shell.
• lead / bronze.

Shell (Bottom) :- steel backing shell for shape & support.

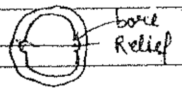
- Some part of the bearing is protuding out of the bearing housing to allow interference fit of bearing in the housing.

- 

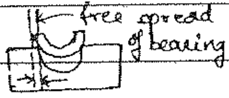
→ to locate bearing in housing.

- Fatigue Resistance $\propto \frac{1}{\text{Thickness of bearing}}$.

Thickness of bearing = (2.4 - 4%) of bearing dia → Thin shell bearing (trimetal)

- 

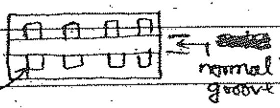
- to take care of misalignment in 2 half of the bearing when fitted.
If not alligned & bore relief not present then it will form a protuding edg which scraps off all oil.

- 

Embeddilility - bearing material should be soft enough to embed any particle that come to avoid any damage to the shaft.

- Oil Grooves :- Ideally Oil grooves are only on the non-loaded part of the bearing
~~No oil groove~~ [Exception - cross head bearing where loaded part also has oil groove
↓
cross head bearing grooves are not axial but circumferential.


to guide oil to loaded part of bearing.

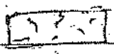


→ Bearing Faults & defects

1) Abrasive wear due to fine scoring by hard particles and impurities in lub oil

2) Wiping of bearing :- bearing removed if shaft touches the overlay of bearing.
Cause :- ovality of shaft & bearing; poor lubrication; fuel, or water mixed with oil:
If all unit have same problem then poor oil quality.

3) Fatigue cracks :- at the areas of stress concentration; excessive load fluctuations;



4) Fretting :- corrosion damage at the asperities of contact surfaces.
due to back support surface where the interference fit /nip is insufficie
for the dynamic forces;

5) Acidic Corrosion :- black spots on surfaces ;
cause - poor oil quality; oil has become acidic (oxidation, water ingress due con
ni

6) Misalignment :- due to distorted bedplate, adjacent bearing failure or imbalanced cyl. pr.

7> Thermal ratcheting :- bearing deformation caused by alternate cooling & heating of bearing. (↑ Bearing temp.)

8> Erosive wear :- due to cavitation (usually at low pr. areas like oil grooves or holes)

9) Incorrect clearances or incorrect tensioning of bolts.

10> Poor design, manufacture or low strength

11> ~~E~~ Electrical potential - caused by incorrect earthing which causes spark erosion damage.

☆ Causes of Bearing Overheat

(I) Improper oil viscosity.

(II) Insufficient lubrication

(III) Improper clearance.

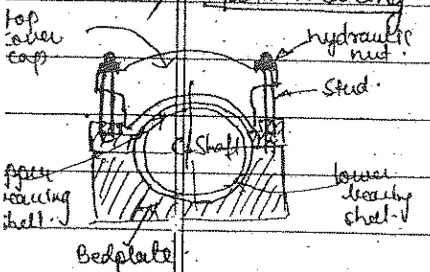
(IV) Misalignment.

(V) foreign matters in oil.

(VI) Improper fitted bearings.

⇒ Bearings in Engine

1> **Main bearing** :- (I) support c/shaft, & keep it aligned.



(II) Remove heat produced by friction.

- Lowerpart of bearing shell is cut into the transverse strength member of the bedplate.
- Uppershell cap is held in place by special jack bolts or secured by waited studs.

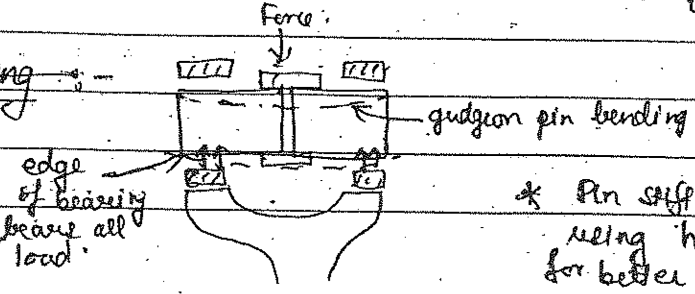
This shell babbitt [white metal] with a steel back is used for the main bearing.

2> **Bottom End Bearing (Crank pin)** :- (I) transmit load from conrod to c/shaft

(II) allow relative movement of con rod & crankpin ~~journal~~.

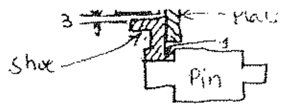
3> **Con Rod Bearing** :- bottom part of crosshead & top part of crank pin. ↳ in 2stroke.

4> **Cross Head bearing** :-



∴ In MAN B&W, Bigger dia; ↓ length
↳ increases area preventing bending

* Pin stiffness ↑ by using hollow pin for better section modulus.



2 - plate Rail - 1.5
3 - Rail wheel - 0.4

4) Crosshead bearings

- Thin shell bearing on either end of crosshead pin
- Material - Sn-Al with Pb-Sn overlay.
- Oil grooves on bottom half to distribute oil [Not till end - only on loaded surface]
- Grooves limited to increase bearing surface.
- L.O directly supplied to crosshead bearing.
- High sudden load → combustion pr. acting directly on bearing; ↓ direction;
- Relative motion is less so difficult for hydrodynamic lubrication.
- Dia & length is less - area limitation - high specific loading.
- Bearing distortion - B.M & deflection max at centre; Less stiffness & ↑ stress conc.

~~Latest~~ Developments in crosshead bearings:-

① Bearing material thickness ↓ by bonding it to lining & steel backing → improve overall strength.

(ii) Increased pin stiffness - hollow pins/bored (Sulzer - conjugate deflection]

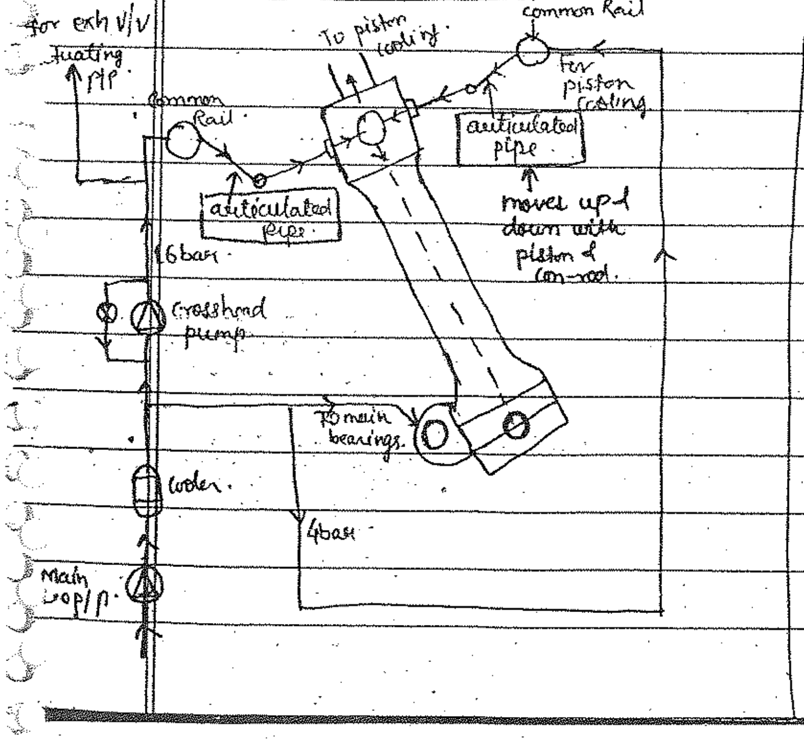
(iii) Cross head mounted mechanical L.O pump · [MAN - oil supplied when load is hi & oil film not broken at ↑ pr]

(iv) Superior surface finish (to maintain oil film]

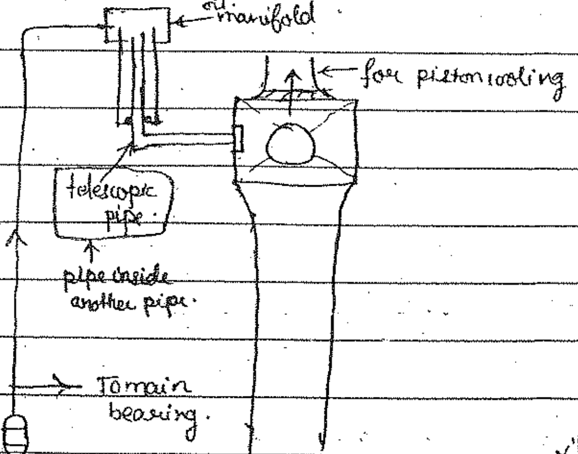
(v) Improved bearing material

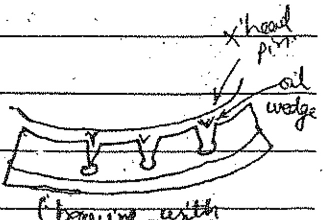
(vi) Continuous full length bottom half.

Cross head lubrication (SULZER)



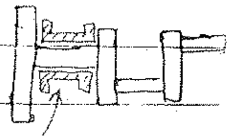
Crosshead lubrication (MAN B&W)





(bearing with grooves)

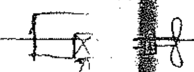
5) Thrust Bea ng :- Aux Eng ~ not subjected to much thrust.
given at flywheel end which is almost
like a main bearing with end sleeves.



Thrust bearing.

bcoz node of vib is 'O' at aft

Main Engine ~ at aft end to take fwd-aft thrust.
(transmit thrust from propeller shaft to hull)



Thru

Bearing clearance

① Telescopic Feeler gauge – no opening of bearings required.
-it may break inside damaging the bearings.

② Pb-wire m d – put lead wire where the clearance is to be taken. put back the upper part & tighten. Remove & measure thickness of lead wire.

③ Bridge gaug

→ where to ta e clearance ??

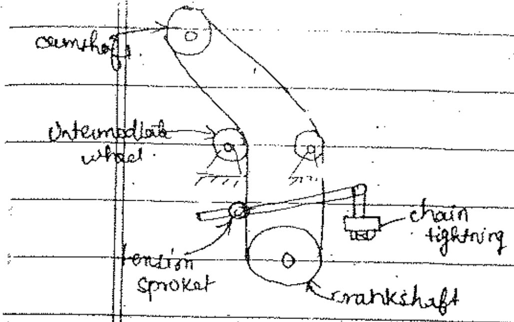
① Main bear → b/w journal & top half.
bcoz bottom always loaded.

(ii) Bottom end bearing → b/w crankpin & bottom half.
bcz top always loaded.

(iii) cross head → b/w cross head pin & top half.
bcoz bottom half always loaded.

→ (i) B w pin & shoe.
(ii) B w shoe & rail.
(iii) C w plate & rain

%. CHAIN DRIVE :- transmits power drive from c/shaft to camshaft. Intermediate wheel (for fuel p/p or exhaust cam drives) serves as a guide. while an adjuster wheel serves to adjust the chain.



Materials:- Link plates :- Cr- Mo steel.
Pin. - hardened steel
Rollers - Alloy steel.

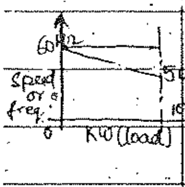
Chain tightness :- Turn the engine to slacken the longest free length of the chain. At the middle of the longest free length of the chain, pull the chain away from the guide bar. The limit of slackness is half to one chain pitch link. If too slack or too tight, adjust the chain tension.

Advantages of chain drive :- ① easy timing adjustment
(ii) max flexibility positioning the gap b/w driven equipment
(iii) economical & less spare parts required.
(iv) ↑ drive η% [98%]
(v) can ope with certain misalignment due to axial movement}

① Chain elongation - due to wear b/w pins & bushing ; roller & sprocket wheel ; bushing & rollers. causes ~~elongation due to~~ change in camshaft position w.r.t to c/shaft i.e. Fuel & ~~v/v~~ timing Changes - Max elongation - 2%. If 1.5% renew chain
② Slack chain - excess strain during starting & reversing.
③ Tight chain - overloading of chain wheel bearings.
↳ wear of rollers, links & bearings & can cause cracking of links.

GOVERNOR – to control engine speed within close limits from no load speed to full rated speed.
– to control either engine speed or engine load.

Isochronous Governor	Variable Speed Governor.
– maintains 'constant speed' irrespective of load & power changes.	– adjust the speed according to the load.
– Aux. Engine Governor	– Main Engine Governor.



→ **Droop** :- drop in speed from 'no load condition' to stable 'full load' condition i.e fall in speed due to load changes.

$$\text{Droop} = \frac{N_o - N_f}{N_o} \times 100$$

N_o → no load speed
N_f → full load speed.

→ **Sensitivity** :- it is the measure of smallest change needed for which the governor responds with the required output signal.

→ **Stability** :- ability to attain a stable speed from varied load condition.

→ **Governor effort** :- force applied by the governor onto the fuel p/p control, when there is a change in load or speed.

→ **Dead Band** :- range or band in speed, only after which the governor will respond.

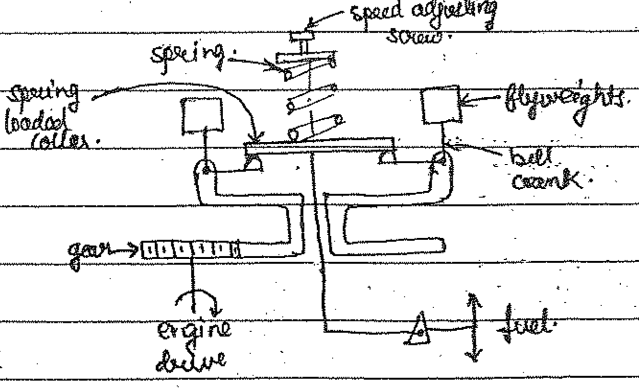
→ **Hunting** :- fluctuation in engine speed due to over or under control of governor. Too much sensitivity can cause 'huting'.

Mechanical Governor

→ Load ↓, speed ↑, the flyweights move outwards, due to ↑ centrifugal force. This cause the bell cranks to push the spring loaded collar to reduce fuel.

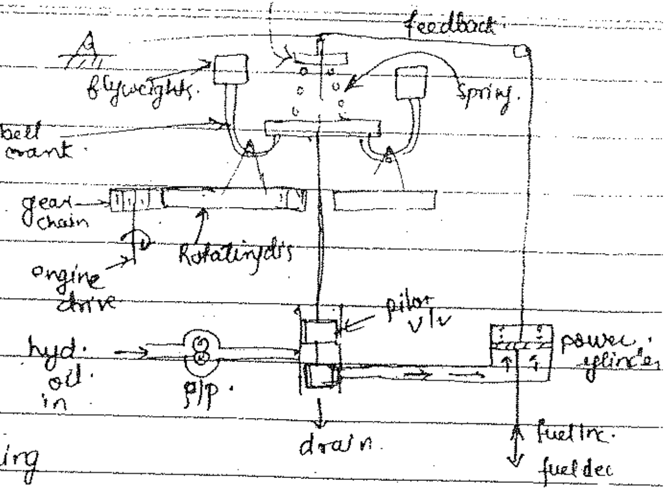
→ Small engines governor.

→ Spring compression decides engine speed.



Drawbacks :- Wear, friction, mechanical damage, bearing failure, instability, limited governor speed.

☆ HYDRAULIC GOVERNOR

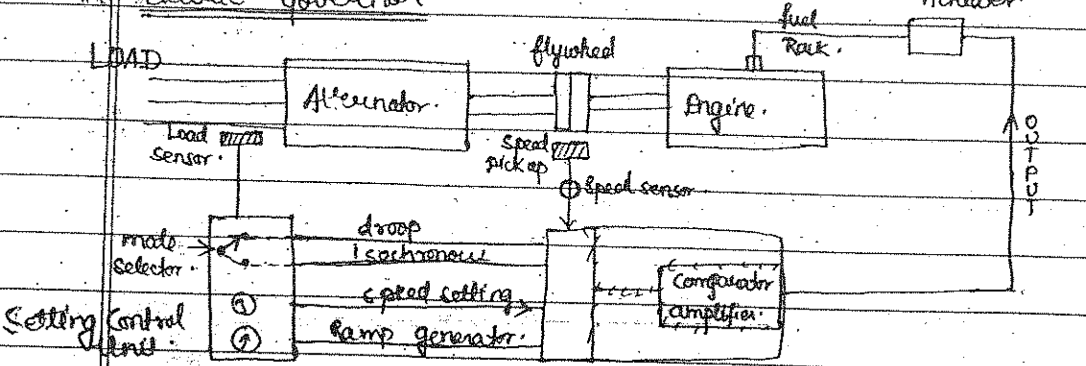


Load ↑, Speed ↓, centrifugal force ↓, spring force ↑, pilot v/v moves down, oil enter servo cylinder, power piston moves ↑, fuel ↑,
Simultaneously the piston applies force onto the ~~receiving~~ ~~piston~~ spring and causes closing of the pilot v/v (pilot v/v moving up).
Thus equilibrium & stability is achieved at a lower speed.

~ Has operational problems — low oil level; dirty oil; incorrect viscosity; air lock; wear at fine clearances.

— for bigger engines

☆ Electric Governor



Advantages :-
- less mechanical components.
- quick response.
- no friction.
- overspeed control.
- ~~easy installation.~~

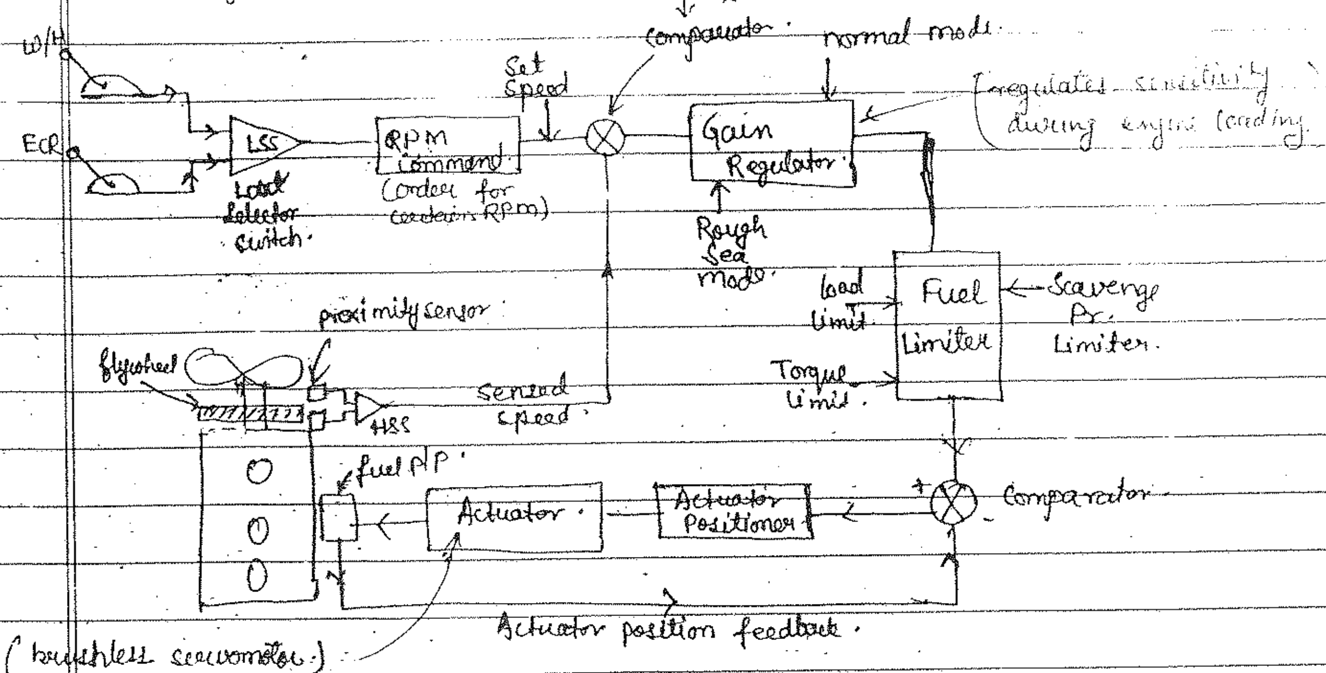
Load sensor senses the load after the governor alternator & sends their input signal to the setting Control Unit. The speed sensor senses the speed at the engine flywheel & send input signal to the comparator amplifier.
Sensing Control Unit has setting for droop or isochronous mode; speed setting signal & ramp Generator. Comparator / Amplifier control unit compare the input signal with reference settings & sends output signal to the actuator to change the rack position of the engine fuel pump.

- Very accurate & sensitive.
- Ramp Generator - testing function without actually changing speed.

Disadvantage :- It can fail in case there is a failure of input current to the governor from any source.

Governor.	Overspeed Trip.
⊙ Speed control device.	⊙ Safety device
⊙ Modulating action.	⊙ ON/OFF action.
⊙ Auto reset.	⊙ Manual Reset

☆ Main Engine Digital Governor (compares set rpm & sensed rpm)



Gain Control: Higher gain, ↑ sensitivity.

Rough Sea Mode – deadband is ↓, sensitivity ↑.

Index mode – Regular mode – ~~more~~ Less sensitive.

Fuel limiter: decides how much fuel is to be given.

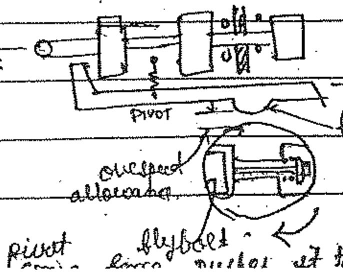
1) Load limiter → RPM set; but load limit is reached before reaching that rpm then fuel is not given further to avoid overloading.

2) Torque limiter → RPM set; but torque limit is reached before reaching ~~that~~ ~~torque~~ the set RPM; no further fuel is given to avoid torque overloading.

3) Scavenge air pr limiter → to avoid smoke at the funnel &. Sudden ↑ in load; T/C takes time to speed up to supply the demanded scavenge air. So depending on scavenge air pressure; fuel is given slowly & steadily.

↳ during starting; scavenge air pr is very less so control air signal is given → more fuel to overcome inertia & generate initial power.

☆ Overspeed Trip:

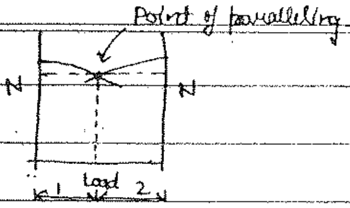


Overspeed trips when
- fuel rack stuck.
- sudden load change
- governor malfunction
- excessive fuel going inside.

Rotating disc, As speed ↑, flybolt keeps coming out & touches at top.

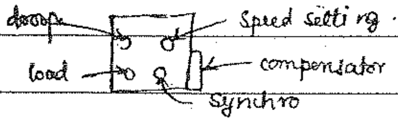
At 15% of normal rpm, when this happens, the lever moves about the pivot and the force pushes it to cut off the fuel.

Load Sharing & Necessity of Droop



In order to achieve sharing of load, the generators lines should intersect.

- If droop of both generator is equal – equal load sharing.
- If trop of one generator is more it will share less load.
- Isochronous Governor – No droop i.e same line at constant speed / frequency of 60Hz. There can be no crossing of G_1 & G_2 lines if constant speed. Hence sharing of load would not be stable.



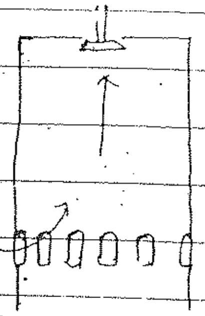
- If gen. share less load than other, its governor speed setting can be adjusted or Increased to share equal load.
  (wear & tear of gears & wheels causes droop to increase)
- If generator is newly overhauled, load setting can be reduced to share only 50% load until breaking in & running in is done.
- Synchro shows diff. b/w set speed & actual speed.
- Compensator – avoid vigrous change in speed due to change in load. If 800 is set rpm. Load ↑ & RPM dropped to 790. Governor takes action & RPM jumps to 805. To avoid this vigrous change, compensator gives hydraulic oil slowly & steadily to bring back RPM to 800.

AIR SYSTEM

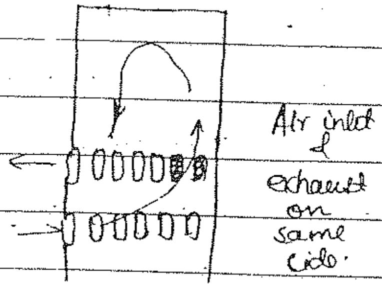
✓ ⁎ **Scavenging** → process in which low pr. air is utilized to blow out the waste gases of combustion & refill the cylinder with fresh pressurized air for next compression stroke.

⁎ Types

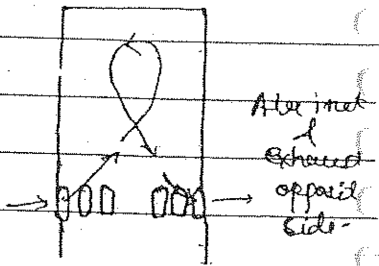
Uniflow



Loop



Cross.



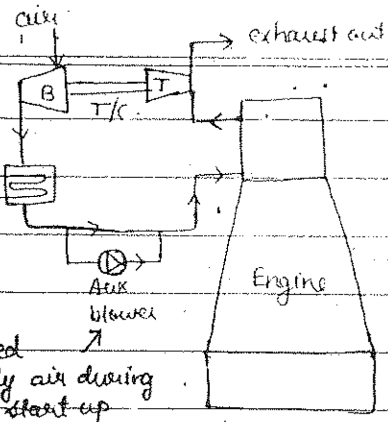
→ η_{scav} ↑ ; No scavenge air and exhaust intermixing; working temp. reduced; L.O consumption reduced; Less residual gases after scavenging inside cylinder; Fresh air loss is nil; Liner design simpler; shorter piston skirt; Thermal stresses ↓.

- η scavenge is less than uniflow.
- LO consumption is more.
- Undesirable mixing of scavenge & exh gases.
- Thermal stresses ↑ ∴ chances of cracks is more. (Temp variation b/w scavenge & exhaust ports is confined to limited area)
- Complicated liner design ∴ costly.
- Exh back pr may ↑ due to narrowing down of exhaust passages with carbon deposits.

⟹ Gas exchange Process :– (I) Blow down of exh. gases.
(II) Scavenging
(III) Post - Scavenging.

→ ⁎ SUPER CHARGING (PRESSURE CHARGING) ~ process of supplying charged air pressure to engine for scavenging using T/C system.

- ↑ η of engine.
- ↑ power of "
- Compact & cheaper.
- fuel consumption ↓
- better utilization of exhaust.



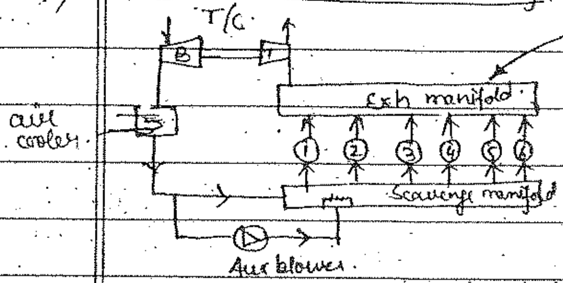
(to increase the density)

fitted to supply air during engine start up till the T/C reaches its desired rpm.

✗. Types of T/C system

1) CONSTANT PRESSURE T/Cing

Since exh pressure pulses are not used, more energy is available for recovery at the turbine & comp. Hence, the compressor output is ↑.



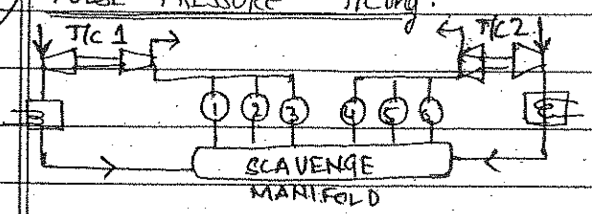
large space to convert the pulse/blowdown energy into pressure energy. Acts as a constant pressure gas reservoir.

T/C → constant pressure exh gas supplied to T/C. This exh gas will expand through nozzle ring & turbine blades thereby rotating the turbine which in turn rotate the blower. Blower will take suction from atmosphere & discharge pressurized air via air cooler into scavenge manifold.

Advantages :-
- (I) η% is ↑
- (II) Better scavenging at higer loads.
- (III) Exhaust manifold becomes simpler.
- (IV) Flexibility in location of fitting T/c.
- (V) exh gas temp is ↓

Disadvantages :-
- (I) Cannot cope up wt low or part load.
- (II) Slow response to load changes due to large exh manifold.
- (III) Aux. blowers required.

2) PULSE PRESSURE T/Cing.



- uses pressure pulse wave to expand the gas further at the turbine nozzles & blades. Exh gas from each cyl is directly led to turbine inlet. Here, pulses are created, when exh v/v suddenly opens & exh is blown down into exh. piping of sam smaller dia, thereby pressurizing it.

Advantage :-
- (I) η ↑ at part load.
- (II) No aux blower required.
- (III) Good response to sudden load change.

Disadvantage :-
- (I) Complicated exh.piping
- (II) location of T/C critical.
- (III) ↑ vibration.
- (IV) Grouping is critical.
- (V) η ↓ at high load.

→ Two stage supercharging

① % η ↑
② Boost air pr ↑
③ work done on compressing ↓.

① Series.
- → 1st stage ~ air compressed by T/C & then cooled in intercooler & applied to 2nd stage in series.
- → 2nd stage ~ air further compressed by a scavenge p/p or under piston space & sent to after cooler & then to scavenge ports.

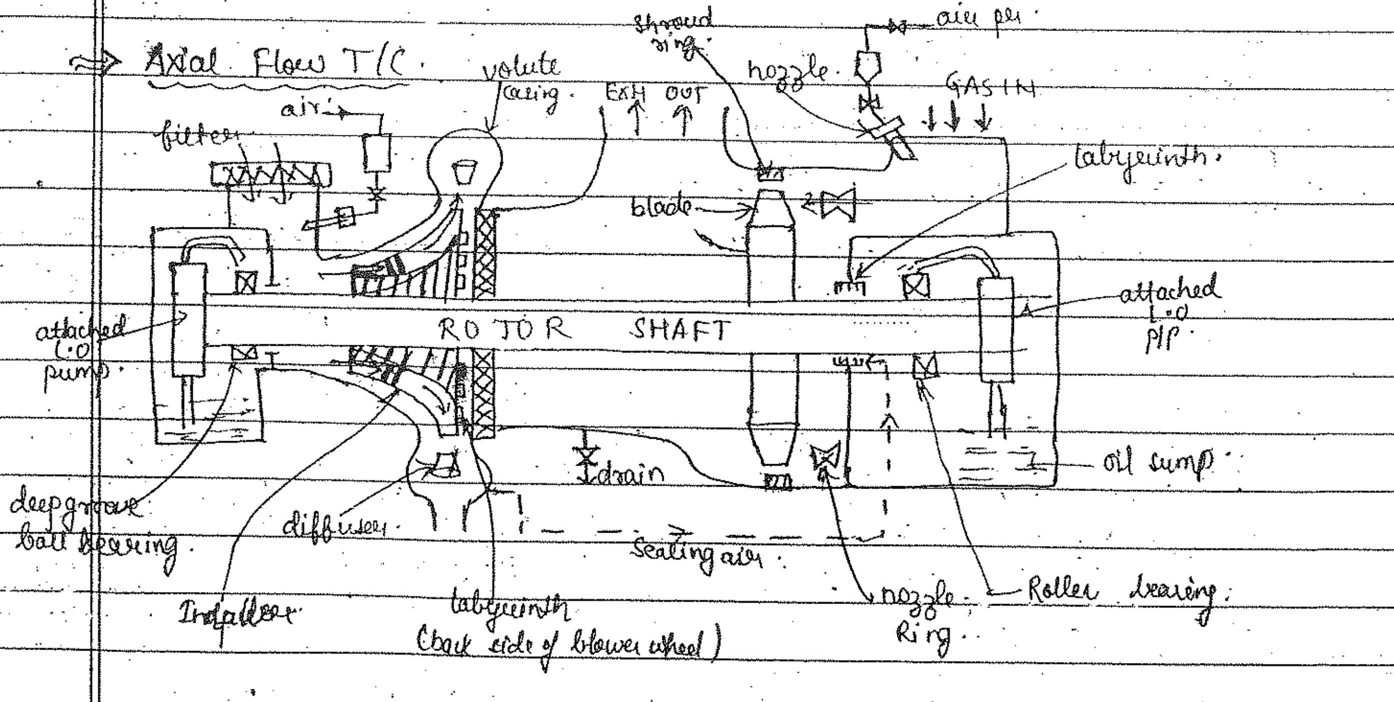
② Parallel.
- → 2 separate air inlets.
- → supercharging done in parallel.
- → Simultaneous delivery of air takes place from a T/C & the under piston space pumping effect.

✓ %. TURBO CHARGER ~ Blower side is always radial.

① Axial flow [TCA]
- → exhaust gas flow in & out of turbine blade along the axis of shaft.
- → marine engines.

② Radial flow [TCR]
- → exhaust gas flow into the turbine blade along the radial direction.
- → small high speed engines.

⇒ Axial Flow T/C.



– Single Stage Impulse Reaction turbine, and a centrifugal compressor.

↓ gas inlet casing with nozzle ring
gas outlet casing.
Turbine wheel forged integral with the shaft.

↓ volute casing.
impeller, inducer & diffuser.

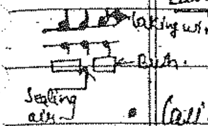
Turbine wheel – nimonic alloy.
Blower – aluminium alloy.

→ Working:– exh. gas passes through the nozzle ring where the pressure energy is converted into K·E & gas impinges on turbine blades thereby results in rotation of turbine. This in turn rotates the blower which acts as a compressor. It takes suction from atmos. & compresses the air.

Impulse reaction ~~TT~~

Blade change the direction
∴ change in momentum
hence forces T/C wheel to rotate.

- Inducer :– guide air to impeller; shrunk fit on shaft; made of Aluminium
- Diffuser (volute casing) :– converts K·E (by impeller) into Pressure energy
- Shroud ring :– minimize clearance b/w wheel & casing.
- Labyrinth :– prevent lub oil ~~interacting~~ contaminating with gas. Sealing air from discharge side is provided to labyrinth. (works on gradual pr. drop)



- Casing :– Cast iron. May be water cooled.
- Turbine blade :– Nimonic-80 A. Can withstand upto 500°c & centrifugal force.
  Blades made separately & fixed by inverted fir tree arrangement.
  This prevents the blade from coming out by centrifugal force.

Damping wire → welded to last blade & passes through holes in other blades. to reduce vibratio

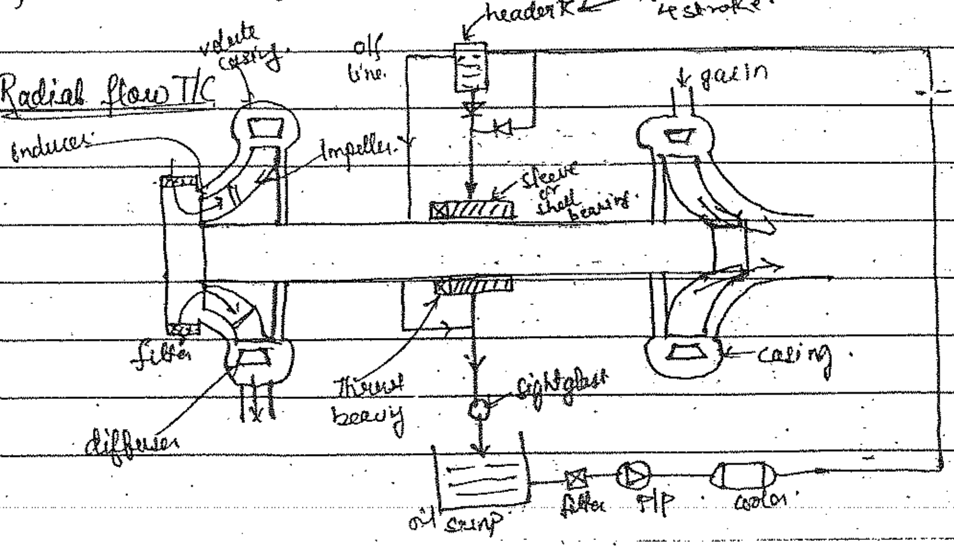
Subjected to CREEP ~ tensile stress + heat lead to failure ∴ Al is added.

- Ball & roller bearing :– less friction losses & accurate alignment.
  No hydrodynamic lubrication. Skinning surface & limited life.

☆ Uncooled Turbochargers.

Exh temp. of ~~moredes~~ modern engine is less. So instead of wasting the heat energy by cooling, this heat is recovered in EGE. ∴ ηthermal of plant ↑.
Also corrosive defects are avoided

⇒ Radial flow T/C



Adv:–
① compact; less wt.
(ii) simple design.
(iii) Bearing life is ↑
(iv) No special grade of oil.

Disadv:–
(i) cannot use on big engines.
(ii) ~~Acc is sleeve~~ Acc. of T/C is slow due to sleeve bearing.
(iii) Effectiveness ↓ with ↑ in power of.

→ Water Washing of Blower

- Done at full load.
- Fresh water sprayed at the blower side under pressure from airsupply
- ~~Once a day~~

→ Waterwashing & Dry cleaning of T/C.

Exh gas side has ash, Carbon deposits etc. Most deposits form on nozzle ring which decreases the T/C efficiency.

$$\eta_{T/C} = \text{Blower } \eta \times \text{Turbine } \eta \times \text{Mechanical } \eta$$

Procedure for water washing :-

- Take permission from bridge & Reduce rpm.
- Bring down the rpm so that exh temp at T/C inlet is 200°C and T/C rpm - 2000. Wait for sometime to stabilize the temp.
- Open waterwashing cock & drain cock after connecting the water hose.
- Water wash for 20 mins. Some part of water gets drained & some get evaporated. [Note :- donot supply water suddenly after reducing speed]
- Once clean water starts coming from drain, stop water washing.
- Slowly increase the rpm.

Disadvantage of waterwashing :- (i) Thermal stresses
(ii) Corrosion.

Procedure of grit washing :- [Grit :- crushed wall nut shells, carbon pallets, rice]

•) ↑ RPM after taking permission from bridge.

•) Put grit in the chamber & open the air cock and the supply cock to Turbine.

* Cleaning is less but no problem regarding corrosion & thermal stresses.

•) Every alternate day.

⇒ Routine checks on T/C

1) Check LO level if independent sump.
2) Check oil flow in sight glass.

3) Check pr. drop across filter if more than 50 mm - then change/clean.
4) Waterwashing as per manufacturer's.
5) Change sump oil after 500 hrs.
6) Complete overhaul 8000 hrs - Replace bearings.
7) Replace attached pumps - 16000 hrs.
8) Vibration monitoring - 200 hrs.
9) Check foundation bolts.

※ Turbocharger Faults / Problems

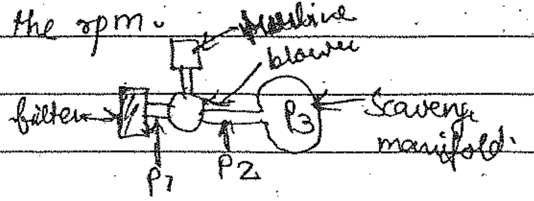
1) Fouling :- intake filter ; turbine nozzle & blade ; exh gas passages ; sealing air pipe to the compressor labyrinth ; cooling side.
~ metal erosion caused by particles in exh gas.
~ defective bearing oil seal cause carryover of oil to air side.

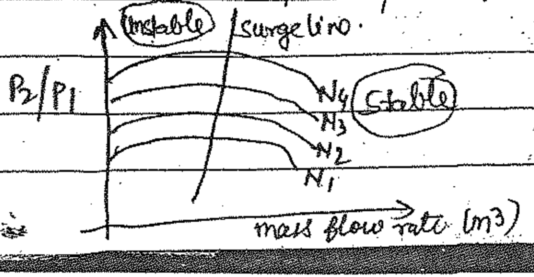
2) Bearing Faults :- due to overheating ; vibration ; poor lubrication ; misalignment; imbalance ; erosion of bearing material.

3) Vibration :- due to loose foundation bolts ; excitation from external sources ; water ingress due to casing leaks ; poor combustion operations.

4) Corrosion :- (i) air side gets corroded due to corrosive pollutants in air intake.
(ii) gas side gets corroded due to exhaust gases ~~teen~~ forming acidic ~~compomen~~ compounds.
(iii) cooling water side get corroded due to improper JCW treatment.

5) Surging :- phenomenon associated with compressible fluid [air/gas] using centrifugal compressor.
If for a given pressure ratio, mass flow rate falls below a critical value then ~~the~~ instead of blower supplying air to scavenge manifold, there is a reversal of air flow i.e from scavenge manifold to atmosphere through the blower with a loud howling noise.
This causes breaking action of blower & rpm drops. Once pr is released to the atmosphere, again pressure ~~is~~ in correct direction & T/C picks up the rpm.





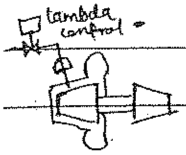
→ Engine operation on left side of surge line will bring about instability & surging.

Reasons :- (I) dirty T/C filter.
(II) rough weather when propeller comes out of water.
(III) T/C fouling on any side.
(IV) Air cooler air or water side chocked.
(V) Scavenge ports partially chocked.
(VI) Blowpast / Scavenge fire.
(VII) Sudden load changes.
(VIII) Exhaust ports chocked
(IX) Turbine nozzle ring, EGE etc chocked.
(X) fuel starvation.

Action :- (I) Reduce rpm & load.
(II) Clean, dirty / fouled components.
(III) Regular washing of gas / air side.

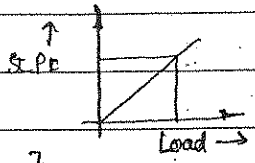
Effects :- (I) torsional stresses on rotor.
(II) damage aluminium blades of ~~blower~~.
(III) Bearings damage.

⟹ LAMBDA CONTROL ~ MAN B&W.



In constant pr. T/Cing, when the engine load is less during starting the lambda control solenoid v/v pushes fresh air at 7 bar on the blower to accelerate it.

⟹ Fault Finding



- If T/C RPM ✓ but Scavenge Pr X then problem is at blower side [Check filter ; waterwashing]
- Turbine speed ↓ – turbine side η ↓ ⇒ Check temp & pr drop across turbine.
  ↳ If no sufficient temp drop → problem with nozzle ring.
  i.e Excessive pr drop ~ nozzle ring chocked [washing of turbine side].

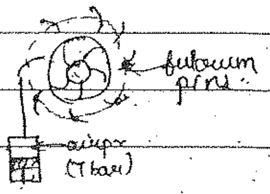
⇒ Matching of Turbocharger :- to provide exact quantity of air by T/C for efficient combustion at a particular load of the engine.

?? ☆ Variable Turbine Area (VTA) :- can match at any variable load of engine.

↳ In order to provide correct quantity of air supply throughout its operational range, the correct choice of impeller is required. The characteristics of impeller flowrate w.r.t pr. ratio is chosen to provide the desired air flow at the normal operation power of engine [80-85 % MCR]. Once impeller o/p is ~~chosen~~ fixed then diffuser is chosen to provide high ~~compression~~ compression efficiency & desired pressure ratio. When compressor side design is finalized the power requirement is calculated. The main variable on the turbine side is the nozzle ring which is then matched to provide desired comp~~ressor~~ressor work with min^m restriction to exhaust gas flow.

Here turbine area changes according to load ∴ Good at all loads.

☆ Variable Turbine Geometry (VTG) :-



when air piston exerts / releases pr. on vanes then the geometry changes i.e vane angle changes. ∴ The Speed is variable.

Air pr. is controlled by S.Pr and inlet & outlet temp of exh

⇒ T/C rapidly looses speed creating high noise :—

1. Bearings damaged / seized ~ friction ↑
2. Blades broken.
3. Thrust side bearing damaged ; rotor side touches stator - heavy noise.
4. Attached p/p looses suction then bearing damages.
5. Brinelling - if bearings develops indentations or dents due to
   - (i) improper mounted during installation.
   - (ii) support excessive load (load greater than elastic limit)
   - (iii) contaminated with debris.

Action :- To By pass the T/C. → ~~Blank~~ Block ~~or~~ rotor ~~or~~ &

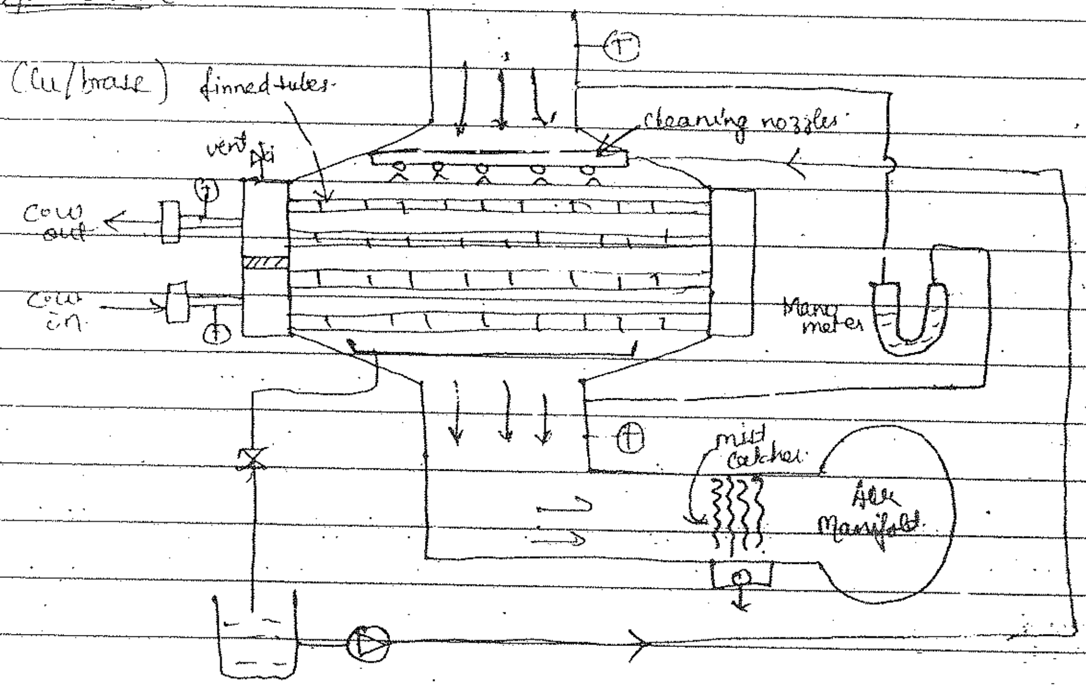
1. Block rotor with locking tool (turbine side) & open turbine bypass
2. On blower side remove bellow & put net.

If no bypass :- Remove rotor & blank it (After this exh. gas goes directly to exh manifold & fresh air from blower directly to scavenge manifold

Eng. Run at 10-15% MCR

* If 2 T/C is present & one is damaged. Blank the damaged T/C lock the rotor of damaged T/C & blank the gas side. Put orifice on air side & blank the air side. Now 2nd T/C can take the load but engine run at 30-40% of MCR.

%. Air Cooler



Water passes through tubes & air over it bcoz we don't want to ↓ velocity. Fins provided to increase the surface area & hence better heat transfer.

→ Cleaning tubes :-

Air side → through cleaning nozzle - spray chemical & then freshwater.
Water side → circulate descaling compound. Remove endcover & clean with brush.

%. T/C Bearings.

Roller Bearings	Sleeve Bearings.
- less friction losses & more accurate alignment.	- high friction.
- expensive	- work at higher temp.
- prone to brinelling.	
- need higher grade lubrication	

FUEL SYSTEM

→ fuel properties :-

•) Density - mass per unit volume - kg/m³

•) Viscosity - resistance to fluid flow due to resistance b/w the adjacent layer in moving fluid.

- Dynamic viscosity :- viscosity of fluid in a laminar stream lined flow containing layers spaced 1 cm apart, which require a tangential force of 1 dyne/cm² to be moved at velocities differing by 1 cm/s. Unit :- Poise. (1P = 0.1 N-sec/m²)
- Kinematic viscosity :- Ratio of dynamic viscosity to density of fluid at same temp. Unit :- Stroke / Centistroke.

•) Viscosity Index - index of an oil which measures the change of viscosity due to a change in temp.

•) Carbon Residue - tendency of fuel to form carbon residue deposits. [0.05 - 0.1 %]

•) Conradson Carbon Residue (CCR) - residual qty of carbon measured as a %ge of the original mass of fuel, after carrying Conradson Test.

•) Sulphur Content - ~~undesirable~~ corrosion-inhibiting constituent of fuel.

•) Flash point - temp at which fuel gives sufficient volatile vapours capable of ignition.

more than 66

- Open flash point :- flash point of oil in open chamber. (always 15°C > than closed ~~flash~~ point.
- Closed flash point :- " " " " closed "

•) Fire point :- temp at which fuel gives sufficient volatile vapours capable of ignition and sustain the ignition. [40°C higher than closed fire point]

•) Self Ignition point - min temp at which fuel is capable of ignition on its own without any external aid. (used when we choose comp. ratio to match fuel grade).

•) Pour point - lowest temp at which oil can be poured.

•) Calorific value - Amount of heat produced by complete combustion of one unit mass of fuel.

•) Cetane Number - index of the ignition quality of fuel which defines the way combustion proceeds in the engine.

↑ cetane no., better is the fuel, shorter ignition delay, easy to start combustion.

Diesel fuels - 35 to 55 ; If density ↑, cetane no. ↑.

•) Octane number - measure of knock rating of fuel combustion in engine.

↑ octane no ; Better is the fuel.

•) Ash - quantity of inorganic incombustible impurities in the fuel.

↳ Sand ; metal oxides like vanadium or sodium.
↑ highly undesirable.

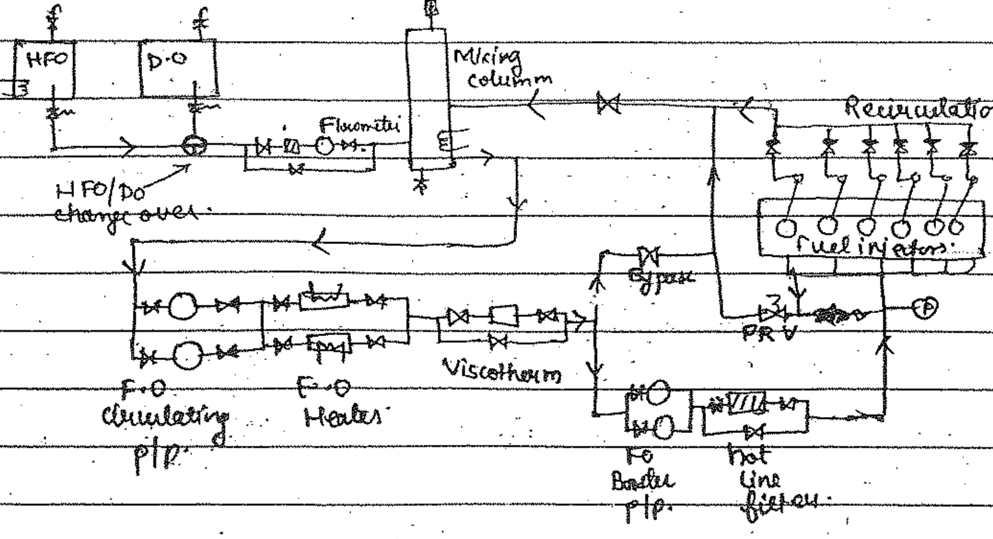
- Specific gravity – used for denoting wt. of oil while handling or storage.
- Catalytic fines – formed as a byproduct of vacuum distillation. Causes abrasive wear.
- Air/fuel Ratio – stoichiometric ratio for proper combustion is 14.5 Kg air to 1 Kg fuel.
  Actual – 30 to 44 Kg of air per 1 Kg of fuel.
- Calculated Carbon Aromacity Index (CCAI) :- rating of fuel which indicates ignition quality bcoz ignition directly depends on the aromatic content in the fuel.
  ↳ compact benzene ring structures in fuel which affect the ease of which a hydro carbon fuel molecule can burn.
  - ↓ CCAI – better ignition ; better fuel quality, less ignition delay.
  - 850 – normal
  - no effect on modern 2 S low speed marine engine but mostly affect ignition in medium speed engines.

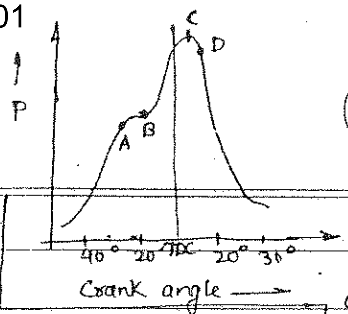
⇒ Fuel Specifications. (HFO)

Density @ 15°C – 991 kg/m3
Kinematic viscosity @ 50°C – 700 cst.
Sulphur – 5 %.
CCR – 10%
Ash – 0.2%
Sediment – 0.1 % m/m.

Water – 1-2%.
CCAI – 880
Sodium – 100 mg/kg
Vanadium – 600 mg/kg.
Aluminium + Silicon – 80 mg/kg.

⇒ Fuel system line





A- start of injection.
A-B- ~~injection~~ ignition delay.
B- Combustion start
B-C - Combustion of already injected fuel & fuel still being injected.
C - Injection finish
D- After burning.

⇒ Combustion Process

① Injection delay/lag :- time delay b/w closing of spill port/valve & opening of fuel injector. It depends on the pr. rise in fuel p/p & pr in injector line.

② Ignition delay/lag :- time delay b/w start of injection & start of combustion.

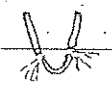
③ Combustion :- of already injected fuel & fuel still being injected.

④ After burning :- burning of fuel after after injection is finished.
↳ due to large ignition delay.

⇒ Factors affecting Combustion

$\boxed{\text{atomization} \propto \frac{1}{\text{viscosity}}}$

1) Atomization :- Breaking up of fuel into smaller particles or minute vapour mist so that the fuel vapour particles posses a very high surface area to self ignite with hot compressed air.

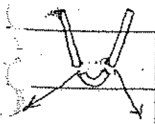


Depends upon :- orifice/hole of injector ; temp, mass flow rate & viscosity of fuel ; pr. diff. b/w fuel line & cylinder ;

Too much atomization = ↓ penetration as small particles will not have enough K.E to go through the whole combustion space. (burns at tip of nozzle)

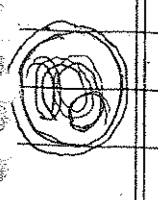
$\boxed{\text{atomization} \propto \frac{1}{\text{penetration}}}$

Too low atomization = larger particles posses more K.E & gets deposited on liner walls (after burning)
↑ This is called Impirgement.



2) Penetration :- distance travelled by fuel particles into the combustion space before ignition takes place.

Depends on :- nozzle diameter size, length of nozzle hole ; ~~to~~ fuel particle size & atomization.



3) Swirl & Turbulence :- Swirl is a motion given to the incoming air charge entering the combustion space. This is done by the shape of combustion space & the direction of entry of air charge.

Turbulence is factor already designed by manufacturer to improve the air fuel mixing.

→ Other factors influencing combustion :-
Combustion chamber & piston crown design ; Compression Ratio ; Impingement ; Scavenging - air pr, temp, quality ; Fuel parameters ; Fuel pump.

☆ Fuel Knock → it is the phenomenon of a high sudden pressure & temperature rise due to burning of accumulated fuel in combustion space.

※ Fuel Injection

1) Ballast Injection :- fuel blown into cylinder by an air blast.
2) Solid / Airless / Mechanical Injection :- fuel is forced into cylinder through a fuel v/v by a High fuel pump pressure.

Individual Unit Injection.	Gas Compression Injection	Common Rail Injection
→ individual fuel p/p & injector meter & supply fuel for combustion in engine cylinder. → timing by camshaft drive to fuel pump plunger. → Governor control fuel pump rack. → Most marine engines use this	→ combustion pr. from M/E combustion chamber is led to drive the fuel p/p piston. → camshaft not required → timing by means of timing v/v operated by an oscillating lever & eccentric fulcrum → Not used now.	→ fuel p/p, distribution blocks, accumulators, a common piping (Rail) & camshaft ~~driven~~ operated spring loaded injectors. → common rail supplies to fuel injectors through fuel timing v/v whose opening & closing is camshaft operated. → Doxford P & J type ~~eto~~. → RT-flex & ME engines (camless) use a type of common rail

☆ Optimum Injection

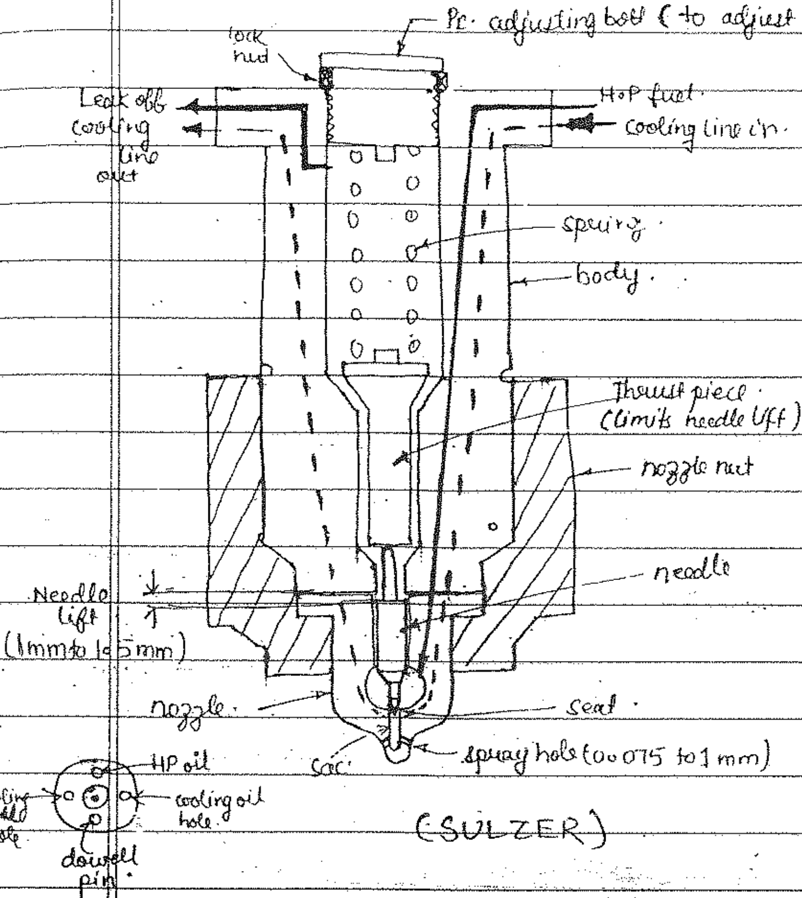
Injection time is only 20° of crank angle at full load, but max^m firing load is reached only in the latter half of injection period. ∴ we must inject more fuel towards the end of injection after the max firing pr is reached & supply the remaining fuel as fast as possible.

Injector requirements :- (i) so that fine atomized spray with good penetration is available.
(ii) should not open till a pre-set pr is built up.
(iii) serves as NRV not allowing combustion gases to enter the fuel system.

✱ FUEL INJECTOR / VALVE – inject & disperse fuel evenly into the cylinder in a finely atomized spray.

(I) Hydraulic operated (II) Open or Closed valve type.

operation of opening & closing of fuel v/v is performed by the fuel pressure delivered by the fuel p/p to the fuel v/v.



(SULZER)

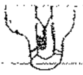
Working :- High pr. F.O from fuel pump acts on the shoulder of the needle, thereby lifting the needle against the spring force & the high pressure fuel is injected through spray nozzle into cylinder. At the end of injection, the oil pressure drops & spring will force the needle down & needle will close on the seat terminating the fuel injection.

→ 320 - 380 bar – V/V opening pr.
→ 1000 - 1500 bar – injection pr.
↳ bcoz it should be more than pr. inside the cylinder so that fuel can be injected.

Testing Fuel V/V:-

- Clean injector. Clean nozzle holes using wire or drill.
- Injection pr. Test :- Put injector on testing stand. Increase the pressure gradually. Note the pressure at which injection takes place. Pressure can be adjusted by the pressure adjusting bolt.
  Crackling sound indicates spring is in good condition.
- Drip Test :- If injection pressure is 300 bar (say), bring the pressure to about 200 bar and wait to check if valve is dripping. Valve & V/V seat to be lapped.
- Leak Test :- leakage b/w needle & guide. After injection if pressure drops suddenly then there is leakage. Usually it takes 30 secs to 1 min for pr. to drop.

- **Spray pattern Test** :- Keep a cardboard below the injector and give strokes. If spray inside shows the hole as chocked.

Mini SACK NOZZLE  Here a slide is given to nozzle to cover the injection holes to avoid dripping of oil trapped sac.

⇒ SLIDE TYPE FUEL V/V

⇒ **Injector faults.**

1) **Improper cooling** :- Too much cooling – sulphur corrosion at the tip due to injector tip temp. falling below condensation temp. Too less cooling causes softening of v/v & seat & allows expansion of trapped fuel in the sac area. – Carbon at tip; poor combustion; smoky exhaust.

2) **Dribbling nozzle** :- fuel burning at nozzle tip → poor seating of fuel v/v due to impurities in fuel causing abrasive wear of seat; poor cooling; ↑ banging of v/v needle; poor maintenance & overhaul; incorrect spring force.

3) **Carbon trumpets** – influence spray pattern – leads to smoky exhaust, ↑ exh temp, poor combustion & loss of power.

4) Wrong Spring Pressure :-

less spring pr - v/v opening & closing at less pr - smoky exh ; ↓ cyl pr.

- due to wrong spring pr at the time of overhauling ; material fatigue or extended life of spring.

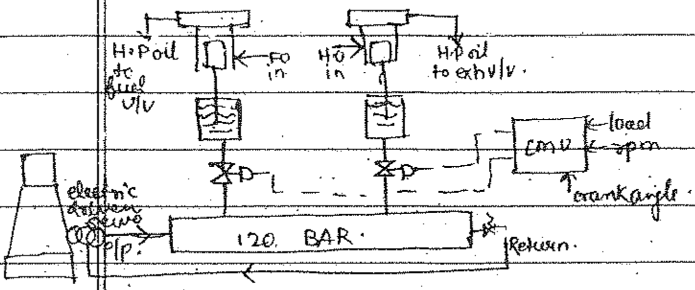
5) Nozzle ~~hole~~ dia, depth & number :- influence penetration, atomization & combustion.

↳ holes chocked with impurities, carbon trumpet, burning of sac area, trapped fuel ; prolonged running at low loads.

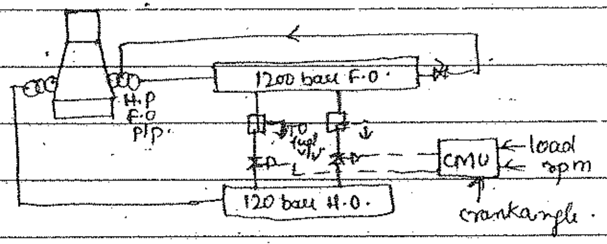
Length of nozzle hole is thrice the size of dia of hole.

Common Rail System

MAN B&W



SULZER



FUEL PUMPS

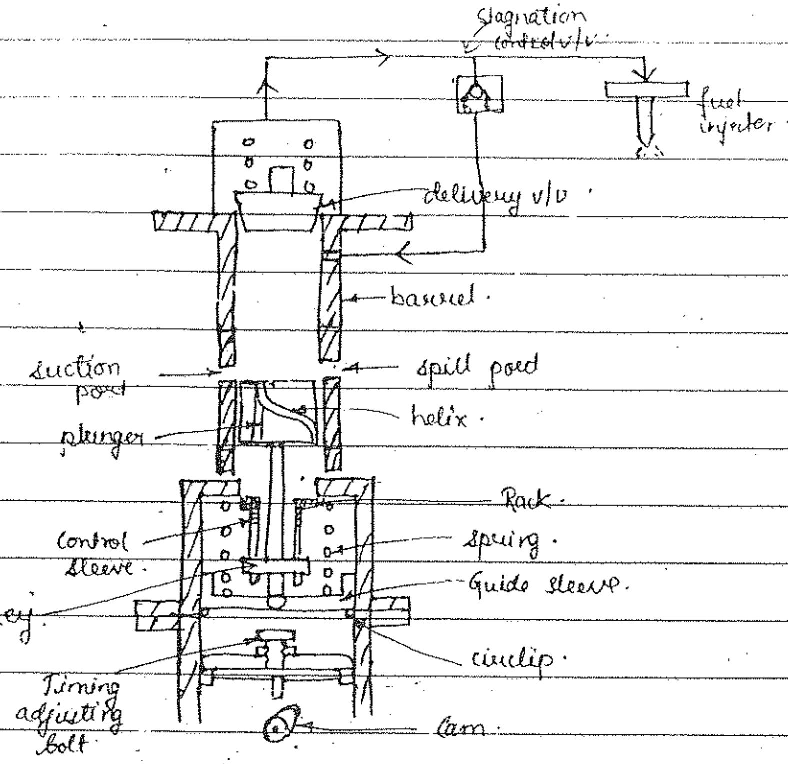
control the quantity & timing of the fuel injected into the combustion space & to provide the high fuel pressure to hydraulically operate the fuel injector.

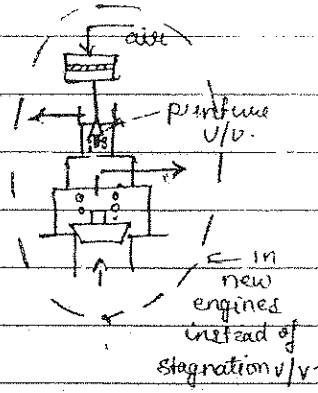
All fuel pump used are jerk type fuel pump.

(i) Helix controlled fuel pump — MAN B&W engines (Bosch pump)

(ii) Valve controlled fuel pump — Sulzer engines

Helix Controlled Pump (BOSCH TYPE)





→ Plunger and barrel forme a pair. The plunger has a key which engages in a slot provided in it's control sleeve. The upper part of control sleeve is provided with a pinion which engages with fuel pump rack whose movement is controlled by governer, depending upon the load on the engine. The bottom most portion of plunger engages with the guide sleeve, which is spring loaded and is held in position by means of circlip.

→ The plunger movement is controlled by cam and roller arrangement. When the roller is on the base circle of the cam, the plunger will be at the bottom most position and the suction & spill port on the barrel is open. The discharge v/v fitted on top is close. At this time the ~~the~~ oil will enter inside the barrel.

→ As the plunger moves upward and covers the suction & spill ports, oil on top of plunger will get compressed. It will increase the oil pressure till the delivery value lifts up and delivers high pressure oil to fuel valve.

→ The plunger continues to move upwards, depending upon the load, at a particular position, the helix ~~will~~ cut on the pluger will match the spill valve which will result in drop in pressure and the delivery v/v shuts. This is end of injection.

→ Vertical movement of plunger b/w beginning & end of injection is called effective delivery stroke. It is higher if load is high. It is zero when fuel rack is zero.

Problems faced with this pump:-

1) Secondary injection:- At the end of injection, delivery v/v closes as the pressure below the valve drops. Fuel with high K.E after the delivery valve gets converted into pressure energy. The pressure cannot be released anywhere because of delivery v/v is Non Return. So it causes secondary injection of at fuel v/v.

2) Cavitation:- When plunger goes down after delivery, vacuum is created above the plunger space. The left over oil starts boiling at this places. This causes cavitation.

3) Side Thrust:- At the end of injection, there is thrust created on the plunger due to H.P oil running out of the port, and the plunger may hit the barrel on side & damage it.

→ ~~To~~ Stagnation control valve:- To avoid secondary injection and cavitation. The H.P oil above the delivery v/v after end of injection is send to the chamber above plunger & below delivery v/v via the stagnation control v/v. This avoids secondary injection. This oil also fills the chamber to avoid vacuum, thus prevent cavitation.

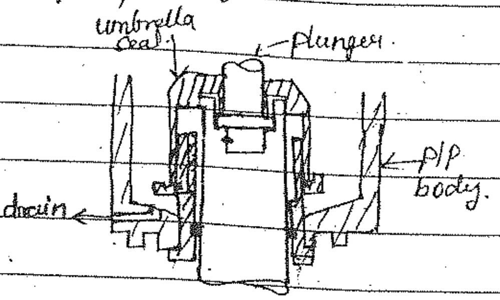
In MAN B&W latest engines there is no delivery v/v, instead there is suction v/v to stop secondary injection & cavitation.

→ Punture value :- It consists of a piston which communicates with the control air system of the engine. In the event of actuation of the shut down system & when 'STOP' is activated, compressed air causes the piston with pin to be pressed downward & 'puncture' the oil flow to the fuel v/v. As long as the puncture v/v is activated, the oil ~~flows~~ is returned through a pipe to the pump housing & no injection takes place.

→ Erosion plug :- Replacable erosion plugs are fitted in the pump housing opposite to the spill ports. The H.P oil, spilling back, as the edge of the helix uncovers the spill ports, hits the plugs, which prevent damage to the pump casing.

→ Umbrella seal

F.O leakage past the plunger to the camcase is prevented using an 'umbrella seal.'



→ Spring Loaded damper [Shock Absorbers]

fitted at the side of pump, connected to the suction side of the p/p. This smoothens the pr. fluctuations as the H.P fuel spills back at the end of injection.

X. Check fuel Injection Timing

→ Method 1

(I) Remove delivery v/v.
(II) Put H.P line to a bucket.
(III) Start turning the engine.
(IV) When plunger covers the spill port, oil starts coming out. This is the begining of ~~ignition~~ injection. Note angle on flywheel.
(V) When oil stops coming out. That is end of injection. Note angle on flywheel.

Method 2

- Remove delivery v/v and vertically put torch light so the light is visible from spill port.
- ~~W~~ Turn the engine, when the light disappears note the angle. This is beginning of injection.
- when the light reappears on turning that is end of injection. Note the angle.

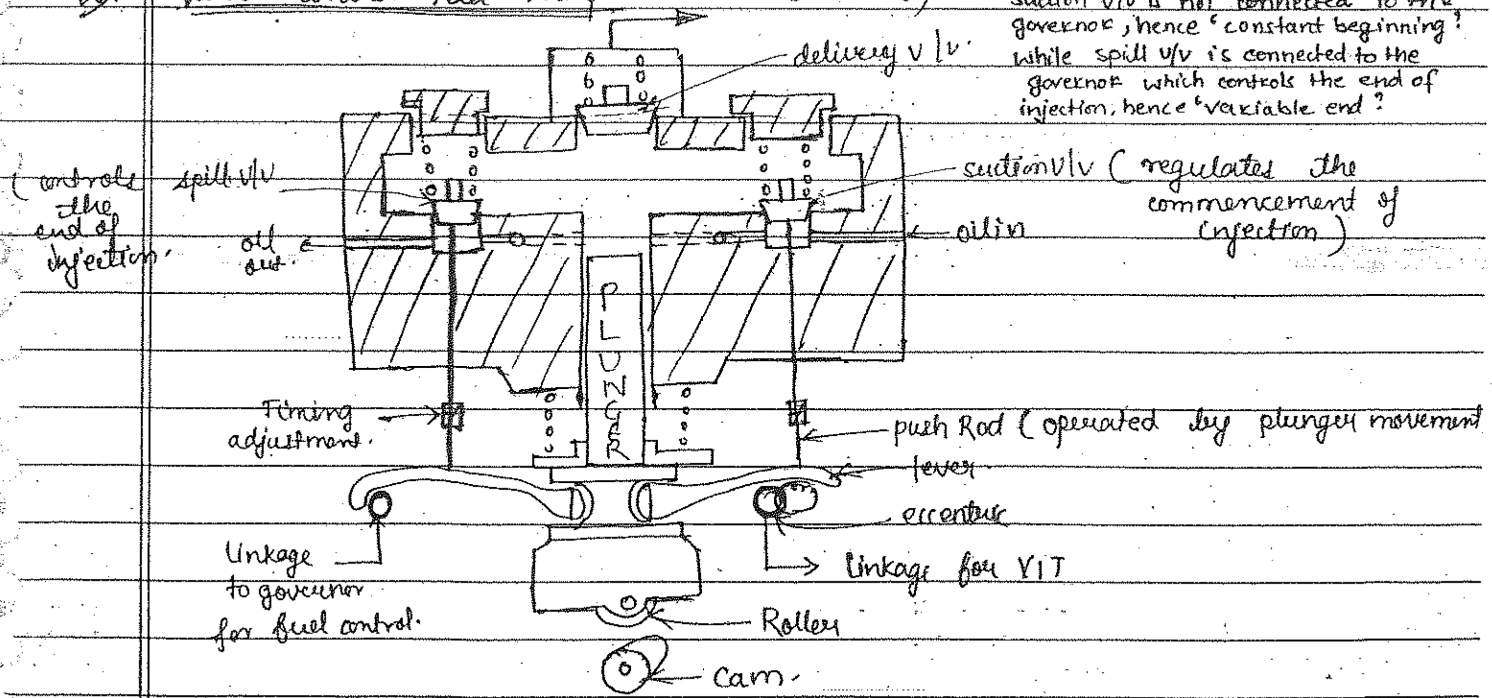
Method 3

There ~~could~~ can be marks on the sleeve of the pump body. The guide sleeve also has mark.

When the guide sleeve coincides the first mark on fuel p/p body sleeve, it is beginning of injection & when it coincides the 2nd mark, it is end of injection.

Valve Control Fuel Pump (SULZER)

★ It is a "constant beginning variable end" type pump in which the suction v/v is not connected to the governor, hence 'constant beginning' while spill v/v is connected to the governor which controls the end of injection, hence 'variable end'.



When the plunger moves ↑ or ↓, 2 pivoted lever operates push rods which opens the suction & spill v/vs. When cam follower is on the base circle of cam the suction v/v is open & spill v/v is closed. As the plunger moves up the barrel, the suction ~~v/v~~ push rod moves downwards & suction v/v closes. This commences injection & fuel is delivered via a NRV to injectors.

As the plunger continues to move upwards, the spill push rod will open the spill v/v, the pressure above the plunger will fall & injection will cease.

→ The quantity of fuel delivered can be controlled by altering the position of the eccentric pivot for the spill v/v operating lever. This will cause spill v/v to open early or late.
By altering the position of suction v/v pivot, the start of ignition can be similarly controlled.

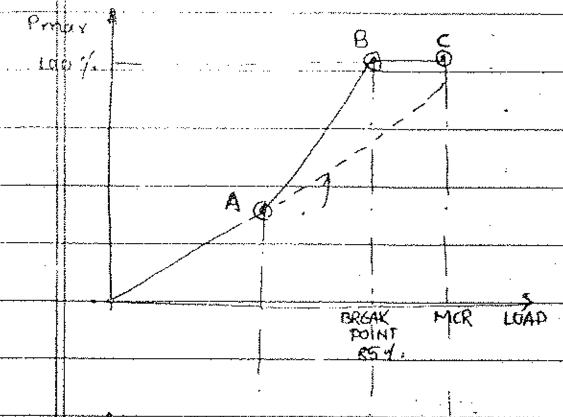
✕ Checking Injection Timing:

- Remove all three v/v's.
- Put a plug in place of delivery v/v and fit a dial gauge on plunger.
- 1 dial gauge on suction & spill v/v.
- Engine stopped in ahead position. Fuel p/p rack to be moved to 4.6. Plunger to BDC & roller on base circle.
- Note how many turns the dial gauge has moved on the suction v/v side bcoz push rod is in touch with dial gauge as plunger is at BDC.
- Start turning; The dial gauge on suction v/v side starts turning in reverse direction & when it shows 0.02 from zero, stop turning. Check the ~~mark~~ angle on flywheel. This is BOI.
- Check the reading on dial gauge of delivery v/v. The plunger movement causes changes of dial gauge. If reading is x. Then (0-x) is idle stroke.
- Continue Turning ~~eng~~, when spill v/v dial gauge shows 0.02 from zero, that is End of injection.
- Now reading on delivery dial gauge is y.
- (x-y) is effective stroke of delivery.

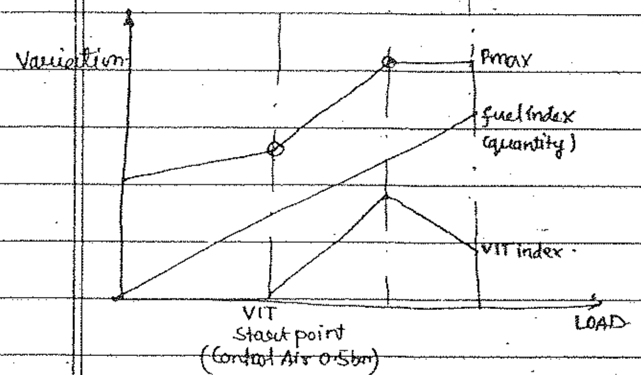
☆ VARIABLE INJECTION TIMING (VIT).

- ↑ η thermal.
- ↑ η combustion.
- ↓ SOFC

There is no dark smoky exhaust, less thermal stress, improved NOx emission improved temp. contro for preventing corrosio



In normal engines Pmax is achieved only at full load power, while in VIT, Pmax is achieved at lower loads.



→ Low Load :- VIT system out of operation i.e delayed injection takes place.

→ Increasing Load :- VIT zero till 'A'

→ Run-up till 85% Load :- From 'A' to 'B' timing is advanced.

→ At 85% Load :- At 'B' Pmax is achieved

→ 85% to 100% load :- Pmax ~ constant

conventional VIT ~ oblique cut on plunger.

SUPER VIT (MAN B&W)

Jerk type fuel pump with double thread, VIT regulation lever, VIT position servo, control air signal, position servo unit with input from Governor FQS lever & reg. Shaft

→ Here the vertical position of pump barrel is raised or lowered to change the commencement of injection by a rack & pinion mechanism & a double threa

⟨i⟩ Upper thread controls the suction ports i.e BOI by changing the vertical position of the pump barrel w.r.t plunger.

⟨ii⟩ lower thread controls the spill port i.e fuel quantity & end of injection by rotating the helix scroll of the plunger w.r.t to spill port.

VIT - rack setting is controlled according to the engine load via regulating shaft & governor. The VIT rack setting position is done by means of a control air signal supply ~~signal~~ which pushes the VIT rack position servo. The control air position sensor V/V gets its input from the governor, the FQS lever & the regulating shaft.

In spill & suction v/v controlled pumps, injection timings can be varied by raising or lowering the position of suction & spill v/v's which is done by changing the position of eccentric.

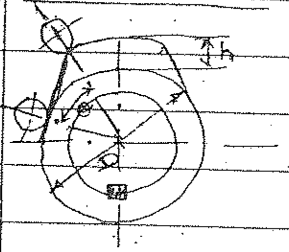
Raising v/v → early injection
Lowering v/v → late injection.

Suction v/v → BOI i.e injection timing.
Spill v/v → End of injection i.e quantity of fuel.

⟹ FQS (fuel Quality Setting) :- a manually adjustable lever whose setting can be changed to compensate for various fuel qualities. The "FQS" angle is a user parameter setting in ~~ECR~~ engine control & can be adjusted within the range of -2 to +2 degree. The governor o/p shaft is connected to the VIT control & superimposed on the FQS linkages

ULZER

FUEL CAM



Cam – mechanical member which can precisely impart a desired motion to its follower.

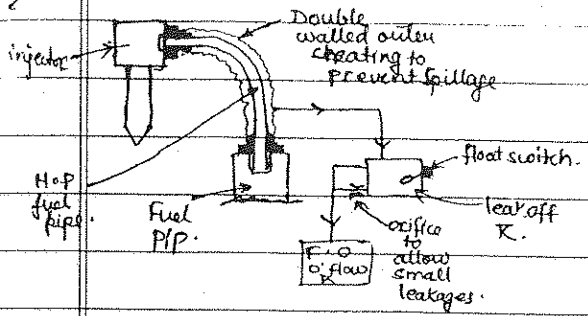
D → base circle
θ → cam angle. (angle of rotation of cam for displacement of follower)
h → lift or throw (max disp. of cam throw from base circle)
Dwell → peak of cam where follower comes to rest.
Profile → working face of cam ⤳ regular, irregular, multi-lobe, single lobe, inverse etc

- Fuel cam is designed for a quick pumping action. The pressure rise before the needle v/v is to be instantaneous so that a full & constant lift is available for entire period of injection.

~ Requirements :- at the beginning of the injection stroke, a high amount of acceleration is desirable, but with a smooth transition to prevent shocks. During the injection stroke, a constant velocity should be maintained without any pressure drop when the fuel v/v opens. At the end of injection stroke, sharp deceleration is required to snap shut the fuel v/v but smoothly in order to avoid bouncing.

HIGH PRESSURE PIPE

→ Fuel line from P/P to injector have very high pressure and is subjected to pressure shock waves & vibration. It is an important fire hazard bcoz pressurized oil leaking from it can spray over numerous hot surfaces of the engine & cause fire. Protection & monitoring of the H.P fuel line is a class requirement, especially for UMS ships.



This H.P line has a protective double skin sheathing. It also has a leak off line from the space b/w the pipe & the outer sheath. This line is led to a leak off tank which monitors leakage & gives off an alarm if the leakage is in excess. In case of minor leakages, there is a small leak off hole connection which directly drains to the o'flow K.

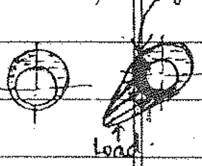
LUBRICATION SYSTEM

→ Function :- reduces friction ; removes frictional heat ; prevents excessive wear ; provides corrosion protection ; helps in cooling ; prevents accumulation of unwanted deposits.

⇒ Types of Lubrication :-

I) Boundary lubrication :- thin film lubrication which exists b/w the rubbing surfaces so that full fluid film is not achieved & some degree of dry patches occur when metal to metal contacts. Usually seen in cases of very ↑ relative movement b/w the rubbing surfaces.

II) Hydrodynamic lubrication :- "Full fluid film lubrication."

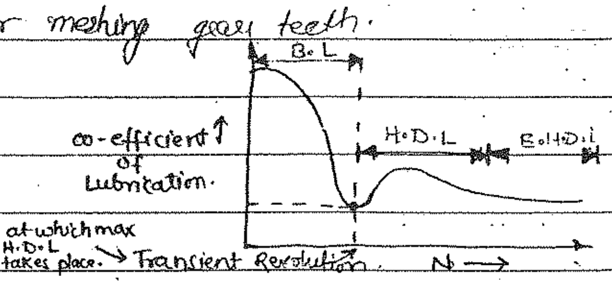


Lubrication b/w moving surfaces which are separated by a continuous unbroken oil film of adequate thickness. Oil pressure is self generated due to the motion of moving surface.
Eg :- Journal Bearing Lubrication.

III) Hydrostatic lubrication :- same as hydrodynamic except that the oil pr. is supplied by an external source.
Seen in slow-moving heavily loaded components.

IV) Elasto-hydrodynamic lubrication :- "squeeze film lubrication"
effect of elastic deformation of metals & effect of H.P on lubricants.
Eg :- Rolling contact bearings or meshing gear teeth.

⇒ LUB OIL PROPERTIES -



1) Viscosity :- resistance of oil internal cohesive forces. & Depends on temp.
Both ↑ & ↓ viscosity is unacceptable.

2) Coking capacity or Carbon Residue :- tendency to form carbon residues while burning at high temp.

3) Corrosiveness :- Tendency of oil to oxidize due to presence of Oxygen in high temp gaseous surroundings.

4) Base Number :- capacity of oil to neutralize the sulphuric compounds which are formed during combustion.

5) Total Acid Number (TAN) :- indicates acidity of oil. combination of strong acid number (SAN) & weak acid Number (WAN)

SAN ↓ measure of inorganic acids ~~due to contamination by~~ acidic products of combustion.

WAN ↓ measure of organic acids due to oxidation of the oil.

6) Total Base Number (TBN) :- measure of alkalinity in oil.

TBN = 70 mg KOH/g for crosshead engines cylinder oil.

TBN = 30 mg KOH/g for trunk engines system oil.

7) Oiliness :- tendency of oil to adhere or wet the moving surface.

8) Anti oxidation :- tendency to resist oxidation.

9) Cracking Stability :- property of oil to be stable & resist cracking at ↑ temp.
↳ break down of molecules into smaller sizes at ↑ temp.

10) Detergency & Dispersancy :- tendency to colloidally suspend, disperse & wash away any harmful combustion products in oil.

11) De-emulsivity :- property of oil to separate from water in a non-miscible emulsion.

12) Foaming :- oil mixing with air resulting in cavitation & overheating.

13) Cloud Point :- temp at which a cloud forms, due to wax crystal formation at low temp. eg :- Paraffin-base oil.

14) Water content :- reduces viscosity & therefore, reduces the load carrying capacity of oil.

⇒ Lub Oil Deterioration - due to reduction in viscosity, TBN, flash point or dispersancy increase in oxidation, water contents or sediments.

☆ Oxidation :- hot oil droplets can combine with the oxygen and get oxidized.

- for every 10°C ↑ in temp, oxidation doubles. if temp is more than 60°
- sludge formed by oxidation acts as a catalyst for further oxidation.
- metal particles such as Al, Sn, Cu accelerate the rate of oxidation.
- water in oil also accelerates the rate of oxidation.

Effects :-
(i) oil looses its lubricating property.
(ii) Sludge formation.
(iii) Discolouration of oil (red or black)
(iv) oil becomes acidic.

Prevention :-
(i) Control Temp (Cooling)
(ii) Continuous Purification & filteration
(iii) Avoid water ingress.
(iv) Heat exchanger to be kept clean.

★ MICROBIAL DEGRADATION OF OIL :- degradation due to micro organisms (like bacteria, yeasts or moulds) thriving in the lub oil.

They require water to grow in the beginning, but later they can self-sustain at 20 to 40 °C in stagnant condition. They multiply at a very rapid rate. Once the aerobic bacteria have consumed the dissolved oxygen, the sulphate reducing bacteria is activated.

- This bacteria attacks the metals & forms H_2S. It results in corrosion.
- Properties of lub oil & additives is detoriated,
- Load bearing capacity of oil is reduced.

Indications :- ① Rotten egg smell.
(ii) sliminess of oil in c/case painted surface.
(iii) ↑ acidity & water content.
(iv) filter chocking more frequently.
(v) Poor heat exchanger performance.
(vi) Black staining of white metal bearings & corrosion of exposed surface.

Prevention :- ① Check c/case oil water content weekly
(ii) Inspection of surface during every c/case inspection.
(iii) Regular circulation of oil to avoid stagnant condition.
(iv) Continue purification & re-circulation even when engine stopped.
(v) Inspection of purifier sludge & choked filter.

Treatment :- ① Use of biocides or fungicides.
(ii) Heating & continuous purification above 75°C.
(iii) Manual cleaning of sump, filters & pipelines

★ Water Contamination

Carry out chloride test.
If chloride is ↑ — SW
" " ↓ — FW.

- Ingress of SW or FW.

SW: L.O coolers
Bilge water if diaphragm has hole.

FW: coolers.
- Telescopic pipe leaking (Piston cooling)
- Jacket water ~~from~~ liner O ring leak or crack in liner

⇛ LUB OIL TEST – to monitor deterioration of oil (condition of oil, contamination etc).
↳ to be done weekly onboard & for shore analysis every 3 months.

OnBoard L.O Test :-

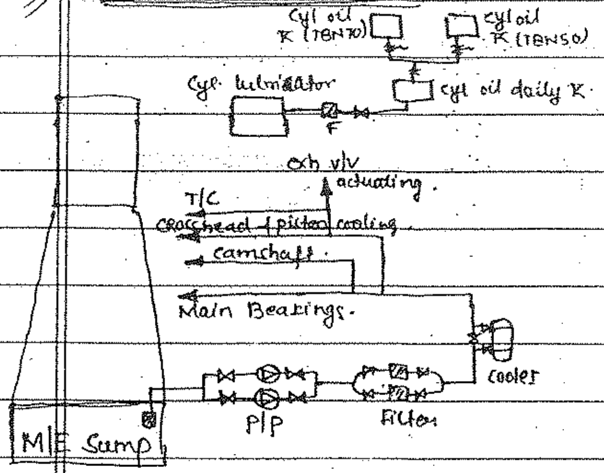
i) Water content – measure of Rise in pr. due to reaction of water with calcium carbide.
ii) TBN – measure of resultant pr. rise of a test mixture.
iii) Alkalinity ↳ pH paper.
iv) Viscosity – flowstick comparator

Oil change in Low speed engine – 10,000 hrs.
Medium & High speed – 5,000 to 10,000 hrs

	Trunk Engine	Crosshead Engine
Viscosity @ 50°C cst.	75-100 (± 15%)	60 – 70 (± 5%)
Flash point (°C)	206 (± 25%)	200 (± 10%)
Water content	0.1 (1)	0.1 (0.5)
Ash content	0.02 (0.13)	0.02 (0.13)
TAN (mg KOH/gm)	Nil (2)	Nil (1)
Pour point (°C)	-10	-15

⇛ LUB OIL SYSTEM

(i) main lub oil system.
(ii) cylinder lubrication system.

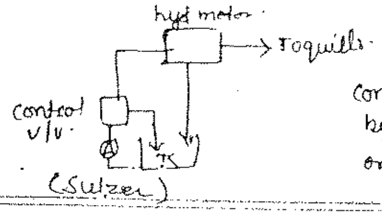


Main lub oil system → journal bearings, bottom end bearing, con rod, gudgeon pin (in 4-S), camshaft, crosshead [see page 43] & piston cooling, T/C, exh v/v actuating.

Cylinder lubrication system.
[A] Accumulation & Quill System ~ Sulzer.
[B] Cylinder lubricator unit pumping to orifices in the liner.

Wet Quill (Sulzer) ↑ passing through jacket.

Dry Quill (MAN B&W) ↑ Donot pass through jacket.



control v/v sends oil to hyd-motor or by pass oil back to K depending on load.

SULZER

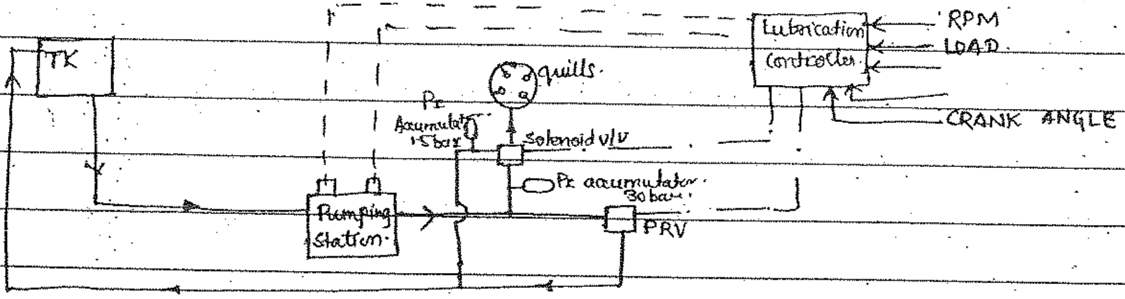
→ Accumulator & Quill - lubricator p/p supplying oil pressure to a quill fitted with an accumulater. In this system, the accumulator gets charged by the lubricator p/p for every 10 to 15 revolutions. This oil under pr. is stored in the accumulator & enters the cylinder whenever cyl pr. falls below the accumulator oil pr. i.e ① when piston is moving down in its exp stroke

when piston ring passes feed grooves → (ii) when piston is moving up in comp. stroke.

★ Quills → NRV fitted at liner oil grooves by screwing into liner.
① dampen pr. pulsations in supply line.
~~(ii) prevent comb. gases/products to enter back into oil line.~~
(iii) provide storage of pressurized oil in the accumulator section..

★ Lubricator p/p unit → gets rotary drive from the driving shaft by means of a gear & ratchet mechanism. This rotational drive is converted into reciprocating motion of the lubricator plunger. The pumping action can be checked in the sight glass which shows a steel ball lifted & pushed up when the oil is pumped.

→ ALPHA LUBRICATOR (in MAN B&W)



A high pressure lubricator pump supplies oil to an injector to inject a fixed volume into the engine cylinder once in 4-5 revolutions. A computer control unit gets input from engine speed, load index & crank angle. It sends an 'ON' signal for lubrication to the solenoid v/v to control the oil injection. Oil is injected b/w 1st & 2nd piston ring during upward stroke.

Advantage:- ① Cyl oil consumption reduced (0.3 gms/bhr-hr)
(ii) lower rate of liner wear.
(iii) ↑ time b/w o'haul.
(iv) Duplication is provided in case of failure (pump, computer unit)

⇛ LOAD DEPENDENT CYLINDER LUBRICATION.

↳ amt of cyl oil to each lubricating point can be individually adjusted / controlled as per the load changes via a remote control system.

↳ Modes :- Pre-lubrication ; Running Mode ; Post-lubrication & Emergency lubrication

The specific oil feed rate ↑ with decreasing engine load. Eg:- at 20% engine load, the specific cyl oil amount will 25% more than at 100% engine load.
The desired ↑ in quantity can be programmed in the control unit.
When there is sudden load fluctuation, the lub oil flow is automatically adjusted. [Signal from load indicator transmitter → Remote control unit → change the speed / freq control electric motor

Below 20% load - oil feed rate is constant.
'Emergency lubrication' mode - when normal lubrication control fails, the cyl lubrication can be adjusted manually by adjusting the knob of lubricator. (In this mode lub oil quantity is not load-dependent).
'Pre & Post lubrication' mode - during slow turning of engine for 1 complete revolution.

%o Specific Cyl. Oil Consumption.

Acc to power. (g / kw-hr OR g / bhp-hr)

$$= \frac{\text{cyl. oil consumption in Kg/hr} \times 1000}{\text{Effective engine power in KW/BHP}}$$

Acc to fuel consumption.

$$= \frac{K \times \text{Assumed SFOC for engine}}{1000} \quad \text{where } K = \frac{\text{cyl. oil consumed in } \text{~~kg~~ per 24 hrs}}{\text{F.O consumed in tons per 24 hrs}}$$

Cyl Lubrication Requirements:-
① provide oil film at liner & piston ring surface.
(II) separate surface & reduce friction.
(III) neutralize acidic products of combustion
(IV) disperse carbon deposits.
(V) help in sealing of piston ring to liner.
(VI) burn without leaving hard deposits.
(VII) to provide correct feed rate at correct time.

Cross head Engines
cyl oil - 70 mg KOH/g.
c/case oil - 5 to 30 mg KOH/g

Trunk type Engines
system oil - 30 mg KOH/hr.

This is bcoz, trunk type engines use the same oil for c/case as well as cyl. lubrication while cross head engine uses separate oil.

Sulphur content in fuel	TBN v/v
less than 0·25%.	10 mg KOH/g.
0·25 - 1·0%.	10-20 mg KOH/g,
1·0 - 3·0%.	70 mg KOH/g.
Above 2·5 %.	more than 70 mg KOH/g

STARTING AND REVERSING

- Marine diesel engines started & reversed by using compressed air of around 30 kg/cm².

✓ % STARTING

The starting torque is achieved by the compressed air acting on the top of the piston to push it down. This reciprocating motion of the piston is converted into a torque at the c/shaft. The amount of starting torque required is the amount of torque needed to rotate the c/shaft at a speed that will produce the desired self ignition temp. to ignite the fuel in the cylinders.

Starting steps :- ⟨I⟩ cranking engine by compressed air to produce sufficient starting torque until some of the cylinders fire.
⟨II⟩ Picking up the combustion cycle on fuel without engines misfire.
⟨III⟩ Acceleration to a speed in accordance with the fuel injection p/p setting.

* The best time to admit starting air is at TDC, to utilize the positive starting torque from the beginning of the stroke. In practice, starting air is admitted slightly before TDC in order to take care of the time lag for pilot v/v activation, starting air v/v opening & full pressure availability to produce the desired starting torque. The start air should be admitted after the firing dead centre to provide a positive torque in the correct direction at the start of the working stroke.

→ Ideal firing speed :- Ideal speed of rotation of the c/shaft created by 'compressed starting air' cranking to compress the 'combustion air' in the cylinder to a temp sufficient enough to self ignite the fuel when injected.

8to12%
MCR speed

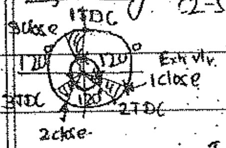
→ Firing interval = $\frac{360^\circ}{\text{no. of cylinder}}$

Eg :- 3cyl 2s engine, $\frac{360}{3} = 120^\circ$ 4cyl 2-str = $\frac{360}{4} = 90^\circ$.

→ **Start Air Period** :- min^m cranking period + overlap period to provide sufficient starting torque to start the engine in any direction at any position. It depends on the exh v/v opening as the start air should shut before the exh v/v opens, or else the pressurized compressed starting air is wasted. In 2 stroke T/C engines, the exh v/v normally opens at 65° before BDC or 115° after TDC. This gives max starting air angle of 115°.

→ **Overlap** :- ~~over~~ period when 2 or more cylinder unit are receiving starting air, where one unit is 'phasing out' while the others is 'phasing into' the ~~starting~~ air period. This is essential to satisfy the requirement that engine be started at any crank position. It ensures that at every crank angle position, there is sufficient air turning moment to enable positive starting. It depends on start air period; exh v/v timing & no. of cylinders. (More the overlap period, more easy to start. More no. of cylinders, starting becomes easier)

If 3 cylinders (2-S) - firing angle is 120°. Since max starting air period is 115°, no overlap is possible.

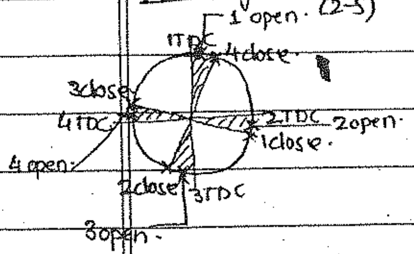


exh v/v close 10° before air starting v/v open of next cylinder.

In 3 cyl if engine stops in b/w shadow region (in diag.) then ~~no~~ start air v/v is not open for any cylinder ∴ Engine can not start on starting air.

If 4 cylinders:- (2-S) firing angle is 90°. Max starting air period is 115°

∴ Overlap = 115° - 90° = 25°



firing sequence = 1-4-3-2.

If engine stops at any position, 1 start air v/v is always open. So engine can start on starting air. (∵ overlap necessary)

☆ **Air Compressor** :- 2 or more - capacity to pressure 2 air bottles to the working pr from atm. pr in 1 hr.

☆ **Air Bottle** :- Capacity — Reversible engine - min 12 consecutive starts < 6 ahead, 6 astern.

Non-Reversible engine - min 6 consecutive start

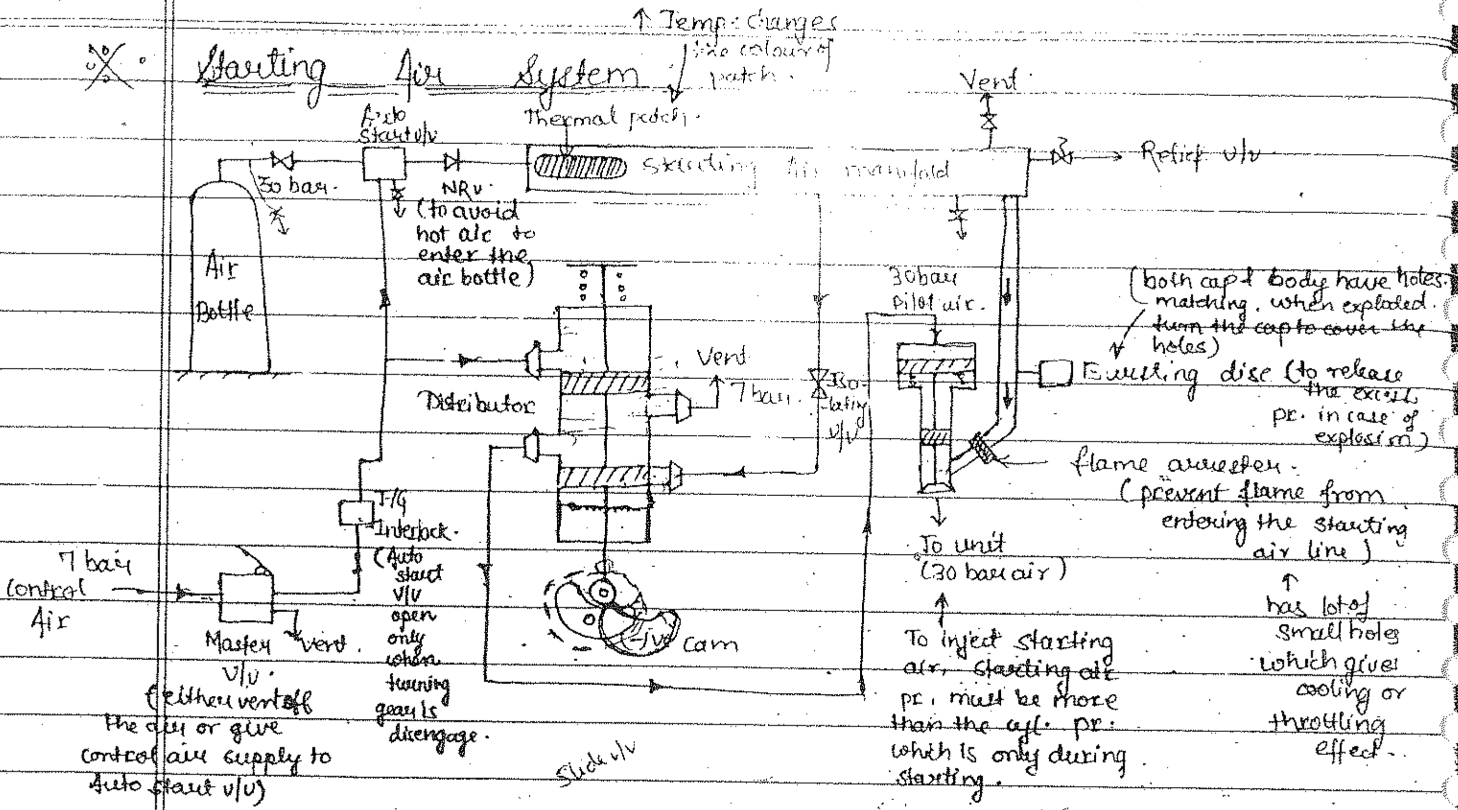
depends on:-

① swept vol. of cylinders.

(ii) ~~Specified no. of starts~~

(iii) Air required per start - 10 to 12 lts of swept vol for cold engine start

※ Starting Air System



When ~~master v/~~ command is given, master v/v vent closes & 7 bar control air supply goes to open the auto start v/v & manifold is filled with 30 bar air. 7bar Air also goes to the distributor & acts on top of the piston, vent closes & pilot air (30 bar) goes for opening the starting v/v. &

⇒ Inverted /(-)ve cam :- follower goes below base circle.
- ensure the (+)ve closing of distributor
- will have 2 peak points, so ~~ca~~ air can be injected in 2units at a time.
- less wear of cam working edge bcoz roller is off the cam during normal running, as there is a definite clearance b/w them when the engine is running.
- allows more flexibility to position the control v/v of distributor so that it does not touch the cam when the engine is running.

⇒ Starting air distributor :- admit pilot air to operate the cyl. air start v/v with proper timing & sequence for starting in ahead & astern directions.
- It is driven by a cam connected to the fuel camshaft which provides the correct sequence of starting.
- during reversing, distributor cam is also turned by the same angle.

⇒ Starting air interlocks

1) Turning gear interlock.
11) L.O ~~[illegible]~~ pressure interlock.
111) Spring air interlock
IV) Safety air interlock.
V) Aux. blower interlock.
VI) Camchaft L.O pr. interlock.
VII) Reversing completed interlock.

Engine fails to turn on Starting Air.

- One of the interlock is operated.
- Engine seized or jammed.
- Master V/V malfunction.
- Auto start V/V malfunction.
- starting Air V/V seized.
- Distributor jammed.
- Low Air bottle pressure.
- Engine stopped in a condition that no starting air V/V in open position.

Engine start on air but fail to fire.

- speed not enough to produce self ignition temp.
- Air bottle V/V not fully open.
- fuel lever not moved to zero position.
- Fuel to cold.
- Vapor lock in fuel system.
- Comp. pr not reached (broken piston rings / liner wear)
- Fuel p/p timing excessively out.
- Engine too cold to start.
- Governor malfunctions.
- Puncture V/V leaking.

Leaking starting air V/V

Indications :- ① Starting air line temp. ↑. Colour ~~Temp~~ of thermal patch may change.
(II) Bursting disc may burst.
(III) Exh. from starting air manifold drain. & burning smell in E/R

Check :- ① open air bottle V/V & shut the isolating V/V to distributor.
(II) Open the indicator cock.
(III) Give air kick. If air ~~starting~~ coming out of indicator cock, starting air V/V is leaking.

Action :- ① Change the starting air V/V.
(II) If not possible - cut off the fuel to that unit.

%: REVERSING — [1] Separate cam for Ahead / Astern i.e axial shifting of camshaft.

[2] Using same cam for Ahead & Astern.

a) turning camshaft in relation to c/shaft [SULZER]

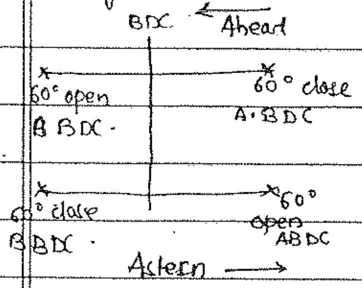
b) turning cam on camshaft [SULZER]

c) Shifting Roller point of contact [B&W]

↓

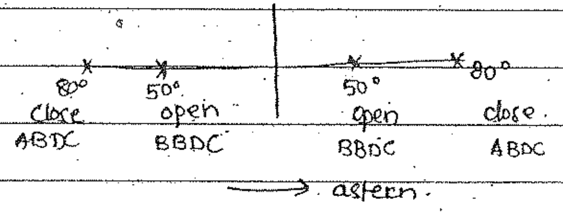
Requires repositioning of (I) fuel cam
(II) air distributor cam
(III) exh. v/v cam — (RD Sulzer Engine)
for correct firing sequence according to reverse direction.

Symmetrical



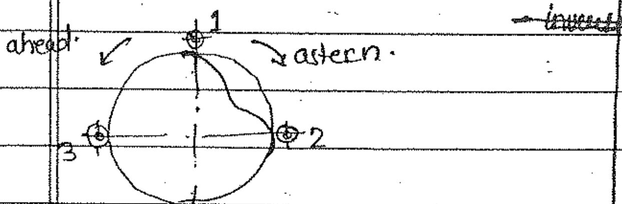
If timing is symmetrical at DC, there is no need of shifting the timing of cams. Only sequence has to be changed to reverse the engine.

Asymmetrical:



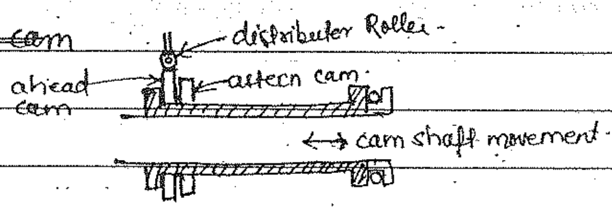
If timing is asymmetrical, timing has to be changed. Angle of opening & closing is changed according to the new direction of rotation.

Sulzer Air Distributor.



- Inverse cam & roller arrangement.
- Only one cam.

MAN B&W Air Distributor.



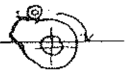
→ 2 cams - 1 for ahead & 1 for astern.

Lost Motion:— it is caused due to the camshaft turning opposite to the required direction when engine is being reversed.

Gain Motion :— it is caused due to the camshaft turning in same direction as the required direction when the engine is being reversed.

⇒ Why fuel cam ~~reversed~~ repositioned ??

Consider a cylinder. Piston is just before TDC & engine running ahead & c/shaft rotating clockwise. Cam follower is rising up at the lift of the cam as it rotates clockwise i.e Begining of injection.

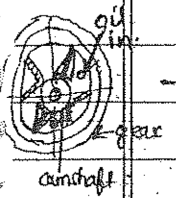


Now if engine is reversed., c/shaft moves in anticlockwise direction. Piston is moving down. At this point fuel injection should finish. ~~But~~ Since the camshaft direction is also reversed, the cam follower is now moving down the cam, which means plunger is finishing the suction stroke i.e it is completely out of time with the engine.

So time needs to be corrected.

Method 1 : Camshaft rotated w.r.t crankshaft. (Sulzer RD & RND engine)

- fuel & start air distributor cams get repositioned by a common servomotor which turns the camshaft by 98° in opposite direction to c/shaft.
- ~~Here~~ Exh rotary v/v cams gets repositioned by another hydraulic servomotor connected to the camshaft drive which turns the exh v/v cam by 160° in opposite direction.



Method 2 : Camshaft stationary but cams turned. (Sulzer RTA Engine)

- fuel ~~& start air distributor~~ cams get repositioned by ~~a common hydraulic servomotor which turns~~ turning the cam by 70° in opposite direction. while camshaft is stationary. The cams are mounted on a reversing servomotor, which is mounted on the main camshaft. One servomotor is used to reposition 2 fuel cams.
- Start air distributor cams are turned by 98° in opposite direction by a separate servomotor while the camshaft is stationary.
- Exh cams are symmetrical about BDC. So no repositioning.

Method 3 : Shifting position of roller.

- fuel p/p roller is shifted by a pneumatic cylinder. During reversing cylinder gets pressurized pneumatically & moves the p/p roller. ~~These~~ which gets self locked in their end position.

- engine drives a rotary disc (distributor) which can be turned by the reversing angle by means of a reversing pneumatic cylinder.
- exhaust cams are symmetrical about BDC so no repositioning required.

⇒ Running Direction Interlock – prevents admission of fuel to engine if the running direction of the engine does not match with the telegraph lever.

⇒ CRASH MANOEUVRING :- application of breake air, whilst engine is still running in the opposite direction.

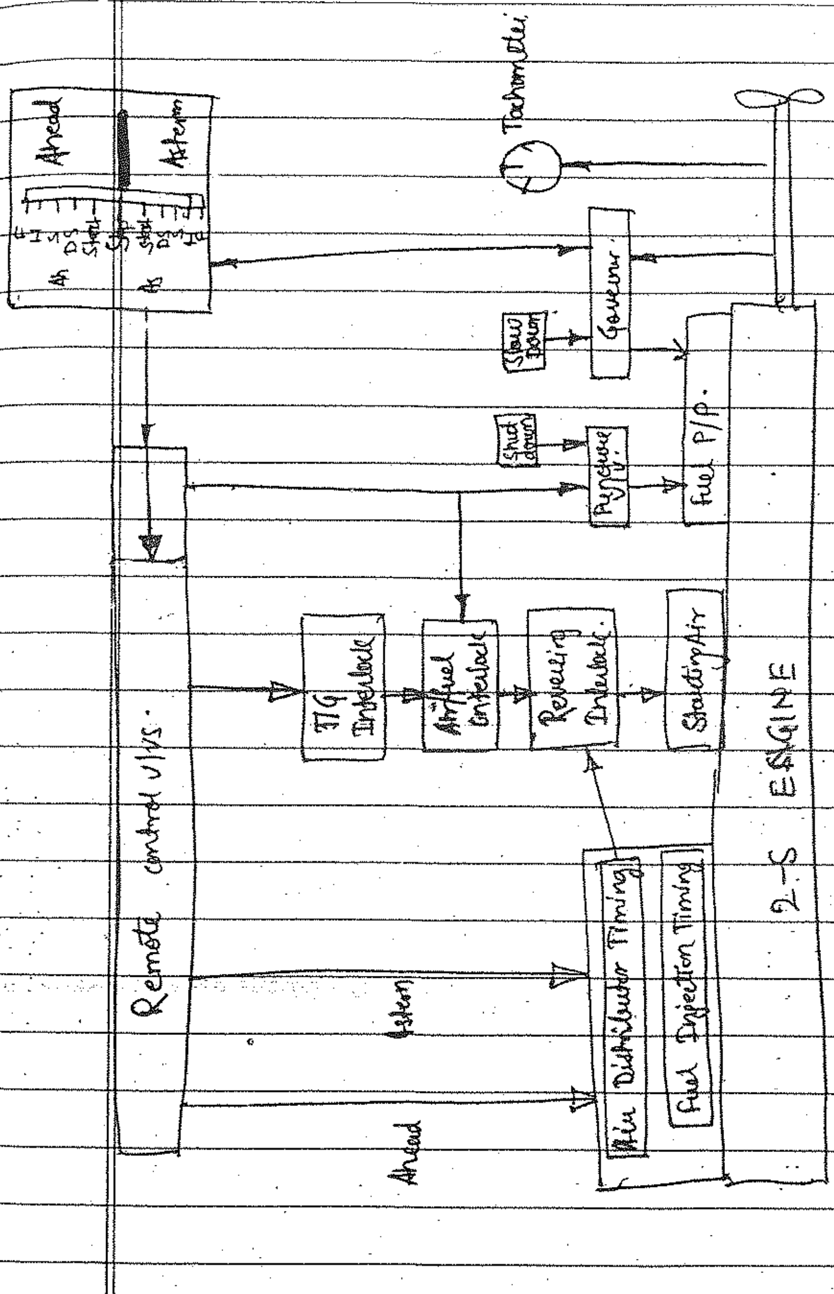
- Start air cam gets reversed due to telegraph order. However, fuel is cut off by running direction interlock since telegraph is opposite to the running direction of the engine.
- Starting air here becomes the breaking air bcoz the start air cam is reversed, thus allowing air supply in for astern timing when the engine is still moving with ahead timing.

MANOEUVRING FLOW CHART // SEQUENCE

- Control from bridge, ECR or local manoeuvring stand.
- Telegraph lever put to ahead or astern. (accordingly reversing will take place)
- Camshaft is in end position (either ahead or astern)
- Running Direction interlock checks the correct direction.
- Fuel lever set to min. setting.
- Start button pressed or starting lever put to 'start position'
- T/G Interlock checked.
- Master v/v sends signal to auto start v/v & distributor.
- Engine turns on air to min^m firing speed.
- Fuel injected & cylinder fires.
- Starting air shut off.
- Engine speed gradually increased.
- Critical speed range is overrided.
- Engine speed brought upto MCR & parameters monitored.

Manoeuvring Diagram

(Simplified diagram)



HAZARDS IN ENGINE OPERATION

CRANKCASE EXPLOSION

Conditions:- (i) a source of heat or ignition which is required to vapourise the oil into a fine vapour.
(ii) correct air to fuel ratio required for explosion.
(iii) fine oil vapour with a high surface area to mass ratio.

→ Source of ignition is mostly a hot spot – (i) bearing running hot.
(ii) blowpast
(iii) gear/chain drive running hot.

→ Heat causes the lub oil in contact with the hot spot to vapourise into a fine vapour.

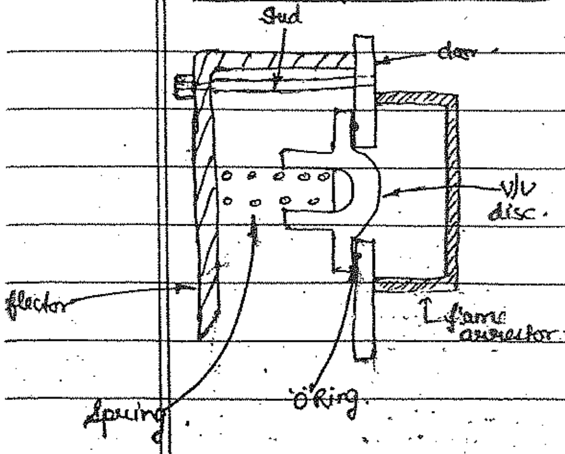
→ When this fine oil mist ignites in the presence of a hot surface, a pressure rise occurs which depends on the weakness or richness of the oil particle to air ratio. An explosion occurs if this mixture is in the explosive range.

→ A primary explosion is relatively slow as the c/case atmosphere is too rich with oil vapour, but may cause a rupture of the c/case allowing ingress of air. This ingress of air to oil particle ratio & a secondary explosion occurs, which is more violent.

→ Warnings:- (I) Oil Mist Detector (II) Bearing high temp. alarm.

→ A remedy for secondary explosion is the use of CRANKCASE RELIEF DOORS which relieves the crankcase pressure if it exceeds 0.05 bar, thereby preventing any rupture to the c/case & ingress of air.

⇒ C/CASE RELIEF DOOR



✓ Requirements as per SOLAS.

① for every 1m³ of c/case vol, c/case relief door shouldnot be less than 115 cm² area.

(II) If c/case volm is less than 0.6 m³ or piston dia less than 200mm, no need of c/case relief door.

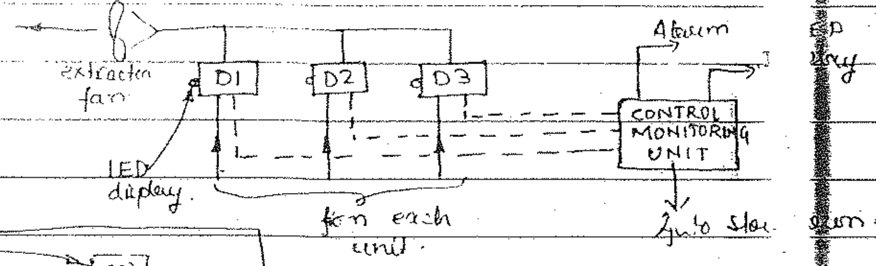
(III) If piston dia
(a) B/w 200 to 250mm — fitted at each end.
(b) b/w 250 to 300mm — very alternate door.
(c) > 300 mm, — fitted to all doors.

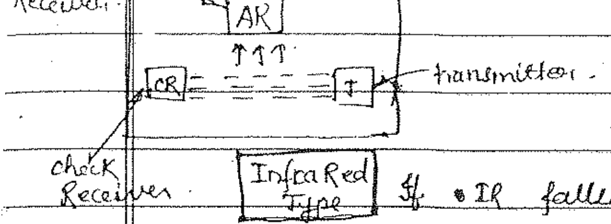
Does not allow pr. of c/case to go above 0.2 bar.

Indication of oil mist :-
i) white smoke from c/case breather pipe.
ii) c/case hot.
iii) Bearing ↑ temp. alarm
iv) metal to metal friction - abnormal noise
~~in c/case & rpm fluctuation~~

⇒ OIL MIST DETECTOR

As per SOLAS, OMD is required :-
① Only in engines having more 2250 KW
② If piston dia > 300m





Alarm : 2.5 % LEL for 2 stroke.
1.25 % LEL for 4 stroke.

Infra Red Type

If IR falls on the alarm receiver bcoz of oil mist, alarm will be sounded & auto slowdown of engine is activated.

⇒ Actions in case of OMD alarm. (As per MAN (i))

① Activate all engineer's alarm.
② Inform wheel house
③ Stop engine, Keep blowers, L.O running.
④ Evacuate engine room for ½ to 1 hr. [c/case should cool down]
⑤ After coming back, stop L.O p/p and feel the c/case doors.
⑥ Open c/case doors (use it as a sheild while opening). Keep fire extinguisher ready.
⑦ Enter c/case with powerful torch and inspect - ① hot spots [Blue colour]
② Bearings.
③ Loose parts.
⑧ Rectify the problem & shut the door.
⑨ Start L.O p/p and turn the engine on turning gear.
⑩ Start engine after 30 mins & slowly rise to full load.
⑪ Keep feeling the c/case door.

⇒ Actual action when ODM alarm comes :-
- Raise ~~Call~~ all engineers alarm.
- Inform W/H & reduce speed if no autoslowdown
- Check 'O' setting and 'span' setting
- Press reset & check if alarm comes again.
- Follow B&W procedure if alarm comes
- If no alarm - problem with OMD.

'O' setting :- A small O_2 cylinder flush the display unit with fresh air. So alarm disappear.

"Span setting :- A pentene gas (high LEL) cylinder is used. If alarm comes OMD is working properly.

SCAVENGE FIRE - fire in scavenge space or under piston space

→ Cause :-
i) Blow past due to worn or damaged piston rings
ii) Stuffing box leaks.
iii) Excessive cylinder lubrication
iv) Accumulation of sludge i.e inadequate draining of scavenge space.

→ Indications :-
i) Increase in scavenge air temp.
ii) High exh temp.
iii) Black smoke.
iv) T/C surging.
v) RPM fluctuations.
(vi) J/W temp. ↑
(vii) Scavenge door paint start blistering.
viii) Flame/smoke/ spark from scavenge drain.

→ Actions :-
i) Activate all engineer's alarm.
ii) Inform wheel house & slow down engine.
iii) ↑ cylinder oil feed rate (120gm/Kwhr)
iv) If fire not subsiding :-
  a) Stop engine & aux blower.
  b) Cover T/C blowers with tarpoline
  c) Inject steam or CO2 . Apply external cooling if possible.
  d) Once extinguished, open scavenge space & clean & rectify the fault.

→ Prevention :-
i) Regular draining, cleaning & monitoring of scavenge space.
ii) Correct rate of cyl. lubrication.
iii) Maintenance - piston rings, cyl. liners & fuel injector.

STARTING AIR LINE EXPLOSION :-

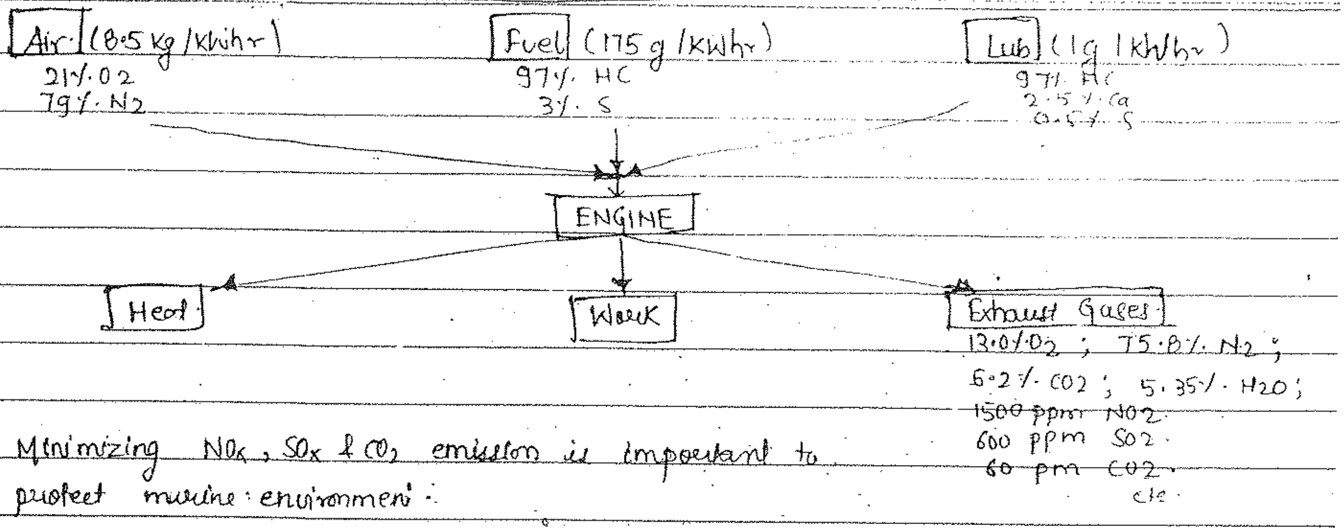
occurs if starting air v/v is leaking. Combustion gases enter the starting air manifold. Carbon & oil deposits, hot spots will lead to explosion.

Safeties :- Flame arrestor, Bursting disc, relief v/v, thermal patch, NRV

Actions :- During manoeuvring - cut off fuel to that unit & turn the bursting disc cap. ~~when~~ when possible stop engine & change the starting air v/v.

Prevention :-
① Good maintenance of air compressor.
(ii) Drain air bottle regularly.
(iii) Auto/Manual draining of water & oil in air line.
(iv) Starting air manifold pipe should be inspected & cleaned.
(v) Starting air v/v o'hauled at regular interval.

ENGINE EMISSIONS



Minimizing NO_x, SO_x & CO_2 emission is important to protect marine environment.

※ NOx – oxides of nitrogen which cause smog formation; local ozone concentration (global warming), health hazard (Cancer, Respiratory problems etc)

During combustion, nitrogen combines with O_2 to form nitrogen oxide which then get converted to NO_2 & N_2O in the ratio 5:1. N_2O destroyes the stratospheric ozone.

Regulation:- 1st Jan 2000 – 31st Dec 2010

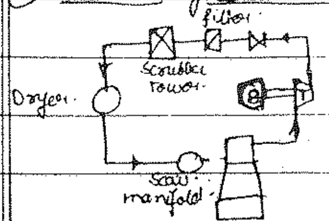
Tier I
Less than 130 rpm = 17g /kWhr
Upto 1999 rpm = $45 \times n^{-0.2}$ = n = engine speed
> 2000 rpm = 9.8 g/kWhr.

Tier II 1st Jan 2011 – 31st Dec 2015
Less than 130 rpm = 14.36 gm/kw-hr.
130 – 1999 rpm = $44 \times n^{-0.23}$
>2000 = 7.66 gm/kw-hr

Tier III 1st Jan 2016 onward, (for ECA region only.)
< 130 rpm = 3.4 gm/kw-hr.
130 – 1999 rpm = $9 \times n^{-0.2}$
> 2000 = 1.96 gm/kw-hr.

⇒ Remedy & Control:–
① ↓ combustion temp. (Retard fuel time but η ↓)
Ⓘ Use of special fuel injector (Slide v/v – zero sac nozzle)
Ⓘⓘ Water injection along fuel – ↑1% water – ↓ 1% NOx but fuel consumption ↑ by 0.3%.
Ⓘⓥ Water injection with air /Humidification
ⓥ Increase fuel injection pr & comp. ratio.
ⓥⓘ Miller's Supercharging: Closing inlet v/v much earlier – This result in air expanding & at the end compression temp ↓, ∴ Combustion temp ↓

Ⓥⅱ Exhaust gas recirculation (EGR) — exh gas is recirculated back to the scavenge side. This reduces the oxygen content of the air supplied to the engine, thereby reducing the amount of NOx produced.



(viii) Selective Catalytic Reduction (SCR) — Exh gas mixed with ammonia & a selective catalyst at a temp of 290 to 450 °C.

$$NO_x + NH_3 \longrightarrow N_2 + H_2O$$

NOx reduced ~~by~~ to 130 ppm - 90% reduction ∴ cost effective method but the SFOC ↑ by 2 to 3%. & SCR plant is bulky.

(Reducing agent urea is injected to the exh gas directly after T/C which decays immediately into NH_3 + CO_2. The mix is then passed over catalyst where NOx is converted into N_2 & H_2O)

⇛ Measurement :- done by Chemical Luminescence method, where NOx is converted to NO & then measured by a portable Electro Chem sensor (ECS) unit.

※ SOx — oxides of sulphur depending mainly on sulphur content in the fuel. Sulphur gets oxidized to form SO_2 & SO_3 in the ratio 15:1. They combine with ~~water~~ moisture in the atmosphere to form sulphuric acid i.e acid rain.

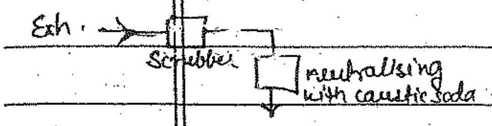
⇒ Regulation :-

Outside SECA	Inside SECA
Before 1st Jan 2012 — 4.5%.	Before 1st July 2010 - 1.5%.
After 1st Jan 2012 - 3.5%.	After 1st July 2010 - 1%.
After 1st Jan 2020 - 0.5%.	After 1st Jan 2015 = 0.1%.

⇒ Remedy & Control :— ⓘ Low sulphur fuel.

(ii) Wash exh gas in scrubber tower & then neutralize.

(iii) Use high alkaline cyl. oil to neutralize the sulphur on fuel.



⇒ Measurement :- Infrared, UV or electro chemical sensor.

※ Carbon Monoxide :- exh. emissions contain large CO bcoz of excess oxygen supplied in combustion air. ↑ in normal operating level indicates poor atomization of fuel by the fuel injectors.

※ Hydrocarbons :- efficient & correct combustion will allow a very small %ge of hydrocarbon in emissions [Hydrocarbons are basically unburnt fuel particles]

※ Particle Emission :- comes from partly burnt lub oil, ash in fuel or lub oil which includes unconsumed calcium additives & deposits peeling off from the cylinder or exh system.

※ Soot :- agglomeration of minute partly burnt fuel particles.
↑ with slow burning asphaltene fuels; burning of fuel impinged on the relatively cooler liner surface & with large fuel droplets.
It is an environment pollutant as well as it fouls the exh. uptake & ↑ exh. boiler back pr, sparking or even soot fire.

⇒ Smoke & Opacity :- it is the degree of blackening of a white filter paper or the amount of light reduction when light is passed through the exh plume.

Engine Stresses, Vibration & Dynamics

⇒ **Forces Acting in single Cylinder Engine :-**

- Force applied on piston due to gas pressure & an inertia force of the reciprocating parts.
  ↓ product of acc of parts & their mass
- Resultant of these force is the motive force (P) applied at the centre of the piston pin & transmitted to c/shaft via con rod.
- Motive force (P) resolved in 2 components :-

  (i) Normal component force (N) :- presses piston against the cylinder liner in trunk-type engine or presses the guide shoe against the guide in cross-head engines

  (ii) Second component force (S) :- applied to crank pin centre.

It is resolved into [A] Tangential Force (T) to the crankpin

[B] Force [Z] coinciding with the crankpin radius

N = produces a recurrent piston thrust against the opposite sides of the cylinder liner.

T = produces a torque which varies with the crank angle ~ causes c/shaft to rotate irregularly.

Z = bends the crankpin & creates wear in the bearings.

⇒ **Multicylinder Engine :-**

- crankshaft rotates by the torque produced by all the cylinders in succession. so it operates more regularly.
- torque will not coincide in time, bcoz the cranks are arranged at certain angles to each other. This implies that the recurrence of torque alterations ↑ directly with the no. of cylinders & the irregularity of the c/shaft rotation ↓.

⇒ **Irregularity Factor :-** ratio of the diff. b/w max & min angular velocities of the c/shaft & the mean angular velocity throughout a cycle of torque alterations.

⇒ **Flywheel :-** fitted at aft end of c/shaft to help reduce the irregularities of the c/shaft rotation. It is an accumulator which stores the energy of the gyrating masses when there is an extra torque & supplying the stored energy during torque deficiency. [↑ no. of engine cylinders, ↓ the irregularities of the c/shaft rotation • A Diesel engine with more than 12 cylinders does not require a flywheel]

※. Static Loads :- caused by the weights of engine components & bolt loads.

Static Balancing → ⊙ it implies that shaft is stationary or stops at a different position, if rotated when supported b/w centres.

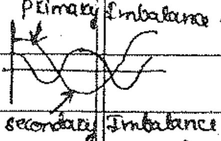
⊙ sum of all moments taken about its centre of rotation should be zero at any angular position.

⊙ done by placing counter weights to balance the moments so that their sum becomes zero.

※. Dynamic Loads :- caused by the cylinder gas fluctuating pressure & inertia loads of the reciprocating & rotating masses.

Dynamic Balancing → balancing unbalanced inertia forces together with their moment.

Inertia force is set up due to



i] Translating (Reciprocating) masses of the con rod - crank mechanism :- tend to either tear the engine off the foundation or to press it against the foundation depending on the direction of action.

- Causes Moment ~~caused~~ only in vertical plane.

ii] Unbalanced gyrating (rotating) masses :- act along crank web & are constant at any angle on the c/shaft at a given engine speed. They tend to shift the engine off the foundation or overturn it.

- causes moment in both vertical & horizontal plane.

★ Both forces cause foundation vibration.

※ VIBRATION :- oscillation caused by disturbing forces. Can be longitudinal, axial, transverse or torsional.

Engine vibration causes :-
i) constantly changing firing pressures.
ii) unbalanced forces, couples & moments due to reciprocating & rotating masses.
iii) Pulsations due to gas forces including exh gasses.
iv) Guide force moments.
v) Axial force due to in-plane bending of crank webs.
vi) Torsional vibration caused by varying torque & propeller thrust.

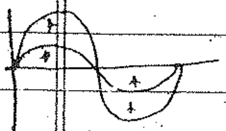
- **Amplitude :-** maxm displacement of vibration from the point of equilibrium.
- **Node :-** point in the vibrating system at which amplitude is zero.
- **Order of vibration :-** no. of vibration cycles in one revolution of the engine.

⇒ **Vibration Types :-**

A) **Natural Vibration :-** caused by the elastic forces of the c/shaft material & the inertia of its masses in absence of external forces.

B) **Forced Vibration :-** vibration of c/shaft & shafting coupled to it, which is induced by a variable engine torque.

⇒ **Resonance :-** coincidence of the frequency of natural vibration & the frequency of forced vibration.



Sine wave is superimposed / automatically added up.

- results in heavy vibration, local overheating & overstressing of the shafting.

⇒ **Critical Speed :-**
- crankshaft speed at which resonance may occur.
- may be more than one critical speed range for an engine.
- manifest itself by a ~~shaft~~ sharp increase in the amplitude of torsional shaft vibration.
- measured by torsiograph, which automatically records the torsional vibration.

⇒ **Barred Zone Range :-** range of operational speed which is 'barred' i.e overridden. This is a critical speed range which must be passed as soon as possible.

- It is specified for a given engine. More fuel can enable the engine to cross over this speed range as fast as possible.
- Means of avoiding these resonant frequencies is to adjust the speed of the engine or the mass of the flywheel or the engine firing order.

*: Reduction of Engine Vibrations.

Moment Compensators:-

1) Vibrations due to reciprocating & rotating masses can be countered by compensating masses rotating at the engine speed for 1st order frequency & twice the engine speed for 2nd order frequency. These compensators or balancers can be positioned in the chain drive. (2nd moment treated only in engines more than 5 cylinders)

2) **Axial Vibration Dampers:-** Axial vibration due to in-plane bending of crank webs (opening-closing of moving parts) countered by fitting an axial vibration damper at the free end of the c/shaft.

3) **Torsional vibration Dampers:-** Torsional vibration due to varying torque & propeller thrust is countered by detuning or damping. Torsional vib. dampers are located @ aft of the engine. while flywheel acts as detuner.

4) **Guide Force moments:-** vibrations due to guide force moments is countered by detuning, by using Top Bracing to increase the stiffness.

⇒ **Dampers:-** devices which absorb part of vibrational energy.
Eg:- Rubber damper (uses elasticity of rubber to absorb part of vib. energy)
Viscous dampers (uses viscous silicone fluid)

⇒ **Detuners:-** frequency control devices used to change frequency of the system.
Eg:- • Top bracing supporting the engine (↑ stiffness & raises natural frequency beyond operating range)
- Flexible couplings (sectionalise the system, flexible element absorbs part of vibrational energy & hence, ↓ its amplitude. ← can be rubber or spring.
- Hydraulic oil-filled mechanical ~~dampers~~ detuners (oil gets passed to & fro past the springs, causing detuning as well as damping).

Main Engine Safeties

→ Crankcase :- Relief door set at 0.05 bar.
OMD set at 2 to 5% LEL
Bearing Temp. sensors
Flame, spark arrestor & deflector incorporated in relief door.
Breather pipe.

→ Scavenge space :- Sight glass
Drain cocks
Temp sensors
Fire fighting system
Relief V/V set at 1.6 bar in MAN B&W engines.

→ Cylinder head :- Relief v/v.
Non return air start V/V - shut by cyl. pr.

→ Exhaust Manifold & Trunking :- Fire fighting system.
Drain cocks.
Test cocks.
Flame & spark arrestor.
Protective grid & bellows before turbine.
Drain cock in trunking of EGB.
Drain cock in turbine housing.
Manometer & safety v/v - EGB.

→ Piston cooling system :- Low pressure cut out 2 bar (approx)
High temp slowdown (60°C) & shut down (65°C)
Sight glass & non-flow alarm.

→ JCW system :- Low inlet pressure shut down 2bar (approx)
High temp slowdown (90°C). Alarm (85°C)
Expansion K low water level
Sight glass in exp. K.
Air separator & vent.

→ Lubricating Oil System :- Sump low & high level alarm.
Main L.O pr. low alarm (2.2 bar) & shut down (2 bar)
High L.O outlet temp alarm (50°C) & slow down (55°C)
Pr. gauges after cooler & filter.
Filter diff. pr. low alarm.
Cyl lubrication non flow alarm & slowdown.

→ Fuel oil system :- Service & settling tanks drains
Fuel high temp alarm (120°C)
Fuel low temp alarm (85°C)
Viscometer, thermometer, Pr. Gauges.

→ Starting Air System :- Air Bottle [Relief v/v (32 bar); fusible plug; drain; Pr. gauge; NRV]
Air Compressor [Low pr (1st stage) & High pr (2nd stage) relief v/v; NRV outlet v/v; bursting disc; ↑ air temp cut out; ↑ cooling water temp cut-out; ↓ L.O pr cutout]
Starting air line (flame trap; bursting cap; Thermal patch; relief v/v; drain; T/G interlocks ; NRV]

→ Control Air System :- PRV.
Oil & moisture separator.
Control Air dries.
Auto / Manual drain.
Relief v/v.
Low spring air pr. for exh v/v - alarm.
Control Air Low pr alarm (6 bar) & shut down (5.5 bar)

$F_R = 3\pi \mu V d$ ← dia of oil particle
V ← vel of oil particle.
μ ← viscosity of oil.

$F_S \frac{\pi}{6} D^3(\rho_w - \rho_o) \omega^2 r$

- Rudder stock dia > 230mm ; power operated steering gear.
- 35° to 30° – 28 sec max draught & full ahead.
- aux steering – 15° to 15° – 60 secs – max draught – 7 knots / half ahead.
- If main steering duplicate – aux steering not required.
- 2 pumps min – 45secs.
- 1 p/p from ESB
- Oil tank – low Level alarm
- overload alarm – 150%.
- short circuit protection – 200%.
- Design pr → 1.25 times working pr.
- 2 way comm → ER & WH & WH & SGR

BDN – 3 years
Bunker line test – 6 monthly.
Hydrostatic pr test –
Air pr – 6 bar.

1 BHP = 0.746
1.01 PS = 0.746 kW

Cetane → index of ignition quality

Fuel v/v opening → 320 → 380 bar
needle lift → 1 – 1.5 mm
spray nozzle → 0.075 –

T/C ~~water~~ wash → 200°C / 2000 rpm

850 ← ↓ Calculated Carbon Aromaticity Index → ignition quality — aromatic content
(CCAI) ↓ benzene ring

14.5 kg air + 1 Kg fuel [30 to 44 kg air + 1 kg fuel]

TBN – 70 mg KOH/g – 2(S) – cyl
4st → 30 mg KOH/g
2st → 5 – 30 mg KOH/g

F = 9/5 C + 32
C = 5/9 (F – 32)

Bed Plate – fabricated steel

A frame – ,,

Tie Rod

Crankshaft – low carbon steel (low alloy mild steel)

Liner – Nodular / spheroidal cast iron [C + Si + Mn + Vn + Sn]

Piston – Alloy steel (Cr, Ni, Mo) ~~cast iron~~ + INCONEL 625 coating – 6mm

Piston Rod – Flame hardened forged steel

1 Nm → 1.82 Km

Piston Ring – Grey cast iron (C + Si + mn + Vn + Sn)

Cylinder head – ,, (Mo – steel)

Exh V/V – seat → Stellite coating on seat + V/V → Nickel based alloy]
Spindle – nimonic + V/V guide – pearlite CI

T/C → Blower – Al wheel.
Turbine – nimonic wheel.

60 / 70 minutes
↓
K / 1000 × SFOC
↓
SFOC
⇒ fuel cons. (t/hr × 1000 × corrected specific gr.) / Power kW/hr

sp.g = @15°C × [R [T – 15°]]
R = 0.00065

Main bearing → Bridge Gauge ↑ 0.3 mm & thickness of bearing ↓ 0.01 mm → ovality.

Liner → weardown – 0.7% of liner dia
0.03 – 0.06 mm / 1000 hr.
0.013 – 0.026 ,,

ovality → 0.02 to 0.03 mm max

Piston Ring → wear 0.1mm / 1000 hrs.

ovality of c/pin → 1/4th of bearing clearance → in situ grinding | Polishing (more 2mm)

fuel cons. t/hr × 1000 / Power kW

con Rod ovality → (a+b)/2 – C → max 0.05 mm

VEC → 10° → 4 bar

Bearing – white metal Sn (88) + Sb (8) + Cu (4)
Thickness → 2.4 to 4% of dia.

Chain slack → 1/2 to 1 of pitch Max chain elongation – 1.5%.

Crank case Relief door → 0.05 bar 1m³ – 115 cm²

< 0.6m³ / piston – 200 mm
200 – 250 → each one
250 – 300 → alternate
300 – all

OMD → > 2250 KW
piston dia → 300 mm
2.5% LEL – 28K
1.25% LEL – 48K

$m r \omega^2 > \rho g h$

1 BHP → 0.780 KW

⇒ MAN B & W : 23280 KW @ 76 rpm.

Engine Parameters
Camshaft driven

6 S 80 MC - C ← compact

6 cylinders   superlong   800 mm dia.

15-34-2-6

Stroke → 3200mm

Bore → 800 mm

S/B → 4

No. of tie rod → 14

ul vtl.
280cst

SFOC → ~~180.41~~ 171.7 g /BHP Hr.

fuel oil consumption in Lt/hr x corrected sp gravity x 1000 ← Kg to gm
power in KW/hr.

PLAN ⇒ * P ~ mean effective pressure = 150.3 bar.   [Pcom → 134.0]

L ~ 3200 mm   T/C speed - 2100 - (MET 66SE)

Area ~ under indicator diag. — Simpson's Rule or Planimeter

Length ~ under " "

N ~ revolutions per sec. (76 rpm)

⇒ Generator :- Daihatsu → 8.DK-20 (8 cylinders) 880 KW X 720 rpm.

Pmax → 160

Bore :- 200 mm

Stroke :- 300   FO comp → 196 gm / kw/hr

S/B → 1.5

Power → 1000 KVA, 60 Hz, 440 V.   Pf = 0.88

⇒ Emergency generater -

4 cycle ~ water cooled with radiator DE.

Capacity → 180 KW. X 1800   [220 KVA X 1800 rpm]

⇒ Propeller → 4 Blade, Solid Skewed

dia → 9650 mm   Pitch = 6796 mm

0.886
1.014