# Mike's Guide

**A study guide for**
**Transport Canada**
**3rd Class Marine Engineer**
**Written Examination**

**Engineering Knowledge Motor**
**(EK Motors) Exam**

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**Martin's Marine Engineering Page**
**www.dieselduck.net**

**Topics:**

1. **Principles and construction of internal combustion engines**
2. **Cooling systems**
3. **Lube oil and fuel**
4. **Compressed air systems**
5. **Control system**
6. **Management of Diesel engines**
7. **Power balance**
8. **Automation and alarms**

Principles and construction of internal combustion engines:
Working principles and constructional details of marine diesel engines, gears, clutches and associated equipment and their seating

Safety:

1. What are the various causes of fire and explosion in internal combustion engines and how could you prevent them? (Diesel Duck)

- Witherby's p. 332
- Fire:
  - Oil/fuel dripping onto hot engine manifolds
    i. Guards/exhaust blankets protecting hot surfaces and pressurized fuel/oil lines.
    ii. Fixing leaks as soon as possible and periodically checking tightness of connections.
  - Scavenge fires
    i. Regular cleaning of scavenge ports (punching carbon)
    ii. Correct maintenance of injectors, fuel pumps, and scavenge blowers.
    iii. Properly loading of engine.
    iv. Checking condition of pistons, rings, and liners.
    v. Proper amount of lube oil to cylinders.
  - Stack fires
    i. Correct loading of engine, monitoring of exhaust temperatures.
    ii. Periodic inspection and cleaning.
  - Wiring shorts
    i. Regular checking of condition of wiring.
- Explosion:
  - Crankcase explosion
    i. Checking condition of lube oil (contamination of fuel, etc)
    ii. Fitting relief doors lessens effect.
    iii. Monitoring of oil mist content (5-7% very dangerous)
    iv. Regular maintenance, avoiding overload and the provision of adequate lubrication.
    v. Checking for hot spots by monitoring for irregular running, engine noise, increase in temperatures and by the presence of white oil mist.
    vi. If hotspot is suspected is to inform the bridge and stop the engine, increase lube oil flow, engage turning gear and turn with indicator cocks open to prevent seizure of overheated parts.
    vii. Crankcase should be allowed to cool for minimum of 30 minutes prior to entry.
  - Air start explosion
    i. Caused by either
      1. continuous leaking of a defective cylinder non-return valve while the engine is running
      2. non-return valve sticking in the open position during repeated starts
    ii. Flame traps, relief valves, bursting discs or caps are fitted to the manifold of each start air valve to minimize the effects of a start air explosion.
    iii. If a leaking start air valve is suspected, the engine should be stopped at the first opportunity and the valve replaced. As a temporary measure, a blank flange may be fitted to the air manifold connection to isolate the valve. Since this valve is inoperable, the engine may not start again so the bridge should be informed.
    iv. When air start system is not in use, it should be shut down and drains open.
    v. Compressor, receiver, piping and fittings must be properly maintained.

2. Describe a crankcase explosion. How does it occur? Why are crankcase relief doors fitted? What can be done to lower the chances of a crankcase explosion? (2008, 2010, 2011 Exams)

- Reed's Deck p. 77, Reed's MEK p. 199, Wharton p. 117
- 3 things are required – fuel, air, source of ignition.
- They have occurred in all types of engines: trunk, crosshead and even steam.
- In a diesel crankcase fuel is lubricating oil, air is always present, and the source of ignition is a hot spot, which vaporizes lube oil to form a dangerous oil mist.
- Normal crankcase oil spay particles are too large to be explosive but if formed at high temperatures of around 360C to 400C, the particle size becomes smaller and more explosive.
- Hot spots can be formed by overheated bearings, piston rod glands, timing chains, hot combustion gas, or sparks from blow by, or from scavenge fires.
- The oil mist with air in the correct ratio can ignite at the hot spot, producing a primary explosion.
- The pressure generated by the resultant flame speed will increase unless relieved.
- If after the primary explosion, air enters the crankcase due to the partial vacuum created by the rushing out of the hot gases, a secondary more violent and dangerous explosion may result with disastrous consequences.
- After a crankcase explosion and assuming damage has not allowed an ingress of air and a subsequent secondary explosion, the engine must be stopped and allowed to cool down.
- On no account should the doors be removed until the engine has cooled down as the ingress of air may result in another explosion.
- To protect personnel, guarded non-return pressure relief valves are normally fitted to the crankcase of each cylinder and to the gear case.
    - This allows the safe exit of excess pressure built up by the primary explosion. They are normally set to open at about 3 bar.
    - The doors are fitted with flame traps to prevent burns to personnel. This involves gauze screening that spreads out the flame.
    - Must be self closing to stop the return of atmospheric air to the crankcase.
- To lower the chances of a crankcase explosion, the following actions are necessary:
    - Checking condition of lube oil (contamination of fuel, etc)
    - Monitoring of oil mist content (5-7% very dangerous)
    - Regular maintenance, avoiding overload and the provision of adequate lubrication.
    - Use of white metal for bearings, which has moderate melting temperature.
    - Subdivision of crankcase will inhibit build up of high velocities of gases.
    - Internal crankcase lighting must be flame proof.
    - Checking for hot spots by monitoring for irregular running, engine noise or smells, increase in temperatures and by the presence of white oil mist.
    - If hotspot is suspected is to inform the bridge and stop the engine, increase lube oil flow, engage turning gear and turn with indicator cocks open to prevent seizure of overheated parts.

3. Sketch and describe an oil mist indicator. (2010, 2011 Exam)

- Reed's Deck p. 78, Reed's MEK p. 203, Wharton p. 118, Taylor p. 37
- Oil mist is dangerous at certain concentrations (5-7%) and this should be monitored to prevent crankcase explosions.
- Indicators will be fit with alarms to alert watch-keeper of rising mist levels well before they reach dangerous levels.
- Photoelectric detection uses a comparison between a set of two photocells to determine a rise in oil mist. One cell measures a reference level and the other measures from several sources through a rotating selector valve.
- The photo-cells are normally in a state of electric balance since both tubes will sense the same level of oil mist.
- Out of balance current due to rise of crankcase mist density can be arranged to indicate on a galvanometer, which can be connected to continuous chart recording and auto visual or audible alarms.
- The suction fan draws a large volume of slow moving oil/air vapor in turn from various crankcase selection points in turn, through the measuring tube and then to atmosphere.
- An average sample is drawn through the reference tube and to the atmosphere at the same time.
- In the event of a hot spot in a certain area of the crankcase, there will be a difference between the optical densities of the two tubes; hence less light will fall on the photo cell of the measuring tube.
- The photo-cell outputs will be different and the current difference reaches a predetermined value, an alarm signal (about 2.5% of lower critical point) is activated and the slow turning rotary valve stops, indicating the location of the overheating.
- Normal oil particles as spray are precipitated in the sampling tubes will drain back into the crankcase.
- Detectors should be tested every day and the sensitivity checked.
- Comparator models as described are used for crosshead engines.
- Trunk type engines use a sealed reference tube for comparison. This is called a level model.

4. What are the precautions necessary before opening crankcase doors? Working in the crankcase of a diesel engine? Before closing up and starting? When using lifting gear for heavy parts? (2011 Exam, Camosun College Sample)

- Allow it to cool after running for 30 minutes minimum, especially if a hotspot is suspected.
- Can be considered an enclosed space, deficient of oxygen.
- Should be well ventilated when cool and oxygen levels should be monitored.
- Spark proof lighting and tools.
- Should be working with another person for safety.
- Safety equipment and apparel should be worn.
- Start system and turning gear must be locked out and tagged.
- Oil is drowning hazard, should be emptied if entering space.

Materials:

5. Of what materials are the following parts of a marine engine made and why is this material used? (Diesel Duck)

- Witherby's p. 274
- Crankshaft
    - Carbon or low carbon alloy steels are used depending on size.
    - High strength, long fatigue life and form good bearing surfaces
- Propeller shaft
    - Solid forged carbon or low carbon alloy steels are used depending on size. Possibly stainless steel.
    - High strength, long fatigue life and form good bearing surfaces
- Cylinder liner
    - Pearlite or close grained grey cast iron.
    - Alloys of vanadium and titanium to increase strength, wear properties and corrosion resistance.
- Piston
    - Crown may have layer of protective alloy.
    - Skirt may be cast iron or aluminum alloy.
    - Withstand high gas load, and transmit the force from this to the piston or connecting rod. Must have long fatigue life to survive fluctuating mechanical and thermal stresses.
- Piston rod
    - Steel forging, round in section for strength and rigidity
    - Surface is treated to minimize friction and wear at the gland.
    - Requires strength to act as strut under axial loading from piston.
- Piston rings
    - Cast iron, alloyed cast iron, spheroidal graphite iron
    - May be coated with chrome or plasma coatings.
- Connecting rod
    - Forged steel, I-section to counter the transverse bending force subjected on it from the reciprocating forces of the pistons.
- Main bearing
    - Thick shelled white metal, lead bronze, copper lead, aluminum, tin alloys, etc.
    - Steel backing.
    - Subjected to heavy loads that fluctuate in magnitude and direction, support weight of crankshaft.
- Bedplate
    - Cast iron or steel plates and castings welded together.
    - Must be strong to transmit and support engine loads.

Bedplate:

6. Describe the bed-plate for a diesel engine and explain how it is secured to the ship. What is it's purpose and what material is it made of? (Diesel Duck, Camosun College Sample)

- Wharton p. 75, Reed's MEK p. 26
- The bedplate of an engine acts as the main strength part of its section, providing rigid support for the main bearings and the crankshaft.
- It is also a platform for other structural components such as frames or columns.
- Guides may be accurately mounted to support the engine cylinders and ensure alignment of all working parts.
- Bedplate must withstand heavy, fluctuating loads from all working parts.
- It must transmit engine loads, including propeller thrust to the ship's structure, distributing these over the necessary area.
- May complement the ship's strength and propeller shaft alignment.

- Bedplate also collects lube oil from the crankcase, returning it to the drain tank for recycling.
- Fabricated from steel plates and castings welded together to form a deep longitudinal box structure with stiffening members and webs to give additional rigidity.
- Cast iron is more expensive and not as strong in tension or as stiff as steel.
- Lightening and access holes are made with compensating sleeves to maintain with lightness and strength.
- Transverse members or girders are fitted between each engine unit and at each end of the bedplate.
- The central section of each is formed by a steel casting shaped to support the main bearing and with holes for a pair of tie bolts.
- The casting has substantial butt welds securing it to the main box structure.
- All welding must be to a very high standard, carefully controlled and inspected.
- It must be stress relieved, shot blasted and tested for flaws.
- All plate edges must be carefully prepared, with double butt welds and complete penetration where possible.
- Flanges are machined for landing on support chocks or assembly to other members.
- Regular inspection must take places, looking for cracks. All nuts must be checked for tightness and to ensure fretting has not taken place between mating surfaces.
- The bedplate is secured to tank tops by bolts or studs that are secured into the tank top and a nut fitted and locked underneath. These must have a clearance in the bedplate to allow for thermal expansion.
- These bolts are tightened hydraulically in a sequence to reach correct tension in the studs and compression in the chocks.

Cylinders:

7. What are volumetric and mechanical clearances? How are they determined? What would be the effects of these clearances on the wearing or adjusting of the engine? How would this effect the running of the engine? (Diesel Duck)

- Reed's MEK p. 142
- Mechanical clearance is defined as the distance between the piston and cylinder head at TDC.
- Volumetric clearance is defined as the volume between the piston and cylinder head at TDC.
- Volumetric capacity is a measure of compressor or engine capacity. It is the ratio of the actual volume of air drawn in each suction stroke to the stroke volume.
- Correct clearance must be maintained and this is usually done by checking the mechanical clearance and adjusting it as required by using inserts under the palm of the connecting rod.
- If clearance is excessive, high pressure air remains in cylinder after exhaust stroke.
- If naturally aspirated, this air must expand to a pressure below atmospheric to admit intake air.
- If supercharged, this exhaust gas will require more work to allow a fresh charge of air.
- Bearing clearances should also be kept at recommended values.
- The clearance is determined by placing a ball of soft lead on to of the piston and rolling the engine over slowly. The thickness of this lead should give the mechanical clearance.
- Multiply this by the area of the piston will give the volumetric clearance.
- Increasing the clearance will lower the compression of the cylinders, lowering the temperature, pressure and therefore power.
- Decreasing the clearance will do the opposite. This may be dangerous since it increases the stresses on the engine parts and may cause failure if the engine cannot withstand this extra load.

8. Describe a liner for a diesel engine. State the materials. What allowance is made for expansion? How is leakage of cooling water prevented? How is the liner held in place? Why are cylinder liners fitted? What might cause a liner to crack and where would the cracks appear? (Diesel Duck, Camosun College Sample)

- Wharton p. 43
- A cylinder liner is a removable sleeve that makes up the cylinder walls.
- Liners are designed for an extensive working life with long periods between overhauls.
- They must maintain low wear rates and friction losses from the sliding motion of piston rings under fluctuating pressure and temperature.
- Materials must provide:
    - adequate strength and fatigue life
    - readily transfer heat
    - resist abrasion and corrosion
    - be able to retain a film of lube oil on working surfaces
    - have a rate of thermal expansion compatible with adjacent parts
- Liners are cast in pearlitic cast iron and alloyed with vanadium and titanium to enhance strength, wear and corrosion resistance.
- Chromium plating can be carried out to reduce wear and corrosion further.

- Upper end of liner forms a flange of sufficient strength to support it. This flange is secured between the cylinder head and the jacket or engine entablature, leaving the lower end free for expansion.
- Liner thickness must give adequate strength to resist internal gas load but is limited the necessity to transfer heat rapidly to reduce the thermal stress.
- For 2 strokes, scavenge ports will be cut or cast into lower end. Engines using loop or cross scavenge systems will also need exhaust ports. All port edges are shaped to direct the flow.
- The top row of ports are exhaust ports at about 75% down the stroke and scavenging ports are lower at about 80% down the stroke on the opposite side.
- For 4 strokes, no ports are necessary and are simpler in shape.
- Silicone rubber o-rings fitted into grooves form seal at bottom end to allow cooling space between liner and block.
- Upper end is sealed by the landing of the liner flange and the head gasket.
- Water enters at the lower end of the jacket, flowing upwards and leaving at the top to pass on to cool the cylinder head.
- Lubrication is often forced into the cylinder by means of a mechanical force feed lubricator. It is fed through openings in the cylinder wall and timed to enter between ring segments when the piston is at or near the end of its stroke.
- Cylinder liners are fitted since they are cheaper and easier to replace than the block itself.
- A liner may crack if it was overheated due to overload or loss of sufficient cooling water or lubricating oil.

9. What could cause loss of power in a diesel engine cylinder? (Diesel Duck)

- Loss of power in a diesel engine could be caused by:
    - Loss of fuel pressure – dirty filters, worn pumps, worn injectors, air in fuel
    - Low compression pressure – broken/worn rings or liners
    - Water in fuel
    - Dirty air filters or worn blowers
    - Engine not timed properly
- Some parameters that will give an automatic reduction in power in an engine equipped with monitoring are:
    - High scavenge temperature
    - High oil mist reading
    - Low piston cooling pressure or flow
    - High piston cooling temperature
    - Low jacket water pressure
    - High jacket water temperature
    - High exhaust gas temperature

10. Describe how you would measure the clearance between the piston and liner on a diesel engine. How much wear would you allow before fitting a new liner. How would you remove the liner and fit a new one? (Diesel Duck)

- Wharton p. 50
- You would measure the piston/liner clearance by first using an inside micrometer on the liner.
- A template can be used to record liner wear at various depths. These results can be compared to the last set of readings to check for abnormalities.
- The manufacturer will give a tolerance for these measurements. The liner will have to be replaced when worn too much.
- Normal wear rates vary but is approximately .1mm per 1000 hours. It is higher during break in.
- Maximum wear allowed will be given by the manufacturer and is usually .6 to .8% less than original bore diameter.
- If cylinder is operated with excessive wear, the rate of wear will rapidly increase.
- Gas blow by may remove lube oil film, piston rings may distort and break, and piston slap may cause scuffing.
- Compression is reduced and exhaust system will be fouled which could cause scavenge fires.
- The ring clearances are also important.
- For the rings, you fit them without the piston in the least worn section of liner and then check the butt clearances.
- If the butt clearance is too large, the liner or rings will have to be replaced.
- In modern engines, lifting arrangements and power tools/jacks are designed and supplied by the engine manufacturers for use in removal of heads, liners, pistons, etc.
- Cooling water is removed. Cylinder head and connections are removed.
- Piston and rod are then removed and lubricators taken out (if fitted).
- A strong-back is used to span the top of the liner and a crossbar is fitted to the bottom of the liner using long bolts.
- By tightening jacking bolts, the liner can be freed from its landings and eye bolts can be fitted for lifting out with crane.
- To fit a new liner, the surfaces must be cleaned and inspected.
- The strong-back is then inverted and fitted to jack down the new liner into place.

- Correct sealing rings are first fitted into place and lubricated for assembly.
- Care must be taken to align liner with markings on its joining faces.
- After the cylinder head is torqued down to secure the liner in place, a water leak test should be completed.
- Lubricators can be refitted and tested.
- The liner should be then checked for inside diameter for future reference.

Pistons:

11. Before fitting new rings to the piston of a diesel engine, what tests and checks must be carried out to ensure that the rings will function properly? What damage may be caused by improperly adjusted rings? What clearance is usually allowed between the butts? (TCMS Sample, Camosun College Sample)

- Wharton p. 63, Reed's MEK p. 55
- Ring clearances are necessary to allow movement and thermal expansion.
- Three types of clearances to consider:
    - Vertical clearances of ring in piston slot
        i. Must be gauged with feeler gauge to see if within manufacturer tolerances.
        ii. Excessive would cause excess movement due to inertia, causing excess wear.
    - Axial clearance in the groove
        i. Must be gauged to allow gas pressure to pass to and from the backs of the rings.
        ii. The clearance will increase with wear and the landings must not be allowed to taper.
        iii. Clearances vary with engine size but for a large engine may be .4mm for the top ring and .2 mm for lower rings.
        iv. If excessive, will form deposits that could lead to sticky rings, breakage, blow by and scuffing.
    - Circumferential clearance at the ring joint
        i. Necessary to allow for thermal expansion but should not allow excessive blow-by of gas.
        ii. If rings are to be re-used, can be measured by looking at reduction in the width of the ring section and by increase in butt clearance at the corresponding liner bore.
        iii. It is measured before fitting by inserting the ring into the least worn (lower) part of the liner bore and ensuring it is lined up in bore by using a flat piston to push it into place. The butt clearance is measured with feeler gauges.
        iv. This clearance will vary by the type of joint used, engine size and rating but for large engines, should be approx .5% of cylinder diameter to 1% diameter for higher rated engines.
- Ring surfaces should be checked for defects and not installed if any cracks or irregularities are found.
- Piston grooves must be very clean prior to installation.
- Placement of rings should be offset 180° from the next in order to prevent excessive blow-by.
- Rings should have proper beveled edges to spread lubrication properly.
- Oil scraper ring will be marked which way is up to ensure it is installed in the correct orientation.
- Excessive wear will cause rings to become slack and will
    - Reduce engine efficiency
    - Cause hot gas to blow past the rings
    - Removing lubrication
    - Causing ring distortion and breakage
    - Piston groove damage
- If the rings are too tight, the rings could seize, causing overheating, excessive wear, increase blow-by.

12. Describe piston rings commonly used in a diesel engine. What is the purpose of piston rings? Why is more than one ring fitted? From what material are rings made and what would be the effects on the engine from leaking or dirty rings? What is the purpose of the scraper ring and where is it fitted in relation to the other rings? (Diesel Duck, Camosun College Sample)

- Wharton p. 63
- The purpose of piston rings is to:
    - Form the flexible connection between piston and cylinder liner, forming a gas seal and to control lubricating oil.
    - Transfer heat from piston to liner.
- Materials for rings must:
    - Good strength
    - Elasticity
    - Wear resistance with low friction
    - Must maintain these properties at high temperatures
    - Must resist corrosion
    - Readily transfer heat
    - Have thermal expansion compatible with the piston in order to maintain groove clearances

    - Ability to bed into liners quickly
    - Self lubricating
    - Must maintain tension to give a good gas seal,
- Often cast iron with some alloys or coatings or spheroidal graphite iron for greater hardness and tensile strength.
- May also be heat treated to improve properties by quenching, tempering or austempering.
- The cross section of rings is rectangular with small radii on all edges. This allows an oil wedge to build up on the outer surface and prevents sticking at the back of the oil groove. The section may vary adjacent to the ring butts.
- Rings are either machined circular or to a cam shape from which they expand to form a circle at working temperatures and avoid port chipping.
- The joints may be:
    - Butt – vertical, rectangular. Gives a robust joint for top rings
    - Scarfed – diagonal. Gives a better gas seal but weaker.
    - Lap or bayonet – Good gas seal but more vulnerable to breakage. Only used in some lower rings.
- Compression rings are fitted in corresponding grooves machined in the piston.
- They grooves must stay true to avoid ring distortion. They are often coated with an alloy or heat treated to provide better strength.
- The piston rings must be free to follow the liner surface irrespective of transverse movement and will build up an oil wedge on the liner, reducing wear and spreading cylinder lubrication.
- The outward pressure is initially due to elasticity in compressed ring but is increased by gas pressure, which acts on the back of the ring.
- Pressure and temperature are greatest in top rings and these rings will have higher wear rates than those further down.
- Ring edges should not be too sharp since this will prevent a good oil film formation.
- Ring gaps should be placed 180° to each other alternating when reinstalled.
- Axial clearance should be measured with feeler gauges against manufacturer specifications.
- Leaky scraper rings reduce the efficiency of the engine and increase liner and ring wear by blowing the lube oil off rubbing surfaces.
- Low compression will cause poor combustion and leakage of gas, lowering power.
- Oil scraper rings, or oil control rings, are fitted below the compression rings on the piston or skirt.
- The section is shaped with a downward wedge or lip that spreads the oil on the up-stroke but scrapes off excess oil on the down-stroke to prevent oil from being burned by combustion.
- They are light in section to conform readily to the liner contour.
- Some are spring-loaded with drain holes that allow rapid drainage of oil back through the piston, which will also be fitted with hole.

13. Describe a crosshead piston. Give the advantages and disadvantages of a trunk piston and name the differences between a crosshead and trunk piston. (2010 Exam)

- Wharton p. 56-61
- These will be subjected to rigorous conditions due to the large bore cylinder and heavy fuels.
- The piston crown must be supported against bending while allowing cooling of underside.
- The shape is concave to give efficient combustion space.
- Pistons are cast in chrome-molybdenum alloy steel and machined on all surfaces.
- Ring grooves are cut into the side wall and to reduce wear and fretting, they are chromium plated and ground.
- The piston diameter may be slightly tapered towards the top due to higher expansion and stress there.
- A thin layer of protective alloy may be welded on to protect piston.
- Cooling of crosshead pistons is necessary to remove excess heat from combustion and to limit thermal stressing.
- Cooling is carried out by circulating internal passages in piston with coolant. This may be oil or fresh water.
- Oil cooled pistons are used in most engines.
- Oil has a lower thermal capacity than water so an adequate supply is necessary.
- Temperature must also be controlled to stop deposit formation.
- Cooling oil is supplied under pressure to the crosshead via either telescopic pipes or swinging links with glands.
- From the crosshead, it passes through holes bored in the piston rod to the cooling spaces in the piston.
- It returns via the crosshead to a collector where its flow and temperature are monitored before it drains to the bottom of the crankcase for recirculation.
- Fresh water cooling has the advantage of higher thermal capacity than oil and a higher outlet temp of 70C may be attained.
- However, telescopic glands are used to convey water to the piston and these may leak if not carefully aligned and maintained.
- Also a separate cooling water system must be installed and there is a high risk of water contamination of the oil.
- The pressure and rate of flow of oil or water must be sufficient to overcome gravitational or shaker effects due to the reciprocating motion of the pistons.

- Crown is bolted to the piston rod flange.
- A short cast iron skirt is secured to the underside of the piston, sealing off the cooling space.
- The major difference between a trunk and crosshead piston is the means by which they are attached to the connecting rod. The trunk type is attached by a wrist pin while the crosshead type is attached by piston rod and crosshead.
- Crosshead pistons using uniflow scavenging have a shorter skirt fitted to stabilize the piston within liner. Those using loop or cross scavenge have long skirts to blank off scavenge and exhaust ports when the piston is above these. The piston rod is bolted onto the bottom of the piston.
- Trunk pistons have the oscillating wrist pin fitted within it and therefore transmits the gas load from the piston to the gudgeon or top end bearing.
- Due to the absence of crosshead guides, skirt acts as guide for piston and transmits side thrust from connecting rod to the liner walls. Skirts therefore will require lubrication and may have oil control rings fitted.

14. How is a crosshead fit? How is the piston rod attached? (Diesel Duck)

- Wharton p. 68, 61
- A crosshead consists of a forged steel block secured to the foot of the piston rod.
- It includes the journal for the top end bearing which acts as a hinge by which the piston thrust is deflected via the connecting rod to the crank.
- A piston rod acts as the main strut to transmit the heavy gas load downwards from the piston to the crosshead and running gear of the engine.
- There is a flange at the top end where bolts or studs attach it to the piston.
- Lower end is attached to the crosshead either by a bolted flange or by passing through the crosshead with a nut underneath.
- Engine guides that are fitted to crossheads are vertical sliding bearings and made of white lined bearing material, line with holes to lubricate the crosshead.
- Crosshead engines are fitted with cylinder diaphragm and piston rod glands to isolate the lower surface of the cylinder and scavenge box from the crankcase in order to prevent lube oil contamination from the combustion residues of heavy oil.
- The diaphragm allows use of different oils for cylinder lubrication and crankcase lubrication.
- The purpose of the upper half of the piston rod gland is to act as a seal for scavenge pressure and scrape off any residue dirt from the piston rod on its downward stroke.
- The contaminated oil can be then conveyed to the sludge tank.
- The purpose of the lower half of the piston rod gland is to act as oil control rings, to scrape off any excess crankcase oil during its upward stroke.
- The oil is returned to the crankcase system via drains.
- A void or vent is often between the two gland seals to check the efficiency of the gland.
- The gland consists of inward sealing metallic or Teflon packing and oil scraper rings.
- Each segment of packing is held in tension by springs and gaps are present to allow for expansion.
- Poor maintenance of the gland can lead to contamination of the scavenge space with oil, loss of scavenge air or cross contamination of oils. This could lead to overheating of the piston rod and possible explosion.
- Maintenance includes checking for correct clearances of sealing rings, checking tension of springs, keeping drains and vents clear.
- Engine guides are fitted to crosshead engines that are vertical sliding bearings that locate and maintain alignment of the crosshead over the length of the engine stroke.
- They are subject to fluctuating load from the transverse connecting rod forces.
- Guide bars or surfaces are secured to the frames adjacent to the unit and have either cast iron or steel bearing surfaces.
- Guide shoes or slippers are attached to the ends of the crosshead and may be free to articulate.
- These are white metal lined with oil grooves lubricated from the crosshead.
- Guide clearances should be checked periodically and should not exceed .7mm for a large engine.
- Excess clearance will cause noise, wear on bearings and glands, uneven loads and fatigue.

15. Explain the difference between a trunk engine and a crosshead engine. (Camosun College Sample)

- The main difference is that a trunk type engine has no piston rod.
- Trunk type:
    - The connecting rod has an eye on top end and a wrist pin passes through this and the sides of the hollow piston to form a swivel connection between rod and piston.
    - The bottom of a trunk style cylinder is open to accommodate the swing of the connecting rod.
    - The trunk type piston therefore performs the additional function of a crosshead as the side thrust at the top of the connecting rod is taken up on the cylinder wall.
    - Trunk piston may have top recess to allow clearance for intake and exhaust valves that are open for scavenging at the end of the exhaust stroke.

- Lighter and smaller than equivalent crossheads.
- Maintenance is easier due to smaller and lighter parts

- Crosshead:
  - In larger crosshead engines, a piston rod and crosshead are fitted so that the side thrust is taken up by the crosshead guide shoes.
  - Normally larger than trunk type engines and slower speed.
  - Slower piston speed and fewer working parts make them more economical in lubricating oil.
  - Lower wear rates and more reliable.

16. Describe a trunk-type piston, giving materials. Describe the action of the wrist pin, how it is fitted and what means are employed to prevent the pin from scoring the cylinder walls. Why is necessary to have skirts on 4-stroke pistons? (Camosun College Sample)

- Wharton p. 61
- Fitted to almost all 4-stroke engine and may be up to 600mm diameter for medium speed.
- Thin sectioned alloy steel piston crown supported on aluminum alloy skirt.
- This gives a strong, light structure capable of resisting high temperatures and corrosion but with low inertial losses.
- The steel crown may be cast or forged and is shaped to give adequate cooling spaces.
- Inner surfaces are cooled by shaker method in which oil from the wrist pin bearing passes to piston and relies on the reciprocating motion to splash it against hot surfaces and force it through passages where necessary.
- The oil drains down the inside of the skirt to the crankcase.
- Piston compression rings are fitted in grooves in the cylindrical part of the steel crown.
- Top surface of the crown may be recessed to allow clearance for inlet and exhaust valves during scavenging overlap.
- A number of pre-stressed bolts are screwed into the crown to secure it to the skirt.
- The skirt of aluminum alloy will contain the wrist pin bearing and its outer diameter may be oval to allow for thermal expansion.
- It must be of sufficient strength to dissipate the side thrust to the liner.
- Oil control rings may be fitted at the top of the skirt to remove excess lube oil splashed from the crankcase.
- Aluminum pistons can't be used in heavy fuel engines since their strength, corrosion and abrasion resistance is reduced at elevated temperatures.
- The floating type wrist pin is free to move both in the eye of the connecting rod and the bosses of the piston casting.
- A spring clip retainer is placed in grooves in each end of the piston boss in order to prevent the pin from scoring the cylinder walls.
- The purpose of having a skirt on a 4 stroke piston is to act as a guide to stabilize the piston's position within the liner.
- Skirts will require lubrication in a trunk type engine and may have oil control rings fitted.
- The length of a 4-stroke piston is dictated by the amount of side thrust it has to dissipate to the liner.
- Some large pistons are fitted with bronze bearing rings to absorb side thrust. These are replaceable.

17. How would you check the alignment of the piston, piston rod and guides of a large engine? (Camosun College Sample)

Cylinder Heads:

18. Describe a cylinder-head relief valve. Why is there a need for it to be fitted and how is it set to lift at the required pressure? Where is it fitted in a four-stroke, two-stroke, and opposed-piston engine? (Diesel Duck, Camosun College Sample)

- Wharton p. 123, Taylor p. 37
- Cylinder head relief valves are fitted to release excess gas pressure from the cylinders in order to protect the liner, pistons, rings and other engine parts that may be distorted due to excess pressure.
- The pressure at which a cylinder relief valve should be opened is from 10 to 20% above engine designed pressure.
- The gas is expelled through the valve to a safe outlet.
- The valve is stainless steel with a miter seat and is loaded by a compressed helical spring.
- The lower end of the spindle is radiused to allow a valve to align with the seat.
- Valve lift is limited by the shoulder at the top of the spindle.
- The spring keep or cap nut (packing piece) is locked in position to regulate the correct spring tension.
- Maintenance consists of cleaning and inspection at the same intervals as cylinder overhaul.
- The valve and seat should be examined and reground if necessary.
- The spring should be checked for free length and warping.
- After assembly the valve should be set and pressure tested.
- Lifting of a safety valve relieves a dangerous situation and warns of incorrect conditions.
- The reasons for must be ascertained and corrective action taken.
- The high temp gas and flame expelled may damage the seat.
- Valves may lift due to:
  - Violent ignition due to poor timing

    - Leaking fuel injector
    - Fuel pump set wrong
    - Overload
- Safety valve area is only designed to relieve excess gas pressure and may be insufficient to prevent damage in the event of cooling water or oil leaks into cylinder.
- Before starting, an engine should be turned over to expel any leakage through an open indicator cock.

19. Name all the valves and fittings on a four-stroke and a two-stroke diesel cylinder head. Explain their purpose. (Diesel Duck, Camosun College Sample)

- Wharton p. 53
- The cylinder head forms the top part of the combustion space and it must be of sufficient strength to withstand gas load at maximum pressure.
- The head lands on the top of the liner flange and is secured to the block by a number of cover studs and nuts.
- These are tightened hydraulically to maintain a gas-tight seal under the arduous fluctuating pressure and temperature conditions.
- On a 4-stroke head:
    - Fuel injector
    - Air start valve
    - Relief valve
    - Indicator cock
    - Intake valve
    - Exhaust valve
- On a 2-stroke head:
    - Fuel injector
    - Air start valve
    - Relief valve
    - Indicator cock
    - Possibly an exhaust valve

20. What defects are 4-stroke cylinder heads subject to and how would you carry out an inspection to find these defects? What causes cracks and where are they usually found? (Diesel Duck)

- Cylinder heads are normally cooled by jacket water and made of cast steel or cast pearlitic iron.
- Material should transfer heat readily, resist bending, be symmetrical in shape and have a coefficient of thermal expansion similar to the liner.
- Deep sections are used to prevent bending under peak pressures of combustion.
- Deep section also allows intake and exhaust passages to pass through head.
- If this water flow was lost or reduced or rose in temperature, this could cause overheating of the heads.
- Overheating could cause cracking due to thermal stress.
- Overloading could also cause cracking due to excess pressure from cylinder. Relief valve should prevent this but may be caused by hydraulic shock due to leaking oil, fuel or water.

Valves

21. Explain how the air intake and the exhaust valves are operated on a four-stroke engine. What effect do they have on the running of the engine? How is the cam shaft driven? How may the timing of the valves be changed? Explain the act of advancing or retarding the cams on the cam shaft. Why would this become necessary? (Pacific Region Sample, Camosun College Sample)

- Reed's Deck p. 66
- The intake, exhaust and in some cases starting air valves are operated by rocking levers pivoted about their centre that are actuated by cams on the camshaft.
- Inlet valves should have an area equivalent to that of exhaust valves.
- Passage of cool intake air will maintain them at moderate temperatures so they will not the same material as exhaust valves and the associate seats.
- Push rods may act as the distance pieces between cams and rocking levers.
- The camshaft is driven by gears or chain or by the crankshaft.
- An overhead camshaft is driven by gears or chain and actuates valves directly without push rods.
- Each cam has a peak that when it comes around to contact the roller on the end of the rocking lever, pushes this end up, and the other end is depressed to open the valve against a spring in the valve housing.
- The cams are set in the correct position relative to the crank so that the valves open and close at the exact moment and for the required period in the working cycle.

- As the timing of opening and closing of the valves is relative to the crank position and direction of movement, separate cams fixed at different relative positions are required to actuate the rocking levers to run the engine in the reverse direction.
- The working cycle constitutes 4 strokes of the piston, which is 2 revolutions of the crankshaft. During one cycle, each valve is opened only once; hence the camshaft is driven at half the speed of the crankshaft.

22. Sketch and describe an exhaust valve for a diesel engine. Describe the following and state the materials and treatment: valve guide, spring, and seat. How is the exhaust valve cooled? Rotated? (2006, 2008 Exam, Camosun College Sample)

- Reed's MEK p. 168, Wharton p. 40
- One or more exhaust valves are fitted to each cylinder head.
- Valve is normally of the poppet type with lid and spindle of inverted mushroom shape, arranged to open inwards in order to maintain positive closing under pressure in the cylinder and ensure non-return action.
- Gas pressure will act on the bottom of the valve to supplement the closing action of the springs.
- Positive action of valve and seat removes carbon and other deposits, which if allowed to build up, causes blow by of hot gases and burning of valves and seats.
- Shape of valve lid protects seat from flame and hot gases of combustion.
- Rotation of the cam peak raises a follower and pushrod to operate a pivoted rocker lever, the other end of which depresses the valve spindle through a tappet and causes it to open.
- The valve spring will force the valve to close when the peak has passed the follower.
- Valves may be separately caged to facilitate removal and repair without removal of head.
- All connections to valves should be readily able to be disassembled for repair.
- Materials have to be able to hold up at high operating temperatures and be able to withstand the corrosive effects of exhaust gas and deposits.
- Valve will be heat resistant alloy steel, possibly protected with a coating of Inconel or Nimonic (high nickel).
- Stellited valve seats are common which is a mixture of cobalt, chromium and tungsten, which gives and extremely hard and corrosion resistant that is fused onto the operating surfaces.
- Exhaust valves are cooled by having the valve cage and seat circulated by fresh water. Cages and components must be of made of good heat transfer materials and able to transfer heat to the cylinder head.
- Tappet clearance is essential to allow for thermal expansion of spindle at working temperatures.
- Effective lubrication of spindle is necessary to avoid risk of seizure and damage due to a valve hanging up.
- Shrouds are fitted to the bottom end of the exhaust valve guides and are then welded in place.
- The fitting of shrouds tends to prevent scale, unburned fuel, lube oil, or carbon from collecting on the valve stem between the stem and guide.
- By this means, turbulence of inlet air is increased and sticky valves are lessened.
- A Rotocap will be used to rotate the exhaust valve to prevent uneven wear or cooling and reduce deposits.
- This device causes rotation of the valve spindle during valve opening.
- The increase in spring force on the valve as it opens flattens the Belleville washer so that it no longer bears on the bearing housing.
- This removes the frictional holding force between the surfaces and causes the balls to move down the ramps in the retainer.
- This imparts a rotational torque on the spindle causing it to spin slightly.
- As the valve closes, the load from the Belleville washer is removed from the balls and they return to original position.
- Alternatively, angled guide vanes may be fitted to cause the exhaust gas to turn the valve as it passes through when open.

23. What are the causes, indications and effects of leaky exhaust valves? What is done to repair a faulty exhaust valve? Sometimes a burnt exhaust valve is not discovered until an attempt is made to restart the engine. If an engine works with a faulty valve, why should it fail to restart?

- Wharton p. 125
- The cylinder with the leaky valve will lose its compression causing incomplete combustion and loss of power.
- Will cause:
    - Overloading of the other cylinders.
    - Cylinders will carbon up and rings will become gummy and stick.
    - An air blow through the valve may cause a muffled explosion if any unburned gases are present.
    - Further damage to exhaust valve and seat
    - Fouled exhaust spaces will cause loss of flow and efficiency
    - Surging of turbo charger
    - Uptake fires or explosions
- Cause of exhaust valve failure are:
    - Incorrect combustion leading to deposits on the working surfaces and burning of metal

- Ash deposits from residual fuel can stop the valve from reseating. This can cause high temperature corrosion.
- Incorrect valve timing.
- Incorrect valve cooling.

- Some methods to help increase exhaust valve life are:
  - Use of corrosion resistant hard metals for valve and seat. Generally in the form of a fused on insert.
  - False seats. These are not fused on and help avoid radial cracking due to thermal stresses.
  - Reducing valve temperature. Done by forced cooling around valve or increasing scavenge period.
  - Rotating the valves on their seats by means of rotocaps. They employ the oscillating motion of the rocker arm converting it into intermittent rotary motion. This makes the settling of deposits between valve and seat difficult.
- Valve should be replaced as soon as possible and fuel should be shut off to that cylinder.
- Valves should be maintained regularly by overhauling them and checking tappet clearances.
- A working engine builds up heat that can compensate for a lack of compression due to a burnt valve and this may not be noticed right away.
- When starting, the engine is colder and requires better compression to start firing.
- It may not be able to build up the required heat to start.

24. Describe how you would adjust the clearance between the valves and the rocker arms of a four-stroke multi-cylinder diesel engine. Why is clearance necessary and what amount is usually given? (TCMS Sample, Camosun College Sample)

- Wharton p. 41
- Tappet clearance is essential to allow for thermal expansion of spindle at working temperatures and to ensure that positive closing of the valve continues as it wears or seats during use.
- Clearances would normally be set while the engine is cold and the cam follower is off its peak. This is when there is clearance between valve and tappet.
- Wear in parts of the valve operating gear will tend to increase clearances.
- Excessive tappet clearance will cause the valve to open late and close early and reduce maximum lift. This will cause noise and damage from the impact of working surfaces.
- Insufficient clearance will cause the valve to open early and close late with increased maximum lift.
- In extreme cases, it may prevent the valve from closing completely as it expands or beds in.
- This will cause hot gases to blow by valve faces causing valve burning and low compression.
- The manufacturer's service manual must be referred to for this procedure.
- The manual will state which timing mark should be lined up on the flywheel to correspond to setting each valve.
- Normally several can be done at each position.
- The turning gear will have to be utilized to turn the engine to each position.
- The crank rotates twice for each revolution of the camshaft so this must be taken into effect when lining up marks.
- The manual will state the required clearance for the intake and exhaust valves. These may be different due to higher temperatures associated with the exhaust valve.
- The clearance spec will get larger with an increase in engine size.
- A feeler gauge of that clearance is placed in between the tappet and valve and a slight drag should be felt as the gauge is pulled through.
- If it is too tight or too loose, the tappet can be move up or down by loosening its locknut and using another wrench or flat screwdriver to make the adjustment.
- The nut should then be tightened again and tested to ensure it did not change during tightening.
- The engine should be rolled over completely (twice for 4-stroke) to ensure the valve mechanisms are not jammed.

Bearings:

25. Describe a main bearing for a diesel engine. What materials are used? How is the bearing adjusted? How would you check to see that the piston clearance had not been altered? (Camosun College Sample)

- Wharton p. 72
- Main bearings are required to support the crankshaft at each journal.
- They support the weight of all working parts and are also subjected to heavy loads, fluctuating in magnitude and directions.
- They must be secure, accurately bored and aligned to prevent bending in the shaft.
- Each bearing is loaded by its adjacent units and wear rates may not be equal.
- This must be checked and recorded regularly.
- Weardown can be measured by bridge gauge and by crank deflections.
- Large crosshead type engines:

- Use thick shelled white metal bearings, each supported in a transverse girder of the bedplate, giving it rigidity to support the high vertical and transverse loads.
- The top half of each bearing is secured either by studs or bolts to the bedplate, or by jack bolts that transmit downward force from the engine frames.

- Trunk type engines:
  - The bearing materials used in medium speed bearings are thin walled materials like:
    i. Lead bronze
    ii. Copper lead
    iii. White metal
    iv. Aluminum
    v. Tin alloys
    vi. All are steel backed.
  - Main bearings are under slung from the main block with bolts or studs securing the lower half.
  - Horizontal bolts are fitted to add transverse rigidity.

26. The bearings of a crankshaft have been re-installed. Describe in the proper sequence how you would proceed to refit the crankshaft so that it would be in true alignment vertically and longitudinally. (Diesel Duck, Camosun College Sample)
27. What would cause the white metal to crack in a bottom end bearing? Describe how you would fit a bottom end bearing, giving clearances. (Diesel Duck)

Two Stroke:

28. Describe the advantages and disadvantages of a 2-stroke engine over a 4-stroke engine. (Diesel Duck)

- Taylor p. 14
- The main difference between the two cycles is the power developed.
- The two stroke engine, with one working power stroke each revolution will theoretically develop twice the power of a four stroke engine of the same swept volume.
- Inefficient scavenging and other losses, however, reduce the power advantage to about 1.8.
- Advantages:
  - Less weight and space per horsepower
  - Greater horsepower per cylinder
  - More uniform turning effect
  - Less complicated cylinder head
  - Better tolerates lower quality fuel
- Disadvantages:
  - Less volumetric efficiency
  - Greater fuel consumption
  - Scavenging system required
  - Trouble with liners due to ports
  - Worse at high speeds
  - More lube oil consumption

29. Describe a two-stroke diesel engine, naming the parts and the materials from which it is made and describe how the cylinder and base are secured to make them rigid.

- Taylor p. 14
- The piston is solidly connected to a piston rod that is attached to a crosshead bearing at the other end.
- The top end of the connecting rod is also joined to the crosshead bearing. Port are arranged in the cylinder liner for air intake and a valve in the cylinder head enables the release of exhaust gases.
- The incoming air is pressurized by a turbo-blower that is driven by outgoing exhaust gases.
- The crankshaft is supported within the engine bedplate by the main bearings.
- A-frames are mounted on the bedplate and house guides in which the crosshead travels up and down.
- The entablature is mounted above the frames and is made up of the cylinders, heads and scavenge trunking.

30. Describe a diesel engine of the opposed piston type. Describe the cycle of an opposed- piston engine. What are the advantages of this type of engine? How is it scavenged? (Diesel Duck, Pacific Region Sample, Camosun College Sample)
31. Sketch and describe a crosshead, opposed piston engine. How is the upper piston connected? (2010, 2011 Exam)

- Wharton p. 9
- Practically all large, slow speed direct drive marine diesel engines operate on the two stroke principle.
- Fitting two pistons per cylinder will add power to the engine without increasing its length.
- Two pistons moving in opposite direction give good primary balance.

32. Describe the complete cycle of a two-cycle engine, naming the various pressures and temperatures during the cycle. Give the degrees for opening and closing of fuel valves. (Diesel Duck, Camosun College Sample)

- Reed's p. 67
- The two stroke diesel engine is so named because it takes two strokes of the piston to complete one working cycle.
- Every downward stroke of the piston is a power stroke, every upward stroke is a compression stroke,
- The exhaust of the burned gases from the cylinder and the fresh charge of air is taken in during the late period of the downward stroke and the early part of the upward stroke.
- In the basic 2 stroke engine, the exhaust gases pass through a set of ports in the lower part of the cylinder and the air is admitted through a similar set of ports.
- The ports are covered and uncovered by the piston itself, which must be a long one or have a skirt attached so that the ports are covered when the piston is at the top of its stroke.
- As there is no complete stroke to draw air into the cylinder, the air must be pumped in at a low pressure from a scavenge pump.
- It is the function of this air to scavenge or clean out the cylinder by pushing the remains of the exhaust gases out, leaving a clean charge of air to be compressed.
- Normally there is no intake or exhaust valve in the head so it is a much simpler design than a 4 stroke.
- There may however be an exhaust valve for uniflow scavenging.
- The crank is driven at the same speed as the cam.
- First stroke – piston moving up, exhaust and scavenge ports covered by the piston and the fuel valve is shut. Air previously taken into the cylinder is being compressed to about 35 bar and 540C.
- The fuel is injected into the cylinder as the piston nears TDC. Fuel is in form of fine spray and readily mixes with hot air so that it burns and gives out heat.
- Fuel is injected at such a rate that there is a slight rise in pressure.
- Second stroke – piston is moving down. Fuel valve closes about 10% down the stroke. The hot gases contain sufficient energy to continue to do work on the piston and push it down towards the end of the stroke. The gas pressure falls with the expansion.
- As the piston moves down, it uncovers the exhaust ports and the first rush of exhaust out of the cylinder starts and pressure falls to zero.
- The piston moves farther down to uncover the scavenge ports and the scavenge air under pressure sweeps into the cylinder. The burnt gases are then being expelled through the exhaust ports.
- When the piston passes BDC, the piston moves up and covers the scavenge and exhaust ports and the cycle starts again.
- Fuel valve open from 10° before TDC and closes around 30° after TDC.

33. Describe a scavenge air pump. What care and maintenance does it require? What type of engine would require this system and how is it driven? What pressure would it deliver? Why are scavenge air pumps used? (Diesel Duck, Camosun College Sample)

- A reciprocating scavenge pump may be driven direct by an additional crank on the engine crankshaft, adding a cylinder to the engine. Or it may be operated by links attached to a crosshead of the engine.

34. Describe the different methods of scavenging. What can affect the path of the scavenge air entering the cylinder? (2011 Exam)
35. How is the low-pressure air necessary for scavenging the cylinders of a two-stroke diesel engine obtained? Describe the different methods of scavenging systems. Explain what can cause fires or explosions in these systems and how they can be extinguished. (TCMS Sample, 2010 Exam)

- Wharton p. 30, Taylor p. 19
- 2 stroke engines need a pump to supply air through scavenging trunk from some outside source to expel the burnt gases and supply fresh air to the cylinder.
- The passage of scavenge air will also cool the cylinder, piston and valves.
- This process takes place when the scavenge and exhaust connections are open and the piston is near BDC.
- Fresh air enters as the inlet port is opened by the downward movement of the piston and continues until the port is closed by the upward moving piston.
- Turbochargers with coolers are the preferred method on modern diesels.
- Blowers, pumps and under piston scavenging all add to maintenance and absorb some of the power of engine.
- Air is admitted through slotted ports in the liner and through valves in the head:
    - Uniflow – uses ports and valves in cylinder head.
        i. Gives the highest scavenge of efficiency – sued on most modern diesels.
        ii. Also helps heat transfer in cylinder.
        iii. Absence of exhaust ports allows cylinder liner to be of simpler construction.
        iv. Long piston skirts are not necessary
        v. Cylinder lubrication is satisfactory and economical.
    - Loop – use ports only on same sides of cylinder

    i. Cause temperature differential problems due to proximity of ports to each other
  - Cross – uses ports on opposite sides of cylinder
    i. Requires fitting of piston skirt to prevent air or exhaust from escaping when near TDC
- Scavenge swirl and turbulence is built up by angled ports and the shape of the piston crown.
- Air is scavenged by either a piston, pump, blower or from the crankcase by under piston scavenging.
- Scavenging pressure varies from 1.5-7 psi, 1.5 psi without supercharging and 3-5 psi with supercharging.
- The air is delivered by the pump unit at about 1.17 bar into feeder trunking which feeds each engine cylinder through its scavenge ports in turn with the necessary air for scavenging and recharging at the correct time in the cycle.
- Rotary scavenge pumps (blowers) are chain or gear driven from the engine crankshaft.
- These have the advantages of steady air delivery and compactness since their rotational speeds are high and constant during normal operation.
- They also have the disadvantage in reversible engines of requiring a changeover valve since their direction of rotation is geared to that of the engine.
- Another method of scavenging is by turbo charger. The turbine uses energy from the engine exhaust gases and drives an air compressor that supplies air for scavenging and supercharging.
- Exhaust gases from the engine enter the single stage gas turbine through the water cooled cast iron inlet casing, expand in the nozzles thereby gaining in velocity and pass through the turbine blades to drive the rotor.
- The exhaust gases leave the turbine through the water cooled outlet casing and flow to the atmosphere.
- Combustion air enters the centrifugal air compressor through a silencer filter. The air is compressed and delivered from the compressor to an air cooler then on to the cylinders.
- In some engines, a scavenge pump unit is formed by sealing the under piston space from the crankcase and fitting appropriate valves.
- This unit is usually in series with a turbocharger as a booster unit when starting and with low loads when insufficient air can be delivered by the turbo.
- Sometimes, electrically driven blowers are fitted for starting and slow running of the engine then under full power the turbocharger takes over and the blowers automatically shut off.
- Accumulation of dirt and oil can occur in the scavenge spaces of an engine due to:
  - Excessive cylinder lubrication
  - Slack, worn or broken piston rings – low compression
  - Uneven cylinder liner wear
  - Damaged air inlet filters
  - Cracked oil-cooled pistons
  - Defective injector
  - Faulty fuel pump or incorrect timing
  - Lack of scavenge air
  - Partially choked exhaust
  - Overloading
- If flames from combustion in the cylinder can blow past the piston into the scavenge trunking, this accumulation of oil and dirt can be ignited, thus resulting in a scavenge fire.
- Indications of a scavenge fire are:
  - Loss of engine power
  - Excessive black smoke
  - High exhaust temperature
  - Paint blistering and peeling from trunking
  - Turbo chargers will surge
  - Sparks will be seen at the scavenge drains
- Normally, this would be local to one cylinder so fuel should be shut off to that cylinder if possible. This would reduce the temperature.
- Cylinder lubrication should be increased to minimize risk of seizure and the engine should be slowed down to reduce air supply to fire.
- Scavenge drains should be closed.
- External surfaces in the vicinity of the fire should be cooled and any combustible material in the area removed.
- If the engine is stopped too quickly, overheated parts may distort and become seized. The fire may spread.
- The fire will burn itself out but may require eventual stoppage and fought with CO2 gas.
- If the scavenge trunking is opened too early, this may allow an ingress of air, which may cause an explosion.
- If the engine is stopped, starting air should not be applied for restarting until the fire is extinguished.

- After a scavenge fire, the liner, piston and other close engine parts should all cleaned and inspected. Damage parts must be replaced.
- Scavenge drains must be opened regularly and passage of oil from them should be noted.
- Trunking should be cleaned regularly.
- Pressure relief valves are fitted and should be inspected and checked regularly.
- Heat sensors will alarm at roughly 200C.

Four Stroke:

36. Describe in detail the construction of a four-stroke diesel engine. How is the cylinder head fastened on? List the materials of each part. How are the cylinders secured to the engine bedplate?

- Taylor p. 13
- A four-stroke engine is made up of a piston that moves up and down in a cylinder, which is covered at the top by a cylinder head.
- The fuel injector, through which fuel enters the cylinder, is located in the head.
- The inlet and exhaust valves are also housed in the head and held shut by springs.
- The piston is joined to the connecting rod by a wrist or gudgeon pin.
- The bottom end or big end of the connecting rod is joined to the crankpin, which form part of the crankshaft.
- With this assembly, the linear up and down movement of the piston is converted into rotary movement of the crankshaft.
- The crankshaft is arranged to drive the camshaft through gears, which either directly or through pushrods, operates rocker arms that open and close the intake and exhaust valves.
- The camshaft is timed to open the valves at the correct point in he cycle.
- The crankshaft is surrounded by the crankcase and the engine framework, which supports the cylinders and houses the crank bearings.
- The cylinder and heads are arranged with water cooling passages around them.
- The cylinder head is fastened to the block by high strength bolts that are torqued on.
- The liners are pressed in by the heads.
- The block is secured to the bedplate with tie-down bolts.

37. Describe a cycle of operation of a four-stroke engine in detail. Mention what happens during the cycle and state the temperatures and pressures at the different stages. At what stage does the fuel valve open and close? (Diesel Duck, Camosun College Sample)

- Reed's Deck p. 65
- A four stroke engine takes four strokes of the piston and two revolutions of the crankshaft to complete one working cycle of operations.
- First stroke is the intake stroke. The piston is moving down, the air intake valve is open and air is being drawn into the cylinder from the atmosphere by the suction effect of the piston.
- At about the end of this stroke the cylinder is full of air and the air induction valve closes.
- Second stroke is compression stroke. The piston is moving up, no valves are open and the air in the cylinder is being compressed.
- When air is compressed, the temperature rises and the reason for compressing air in a diesel is to obtain a sufficiently high temperature to cause the oil to ignite and burn rapidly when it is injected into the cylinder at the end of this stroke.
- The pressure of the air at the end of compression is in the region of 35 bar to obtain a temperature of about 540C.
- The third stroke is the power stroke.
- The piston is moving down and the fuel is injected into the cylinder in the form of a fine spray through the fuel valve.
- The fuel mixes with hot air and burns rapidly; valve remains open for about 10% of downward stroke.
- As the oil burns, it heats the air, which causes it to rise in pressure or increase in volume. In the ideal cycle, the admission of oil is controlled so that the pressure of the gases remains constant while the piston is moving down. In actual practice, pressure does rise a little during combustion.
- When the fuel is shut off, the gases continue to push the piston forward and the pressure consequently falls toward the end of the stroke.
- At the end of this stroke, when the pressure has fallen to be of little use, the temperature is about 1650C and the exhaust valve opens.
- The fourth stroke is the exhaust stroke. The piston is again moving up, the exhaust valve is open and the gases are being expelled from the cylinder.
- At the end of the stroke, the exhaust valve closes and the air induction valve opens to begin the cycle of operations again. There is a certain amount of overlapping with regard to the closing of the exhaust valve and the opening of the intake to help scavenge the cylinder.
- Scavenging takes place during the period of about 10° before TDC to about 15° after TDC when the piston is completing exhaust stroke in a 4 stroke engine.

Crankshaft:

38. What are deflections in a crankshaft? How are crankshaft deflections measured? What causes a crankshaft to deflect and what could result from excessive crankshaft deflections in an engine? (2006 Exam, Camosun College Sample)

- Reed's MEK p. 36, Wharton p. 73
- Misalignment of an engine crankshaft can occur due to:
    - Wear of main bearings
    - Distortion of the engine bedplate
    - Damage to ship's structure.
- Crankshaft alignment can be checked by taking deflections. They should be taken regularly to observe condition of main bearings or after the ship or propulsion system has sustained damage.
- Excessive misalignment will cause bending of the crankshaft and webs with fluctuating and alternating stresses, causing fatigue and possibility of shaft failure.
- It will set up vibration and cause damage to main bearings.
- If a crank throw supported on two main bearings is considered, the vertical deflection of the throw in mid span is dependent upon:
    - Shaft diameter
    - Distance between main bearings
    - Type of main bearing
    - Central load due to the running gear
- A dial gauge arranged horizontally between the crank webs opposite the crank pin and ideally at the outer circumference of the main journal, will give a horizontal defection when the crank is rotated through one revolution.
- If the bearings are in alignment, gauge deflection will be zero.
- If the webs close in on each other during rotation, this is referred to as negative deflection.
- If the webs spread from each other during rotation, this is referred to as positive deflection.
- Gauge must be set up in the same location of webs each time, otherwise, results will be random.
- Due to the placement of the connecting rod, it is generally not possible to place the gauge opposite to the crank pin at BDC. An average of two readings from either side of the crank is taken to accommodate this.
- Gauge readings would be taken:
    - Port side near bottom position (x)
    - Port horizontal (p)
    - Top centre (t)
    - Starboard horizontal (s)
    - Starboard side near bottom (y)
    - Bottom (b) would equal (x + y)/2
- Before taking each reading, the turning gear should be reversed to unload the gear teeth, otherwise, readings may be inaccurate.
- The vertical misalignment will be proportional to misalignment between the bearings due to wear down.
- The horizontal total indicates side wear in bearings.
- Spherical bearings have more allowance for deflection than flat bearings. Some opposed piston engine use these.
- The vertical and horizontal misalignment can be checked against the permissible values given by the engine builder.
- If any values exceed maximum permissible values, bearings will have to be adjusted or renewed.
- Feeler gauges should be used to ascertain that the crankshaft has not sprung or lifted in adjacent main bearings.

39. Describe the construction of a crankshaft as used in a large diesel engine. State dimensions. What material is it made of? Why is it necessary to fit a flywheel? (Camosun College Sample)

- Reed's MEK p. 29, Wharton p. 70
- A crankshaft is the backbone of the reciprocating diesel engine.
- It consists of a number of cranks or throws, which are rotated by piston forces transmitted by connecting rods and bottom end bearings.
- In-line engines have one crank for each cylinder.
- Each crank is made up of two crank webs joined by a common crankpin to which the bottom end bearing is fitted.
- It must be extremely reliable as replacing it would be timely and expensive.
- Crankshafts for diesels are usually made of open hearth steel although sometimes alloy steel is used.
- Properties for material:
    1. High strength
    2. Long fatigue life
    3. Form good bearing surfaces
- They are made in 3 different ways:

1. Unit - Forged from one single billet, small engines, high speed engines
2. Semi-unit or semi built-up – Made in several sections, larger engines, medium speed
3. Fully built-up – Each journal and web made separately, then later shrunk together, larger engines

- Counterweights are applied to the webs to absorb some of the energy of the power stroke and to give it again in the compression stroke. Helps to give the engine an even turning motion.
- Cast steel:
  1. Carbon: .2%
  2. Silicon: .32%
  3. Manganese: .7%
  4. Phosphorous: .01%
  5. Sulphur: .015%
  6. Iron: remainder
- Process:
  1. Raw material
  2. Raw material refined to remove bulk of impurities
  3. Metal is degassed in a vacuum furnace to remove hydrogen and nitrogen, etc.
  4. Molten metal poured into prepared mould.
  5. After removal from mould, casting is rough machined to remove surface and subsurface defects
  6. Casting normalized to improve grain structure
  7. Stresses removed by tempering
  8. Casting is rough machined to final dimensions
  9. Crank pin is cold rolled. Bending fatigue resistance is increased, small defects are reduced and corrosion fatigue resistance is increased.
  10. Finish machining
  11. Web crank units are shrunk onto journals.
- Oil holes in crankshafts must be rounded to an even contour with smooth finish.
- Material tested to determine strength, fatigue resistance, etc.
- Crankpin and journal diameters have increased to support high piston loads but length is kept short to minimize bending.
- Flywheels are fitted to the non drive end to increase the inertia of the engine to dampen out fluctuations and maintain constant speed.
- Due to individual cylinders firing, there is non-uniform torque on the crankshaft and this effect is lessened by a flywheel.

40. Explain how the wear down of the crankshaft of a large diesel engine is measured. What could happen if the wear down was excessive and how could this be corrected? (Camosun College Sample)

- Wear down is measured by comparing the outside diameter of the crankshaft bearing surfaces with the inside diameter of the bearings.
- This can be done using plastic gauging material that can be measured after the bearings is torqued on and then split.
- This can also be done with a bridge gauge and by crankshaft deflections.
- If wear down was excessive, this would cause the shaft to whip around and will lower compression due to the fact that the top clearance may be increased.
- The gear teeth at the end of the crank will also become misaligned and may break.
- Loud knocking would take place and white metal material may get hammered out of the bearing.

41. Explain how the alignment of a crankshaft with the cylinder is checked. (Camosun College Sample)
42. Describe a method of checking the alignment of the crankshaft in relation to the thrust shaft. How would you remedy the situation if the shafts were not aligned? (Camosun College Sample)

Flywheel:

43. Describe a flywheel fitted to a diesel engine. What are the components made of? Why are they fitted to diesel engines? Why are dampeners fitted? (2008 Exam)

- Wharton p. 73
- High speed engines or those with few cylinders are often fitted with flywheels.
- They are solid and wheel shaped to have high mass and inertia to store energy while the engine is running.
- This energy is proportional to the engine speed squared.
- If engine speed falls, kinetic energy in the flywheel will also fall, and some is returned to the crankshaft.
- In this way, the flywheel absorbs energy during peak torque and acceleration of the shaft and returns it during low torque and deceleration, smoothing out fluctuations in engine speed.
- Inertia builds with higher speeds so flywheel has negligible effect at slow speeds.
- The wheel is fitted to the end of the crankshaft and commonly used to engage turning gear.

- It is also convenient for marking crank angles and TDC positions for valve timing and injection timing.
- It is normally made of cast steel and bolted to the end of the crankshaft,
- Vibration dampeners are fitted to the opposite end of the flywheel to perform the same function of balancing the rotary motion of the crankshaft.
- Sometimes they are used to drive belts or chains to run pumps.

Ventilation:

44. Why is ventilation necessary in motor ships and steam ships? Why is it dangerous not to have proper ventilation? Describe a ventilation system. How is closing of a ventilation system done to prevent air entering an engine row in case of fire?

Gasoline Engines:

45. What two types of ignition systems are used on gasoline engines? List some of the common defects found with these systems and explain the function of a distributor in a multi-cylinder engine. (TCMS Sample, Diesel Duck, Camosun College Sample)

- The purpose of an ignition system in a gas engine is to:
    - To provide a consistent, strong spark to the spark plug
    - To provide the spark at the time it is needed for combustion – near the end of the compression stroke
- Two types:
    - Magneto
    - Mechanically timed
- One method of creating a spark is the use of a magneto (or permanent magnet) built into the flywheel.
    - A primary circuit contains points that open and close to allow low-voltage spark crated by magneto on flywheel to go through transformer winding.
    - A condenser is used to prevent electricity from arcing across points as they open.
    - A secondary circuit is charged by primary circuit to increase voltage across a step-up transformer to create a spark at tip of spark plug.
    - The points have a clearance that can be adjusted with feeler gauges to adjust gap at its maximum opening.
    - A lobe on the camshaft operates the points.
    - The magnet passes by the transformer, and as the pole orientation switches, a magnetic field is built up, passing through the secondary coil.
    - When the breaker points snap open, the current in the primary coil stops and its magnetic field suddenly collapses.
    - This rapid decrease in the magnetic field causes a great voltage in the secondary coil, and a spark jumps across the spark plug gap.
- Mechanically timed ignition
    - Magneto systems were abandoned for systems that interrupted current at battery voltage, used an ignition coil (a type of autotransformer) to step the voltage up to the needs of the ignition, and a distributor to route the ensuing pulse to the correct spark plug at the correct time.
    - A distributor-based system is not greatly different from a magneto system except that more separate elements are involved. There are also advantages to this arrangement. For example, the position of the contact breaker points relative to the engine angle can be changed a small amount dynamically, allowing the ignition timing to be automatically advanced with increasing revolutions per minute (RPM), giving better efficiency and performance.
    - The heart of the system is the distributor. The distributor contains a rotating cam driven by the engine's drive, a set of breaker points, a condenser, a rotor and a distributor cap. External to the distributor is the ignition coil, the spark plugs and wires linking the distributor to the spark plugs and ignition coil.
    - The points allow the coil to charge magnetically and then, when they are opened by a cam arrangement, the magnetic field collapses and a large (20 kV or greater) voltage is produced. The capacitor is used to absorb the back EMF from the magnetic field in the coil to minimize point contact burning and maximize point life.
    - The ignition coil consists of two transformer windings sharing a common magnetic core—the primary and secondary windings. An alternating current in the primary induces alternating magnetic field in the coil's core. Because the ignition coil's secondary has far more windings than the primary, the coil is a step-up transformer, which induces a much higher voltage across the secondary windings. For an ignition coil, one end of windings of both the primary and secondary are connected together. This common point is connected to the battery (usually through a current-limiting ballast resistor). The other end of the primary is connected to the points within the distributor. The other end of the secondary is connected, via the distributor cap and rotor, to the spark plugs.
    - The ignition firing sequence begins with the points (or contact breaker) closed. A steady charge flows from the battery, through the current-limiting resistor, through the coil primary, across the closed breaker points and finally back to the battery. This steady current produces a magnetic field within the coil's core. This magnetic field forms the energy reservoir that will be used to drive the ignition spark.

- As the engine turns, so does the cam inside the distributor. The points ride on the cam so that as the engine turns and reaches the top of the engine's compression cycle, a high point in the cam causes the breaker points to open. This breaks the primary winding's circuit and abruptly stops the current through the breaker points. Without the steady current through the points, the magnetic field generated in the coil immediately and rapidly collapses. This change in the magnetic field induces a high voltage in the coil's secondary windings.
- The ignition coil's secondary windings are connected to the distributor cap. A turning rotor, located on top of the breaker cam within the distributor cap, sequentially connects the coil's secondary windings to one of the several wires leading to each cylinder's spark plug. The extremely high voltage from the coil's secondary -– often higher than 1000 volts—causes a spark to form across the gap of the spark plug. This, in turn, ignites the compressed air-fuel mixture within the engine. It is the creation of this spark which consumes the energy that was stored in the ignition coil's magnetic field.
- However it is necessary to check periodically the maximum opening gap of the breaker(s), using a feeler gauge, since this mechanical adjustment affects the "dwell" time during which the coil charges, and breakers should be re-dressed or replaced when they have become pitted by electric arcing. This system was used almost universally until the late 1970s, when electronic ignition systems started to appear.

- Problems with ignition are normally due to loss of spark. This could occur due to:
  - A sheared flywheel key
  - Incorrect ignition point gap
  - Dirty or burned ignition points
  - Coil failure
  - Incorrect armature air gap
  - Condenser failure
  - Defective spark plug wire

46. What is a carburetor? Show where it is located on a gasoline engine. What is its purpose and describe its operation. (Diesel Duck, Camosun College Sample)

- A carburetor basically consists of an open pipe through which the air passes into the inlet manifold of the engine.
- Its purpose is to mix the air and fuel to create a vapor that is readily combustible.
- The pipe is in the form of a venturi: it narrows in section and then widens again, causing the airflow to increase in speed in the narrowest part.
- Below the venturi is a butterfly valve called the throttle valve — a rotating disc that can be turned end-on to the airflow, so as to hardly restrict the flow at all, or can be rotated so that it (almost) completely blocks the flow of air.
- This valve controls the flow of air through the carburetor throat and thus the quantity of air/fuel mixture the system will deliver, thereby regulating engine power and speed.
- The throttle is connected, usually through a cable or a mechanical linkage of rods and joints or rarely by pneumatic link, to the accelerator pedal on a car or the equivalent control on other vehicles or equipment.
- Fuel is introduced into the air stream through small holes at the narrowest part of the venturi and at other places where pressure will be lowered when not running on full throttle. Fuel flow is adjusted by means of precisely-calibrated orifices, referred to as jets, in the fuel path.
- It will be attached to the air intake of an engine.

47. Why are push rods used in a gas engine, how do they operate and what allowances are made for their use?

- Pushrods are used transmit cam motion to operate valves.
- The bear on the cam lobes that rotate and lift the push rods with their high points.
- This pushes the rocker arm upwards, which pivots on a central point to push down the spring loaded valve to open it.
- The allowances made for their use is through clearances between the valve and the rocker tappet.
- This clearance is necessary to allow for thermal expansion of the moving parts due to heat formed during combustion.

48. Sketch and describe a 4-stroke petrol engine. How is this engine different from a diesel? What are the pressure and temperatures at the end of compression for each? (2006, 2010 Exams, Pacific Region Sample, Diesel Duck, Camosun College Sample)

- Reed's Deck p. 63
- Diesel:
  - In diesel engines, the air in the cylinders is compressed to a high pressure so that it attains a high temperature, the oil is injected into the high temperature air and the fuel immediately ignites.
  - The diesel may use low-grade fuel and ignite it directly by the heat of compression.
  - Diesel compression ratio is about 14:1
  - Combustion in the diesel engine takes place more nearly in the Constant Pressure cycle. All heat is taken in and rejected at constant pressure.
  - Fuel is being injected and burned constantly since it takes place at a slower pace than an explosion.

- The pressure of the air is in the region of 35 bar to obtain a temperature of about 540C.
- Gasoline:
  - Gasoline engines require high-grade fuel and ignites it by an electric spark after the gas has been mixed with air in the carburetor and then compressed.
  - Combustion in the gas engine takes place more nearly according to the Constant Volume cycle or Otto cycle.
  - All heat is taken in at constant volume and rejected in constant volume.
  - Combustion takes place practically instantaneously and is in effect an explosion.
  - Gasoline compression ratio is about 8:1 or 10:1. This prevents mixture from firing due to heat of compression alone without spark.
  - The pressure of the air is roughly 12 bar and temperature 420C.

Charge Air

49. What is supercharging? What effect does supercharging have on the pressures and temperatures of a diesel engine? What is the effect of supercharging on the power output of a diesel engine? How is supercharging air supplied to the engine and what are the precautions on a supercharged engine? (Diesel Duck, Camosun College Sample)

- Reed's Deck p. 76
- The mass of fuel that can be burned in the cylinder depends upon the mass of air present in the cylinder at the end of compression.
- Supercharging is supplying the engine with air at a pressure greater than atmospheric. In this way, air trapped in the cylinder at the beginning of the compression stroke is at a pressure slightly above atmospheric.
- Supercharging increase the mechanical efficiency because there is more horsepower produced per pound weight of the engine.
- Thermal efficiency is increased because of more complete combustion.
- The air supply pressure in supercharged engines is normally around 200 millibars above atmospheric.

Exhaust Systems

50. Describe a silencer fitted to an internal combustion engine and explain its action. What could cause an explosion in a silencer and how can this be prevented? (Camosun College Sample)

- Reed's MEK p. 184
- Silencers are used to muffle energy pulsations and sound waves from the engine exhaust by changing its direction repeatedly.
- An explosion in a silencer can be prevented by the use of a spark arrestor.
- Exhaust gases rising in the stack meet the outside of an inverted cone mounted in or near the muffler. Rising to its top, the gases are redirected downward inside the cone after having been given a whirling rotary motion by curved blading in the cone crown.
- The gases whirling downwards to the apex will deposit any heavy particles of carbon in the bottom of the cone.
- The lighter gases will rise again and ascend to the atmosphere through a pipe extended into the top or wide part of the inverted cone.
- 3 other types:
  - A tank type silencer has a reservoir about 30 times engine cylinder volume.
    i. Baffles are arranged to give about 4 gas reversals.
  - A diffuser type has a central perforated discharge pipe surrounded by a number of chambers of varying volume.
  - The orifice type has a series of holes in horizontal baffles and the energy is dissipated by repeated throttling and expansion.
- A soot box on the bottom of the silencer allows particles to gather and be cleaned out regularly.

51. Describe an instrument for measuring exhaust temperature in a diesel engine. What would the exhaust temperatures of two stroke and four stroke engines be? (Diesel Duck)

- A pyrometer is a millivolt meter calibrated in temperature units that is attached through a selector switch to each individual cylinder exhaust thermocouple.
- The thermocouple is made of 2 rods of different metals that are welded at one end.
- When heated at the welded junction, and EMF is produced between the terminals.
- The temperature reading on a pyrometer is usually a direct interpretation of the amount of power being developed in a cylinder.
- A high pyrometer reading means possibility of overload while a low reading means that particular cylinder is not carrying its required load.

Clutches / Couplings

52. Name 4 types of clutches and describe one clutch suitable for an internal combustion engine. (Camosun College Sample)

- A clutch is a device to connect or separate a driving unit from the unit it drives.
- Four types of clutches are:
  - Dog or positive clutch
  - Disc or cone clutch
  - Air flex clutch
  - Fluid drive
- Description of air flex clutch:

- The clutch consists of a ring shaped cord reinforced rubber gland of special shape.
- It contains a cavity that serves as a compressed air reservoir.
- The walls of the gland are flexible and the admission of air to the cavity results in the expansion of the gland with consequent engagement of the friction surfaces.
- Two types are available:
    i. Constricting type – more popular
    ii. Expanding type
- When the gland is inflated, the pressure between the friction surfaces is maintained at a high value.
- The air volume and pressure requirements are low. Max pressure of 125 psi and volume is only that to fill gland.
- The rubber gland is vulcanized to the support ring and is provided with integral lugs to allow for the fitting of drive pins to attach to the friction pads.
- The friction liner blocks are riveted to aluminum shoes that have axial air passages for ventilation.
- The cooling affect of theses passages easily dissipates the heat generated during clutching in or power reversals.
- The rubber gland is also provided with integral driving keys that fit into slots in the back of the aluminum shoes.
- Double clutches are often fitted to gearboxes for reversing. Both glands are housed in their respective rings side by side and are connected to ahead and astern air passages.

53. Sketch and describe an electromagnetic coupling. Name 2 other methods of coupling an engine to a gearbox (2010, 2011 Exam)

- This device transmits torque by means of electro-magnetic forces without mechanical contact.
- It consists of two steel spiders with rims and flanges.
- The principle of operation is the development of torque by inducing current in a squirrel cage induction motor type winding by rotating a magnetic field around the winding.
- Outer:
    - The outer rim carries a number of poles that can be excited by an outside source through slip rings.
    - The outer element is normally connected to the driven shaft.
- Inner:
    - The inner element is a laminated core surrounding the rim, which carries a squirrel cage winding.
    - The inner element is usually coupled to the prime mover.
- The air gap between the two elements is about 1/4".
- These clutches are rated for horse powers between 1000 and 4000.
- The driven shaft rotates in the same direction as the driver but at a slightly slower speed.
- The amount of slip is just that required for the development of the necessary torque.
- In order for the coupling to be suitable for maneuvering the ship, it must be capable of producing large amounts of torque at high slip.
- The efficiency of the clutch is about 97%, with losses caused by excitation, slip and windage.
- These clutches act as torsionally flexible members and torsional dampers.
- This makes them ideal for installation between the diesel engine and gearbox.

54. Describe a fluid coupling.

- Reed's MEK p. 163, Taylor p. 41
- A fluid coupling is completely self-contained, apart from a cooling water supply.
- They require no external auxiliary pump or oil feed tank.
- A scoop tube when lowered picks up oil from the rotating casing reservoir and supplies it to the vanes for coupling and power transmission.
- Withdrawal of the scoop tube from the oil stops the flow of oil from the vanes, which then drains to the reservoir.
- During power transmission, a flow of oil takes place continuously through the cooler and clutch.
- Fluid clutches operate smoothly and effectively. They use a fine mineral lubricating oil and have no contact and no wear between driving and driven members.
- Torsional vibrations are dampened out to some extent and transmitted speeds can be considerably less than engine speed if required by adjustment of scoop tube.
- It is possible to have dual entry scoop tube for reversible engines.
- Thrust bearings must be fitted on either side of the coupling because of the axial thrust developed by this coupling.

55. Describe a coupling suitable for a medium speed diesel to a gearbox. What are the purposes of the coupling? (2006 Exam)

- Reed's MEK p. 167
- Flexible couplings are used between engine and gearbox to dampen down torque fluctuations, reduce the effect of shock loading on the gears and engine and allow for slight misalignments.
- They may consist of multi-tooth or use diaphragms or rubber blocks.

- The rubber will also allow electrical insulation between driving and driven members.
- Will reduce vibration and noise.
- Will give a smooth transition of speed and torque during clutch engagement.
- Rubber blocks would be synthetic to stop oil degradation.

56. Describe a clutch and reverse gear for a diesel engine. How is the wear taken up? (Diesel Duck)

- A clutch is a device to connect or separate a driving unit from the driven unit.
- The usual design for a clutch is the plate type clutch, which consists of pressure plates and clutch plates arranged in a spider.

Gearing:

57. Describe a type of speed reducing gearing suitable for use with a high speed marine diesel engine. Explain how the gears are lubricated and how the engine is coupled to the gearbox. What would the typical speeds for the engine and the propeller. (Pacific Region Sample, Camosun College Sample)

- Reed's p. 165
- Gearboxes are fitted because the shift speed of medium speed diesel is not suitable where a low speed propeller is required.
- The ratio of gearbox installations is normally between 2:1 and 4:1.
- Usually single reduction with single or double helical gearing.
- Typical for high speed engine: 1000 RPM and higher
- The propeller RPM would be roughly 250 RPM.

58. With the aid of a proper line diagram, describe a lube oil system suitable for use on a large reduction gearbox. Explain any maintenance procedures you would implement to keep the system in good order. (CCGC Sample)

- The basic requirement for gear drives is lubrication. The 3 basic methods for lubricating are splash, slinger and spray.
- A large engine would use the spray method, utilizing a pump to distribute the lubricant.
- The pump may be powered by the turning shaft in the gear case or may be powered by an external source.
- The pump picks up the oil from the gear case and distributes it to the sprayers that direct the oil into the gear mesh areas.
- The lubricant provides a hydrodynamic, protective coating that prevents metal to metal contact or wear.
- Proper filtration is required to prevent contaminants from causing wear between the teeth.
- The gearbox will also be fitted with a breather to allow venting of heat but only allow filtered air into the gearbox.
- The oil should be changed regularly.
- The manufacturer's recommended maintenance routine should be followed.
- Safety authorities will want to inspect every 5 years and bearings should be replaced when worn.

59. Define the following with reduction gearing: (Limnos Sample)

- Helical and Double Helical
    a. All reduction gearing employs helical gearing.
    b. The majority of gears have a helix angle of 30° to the axis of the shaft.
    c. Helical teeth provide smooth running, the teeth sliding on one another without impact and several teeth are meshing at one time.
    d. Helical teeth create an axial thrust that must be accommodated for by fitting double gears (in opposite direction) or a thrust bearing.
- Articulated
    a. A term to describe gear trains that make use of flexible couplings
- Tandem
- Dual

60. Make a sketch of single and double reduction gearing. Describe the materials and construction of the gear wheels. Explain why double helical gears are used. What are the approximate ratios used? Does the gearing take any thrust from the propeller or engine? (Limnos Sample)

- Reed's Deck p. 55, Taylor p. 68
- Double reduction gearing consists of two stages of speed reduction by means of a pinion on the engine or turbine shaft meshing with an intermediate wheel on the intermediate shaft which in turn meshes with a gear wheel on the main shaft.
- All modern marine gearing is of the double helical type.
- Helical means that the teeth form part of a helix on the periphery of the pinion or gear wheel.
- This means that at any time, several teeth are in contact and thus spread and transfer of load is much smoother.
- Double helical refers to the use of two wheels or pinions on each shaft with the teeth cut in opposite directions.
- This is to prevent a sideways thrust, thereby centering the gear forces.

Cooling systems:

Cooling systems for diesel engines and their protection from damage by freezing and corrosion

61. What are the effects of using dirty cooling water in the internals of a diesel engine? (Camosun College Sample)
- Using dirty cooling water would foul the surfaces inside a diesel engine.
- This could form a boundary that would interfere with heat transfer from the hot parts to the water.
- This would cause overheating of the engine unless the system was cleaned.

62. What would be the causes of a poor cooling system of a diesel engine? What effect would it have on the engine?
- Reed's p. 79
- The working temperatures of the gases inside the cylinder of diesel engines are very high, therefore the parts in close proximity to the combustion space must be cooled to prevent the metal from overheating.
- These parts are the head, liner, piston and sometimes exhaust valve.

63. Describe the difference between S.W. and F.W. cooling for a diesel engine. What advantages does F.W. cooling have over S.W. cooling? What possible damages might result if S.W. were used for engine cooling? (Camosun College Sample)
- In an open or SW cooling system, the circulating pump takes suction from the sea and discharges salt water through the engine then overboard, the engine being cooled by the seawater.
- In a closed or FW cooling system, the fresh water is taken from a tank and recirculated through the engine by a FW pump.
- This water is cooled by a heat exchanger using SW supplied by the SW pump as a cooling medium.
- Disadvantages of FW:
    - More complicated
    - More parts (heat exchanger, second pump)
- Advantages of FW
    - Less risk of scale deposits
    - Engine can be kept warmer, helping heat efficiency
    - More foreign material can be kept out of cooling passages
    - Less danger of galvanic action
- The outlet SW temperature should not be permitted to exceed 120F. This will prevent the formation of scale and local hot spots. Circulation should be continued after shut down until engine has cooled sufficiently.

64. Describe a fresh-water cooling system for a diesel engine. State temperatures and pressures throughout the system. How and why is the temperature regulated? What parts are required to be cooled? (2006 exam, Diesel Duck, Camosun College Sample)
- Taylor p. 30
- Cooling of engines is achieved by circulating a cooling liquid around internal passages within the engine.
- Modern engines use FW to cool the engine including the cylinder jackets, cylinder heads, exhaust valves and turbochargers.
- The coolant is thus heated and must be cooled by seawater to maintain proper temperature. The SW is at a lower pressure to prevent SW ingress.
- Without adequate cooling, certain parts of the engine that are exposed to very high temperatures due to combustion of fuel, would soon fail.
- Pumps may be engine run or electrically run and must be in duplicate to have standby capability.
- Pressure relief valves are fitted and alarms to give warnings of:
    - Low pressure
    - High or low tank level
    - High Temperature
- The system may be divided into:
    - Low temperature – lube oil cooler, second stage of charge air cooler
    - High temperature – cylinder jackets, heads, exhaust valves, turbocharger, first stage of charge air cooler
- An electric heater and circulating pump are fitted to warm up FW prior to starting.
- The water passes through strainers and into the suction side of the circulating pump that is usually of the centrifugal type.
- It is discharged from the pump through the oil cooler and then to the engine.
- The water enters at the coolest part, which is usually the bottom of each cylinder water jacket and circulates upward toward the head.
- There may be either water jumpers or passages to carry the water from the cylinder to the head and the exhaust valve cages and seats.
- From the cylinder head, the water passes through the passages around the exhaust manifold, turbochargers and then to the seawater cooler.
- In order to prevent air pockets in any part of cooling system that would interfere with circulation and may cause overheating, FW cooling systems are vented.
- An expansion tank is fitted at a reasonable height to pressurize system and allow venting and pressurizing of system.

- Vents should be placed on the circulating pump, the coolers and at sufficient places in the top of the system (expansion tank) to bleed off all entrapped air.
- Fresh water may cause scale on heated surfaces so should be chemically treated to prevent this.
- Corrosion inhibitors and alkaline agents are added to prevent acidic attack.
- Frequent checks must take place to ensure proper concentration of chemicals.

65. Sketch and describe a system of piston cooling. What mediums are used and what special care and attention does each system require? (Pacific Region Sample)

- Reed's Deck. 79
- The cooling medium for pistons may be fresh water, distilled water or lubricating oil.
- If the piston cooling system uses water, it is separate from the main cooling system in order to limit contamination to its own system.
- In some opposed piston engines, lube oil is used to cool the bottom pistons and distilled water for the top.
- When water is used for cooling a piston, it is led through grasshopper joints, telescopic pipes or rubber hose into the piston.
- The moving member of the telescopic pipes may be attached to the underside of the piston and the stationary block.
- In crosshead engines, the inlet and outlet pipes from the piston are fixed and lead to the crosshead, then to the outer end of a bracket bolted to the crosshead where connection is made to the moving member of the telescopic assembly.
- These pipes operate in trombone fashion in larger diameter pipes that are fitted with glands at entry to prevent loss of coolant.
- A sight glass is included in the return pipe so that the flow of cooling medium can be observed.
- A means of temperature measurement is incorporated in the supply and return pipes.
- In some cases, it is sprayed on the inner head of the piston.
- Could use shaker effect, using the inertia of the water hitting the bottom surface of the crown as the piston passes TDC. More effective at high speed than low.
- Temperature of the water is raised from 140 to 160F in the piston casting and then it flows back to the supply source where it is passes through a heat exchanger cooled by seawater and recirculated.
- The quantity of cooling medium is checked often as a check against leakages in the system.
- For engines of moderate power rating, oil cooling of pistons is normally used.
- The oil is directed to flow radially across the underside of the crown.
- Piston cooling system is kept running after the engine is shut down in order to allow gradual reduction in temperature and consequent thermal stress.

66. What are the advantages of air cooling over water cooling? (Camosun College Sample)

- Air cooling advantages are:
    - Simpler construction
    - Cheaper
    - Lighter

Lube oil and fuel:
Fuel and lubricating oil systems, properties of fuels and lubricating oils used in diesel engines
Lube Oil:

67. Sketch and describe one type of lube oil filter and name at least two other types. (Camosun College Sample)

- The five ways of filtering oil are:
    - Simple settling out of contaminants under static conditions
    - Centrifugal separators / filters
        i. Fine filtration of oil is required even with centrifuge use since solids can be carried in suspension and not filtered out this way.
        ii. A centrifugal filter can be used in a bypass system where the oil passes through a rotor and spins it at high speed.
        iii. Dirt particles in the oil are then deposited on the walls of the rotor and the clean oil returns to the sump.
        iv. It must be dismantled for cleaning of the rotor at regular intervals.
    - Mechanical strainers and filters – coarse and fine
        i. Mechanical separation of solid contaminants from oil systems is achieved by the use of filters and strainers.
        ii. Both are arranged as full-flow units, usually mounted in pairs (duplex) with one on standby.
        iii. The strainer usually employs a mesh screen, an assembly of closely packed metal plates or wire coils that effectively block all but the smallest particles.
        iv. It is usually fitted on the suction side of a pump and must be cleaned regularly or when the pressure differential across it becomes unacceptable.
        v. When cleaning is required, the other is brought online by a changeover valve and oil circulation will continue.

vi. The particles of dirt collect on the outside of the strainer element or basket and can be removed by compressed air or brushing.
vii. Fine filters are full flow units that remove smaller particles before fuel reaches injection system.
viii. Filtering substance may be synthetic or natural fibrous woolen felt or paper.

- Absorbent / coalescing filters
  i. Coalescing action filters normally consist of some form of pre-filter to remove particles, then followed by a compressed inorganic fiber coalescing unit in which water is collected into larger globules.
  ii. Coalescing action uses the molecular attraction between water droplets and inorganic fibers is greater that is stronger than that between the oil and fibers. When the globules are large enough, they will move with a stream out of the unit.
  iii. Downstream of the coalescing cartridges are PTFE covered stainless steel water repelling screens that act as a final barrier for the water.
  iv. Water gravitates from them and from the outlet of the coalescing cartridge into the well of the filter body from where they are periodically removed
- Chemically active filters

68. Sketch a self-cleaning filter and describe its operation. Explain the function of a magnetic filter. State why magnetic filters complement self-cleaning filters and why centrifuges do not render these filters redundant. (CCGC Sample)

- An Auto-Klean filter can be cleaned while in operation.
- Type of knife-edge filter that can filter out particles 25-75 micron.
- Dirty oil passes through series of thin metal discs mounted on a square central spindle. Between discs are thin metal star shaped spacing washers of slightly smaller overall diameter than the discs.
- As oil passes through discs, solid matter of size larger than the space remains on periphery.
- The filter is cleaned by rotating the center square spindle that rotates the disc stack and the stationary blades scrape off filtered solids that fall to the bottom sludge well of the filter.
- Periodically, the flow of oil is disrupted and the sludge well is cleaned out. To facilitate this, the filters are generally fitted in pairs.
- Some are fitted with electric motors to turn spindle automatically.
- The streamline lube oil filter consists of two compartment pressure vessels containing filter cartridges.
- Each cartridge is made up of thin discs threaded onto a Y or X shaped rod and held in compression.
- The oil flows from the dirty to the clean side of the filter via small spaces between the compressed discs, then up the spaces formed by the poles in the centre.
- In this way, dirt is left at the edge of the stack.
- It is claimed 1 micron particles can be filtered out.
- For cleaning, generally compressed air is used and a drain valve is used to force impurities to a sludge tank.
- Centrifugal, magnetic and static filters complement each other in a lube oil system because they each filter out a different impurity very well – centrifugal gets out water, magnetic gets out ferrous wear particles and static gets out dirt/solids.

69. Describe a lubricating oil filter for a diesel engine of the magnetic type and state where it is placed in the lube oil system. What is the purpose of this type of filter and how does it work? How would you clean it when the engine was in service? What would you look for when cleaning this type of filter? (Pacific Region Sample)

- McGeorge MAM p. 137-138,
- Offer extra protection for engines and gearboxes where ferrous wear particles are likely to be present.
- Use permanent magnets to attract ferrous particles and prevent them from damaging machinery.
- Must be periodically cleaned to ensure it does not get clogged with material.

70. What action would you take if the oil temperature started to rise? How is engine lubricating oil cleaned? What causes the breakdown of oil? (Pacific Region Sample)

- If I was on watch and the oil temperature started to rise, this is an indication of a problem that could be serious in nature.
- I would first call the bridge and let them know the situation. I would request them to slow down the engine for investigation.
- I would make a round of the system to check:
  - The level of oil dropping? Any major leaks? Does it smell like water or fuel?
  - The pressure at normal level?
  - Cooling water temperatures and flow at proper levels?
  - Are the pyrometers showing any imbalance?
  - Is the crankcase mist detector at a normal level?
  - Are the filters OK? Look at pressure differential.
  - Are the cooling pumps working properly?
- Lube oil is cleaned by settling, filtration and purification.

71. If a diesel engine stopped due to water in the lube oil, what steps would you take? (Camosun College Sample)
- If an engine stopped due to water in the lube oil, chances are there has been a seizure of engine parts due to loss of proper hydrodynamic lubrication.
- This will require an inspection for damage to see what cause the stoppage.
- When remedied, the oil would have to be purified to get rid of the water, or more preferably, changed out with new.

72. Sketch and describe a centrifuge or lubricating oil purifier. Explain how it operates and how it is used in connection with diesel engines. What is the maintenance required? What are the consequences of operating an engine with dirty or contaminated oil? (TCMS Sample, Diesel Duck, Pacific Region Sample, Limnos Sample, Camosun College Sample)
- Taylor p. 153
- In its passage through a diesel engine, lube oil will become contaminated by wear particles, combustion products and water.
- Normally, a bypass system is used to draw dirty oil from the bottom of the engine sump and return clean oil.
- A centrifuge arranged to separate two liquids is called a purifier.
- A centrifuge arranged to separate impurities and small amounts of water is called a clarifier.
- The separation of impurities and water from lube oil is essential to reduce wear and possible breakdowns.
- The force that acts on particles in a centrifuge is radial outward centrifugal force.
- A centrifuge consists of an electric motor drive to a vertical shaft on the top of which is mounted the bowl assembly. Rotates in balance at 5000-8000 RPM.
- An outer framework surrounds the assembly and carries the various feed and discharge connections.
- The bowl can be a solid assembly, which retains the separated sludge and operates non-continuously, or the bowl can be arranged so that the upper and lower parts separate and the sludge can be discharged automatically while the centrifuge operates continuously.
- The dirty oil is admitted into the centre of the bowl, passes up through a stack of discs and out through the top.
- Dirt particles move down the underside of the discs in a centrifuge against the oil flow since they are heavier than the oil and eventually into the sludge space of the bowl.
- The process of purification requires the formation of a cylindrical interface between the two.
- The positioning of the interface is very important for correct operation and is achieved by the use of a gravity disc at the outlet of the centrifuge.
- Various diameter rings are available when different density oils are used.
- Clarification does not require a gravity disc since there is no interface formed.
- The factors that effect the size of particle removed are:
    - Velocity of the oil in the centrifuge
    - Disc spacing, diameter and inclination to the vertical
    - Speed rotation of the bowl
    - Throughput
- Should be kept running after engine shut down to get rid of condensation as engine cools.
- Lubricating oil purification takes place at about 82C - 85C.
- An efficient purifier can handle up to 10% water.
- The bowl and disc stack will require periodical cleaning whether or not an ejection process is in operation.
- Care should be taken in stripping down the bowl, using only the special tools provided and noting that some left handed threads are used.

73. Why is it necessary to "change" or "purify" lubricating oil at intervals in a diesel engine? What would you consider an interval in terms of "engine-running hours"? How often should the oil level be checked? How would you dispose of dirty oil?
- Reed's MEK p. 41
- The different types of contaminants in lube oil are:
    - Water
    - Mineral or organic acids
    - Dirt / rust / scale
    - Wear particles from bearing surfaces
    - Paint and jointing compounds
    - Carbon compounds and sludge from poor combustion
    - Oxidation
- For medium and high speed engines, oil samples and changes for shore analysis should be taken about every 500 to 1000 hours or more if suspect.
- For slow speed engines, samples can be taken at 3000 hours and changes upwards of 15000 hours.

- Should be changed when:
    - Viscosity has changed. Contamination can raise or lower it.
    - Excessive contamination.
    - Excessive emulsification.
    - Excessive carbon residue.
    - Excessive acidity or too basic.
- Additives increase the life of lube oil by giving the oil properties it doesn't have, replacing desirable properties that may have been removed during refining and improving those naturally found in oil.
- Oxidation in oil reduces life, plus viscosity normally increases.

74. Describe a lube oil system for a diesel engine and state the engine you are referring to. What would you suspect if there were a drop in oil pressure? What is the normal oil pressure and what is the minimum? (Pacific Region Sample, Diesel Duck, Camosun College Sample)

- Reed's Deck p. 80, Wharton p. 98, Taylor p. 29
- The functions of a lubricant are to:
    - Reduce friction and wear
    - Carry away deposits and provide a seal to keep dirt out
    - Carry heat away from bearings and gears, etc.
    - Prevent rust and corrosion
- A forced lubrication system is always employed to provide a good hydrodynamic film of lubricant.
- The lubricating oil is fed under pressure from a pump either from storage in the bottom of the crankcase (wet sump) or in a drain tank beneath the engine (dry sump), typically around 6 bar.
- A typical path for oil may be:
    - Sump to suction strainer (at least 100mm above bottom) to engine driven pump or stand alone pump(s) to discharge filters to oil cooler to branch line to main bearings through drilled passage in crankshaft to crankpin bearings (bottom end), through drilled holes in connecting rods to the wrist pin bearings or crosshead bearing to lubricate the crosshead guide and slipper.
    - For oil cooled pistons, oil continues through a drilled passage in piston pin or crosshead pin, through passage in piston, to piston head, to enclosed return line to sump.
    - Oil from main header would also be taken to lubricate camshaft bearings and gear drive and any auxiliary pump bearings.
    - The exhaust valve actuators (if hydraulic), sprayers, turbochargers (if fed from same oil) and control systems.
    - After use in engine, oil will drain back to sump or drain tank for re-use.
- A centrifuge is arranged for cleaning the lube oil in the system and clean oil can be provided for top-up from a storage tank.
- The lubricating oil carries away a great deal of heat generated by friction at the various bearings and therefore must be cooled by passing it through a heat exchanger cooled by seawater.
- Items duplicated in a lube oils system may be pumps, strainers and fine filters. One of each will be on standby.
- The filters should be able to be cleaned one at a time with one remaining online.
- Capacity of oil must be sufficient enough to maintain a proper temperature.
- If the engine has oil cooled pistons, the capacity will have to be increased.
- Various sections will require more or less oil pressure than the main system. This requires use of booster pumps or orifice plates and reducing valves.
- An alarm sensor at the end of the branches will monitor for falling pressure and warn the engineer if it drops below a certain level.

75. What type of alarm system is installed to warn of failing conditions in the system? Describe how this alarm system operates. (Diesel Duck)

- A basic alarm system comprises a series of pressure or temperature operated electrical switches.
- When the operating parameter rises or falls outside of a preset limit, the switch will close the circuit to an alarm light and audible alarm to alert the engineer.
- After accepting the alarm, the condition should be immediately investigated and the necessary action taken.

76. Describe the methods of lubricating the piston and cylinder walls in diesel engines. How is lubricating oil introduced to main bearings, bottom ends and wrist pins on trunk piston engines? (2008 Exam, Pacific Region Sample, Camosun College Sample)

- Reed's MEK p. 50
- The principal objects of cylinder lubrication are:
    - To separate sliding surfaces with an unbroken oil film to prevent scuffing and wear
    - To form an effective seal between piston rings and cylinder liner surface to prevent blow by of gas
    - To neutralize corrosive combustion products and thus protect liner, piston and rings from corrosive attack
    - To soften deposits and thus prevent wear due to abrasion.

  - To remove, dissipate and cause the loss of deposits to exhaust, hence preventing seizure of piston rings and keeping engine clean.
  - To cool hot surfaces without burning.
- Insufficient cylinder lubrication will lead to blow by of hot gases that can lead to overheating, rapid breakdown of surfaces, seizure of pistons and possible crankcase explosion.
- Excessive cylinder lubrication can cause carbon deposits, piston rings sticking in grooves, allowing possible breakage or blow by. There will be fouling of exhaust system including turbochargers and contamination of scavenge spaces.
- In practice, some oil burning will take place. If excessive, this will be indicated by blue smoke and increased oil consumption.
- As the oil burns, it should leave only a soft deposit.
- Over lubrication should be avoided.
- When engine is getting worn in, lubrication should be increased if possible to flush away deposits, seal roughly machined surfaces and deal with increased oxidation of oil.
- The cylinder of medium or high speed diesel is usually lubricated by oil thrown from the crankpin bearings.
- Oil scraper bearings spread the oil on upstroke and scrape it to the crankcase on the down stroke.
- In larger slower speed engines, the oil is fed through from several small openings in the cylinder walls, usually located about the second ring level when at BDC.
- This oil is supplied by a small positive displacement pump to each line that measures the amount of oil used and is timed by the camshaft drive to hit the rings as they pass by.
- Lubricators should not be placed too near the ports or too near the combustion zone.
- The oil is a special type that is not recovered. It contains additives for cleaning the cylinder.

77. Describe a lube oil pump for a reversible diesel engine. How is the pump constructed, what materials are used and how is the oil controlled going to the engine? (Diesel Duck)

- Reed's Deck p. 94, McGeorge MAM p. 171, Reed's GEK p. 365
- Normally, the lube oil pump for an engine is a crank driven gear pump.
- Defined as a rotary displacement pump. Used because it is self priming and positive displacement for applications that require constant pressure and flow.
- Often driven off engine crankshaft for medium and high speed engines.
- Slow speed engines are normally independently driven.
- Consist of two geared wheels meshed together that are driven by one shaft so there is a master and slave.
- The casing around the wheels is fit to tight tolerances to prevent oil pressure loss.
- As each tooth in one wheel leaves its corresponding space in the other wheel, a partial vacuum is created in that space into which the oil flows.
- The oil is the carried around in the outside of the space through almost 360 degrees when a tooth entering the discharge space pushes it out of the pump.
- Centrifugal effect contributes to pumping action.
- Rotors and shaft integrally forged of nitralloy steel. They are hardened all over then ground finished.
- Cast iron used for casing and bearing housings.
- Bearings are white metal or roller bearings.
- Lubrication by oil passing through.
- No side thrust with straight gear teeth. Single helical gears will cause side thrust. Double helical necessary to prevent this thrust wear.
- Spring loaded relief valves fitted, normally adjustable to set system pressure.
- In reversible engines, the lube oil pump is made to flow in the proper direction by adding a pair of non-return suction and delivery valves at each side with communicating ports to the suction and delivery branches.

78. Why is it undesirable to have water in the lubricating oil, and what possible harm will it cause to a diesel engine? Name the ways how water can enter the lubrication system. How can this water be disposed of? How can you tell when there is water present in the oil? (Diesel Duck, Limnos Sample)

- Water in oil lease to emulsification, which lessens the lubricating properties of oil.
- This could lead to overheating of bearing surfaces and eventual seizure of engine.
- Water also enhances biological degradation of oil. Can cause corrosion, wear and a harmful sludge that will block filters.
- .2% water is max for water content.
- Water finding paper or paste can be used to detect water in oil. Copper sulfate crystals change color from white to blue in the presence of water.
- The amount of watery sludge discharge from the oil purifier can be monitored. An increase would show an indication of water in the oil.

79. Describe an oil cooler suitable for an internal combustion engine. Name the materials in construction. Name all the fittings, valves, and piping you would find and the temperatures of oil entering and leaving the cooler. (2006, 2010, 2011 Exams, Diesel Duck, Camosun College Sample)

- The usual cooling medium in lube oil coolers is seawater or freshly cooled jacket water.
- The water is at lower pressure than oil to prevent ingress in case of leak.
- In a shell and tube coolers, the oil is in contact with the outside of the tubes and shell of the cooler.
- Tubes are normally made from aluminum brass – 76% copper, 22% zinc and 2% aluminum.
- Casing (shell) is normally steel or cast iron with zinc anodes fitted.
- Tube plates are secured in a cooler by having one end that is fixed and the other end that is free to move with expansion of the tubes.
- Seawater or cooling water enters at the bottom and exits at the top.
- Vent cocks are fitted to allow bleeding of air that would otherwise cause corrosion and lessen cooling effect of water.
- Tubes can be regularly cleaned with special soft brushes and cleaning chemicals.
- Coolers are normally double pass so that the cooling fluid passes through the tubes twice in order to provide for more cooling.
- The coolant passes through the lower half of tubes then hits a curved bonnet that directs it the opposite way for the second pass through the upper half of tubes.
- The lube oil will enter at one end of the shell and leave at the other and will be directed by baffles to allow for turbulent flow, thereby increasing cooling efficiency.
- Fitted into the cooler at one is a packed end that allows expansion of the tube bundle.
- The packing arrangement consists of a lantern gland surrounded by two packing rings, all of which is compressed between the recessed faces machined in the packed end bonnet and the tube bundle.
- The packing rings can be considered floating since they allow light movement of the bundle by sliding within the recesses, while still providing a seal between oil and water.
- If there is a leak within the seal, a telltale hole inside the lantern gland will show from which side the liquid is leaking.
- The other end is stationary and sealed with two gaskets.

Fuel

80. Describe a fuel pump suitable for a diesel engine. What pressure is delivered to the injector? How is the fuel regulated? (Diesel Duck, Camosun College Sample)

- Reed's p. 70
- The purpose of a fuel pump is to supply the proper amount of pressurized fuel at the proper time to the injectors.
- The amount of fuel injected per stroke can be varied by:
    - Mechanically varying the plunger stroke
    - Throttling the intake fuel
    - Varying the effective plunger stroke by cut off or spill
- The latter method is generally preferred and control is arranged to be either:
    - Constant beginning on injection (delivery spill – Bosch)
    - Constant end of injection (variable start of delivery)
    - Both types combined
- The Bosch system uses a plunger with constant stroke and the amount of fuel discharged into the injector is determined by the degree of rotation of the pump plunger in its barrel.
- One plunger and barrel is fitted for each cylinder.
- Helical springs are fitted to return the plunger on its down stroke to maintain contact of follower on cam.
- Rotation regulates the vertical length of the helix when it is line with the suction port.
- Rotation of the plunger in the barrel causes a higher or lower point of the scroll to uncover the port. This cuts of the discharge earlier or later.
- This rotation is controlled by a pinion machined on the outside of the sleeve that will turn the plunger when the rack is moved.
- One helix will control timing and the other metering.
- Fuel delivery starts on this type of pump on a fixed point on the upward stroke of the plunger when the top edge of the plunger blanks off the suction port.
- Delivery stops on the upward stroke when the curved surface of the helix or scroll machined in the plunger uncovers the suction port.
- This allows fuel pressure above the plunger to fall to the suction pressure through a vertical slot or hole.
- Fuel pressure is supplied by a continuously operated pump that cause the barrels to flood as soon as the suction port is uncovered by the plunger.
- A priming or vent plug is fitted to the discharge.
- The plunger is lubricated by leakage of fuel in the small clearance between the plunger and barrel.

81. State how you would proceed to free a Bosch fuel system of air before attempting to start the engine (priming). What effect does air have on the fuel system of a diesel engine? What causes air in the fuel system and how would you notice it? (2006 Exam)

- Air in a diesel fuel system will cause an air lock of the system.
- The Bosch fuel system uses solid injection, meaning that the fuel acts as a solid, incompressible fluid medium.
- When air is entrained in the fuel, the mixture becomes compressible. This will cause the system to malfunction until the air is freed.
- The entire fuel system will have to be primed before the engine will run properly.
- The priming plug on the discharge side of the pump can be removed, along with those of the injectors and filters and any other high points where air may be trapped.
- These can be done one at a time, working from the source to the injectors.
- Gravity or a hand pump can be used to fill the line and casing. Air is free to escape out of the vent plugs holes and when a solid stream of fuel exits, the plug can be replaced.
- The spilled fuel will have to cleaned up to prevent a fire.
- As a solid fuel stream appears at the injector bleeds, the engine can be turned over to ensure the pump is properly primed.
- Air will cause poor combustion and misfiring since the cylinder is not getting a full charge of fuel.
- This may also cause overheating if the fuel is used for cooling since air does not transfer heat well.

82. Explain how the fuel pump, injection valve and speed control are operated in: (Camosun College Sample)

- Taylor p. 22
- Common Rail:
    - The fuel pump(s) that are directly connected to engine, supply fuel to a common rail or header at a constant pressure of 1500 to 10000 psi.
    - There is a connecting line leading from the common rail to each cylinder injection valve (injector).
    - The injection valve is mechanically operated and timed to spray fuel into the combustion chamber when needed.
    - Between the rail and injection valve(s) for each cylinder is a timing valve that determines the timing and extent of fuel delivery.
    - Spill valves are connected to the manifold or rail to release excess pressure and accumulator bottles that dampen out pump pressure pulses.
    - The operator can change the amount of fuel the engine gets, therefore the power and speed, by:
        i. Varying the lift of the injection valve
        ii. Varying the pressure of the common rail
    - The timing valve is operated by the cam and lever.
    - When the timing valve is lifted by the cam and lever, the high pressure fuel flows to the injection valve.
    - The timing valve operating lever is fixed to a sliding rod that is positioned according to the maneuvering lever setting to provide the correct fuel quantity to the cylinder.
- Pump Injection:
    - Jerk type:
        i. Two types – helix or valve controlled
        ii. A separate pump for each cylinder.
        iii. Injector pump is operated once every cycle by a cam shaft
        iv. Barrel and plunger are suited to engine fuel requirements.
        v. Ports in the barrel and slots in the plunger or adjustable spill valves serve to regulate the fuel delivery.
        vi. Injector will lift at preset pressure, which ensures that fuel will atomize once it enters cylinder
    - Helix type (Bosch):
        i. Used on medium and high speed 4 strokes
        ii. An individual pump plunger is used for each individual cylinder of the engine.
        iii. Pump has constant stroke an amount of fuel delivered is regulated by rotating the pump plunger, which has a specially arranged helical groove cut into it.
        iv. This plunger must both meter and time the injection of the fuel.
        v. Timing is done by raising or lowering plunger in relation to cam.
        vi. Pressure is only present at the time fuel injection takes place.
        vii. Non return valve stops fuel from flowing back into pump.
        viii. Fuel drawn in on plunger down stroke.
        ix. Injection valve is a check valve that is lifted by the pressure of the fuel at the time of injection.
        x. Pressures found in this type of injection are 1500 to 50000 psi.
        xi. Plunger is rotated by rack and pinion connected to throttle.
    - Valve-controlled pump:

i. The governor is connected to a suction valve and a spill valve.
ii. The closing of the pump suction valve determines the beginning of injection.
iii. Operation of the spill valve will control the end of injection by releasing fuel pressure.
iv. No helix is therefore present on the pump plunger.

83. Describe in detail a common rail fuel injection system. What are the advantages and disadvantages? What is necessary to keep it in good working order? How is the fuel pump driven? (Diesel Duck, Camosun College Sample)

- Reed's MEK p. 64, also see above
- Common rail is a system in which fuel pumps deliver to a pressure main and various valves open to the main to allow fuel injection to the appropriate cylinder.
- This requires either:
    - Mechanically operated fuel valves
    - Mechanically operated timing valves
- These valves allow connection between rail and injector at the correct time.

84. How are the following fuels prepared for combustion: Gasoline, Kerosene, and Diesel? Why is it necessary to maintain oil at the proper temperature and pressure? (Diesel Duck, Limnos Sample)

- Gasoline is prepared for combustion by mixing it with air in a carburetor to form a charge of fuel vapor and air. This will be ignited by an electric spark. It requires no heat under normal circumstances.
- Diesel is prepared for combustion by atomizing it through a hydraulic injector. This forms a fuel air mixture that can be combusted through high compression. It requires no heat under normal conditions but a glow plug may be used to get the engine started.
- Kerosene is prepared in the same way as diesel.
- It is necessary to maintain heavy fuel at the proper temperature and pressure since it is not as readily combustible as the lighter oils mentioned.
- It carries a lower calorific value and a much higher viscosity.
- To get it to flow properly, it must be heated, which will lower its viscosity.
- It must be at the proper pressure to operate the hydraulic injector properly and allow a sufficient amount of fuel for combustion.

85. Describe the maintenance required for a fuel injector. What parts of a fuel valve are most liable to be exposed to wear and tear and why? How is the injector tested after assembly? (2011 Exam)

- Defects that are found with injectors are:
    - Choking up due to fuel contaminants
    - Carbon building up at the atomizer holes
    - Leaking needle valves
- The consequences of a leaking injector are:
    - Loss of power
    - High exhaust temperature
    - Smoking exhaust
    - A diesel knock due to pre-ignition or secondary burning
- Fuel injectors must be overhauled at regular intervals to ensure correct operation and combustion.
- The injector compression spring must be screwed back before slackening the retaining nut.
- Parts are cleaned, inspected and renewed if necessary.
- Lapped surfaces must be free of damage and correctly aligned.
- Springs must be inspected for distortion.
- Atomizer holes must be clear and unworn.
- After assembly, the injector is tested with a test pump.
- Operating fuel pressure is observed and spray pattern is checked and there must be no leakages.
- Fuel injectors are inserted into pockets in the cylinder head and must form a tight joint.

86. Sketch and describe a fuel injector for a diesel engine. What material is it made from? What would you look for when overhauling a faulty fuel injector? What maintenance is required for injectors? (2010 Exam, Diesel Duck, Camosun College Sample)

- Wharton p. 90
- The purpose of an injector is to deliver atomized fuel to the cylinder for combustion.
- Atomized means that the fuel is broken up into tiny spray particles so as to ensure an intimate mixing of air and fuel. This will allow maximum availability of oxygen contact with fuel droplets so giving complete combustion and maximum heat release from the fuel.
- The ideal position for a fuel injector is the centre of the cylinder head, allowing symmetrical, conical spray pattern in the combustion chamber.
- The two basic parts of an injector are the nozzle and the nozzle holder or body. These parts are joined by a nozzle nut.
- There are two chambers in the nozzle: an upper and a lower.

- Upper chamber is charged with fuel from the pump and sealed by the needle valve when closed.
- The lower chamber is sealed by the seat of the needle valve and has a umber of tiny holes.
- In a modern hydraulic fuel injector, fuel pressure acts on the needle in the lower chamber and when the force is sufficient to overcome the spring, the needle lifts.
- Full lift occurs quickly since the extra surface area of the needle seat is exposed after initial lift.
- The full action of lift is limited by the needle shoulder, which stops against a thrust face on the holder.
- The fuel then flows into the lower chamber and is forced out through the series of tiny holes.
- The spray pattern of the fuel is determined by the number of atomizer holes and their position.
- Once the injector pump has ceased delivery of high pressure fuel, the needle valve will shut quickly under spring compression force.
- The needle should be lapped into the atomizer to form an oil tight seal.
- The injector lift pressure varies but may be about 140 – 250 bar.
- Injectors may be cooled by water or oil through passes drilled in body. Should be on a separate circuit than the remainder of cooling systems.
- Injectors have a lift of approx. 1 mm and the action is almost instantaneous.
- A fine strainer may be fitted at the fuel inlet.
- A priming or vent plug is fitted to purge air out of system

87. State and explain the various physical properties of fuel oil. Describe briefly the experiments to determine their value. Why is it necessary to know these properties before taking on fuel oil? (2008 Exam, Diesel Duck)

- The key fuel properties are:
    - Ignition quality
        i. A cetane number indicates the amount of time between fuel injection and a rapid rise in pressure (lag).
        ii. Is important when starting an engine or operating at low load for extended periods.
        iii. The higher the better for good combustion.
        iv. Affects: cold starting, misfiring, noise, smoke
    - Flow properties
        i. The pour point of a fuel is the lowest temperature at which an oil remains fluid and is important to know for onboard handling properties.
            1. Affects flow, cetane value, and cetane number
        ii. Cloud point is the point which waxes start to appear as solids
            1. Affects filters and fuel flow
    - Flash Point
        i. The flash point of a fuel is the lowest temperature at which the oil gives off combustible vapors that can be ignited by a flame or spark.
        ii. Affects the safe storage of fuel.
    - Viscosity
        i. Viscosity is defined as internal fluid molecular friction that causes a resistance to flow.
        ii. It is normally measured in Seconds Redwood, Degrees Engler or centistokes from measurement using standard apparatus in which a given quantity of fuel is run through a standard orifice at a given temperature.
        iii. Viscosity is used to gauge the proper temperature required for pumping, injection and burning of fuel.
        iv. Normal diesel viscosity: 5 centistokes at 50C and heavy fuel: 350 centistokes at 50C.
        v. Affects the quality of atomization and the lubrication and wear of injection equipment.
    - Density
        i. The specific gravity of a fuel is used to calculate the weight of a certain amount of fuel. It is also required to choose purifier gravity discs to ensure proper separation.
        ii. Affects heating value and mass of fuel injected
    - Cleanliness
        i. The Conradson carbon value is a measure of the percentage carbon residue after evaporation of the fuel in a closed space under control.
        ii. The ash content in fuel is a measure of the inorganic impurities in the fuel. These are typically sand, nickel, aluminum, silicon and vanadium. They cause problems when they combine to build up harmful deposits and cause corrosion.
            1. Sulphur levels are important to know since high levels can cause corrosive acids to form. Sulphur burns to become SO2 or SO3, which can combine with water to become sulphuric acid.
            2. Affects cylinder and ring wear and engine deposits.
        iii. Water and sediment
            1. The water content in fuel is determined by centrifuging or distillation.

a. Affects combustion of fuel, filter plugging, pump wear, injector nozzle wear, tank sludge

iv. Fuel stability
1. Affects injector sticking, pump deposits, filter plugging, deterioration in storage

v. Quality of distillation
1. Affects exhaust smoke and odor, power, economy and engine cleanliness

88. Describe the composition of fuel. What would be the undesirable elements? What is the calorific value of fuel oil and coal? Why is large sulphur content undesirable? What other impurities may be found in fuel that could cause engine defects and what are the defects possible? (Limnos Sample, Camosun College Sample)

- The normal impurities found in fuel are:
  - Rust, sand, dust
  - Refinery catalysts
  - Ash and sediment compounds
  - Solid metals such as sodium, nickel, vanadium, calcium and silica
  - Salt or fresh water
- These impurities can result in wear of fuel injection equipment, cylinder liners, piston rings and ring grooves
- Water in the fuel system can seriously damage fuel injection equipment, cause poor combustion and increase liner wear.
- Calorific Value of diesel is approx. 45MJ/kg and coal is approx. 32 MJ/kg.
- Sulphur levels are important to know since high levels can cause corrosive acids to form. Sulphur burns to become SO2 or SO3, which can combine with water to become sulphuric acid.

89. What is flash point? How is the flash point of a fuel oil tested? What is the flash point and viscosity of the following? (Pacific Region Sample, Limnos Sample)
    - Reed's GEK p. 55-57
    - Flash point is the lowest temperature at which oil will give off a flammable vapor.
    - As flashpoint is indicative of fire and explosion risk for storage and transport, it is an important property of the oil.
    - The minimum flash point on diesel vessels is 60C. This is to prevent flammable vapors from forming in the storage tanks under atmospheric conditions.
    - Test determines the temperature at which fuel will give off sufficient vapors to ignite when a flame is applied.
    - Involves using the Pensky Marten Closed Flashpoint test apparatus.
    - The flame element is depressed through a port just above oil surface at a timed sequence as the oil is heated.
    - A blue flame appears just before flashpoint and the temperature is recorded when the vapors flash off.
      - 22C and below – Dangerous – gasoline, benzene
      - 22 – 60C - Medium Risk – kerosene and vaporizing oils
      - 60C and higher – Safe for marine fuel
    - The closed-cup method prevents vapors from escaping and therefore usually results in a flash point that is a few degrees lower than in an open cup.
      - Diesel – 85C
      - Kerosene – 50C
      - Gasoline – -17C
      - Bunker C –100C
      - Lube Oil – 230C

90. Sketch and describe a fuel system for a large diesel engine. Trace the path of the fuel from the storage tank to the fuel pump including storage tank, settling tank, and daily service tank and associated piping, fittings and auxiliaries. How is water taken out of the fuel? (Camosun College Sample)

- Reed's Deck p. 74, Wharton p. 85, Taylor p. 20
- Most diesel engine fuel systems are designed to use residual fuel (which requires heating) for normal running and diesel oil for abnormal conditions and sometimes maneuvering.
- Oil is pumped from a storage tank (often double bottom) to a settling tank.
- The settling tanks are in duplicate and fitted with internal heaters so that when one tank is in use, the oil in the other tank can be settling and impurities drained off.
- The settling process can be accelerated by controlled heating.
- The oil passes from the settling tank in use through a heater unit to centrifugal purifiers and then to the daily service tank. Possibly duplicated tank here as well so that one can be filled while the other is in use.
- Settling and day tanks are normally lagged to conserve heat.
- A booster pump draws the oil from this tank and discharges it through to the circulating pumps. Pressure here will be approx. 4 bar.

- The oil is then pumped through by circulating pumps constantly to maintain proper temperature. Pressure here will be approx. 10.5 bar.
- A diesel day tank may be installed and is connected to the system via a 3 way valve. This can be used for maneuvering or for flushing the system with lighter oil.
- It is pumped next through a heater, viscosity controller, filter and finally to the engine fuel pumps.
- The engine fuel pumps deliver the oil into the cylinders via the fuel injectors.
- Fuel that is not burned returns to the day tank through a mixing/venting day that will also provide fuel to the circulating pump suction.
- All pumps are duplicated and pressure relief valves are fitted.
- All pipes carrying hot oil are lagged and fitted with heat tracing.
- A tank containing diesel will be connected to the heavy fuel system to allow flushing with light fuel and for maneuvering.
- Safety devices include:
    - Low fuel pressure
    - Low tank level
    - High and low fuel temperature
- Quick closing valves that can be operated outside of engine room must be fitted to all tanks and to the main inlet to the engine.
- Fuel pumps and purifiers must have remote emergency shut offs.
- There must be an arrangement for venting and draining the system and cleaning filters and strainers.
- Drain trays and save-alls must be kept clean, all joints must be kept tight and guards must be in place to prevent hot oil from hitting hot surfaces.
- Oil contained in tanks should not normally exceed 50C or 20C below flashpoint.
- Water is removed from bunker tanks by draining or sludging tanks. Heat is used to help separation.
- Water can also be removed by centrifugal separators or water separating filters.

91. Describe a fuel filtering system for a motor ship and for a steam ship. What precautions are taken when opening filters? How would you tell if a filter was plugged? How do you clean the filter? What are the consequences of a dirty filter? (Diesel Duck)

- Wharton p. 85
- A recommended standard of treatment for residual fuels is to use two centrifuges in series.
- The first acts as a purifier to remove water, solubles, sludge, etc.
- The second acts as a clarifier to remove solids.
- The purifier must be fitted with the correct gravity disc to match the oil density.
- The oil is heated prior to purification (max 98C) and the rate of throughput is limited to assist efficient separation.
- Both centrifuges must be cleaned frequently, less so if automatic in nature.
- The mesh of a fine strainer on a fuel system will be able to filter out particles 50 micron or less.
- When opening a filter the precautions are:
    - Ensure it is isolated and the other is online
    - Wear protective equipment including goggles, coveralls and gloves
    - Crack the bolts slowly and keep some in place to ensure the cover will not come off with high velocity.
    - Have a spare handy or the required cleaning materials.
- You could tell if a filter was plugged by looking at the pressure differential before and after the filter. If this reaches too high a level, it means that the filter is blocking flow, meaning it is plugged.

92. Define combustion. What part does air play in combustion and what are the requirements for good combustion? What would be the cause of smoky exhaust? (Diesel Duck)

- Wharton p. 88
- In a diesel engine cylinder, combustion takes place in 3 stages:
    - First, a delay period during which the surface of each individual droplet of fuel is surrounding itself with an envelope of vapor, the outer surface of which must retain a temperature high enough to bring about self ignition. The time elapsed during this phase is termed ignition delay or lag.
    - Second, a period of very rapid burning during which the many droplets burst into flame in rapid succession causing a very rapid generation of heat with corresponding rise in pressure and temperature.
    - Third, a period of controlled burning when, because of the high temperatures within the cylinder, the last droplets of fuel burst into flame almost as they enter the combustion chamber.
- The factors that control combustion are:
    - Proper amount of air
    - Proper amount of fuel (and viscosity)
    - Proper mixture of fuel and air (penetration and turbulence in cylinder)

- Proper temperature of fuel and air for ignition (atomization)
- The significant problem caused by poor or incompatible combustion is the fouling of fuel injectors, exhaust ports, passages and the turbocharger exhaust side.
- To achieve atomization, it is important to ensure proper use of separators, settling tanks and filters, and that correct fuel viscosity is maintained (around 15 cSt @ 50C).
- The general indications of good combustion are:
  - Clear exhaust
  - Power produced
  - Normal exhaust temperatures
  - No uneven running or knock
- The causes of black smoke is due to incomplete combustion. This may be due to a number of reasons:
  - Injector faults such as a choked atomizer, leaking valve, broken or incorrectly set spring
  - Fuel pump faults such as incorrect timing, worn plunger, slack or wrongly positioned cam
  - Low compression due to worn rings or liner or leaking valves
  - Insufficient combustion air due to turbocharger faults or choked air filters or charge air cooler
  - Fuel issues such as bad quality, improper viscosity
  - Exhaust back pressure
  - Overloading or too high acceleration can cause smoke due to turbo lag
  - Scavenge or uptake fire

Compressed air systems:
Constructional details and working principles of compressed air systems, starting and reversing systems for diesel engines
Systems:

93. Sketch and describe an air system that would be found on a diesel ship. (Camosun College Sample)

- Compressed air is used for starting engines and generators, operating whistles, and for workshop services. It can also be used for operating clutches and propulsion controls.
- Regulations state that there must be enough air capacity for 6 consecutive starts for non-reversible engines and 12 consecutive starts for reversible engines.

Starting:

94. State the different starting systems on internal combustion engines. Explain in detail one system and what attention starting systems require.

- Reed's Deck p. 81, Wharton p. 103, Taylor p. 33
- Five methods of starting diesel engines are:
  - Compressed air injection
  - Compressed air start motor
  - Electrical starter – normally by DC batteries
  - Hand crank
  - Using auxiliary engine
- Heavy marine diesel engines are normally started by supplying compressed air into the cylinders in the appropriate sequence for the required direction (ahead or astern).
- The compressed air is stored in reservoirs containing from 20 to 40 bar air pressure and minimum 12 start volume capacity for reversing engines and 6 start volume capacity for non-reversing engines.
- For an engine to begin firing, air must be first drawn in or pumped into the cylinder and compressed by the upward movement of the piston to obtain the high temperature necessary to burn the fuel when it is injected.
- Hence, the engine must be driven for a few revolutions by some outside source before allowing fuel into the cylinders.
- When this main air start valve is open, air charges the main manifold, passing through the non-return valve and flame arrestors to the cylinder air start valves.
- The cylinder air start valve purpose is to admit compressed air into the cylinders and they are controlled by the pilot air system.
- They are normally held shut by a compression spring and cylinder pressure acting on the valve lid.
- Air from the manifold enters these valves where if forms a pressure balance between the top of the valve lid and a balance piston of equal area on the valve spindle. Consequently, this does not cause the valve to open.
- They are opened when pilot air, transmitted from the distributor, applies pressure to the larger start piston on the valve spindle.
- The two connections on the air start distributor are:
  - Timing: one for depressing each timing valve in the distributor from its free position to engage it with the timing cam. Can be locked out for testing or safety. Until air pressure is applied, the timing valves are held clear of the cam by springs.

    - Pilot: another for supplying air to the operating ports, from which it will pass through any timing valves that are open, to the corresponding valves causing them to open.
- As the valve is opened, starting air from the manifold enters the cylinder, applying pressure on the cylinder piston pushing it downwards.
- To close the cylinder valves, the connection from the distributor is vented to atmosphere, allowing the spring to close the valve and return the operating piston.
- The compressed air is admitted to each cylinder when the piston has just passed TDC and starting what would be its power stroke and remaining open until the piston has traveled part of that stroke.
- The period of opening depends upon the number of cylinders and whether it is a 2 or 4 stroke engine.
- When the starting air valve closes on one cylinder, another starting air valve has opened on another cylinder whose piston has commenced its downward stroke and so on. The usual overlap is 15°.
- This means that the engine can start in any crank position.
- When the engine attains sufficient speed, the fuel pumps and valves are brought into operation and the starting air valves put out of commission.
- In V-type engines, starting air may only be connected to one bank of cylinders.
- There may be a connection to allowing less air in to slowly turn over engine with indicator cocks open.
- A relief valve must be fitted between on the manifold.
- Flame arresters or bursting caps/discs must be fitted to each cylinder in reversible engines. Non-reversing only require one fitted between the non-return valve and the cylinder.
- The main air start valve can be locked out and this must be done before the turning gear is engaged.

95. Describe an air starting valve as used on the cylinder of a diesel engine. How is this valve operated? At what part of the cycle is air admitted to the cylinder and what regular attention do air-starting valves require. (TCMS Sample, Diesel Duck, Camosun College Sample)

- Reed's MEK p. 102, Wharton p. 103, Taylor p. 35
- The valve is fitted to the cylinder and opened by pilot air pressure directed to it from the air distributor
- It is closed when the air distributor vents the line to atmosphere via a silencer.
- The body of the valve could be of mild steel, the spindle of high tensile steel and the steel valve could have the faces hardened or stellited.
- May be water cooled.
- Lubricated by grease.
- Normal valve lift is about 20 mm.
- A non-return safety valve and flame trap would be fitted in the main air supply to the cylinders.
- Relay Operated:
    - The main air enters and the down force on the valve tending to open it is same as up force on the spindle guide since these areas are nearly equal.
    - The spring force up ensures that the valve will remain closed provided there is no real pressure above the piston since the distributor is venting the valve.
    - Now if the distributor connects the space above the piston to high pressure air, this is sufficient to overcome the spring and move the valve downwards to admit air into the cylinder.
- Direct Opening:
    - The operating principle is that opening will occur when main air inlet pressure acting on the valve overcomes the spring force.
    - This type of valve is most generally used when the main air supply is only admitted via a cam operated valve so that air enters the valve just before opening is required.
- Air start valves are open from approximately 15° to 50° after TDC to 100° to 130° after TDC.
- The valve must close before the exhaust valve/port opens so as not to pump compressed air straight to the exhaust.
- To recognize a leaking air start valve, check the temperature of the pipe. If it is hot, a leak is likely.
- Also when shut down, you could break the air line and jack the engine over. If you can hear air escaping, there is a leak.
- The timing air can be shut off and then pressure applied to the cylinders with the indicator cocks open. If air is observed, then an air start valve is leaking.

96. Describe the maneuvering controls found on the starting platform of a large reversible diesel engine. Describe how it is reversed. (Camosun College Sample, 2011 Exam)

- Reed's Deck p. 82, Wharton p. 111
- In many ships, it is necessary for the main engine to be reversible and be able to operate efficiently in both directions.
- To run in the astern direction, all the operations in the engine cycle may need retiming.

- The starting air must first rotate the engine in the reverse direction and this will require retiming of the distributor to supply starting air to the cylinders on correct order.
- This can be done by repositioning distributor cams with respect to crankshaft.
- There are two cams for each valve, one is set so that its peak will lift the valve rocking lever to open the valve and keep it open for the correct period of the cycle when the engine is running in one direction.
- The other cam alongside is set for running in the opposite direction.
- The reversing mechanism is therefore arranged to bring either ahead or astern cams into line with the valve rocking lever as required.
- The action of one type of reversing gear is first to lift the rocking levers clear of the cams, slide the camshaft along so that its opposite cam comes into line and then return the rocking lever to its working position.
- The movement of the cams can be done by a hydraulic cylinder or servomotor.
- Locking devices and safety cutouts ensure that the cam is fully in position before starting can occur.
- Engine driven pumps must be reversible.

97. State the causes and means of preventing explosions in starting air lines and air receivers. (Limnos Sample, Camosun College Sample)

- Wharton p. 122
- Possible cause of an explosion in a high pressure starting air pipelines are:
    - Continuous leaking of a defective cylinder non-return valve while the engine is running
    - Or valve sticking in the open position when starting and stopping engine.
- Under normal operation, some lube oil mist may be discharged from the air compressor to the air start system.
- This oil may be from excess compressor cylinder lubrication, faulty oil scraper rings or contaminated from engine room atmosphere and drain through the air intake filter.
- Oil discharge is kept to a minimum by draining the aftercooler, air receiver and starting system.
- If small quantities of lube oil do get passed into the air start system, they will deposit as a thin moist film over internal pipes and surfaces but are not readily combustible.
- If a cylinder non-return valve should leak during engine operation, some hot gas possibly with unburned fuel and lube oil may be blown through this valve to the adjacent air manifold.
- With further heating, these deposits will carbonize and from incandescent carbon.
- If starting air is applied to the system while hot, the high pressure air may contact the carbon and cause an explosion.
- Such an explosion will cause a flame to pass back through the start air system, burning any oil film and generating shockwaves that may rupture fittings or the receiver.
- Alternatively, if excessive oil has entered the system, a mixture of oil droplets and air may be discharged through the open cylinder non return valve when starting.
- This spray may ignite due to high temperatures in the cylinder, causing a flame through the open valve to the manifold.
- To prevent an explosion, air start valves must be correctly maintained and lubricated to ensure correct timing and free movement with positive closing.
- Oil in the system must be kept to a minimum, pipes must be drained and cleaned and oil discharge from compressors must be kept minimum by good maintenance.
- To minimize effects of such explosions, air start manifold to each cylinder valve must be fitted with a flame trap and ample relief valves.
- Bursting caps or discs can also be used to relieve pressure.
- An isolating non return valve is fitted at the outlet from the main control valve.
- Air compressor explosions can occur when excess oil results in carbon deposits on discharge valves, pipes and intercoolers. Under excessive temperatures, these deposits become incandescent and give off vapors and ignition results.
- They are prevented by frequently draining grit, dirt, water or other impurities from the air.
- Intercoolers also remove heat of compression, moisture, oil vapors and carbon particles and are also drained off regularly.

Compressors:

98. How many compressors would be installed in the engine room of a single screw motor ship? Why? How would they be driven? (Limnos Sample, Camosun College Sample)

- There must be at least two starting air compressors, each capable of supplying all demands.
- One must have an independent drive for emergency use.
- Redundancy is necessary to allow for capability of charging the engine starting system at any time, for safety of the vessel.

99. What routine attention should be given to air compressors and intercoolers? (Limnos Sample, Camosun College Sample)

- Routine maintenance for compressors:
    - Regular draining of condensate
    - Lube oil kept at proper level and is of proper type. Changed at manufacturers specifications or when dirty.

- Valves must be resurfaced regularly due to constant pounding.
- Valve lift must be kept to specification.

100. What inspection and testing is carried out on air compressors? How would you prepare such a compressor for inspection and testing? Which parts would you check? What would you check after you finished? (Limnos Sample, Camosun College Sample)

- Wharton p. 107
- Before overhaul, the manufacturer's manual should be read and any special instructions adhered to.
- Ensure that all receivers are charged if necessary and other compressors are online.
- All systems must be totally locked out to compressor being worked on, including power, cooling water and any compressed air connections.
- The manual should give a procedure for dismantling.
- All parts should be cleaned upon removal and carefully inspected for condition.
- Crankcase is drained, oil strainer and internals cleaned.
- Lube oil pump overhauled and clearances checked.
- Cooling spaces are drained, opened, cleaned and inspected.
- Corrosion fittings or anodes are replaced if necessary.
- Cooling water pump is overhauled with new bearings, glands, etc if necessary.
- Cylinder heads, bottom end and top end bearings, main bearings, pistons, piston rings, liners and wrist pins should all be check as per specifications.
- Lube oil passages should be cleaned and aligned properly.
- Suction and discharge valves, relief valves and Unloaders should be checked.
- Intercooler and after-cooler should be cleaned and inspected.
- Overhaul electric motor.
- After boxing up, the water side should be checked for leaks.
- Oil should be refilled.
- Compressor should be barred over with drains open.
- All connections should be checked again for tightness.
- Run compressor for ten minutes with drains open.
- Shut off and check bearings for heat. Check for proper cooler flow.
- Check pressure gauges and alarms and automatic operation.

101. How are air compressors lubricated (bearings, cylinders, etc)? State what parts are lubricated and the possible results if over lubrication were to take place. What kind of lubricating oils are used and state the flash point. (Diesel Duck, Limnos Sample, Camosun College Sample)

- Air compressor explosions can occur when excess oil results in carbon deposits on discharge valves, pipes and intercoolers. Under excessive temperatures, these deposits become incandescent and give off vapors and ignition results.
- Since air compressors run at high temperatures, the correct viscosity must be maintained to ensure oil is distributed properly by will also maintain a good layer strength to prevent wear.
- High pressure will also have to be dealt with so the oil must maintain this film strength in spite of this.
- The oil must also be able to deal with water content and still maintain lubricating properties.
- Air compressor oil should have:
  - High grade blended oil
  - High flash point
  - Low viscosity
  - Good stability
  - Non-emulsifying
  - No carbon residue (to prevent fires)
- Oil deposits must be prevented, especially on coolers.
- Observe air temperature is not getting too high.
- Drain moisture regularly.

102. Describe an intercooler, naming all its fittings and safety devices (drains, bursting disc, safety valves and pressure gauges) suitable for a multi-stage air compressor. State the materials from which the fittings made. What is the purpose of an intercooler? What are the temperatures of air entering and leaving cooler? (2006 Exam, Limnos Sample, Camosun College Sample)

- Purposes of intercooling:
  - Reduce volume of air so less work is needed to compress it (try for isothermal compression)
  - Reduces moisture in air

- Can be cooled by water or air but mainly water for larger machines.
- Contains banks of copper/cupro-nickel/aluminum bronze tubes through which the air passes.
- These are expanded into a naval brass tube plate.
- If straight tubes are used, a header is required to permit thermal expansion.
- If u-tubes are used, the air makes two passes and tubes are free to expand.
- A cast iron or cast brass outer casing permits circulation with cooling seawater.
- Compressed air circulates inside tubes unlike engine air intake intercoolers.
- The relief valve should be fitted to the air connection, set for no higher than 10% above normal pressure.
- To protect the water side, bursting discs are fitted to relieve excess pressure in the water casing if an air tube fails.
- Little maintenance is required. Correct temperatures and adequate water circulation must be maintained.
- Drains valves should be opened frequently to purge water and oily sludge and when the compressor is shut down.
- Drains may be automatic for larger compressors.
- Automatic water valves are fitted to admit cooling water only when compressor is running to prevent overcooling and the resultant condensate.
- During overhaul, cooler must be checked and cleaned.
- The effect of operating with dirty intercoolers would be:
    - Higher air temperature
    - Lubrication difficultly in compressor
    - Efficiency will drop
    - Risk of explosion due to possible overheating.
- The maximum air temperature at compressor discharge must not exceeds 93C and a fusible plug or alarm may be fitted.
- Intercooler pockets and drain valves allow removal of moisture condensed during cooling together with any excess lube oil mist carried over in the air.

103. Describe a multi-stage air compressor. Give the materials used in its construction including cylinders, pistons and suction/deliver valves. Give the approximate temperatures and pressures of the air passing through the compressor at each stage. What provisions are made against overheating and excessive pressure? Where are drains fitted? (Diesel Duck, Limnos Sample, Camosun College Sample)

- Reed's MEK p. 145, Wharton p. 106
- Reciprocating air compressors at sea are generally two or three stage types with inter stage cooling.
- Pistons may be trunk or crosshead type and may be of tandem type (one on top of other).
- Compression and oil control rings are fitted to the pistons.
- Cylinders and heads are either air or water cooled.
- The second stage (HP) has smaller piston and cylinder to further pressurize air.
- The pressures and temperatures at various points would be: (for cooling water temp of 16C)
- Each stage has light, spring loaded non return suction and deliver valves of low inertia stainless steel plates.
- Limited lift reduces hammering and will create high air velocity to maintain cleanliness.

| Stage | Delivery Pressure | Air Temp before Cooler | Air Temp after Cooler |
|---|---|---|---|
| First | 4 bar | 110C | 35C |
| Second | 16 bar | 110C | 35C |
| Third | 40 bar | 70C | 25C |

- Fitted after each cooler is a drain, which is essential to rid inevitable condensation. Especially important in high humidity areas. All drains must be opened regularly to drain water.
- Air intake is fitted with a filter to prevent entry of foreign matter, much of which is abrasive.
- Filter should be regularly cleaned and changed when necessary and the compressor must never be run without one fitted.
- If this were to be allowed to enter compressor, it will combine with the lube oil to form an abrasive paste that increases wear on piston rings, liners and valves.
- The paste can adhere to the valves and prevent them from closing properly, which is turn can lead to higher discharge temperatures and the formation of harmful deposits on valves, etc.
- These deposits can become extremely hot on valves and could act as ignition points for air-oil vapors, leading to possible fires and explosions in the compressor.
- After each stage of compression, a relief valve will be fitted.
- Bursting discs or some other relieving device are fitted to the water side of coolers in the event of an air tube bursting and pressurizing the cooler. This will protect the cooler from hydraulic shock.
- Most modern diesels can start at a pressure of about 26 bar and a two stage compressor can adequately provide this.

| Stage | Delivery Pressure | Air Temp before Cooler | Air Temp after Cooler |
|---|---|---|---|
| First | 4.67 bar | 130C | 35C |
| Second | 26.67 bar | 130C | 35C |

- Drains should be fitted and they should be open when starting, intermittently when running and again on shut down. The automatic unloader may accomplish this at start and shut down.

104. Why are air compressors constructed to compress air in two or three stages in preference to compressing it in a single stage? Explain how excessive piston end clearance reduces the volumetric efficiency of an air compressor. Using a line diagram, sketch and describe an automatic system for compressor unloading. Why are automatic un-loaders fitted? (CCGC Sample, Limnos Sample, Camosun College Sample)

- Reed's MEK p. 141, Wharton p. 109
- Multi-staging with a number of separate pistons will give:
    - Mechanical improvements of compressor load and balance
    - Reductions is size and mass
    - Robust construction of smaller high pressure parts
    - Reduction in clearance volume losses.
- Compressors are constructed to compress air in several stages in order to help with efficient, isothermal compression.
- Cooling in between stages allows more air to be compressed with less work since cooler air is denser.
- Cooling helps maintain safer temperatures that reduce stress on piston rings, piston and cylinder.
- Helps lubrication and adds safety to the system.
- Unloaders are fitted with a constant speed motor driven compressor.
- They permit greater flexibility in operation and capacity.
- The compressor can start in the unloaded condition, thereby reducing starting torque on motor.
- Unloaders commonly on the suction side of compressor. If the compressor receives no air, it cannot deliver any.
- Often a solenoid valve on a timer that will remain open until the compressor is started and running at its operating speed.
- Volumetric efficiency is the proportion existing between the mass of suction air contained in the cylinder at the start of the compression stroke and that mass of air evacuated from the cylinder swept volume. Normal value about 90%.
- Excessive piston end clearance will reduce the volumetric efficiency of a compressor due to the fact that less air will be swept out of the cylinder each stroke.
- The extra high pressure will remain in the cylinder and require more work to be flushed out.
- It will take more time to open the suction valves that open due to vacuum under atmospheric pressure.

105. Sketch and describe a compressor delivery valve. Show how the valve is closed. (Camosun College Sample)

- Reed's MEK p. 149
- Valves used in air compressors are commonly simple disc valves with a light spring load.
- When this type of valve is used, the valve seat, disc and spring are often fitted to the cylinder as one unit.
- This allows servicing of the valves without disturbing the cylinder head and replacement of valve components when they become worn without replacing the head.
- A good seating surface must be maintained between the valve seat and cylinder head, if leakage occurs here the compressor efficiency will be greatly diminished.
- The valve seat securing system and the landing surface between the seat and head must be carefully inspected regularly.
- Valves require resurfacing from time to time due to the constant pounding they undergo in service.
- The valve lift must be maintained to specification after resurfacing is carried out.
- Valve discs should be inspected for warpage and overheating and they should be replaced when defective.
- Fouling of valves indicates an abnormal operating condition and the cause of the symptom should be tracked down and repaired before putting the compressor back in service.
- Faulty valves are indicated by changes in temperature and pressure between stages and by changes in operating characteristics.
- Valve leakage tends to lead to a loss on efficiency and increased running time.
- Valve seat is made of .4% carbon steel hardened and polished on working surfaces.
- Valve is either nickel steel, chrome vanadium steel or stainless steel that is hardened and ground, then polished to a mirror finish.
- Spring is hardened steel.

106. How is a blower different than a compressor? (Camosun College Sample)

Receivers:

107. Describe an air receiver. State the materials of which it is made. Name all its fittings, their purpose and their location. What is the working pressure of this receiver? What are compensation rings and why are they fitted? (CCGC Sample, Limnos Sample, Camosun College Sample)

- Reed's MEK p. 153, Wharton p. 105
- Air receivers are used to store compressed air for starting engines and to supply auxiliary air for other vessel needs.
- Air is normally stored at about 30 bar for engine starting, there may be reducing stations to feed other systems with lower pressure.
- Two receivers are normally fitted with enough capacity for 12 starts of a reversing engine and 6 starts of a non-reversing engine.
- Material used in construction must be good quality low carbon steel similar to that used for boilers.
- .2% max carbon, .35% max silicon, .1% manganese, .05% max sulphur, .05% max phosphorus.
- They are normally cylindrical in shape with dished ends and must meet all regulations for pressure vessels.
- Welded construction has superceded riveted types and welding must be done to class 1 or class 2 depending on operating pressure. Above 35 bar = class 1.
- Welding must be radiographed, annealing must take place at 600C and a test piece must be provided to bend, impact and tensile tests together with microscopic examination.
- Compensating rings are necessary to strengthen areas that have had holes cut for connections. These are doubler plates welded in to strengthen joint.
- Before filling after inspection, receiver must be checked for anything left inside, especially rags or oil.
- All inspection hatches must be centered and tightened in place.
- Run the compressor with drains open to flush out any contaminants.
- Check for leaks and tightness of hatches and fittings.
- Interior is coated with anti-corrosion treatment that is checked and patched regularly.
- Fittings:
    - Stop valves allow slow opening to gradually charge system.
    - Piping to starting air has flame guards and non return valves to prevent air start explosion.
    - Drains for accumulated oil and water are fitted to the compressor, filters, separators, receivers and lower parts of pipe lines. Must be of sufficient size to prevent choking by sediments.
    - Safety valve.
    - Pressure gauge – must be directly connected. Pressure gauges should be checked for calibration.
    - Filling valve from compressors – must be independent
    - Auxiliary stop valves – ship's whistle, pneumatic control systems, etc.
    - If it is possible for the receiver to be isolated from the safety valve, then it must have a fusible plug fitted with discharge external to engine room. Plug will melt at approx. 150C.
    - Manholes for inspection with flat gasketed edges.

108. Name at least 5 methods of non-destructive testing that could be used on an air receiver. Describe one of these tests. (Camosun College Sample)

- Non-destructive tests that can be done to check integrity of steel are:
    - Liquid penetrant with ultra-violet light
    - Radiography
    - Ultrasonic testing

109. Describe a hydrostatic test. What pressures are used? (Camosun College Sample)

- Pressure vessel blanked off and filled with water. Air pressure tops pressure up to 150% for a designated amount of time.
- Pressure gauge should hold to show that vessel does not leak.

110. What factors govern the selection of a safety valve for an air receiver? (Camosun College Sample)
111. Name all the safety valves and relief valves on board ship. What are they for and how are they adjusted? What regular service is given to them and what is inspected when they are overhauled?
112. Describe a safety valve for an air receiver. State the materials used in the construction of the safety valve and how you would go about adjusting the safety valve. State and locate all mountings fitted to an air receiver. (2008 Exam)

- Wharton p. 105
- The safety valve must be set to relieve the receiver of excess pressure rise and must have sufficient area to prevent accumulation of pressure for any reason.

113. What maintenance and checking does an air storage bottle require? What is done to prevent corrosion? Why does corrosion take place in air bottles if this is not done? (Pacific Region Sample, CCGC Sample, Limnos Sample)

- Interior is coated with anti-corrosion treatment that is checked and patched regularly.
- Draining of condensation frequently.
- Moisture and air together on surface of steel will cause oxidation.

Control system:
Diesel engine controls, protective devices and remote sensing and monitoring

Controllable Pitch Propellers:

114. Describe a main propulsion system for a ship using a variable pitch propeller. How is the ship reversed? Describe how the blades are operated. How is the ship's speed and reversing controlled?

- McGeorge MAM p. 277
- The pitch can be changed to alter ship speed or direction thereby allowing the engine to be unidirectional.
- Controllable pitch propellers are normally fitted to a flanged tail shaft and the operating mechanism is housed in the propeller boss.
- This change in pitch is effected by rotating the blades about their vertical axes, either by hydraulic or mechanical means.
- This allows a shaft generator to be run due to constant engine speed.
- In a hydraulic unit, the blade pitch is altered by a servomotor piston housed within the hub body.
- The piston moves in response to the difference in oil pressure on its ends.
- Oil flow to and from the servomotor is controlled by a slide valve in the piston rod.
- The slide valve is part of a hollow rod that passes through a hole bored in the propeller shaft and is mechanically operated by levers in the oil distribution box.
- When the piston moves, a crosshead with sliding shoes moves with it.
- A pin on a crank pin ring, attached to each propeller blade, located in each of the sliding shoes, so that any movement of the servo piston causes a pitch change simultaneously in the blades.
- Oil is provided at about 40 bar from an electrically driven pump that has a standby.

115. Describe in detail the procedure you would follow to start and warm up a direct drive diesel fitted with a controllable pitch propeller. (CCGC Sample)

- Reed's Deck p. 809
- It is good practice to warm a diesel to make starting easier and minimize corrosion, wear, thermal shock and damage due to unequal expansion.
- Ensure jacket water is heated sufficiently. The reservoir or block is fitted with a heating element and pump to circulate water to get temperature up to about 70C.
- The water circulates through cylinder jackets, pistons, cylinder heads, etc.
- In engines burning heavy fuels, the fuel valves and pipe lines must also be heated before starting. The temperature depends on viscosity required.
- The cooling circuit for the fuel valves may be independent and may use water or a fine mineral oil. It will also have a reservoir fitted with a heating element.
- Some oil pipes may be steam jacketed or have a small bore heating line wrapped around them to heat the cold oil standing in the pipes.
- A small pump may also circulate heated oil within the fuel system.
- Failure to heat oil will prevent engine from starting.
- Start pre-lube pump and check pressures.
- Turn the engine over to check it is clear all around.
- Prime fuel system.

Governors:

116. Name two types of governors. Explain the operation of each type. What is the purpose of each? What might be the results if a governor failed to operate? (Camosun College Sample)

- Two types:
    - Mechanical hydraulic
    - Electronic
- Many engines are fitted with mechanical-hydraulic governors.
- They use a hydraulic servo-piston that creates sufficient power to operate the engine fuel pump controls without any loss in sensitivity of the mechanical speed-sensing ball-head.
- Hydraulic pressure is taken from the engines lube oil system or from a separate gear pump operated by the governor drive.
- This is usually preferred as it allows the governor oil to remain clean.
- It will require oil pressure boosters, charged from the starting air system to ensure sufficient power to manipulate the engine fuel pump controls when starting from rest.
- The ball-head consists of two identical, eccentrically pivoted flyweights mounted on opposite sides of a rotating sleeve.
- Speed of rotation is proportional to engine speed and may be direct drive from the camshaft or through a step up gear to increase governor speed and sensitivity.
- Dampers are fitted in the drive to reduce any torsional vibrations.

- A crank on each flyweight bears on a sliding compression plate, which is held in equilibrium between forces from the flyweight and a compressive force from the governor speeder spring.
- A conical spring is used to give a more effective relationship between spring force and centrifugal force on flyweights.
- If the engine speed slows, the centrifugal force on the flyweights decreases allowing the moving sleeve to be lowered by the spring.
- If the engine speed increases, the centrifugal force increases and the flyweights raise the sleeve.
- If the engine speed slows, forces on the ball-head move the piston down, uncovering the port an allowing oil pressure to pass into the servo system.
- The pressure acts on the buffer piston forcing it to the right, displacing oil on that side and raising the power piston, which will raise the fuel pump settings.
- Simple electronic control systems can be designed to carry out the functions of a governor including capabilities to control:
    - Load sharing
    - Synchronizing
    - Power sensing
- They may readily be incorporated as part of an overall control system to include:
    - Starting and stopping procedures
    - Avoiding critical speeds
    - Prevent overspeed
    - Other safety measures
- A speed sensor such as a magnetic pickup transmits a signal representing the actual engine speed and this signal is compared to the desired value.
- The error in these is amplified and passed to a controller and actuator that generates sufficient mechanical force and power to operate the engine pump controls.

117. What types of governors are used on diesel engines? Describe what is meant by the hunting action of governors. What is installed to prevent hunting of a governor and how does it work?

- Wharton p. 113
- A governor automatically controls engine speed by regulating fuel supply.
- Modern practice requires a governor to be sensitive to small changes in speed and then be capable of returning the engine to a set speed.
- This allows fuel economy and ability to run electric generators or shaft generators.
- Four types of governors are commonly used in diesels:
    - Constant speed (isochronous) – maintains engine at a set speed, irrespective of changes in load and power
    - Variable Speed – ability to adjust speed on governor
    - Speed Limiting
    - Load Limiting
- Hunting is defined as the fluctuation of the governor.
- Centrifugal governors are not suitable for driving alternator engines because they cannot be made truly synchronous (constant speed).
- Droop is the fall in speed of an engine when load is applied, usually around 5%.
- Governor spring normally conical as this gives a more effective relationship between compression force and centrifugal force on the flyweights.
- To indicate the load limit of an engine, limits of exhaust temperatures, water temperatures are taken from test data and most governors have built in load limiting devices.
- The governor should be situated as close as practical to the fuel pump, limiting the mass/inertia of the operating linkage.

118. What is racing and over speeding of a diesel engine? What are the causes of these conditions in a main engine? What damage may result from racing and over speeding and what methods are used to prevent this? (2006 Exam)

- Wharton p. 116, McGeorge MAM p. 239
- Over-speed trips are fitted since governors may not act quickly enough in an emergency or may fail during operation.
- Overspeed occurs when the load is suddenly thrown off and the governor cannot bring the engine speed down fast enough.
- Trips should act independently of the main speed governor and in the event of over-speeding, will immediately cut power to the engine.
- This is accomplished by wither raising the fuel pump plunger followers clear of the cams or by opening fuel suction valves. Either of which will cut fuel to cylinders.
- Cutouts are fitted to each pump and they can also be used to shut fuel off of an injector without affecting the rest of the system.
- Power to operate the emergency system may be electrical, pneumatic or hydraulic.

- Any override of the overspeed trip can only be carried out manually at the engine.
- A common type works by interrupting oil flow to the low oil pressure cutout switch that shuts the engine down.
- An unbalanced steel valve, located in the pinion shaft extension, is held on to the valve seat by a helical spring while the engine is below tripping speed.
- If the speed increases 10-15% above the engine rated speed, the centrifugal effect on the valve overcomes the spring force and the valve lifts from its seat.
- This allows lube oil fed to the valve to escape and pressure to the oil pressure cut out falls.
- This trips the fuel rack to zero delivery and the engine stops.
- The overspeed must be reset locally for the engine to start again.
- This trip should be tested regularly.

119. Describe a governor you are familiar with. Explain how it operates and why it is fitted to the engine. (2008 Exam)

- Taylor p. 35, Wharton p. 116
- The principal control device on any engine is the governor.
- It governs or controls the engine speed at some fixed value while power output changes to meet demand.
- This is achieved by the governor automatically adjusting the engine fuel pump settings to meet the desired load at the set speed.
- Governors for diesel engines are normally made up of two systems:
    - A speed sensing arrangement
    - Hydraulic unit that operates the fuel pumps to change power output.
- Mechanical governor:
    - A flyweight assembly is used to detect engine speed.
    - Two flyweights are fitted to a plate or ball head that rotates about a vertical axis driven by a gear wheel.
    - The action of centrifugal force throws the weights outward, this lifts the vertical spindle and compresses the spring until an equilibrium situation is reached.
    - The equilibrium position or set speed may be changed by the speed selector that alters the spring compression.
    - As the engine speed increases, the weights move outwards and raise the spindle, a speed decrease will lower the spindle.
    - The hydraulic unit is connected to this vertical spindle and acts as a power source to move the engine fuel controls.
    - A piston valve connected to the vertical spindle supplies or drains oil from the power piston that moves the fuel controls depending on the flyweight movement.
    - If the piston valve rises due to an increase in engine speed and oil is drained from the power piston. This results in a fuel control movement by reducing fuel supply to slow engine down.
- Electric governor
    - Has proportional control and reset action, with addition of load sensing.
    - Uses a combination of electrical and mechanical components in its operation.
    - The speed sensing device is a small magnetic pick-up coil with a rotating permanent magnet.
    - No slip rings or brushes, so limited wear.
    - Speed signal is AC voltage impulses that is rectified to DC voltage signal.
    - This voltage is proportional to the speed and is compared to the desired operating speed, that is also a DC voltage.
    - The two voltages are connected to the input of an electronic amplifier.
    - If the two voltages are equal and opposite, they cancel and there will be no change in amplifier voltage output.
    - If they are different, then the amplifier will send a signal through the controller to the electro-hydraulic converter that will operate a hydraulic servo-motor to move the fuel rack to control the engine speed.
    - In order that the system be isochronous the amplifier-controller has internal feedback.

120. Sketch and describe an inertia type governor. Would this governor be more suitable for a ship service generator or main engine? (Camosun College Sample)
121. Describe a governor suitable for a generator. Name another type of governor fitted to the main engine. How does it operate? Would the governor suitable for a main engine also be suitable for a generator governor? (Limnos Sample)

Management of Diesel engines:

Operation and maintenance of diesel engines, determination of engine power

122. Explain how you would take over the watch on a motor ship. Mention what gauges (pressures and temperatures) and soundings you would note to satisfy yourself that everything was in order. (2008 Exam, Camosun College Sample)

- Check day tank fuel level; ensure it is constantly filled with purified fuel.
- Check lube oil pressure and temperature gauges and level.
- Check cooling water pressure, temperature and level.

- Check pyrometers to see if all cylinder are firing evenly and not overloaded.
- Check for indications of a hot bearing and crankcase mist level.
- Drain air start tanks regularly.

123. Describe the general location and purpose of all the auxiliary machinery, including that required to service the main engines, found in the machinery spaces of a motor ship. (TCMS Sample)

- The auxiliary machinery found in the machinery spaces of a motor ship are:
    - Compressed air system – compressors are used to provide pressurized air to start engines, emergency air compressor (battery or hand start)
    - Fuel system – purifiers, transfer pumps, filters, heaters to clean, treat and move fuel from storage and settling tanks to the engines for combustion
    - Seawater cooling water pumps
    - Preheat circulation pumps and heaters
    - Pre lube pumps
    - Bearing oil pumps

124. Define IHP and BHP, giving a brief description of the methods employed to find them. (Diesel Duck)

- Taylor p. 15, Wharton p. 21
- Indicated power = power developed in the cylinders. Found with indicator cards for each cylinder and then added together.
- An indicator card diagram is a pressure/volume graph taken from the cylinder of a working engine.
- It is plotted as a continuous line showing all pressure changes during one complete engine cycle.
- For some slow speed engines, it is possible to obtain indicator diagrams from each cylinder by using an engine indicator.
- An engine indicator is made up of a small piston of known size that operates in a cylinder against a specially calibrated spring.
- A magnifying linkage transfers the piston movement to a drum on which is mounted a piece of paper.
- The drum oscillates under the pull of the cord.
- The cord is moved by a reciprocating mechanism that is proportional to the engine piston's movement in the cylinder.
- The stylus draws out an indicator diagram that represents the gas pressure on the engine piston at different points in the stroke.
- Corresponding cylinder swept volume is recorded on a horizontal scale due to rotation of the drum.
- By turning the indicator cock to a vent connection, a horizontal line representing atmospheric pressure is added to the diagram. This can act as a pressure datum line.
- Irregularities in the shape of the diagram will show operational faults.
- Four types of indicator diagrams can be obtained:
    - Power card
        i. Indicator drum is in phase with piston movement
        ii. Can find power or mean indicated pressure
        iii. The area of the indicator diagram produced represents the power developed in the particular cylinder.
        iv. The cylinder power can be measured if the scaling factors, spring calibration and some basic engine details are known.
    - Compression diagram
        i. Fuel is shut off to cylinder
        ii. Height of curve shows max compression pressure
        iii. Can show faulty rings, worn liner, poor scavenging, leaky exhaust valve, etc.
    - Draw card or out of phase diagram
        i. Fuel pump is engaged but indicator drum is 90° out of phase with piston stroke.
        ii. Illustrates more clearly pressure changes during combustion.
        iii. Fuel timing or injector faults can be detected.
    - Light or weak spring diagram
        i. In phase with engine but taken with a light compression spring fitted to the indicator showing pressure changes during exhaust and scavenge to an enlarged scale.
        ii. Can show faults with air exchange.
- The cylinder results are compared and used to balance load with adjustments to the fuel supply.
- Brake power = power available at shaft. IHP – friction power. Found with dynamometer.

125. Describe a dynamometer and explain how it is used to determine the brake horsepower of an engine. Having obtained the brake horsepower, how would you then determine the mechanical efficiency of the engine? (Limnos Sample)

- Taylor p. 16
- If the torque transmitted by a shaft is know, together with the angular velocity, then the power can be measured.
- Shaft power = torque x angular velocity

- The torque can be found by measuring the shear stress of angle of twist with a torsion meter.
- Mechanical Efficiency = BHP/IHP

126. Where do the highest heat losses take place in a diesel engine?

- Reed's Deck p. 83
- Approximately 60% of the heat from fuel is divided into losses.
- The highest losses are to exhaust (about 30%) and to cooling water (about 28%)
- The remaining 2% of heat is lost through radiation.

Inspection and Troubleshooting:

127. State several causes of a diesel engine failing to start. Explain how you would check out these faults and what action you would take to overcome them. (TCMS Sample, Diesel Duck, Camosun College Sample)

- Several causes for an engine not to start are:
    - Not enough starting air pressure
    - Battery not charged or not powerful enough.
    - Poor compression.
    - Air start system not distributing properly.
    - Safety trips have not been reset properly.
    - Engine not warm enough to develop sufficient combustion.
    - Fuel system not primed.

128. What steps should be taken when (a) knocking in crankcase is heard, and (b) when smoke is discovered issuing from openings in the crankcase, and why?

- Wharton p. 125
- If knocking in the crankcase was hear, this could be indicative of a major problem. The bridge and Chief should be informed right a way and the engine slowed and stopped if possible.
- Sudden, loud noises indicate the breakage of parts and may cause overheating.
- The engine should be left to cool for 30 minutes to cool down, with the turning gear running so that parts will not seize and to prevent a crankcase explosion.
- When safe, the engine start system should be locked out and the inspection doors removed to check for source of sound.
- It could be a worn bearing, worn camshaft gear, overheated bearing or gland, slack crosshead guide.
- Could be a result of misalignment or the breakage of bolts, studs or other fixtures.
- Piston cooling system noises include water hammer or knocking from pipes or glands.
- Lubrication faults of insufficient oil pressure, failure or choking of connections or passages, reduction in lubricating properties due to excessive temperature or deterioration, and jets of oil splashing against fast moving surfaces will add to the noise level.
- Overloading the engine or early ignition will transmit shock loads through the running gear and bearings.
- In trunk engines, additional noise may be heard in the event of blow by or an overheated piston or liner.
- If smoke was seen exiting from the crankcase, the engine should be slowed as soon as possible and stopped when it is safely cooled down.
- The doors should not be open until all parts have cooled (at least 30 minutes) so that an inrush of oxygen will not cause a crankcase explosion.
- It could be excessive blow-by in one or more cylinders causing smoke to exit from the cylinders down into the crankcase.

129. A diesel engine has been completely overhauled. What precautions would you take before starting it up? What checks would you make on cooling water and lube oil systems?

- Before starting a recently overhauled engine, many checks must be made.
- The manufacturer's manual should be consulted for a special procedure.
- The cooling system should be fully charged and checked for leakage. If OK, then heat should be applied and FW should be circulated to warm up the engine block. Constant checks for leaks should take place during warming.
- The lube oil should be changed or if not, the sample should prove that it is OK for further use.
- This system should also be charged with a pre-lube pump that will circulate oil throughout the system and flush sediment from working on the engine. The filters and strainers should be cleaned after flushing through for a day or so.
- Oil leaks should be investigated and fixed if present.
- The fuel system should be charged and primed. Air to be bled from the system.
- A check should be made that any foreign material such as rags or tools is out of the engine.
- The indicator cocks should be opened and the turning gear engaged to rotate the engine very slowly to ensure it is free to turn.
- After start up, the bearings should be checked to ensure they are not hot.

- Oil should be changed and filters cleaned sooner than a normal cycle due to presence of break in particles and dirt from the rebuild.

130. Explain how you would go about preparing a large diesel engine for inspection after a long voyage. What parts would you inspect and what defects would you be likely to find? Suggest a remedy for some of these defects. (Camosun College Sample)

- After a long voyage, a propulsion engine should be inspected and necessary maintenance performed in order to prevent possible trouble when underway and the conditions are less controlled.
- After the engine has cooled, the air start system should be locked out to prevent an accidental start during maintenance.
- The turning gear should be engaged unless work is taking place, when it too should be locked out to prevent accidental turning.
- Fuel system should also be locked out and anything else that could cause a hazard to personnel working on the engine.
- The manufacturers manual should be consulted to see what maintenance and parts may be required for hourly or calendar based maintenance that is soon due. Order parts well in advance and ensure inventory levels are kept up.
- The crankcase inspection doors should be opened up and inspection should take place looking for anything out of the ordinary.
- Crankshaft deflections should be taken to confirm main bearings are in acceptable condition.
- Injectors should be pulled, tested and replaced/rebuilt as necessary.
- Oil should sample and analyzed.
- Valve clearances should be checked and adjusted as necessary.
- Scavenge spaces should be cleaned of carbon and inspected.
- Timing marks should be checked.
- Coolant condition should be analyzed.
- Hold down bolts should be hammer tested and checked for proper torque.
- Air start valves should be inspected.
- Cylinder relief valves should be checked.
- Alarm and shut downs should be inspected and tested.

131. Explain what you would do as engineer in charge of the watch after a diesel driven ship docked and the telegraph had rung finished with engines. (Camosun College Sample)

- After the wheelhouse is finished with the engines, it is the engineer's duty to begin to safely shut down propulsion machinery.
- Propulsion control can be transferred to the engine room.
- Steering motors should be shut off.
- Thrusters and shaft generators can be shut down and switched to ship service generators.
- Engine should be cooled down off load long enough to prevent hot spots and for the turbocharger to stop rotating.
- Once cool, the engine can be shut off and the turning gear can engaged temporarily to cool bearings down slowly.
- The controllable pitch propeller system can be shut down.
- The bearing pumps can be shut off.
- Intake and exhaust fans can be slowed down when engine room has reached proper temperature.
- Jacket water heaters and circulation pumps can be turned on.
- Air start system can be locked out for maintenance depending on the standby time given by the bridge.

132. The exhaust temperatures in the cylinder of a four-stroke engine are:

- Cylinder 1 470, Cylinder 2 520, Cylinder 3 600,
- Cylinder 4 420, Cylinder 5 620, Cylinder 6 490

What would you assume the trouble to be and how would you rectify it?

- Exhaust temperatures are a good indicator as to how well a cylinder is running in comparison with the rest of the engine.
- This engine seems very imbalanced and each cylinder is providing a different amount of power.
- I would suspect something is very wrong and recommend a shut down before an overload or more serious damage occurs.
- Due to the variance, I would suspect the engine has somehow slipped its proper timing. I would check this first. Normally there is a timing mark on the flywheel and fuel pump that are aligned as per the manufacturer specification. If it is a timing chain, then it is possible it has slipped a link.
- If driven by gear, perhaps a tooth has been damaged or the coupling bolts are loose.

133. The exhaust temperatures at port are:

- Cylinder 1 400, Cylinder 2 400, Cylinder 3 350,
- Cylinder 4 400, Cylinder 5 450, Cylinder 6 400

What are the possible causes and how would you correct the issue? (Diesel Duck)

- Looks like cylinder 3 is under producing power and cylinder 4 is over producing power.
- This is causing an imbalance in exhaust temperatures that could lead to problems due to overheating and bearing wear.
- If possible, I would shut the engine down and pull the injectors to those cylinder to check they were operating correctly.

- If the injectors were in good shape, I would check valve tappet clearance for the engine to ensure they were opening and closing correctly.
- The camshaft and fuel pump should then be checked to see if they are timed properly.

134. What causes would result in a major breakdown of a diesel engine? Describe a serious breakdown with which you are familiar. What was the cause of the breakdown, what was the extent of the damage and what was done to get the engine running again?

- A major breakdown of a diesel engine could occur due to many conditions:
    - Loss in lubrication causing a bearing to wipe or piston to seize
    - Valve contacting piston
    - Connecting rod splitting from bottom end.
    - Crankcase explosion
    - Scavenge fire

135. What would the effect on a diesel be with the following conditions: (Diesel Duck, Camosun College Sample)

- Water in fuel
    a. This reduces the calorific value of fuel. It will be harder to combust properly and the engine may start to misfire. There will be a power loss and excess white smoke (steam). Will also cause loss in lubrication due to water washing of the cylinders. Acid may also be created if sulphur is present, this can cause corrosion.
- Leaky fuel valve
    a. Causes afterburning of fuel and excess carbon build up. Black smoke should indicate this. If dripping, chances are the injector is not atomizing fuel. This will cause incomplete combustion and power loss.
- Fuel pump wrongly set
    a. Engine will not produce proper power due to incomplete combustion. May causing knocking due to early firing or after burning. Engine may sound different and will vibrate. Overheating could occur due to imbalance.
- Fuel valve sticking open
    a. Causes excess fuel into cylinders which can lead to afterburning, excess carbon build up, power loss and diesel knock. This could lead to scavenge fires.
- Unequal fuel distribution to each cylinder
    a. This will cause an imbalance in the system that will lead to overheating in some cylinders and possible bearing damage due to crankshaft stress fluctuations.
- Air in fuel pump
    a. Will cause unpredictable injection causing the engine to surge and lag. May air lock pump or injectors, which may cause the engine to stop. This will require bleeding of the air.
- Fuel valve lift insufficient
    a. For a common rail system, a fuel valve with insufficient lift will cause a reduction in fuel delivery. This will cause a loss in power and excessive white smoke.
- Leaky piston rings
    a. Will cause poor compression causing power loss. Will also cause blow-by of hot gases on sides of piston, which will cause loss of lubrication causing overheating and contamination of oil.
    b. This could lead to scavenge fires due to unburned fuel and oil in exhaust spaces, crankcase explosions and eventual engine failure.
- Choked lubricating system
    a. Will cause loss of proper flow and pressure of oil to bearing surfaces such as the liners and main bearings. This will cause excess wear and possible overheating.
    b. The bearings may be wiped or the moving parts may become seized, causing considerable engine damage.
- Oil too thick
    a. Will cause loss of proper lubrication flow causing the same issues as a choked lubricating system.

Power Balance:

Adjusting of fuel pumps, injectors, valves and power balancing of diesel engines

136. State the causes of loss of power in a diesel engine and state how to remedy them.

- Some parameters that will give an automatic reduction in power in an engine equipped with monitoring are:
    - High scavenge temperature
    - High oil mist reading
    - Low piston cooling pressure or flow
    - High piston cooling temperature
    - Low jacket water pressure

- High jacket water temperature
- High exhaust gas temperature

137. What would the effect of too much clearance between a fuel valve cam and its roller? How is a fuel valve timed? What would the effect of a worn cam be? (Diesel Duck, Camosun College Sample)

- Too much clearance causes late valve opening, early closing, decreased lift and noisy operation.
- Too little clearance causes early opening, late closing, increased valve lift and may prevent complete closure.
- The effect of a worn cam would be improper and inconsistent timing.
- If the bearings are worn, the shaft will whip around and may this may cause overheating, excess torsional stress on shaft or shaft failure.
- If the cams are worn, the same effect as too much clearance would take place.
- Mechanical fuel valves are no longer in use.
- Timing is adjusted by changing the setting on the screw on the valve lifter or by varying the lifter fulcrum by adjustment of the eccentric sector shaft.

138. What is the purpose of a camshaft for a two stroke and a four stroke engine? What materials are used for fabrication? How are camshafts driven?

- Wharton p. 81
- Purpose of the crankshaft is to mechanically actuate the intake and exhaust valves and fuel pump (or valves), all of which control the engine cycle.
- The shaft is fitted with cams that raise the follower and push rod to operate a pivoted rocker lever. The other end of the rocker lever depresses the valve spindle through a tappet and causes the valve to open.
- The profile of each cam is designed to give the correct timing, speed and height of lift to its corresponding follower.
- Cams are made of steel with a hardened surface.
- May consist of several lengths bolted together at flanges with fitted bolts.
- The whole shaft must be supported by bearings with adequate lubrication.
- Camshaft rotation must be accurately synchronized with crankshaft and timing must be checked periodically and after any adjustment or repairs have been carried out.
- V-type engines require a separate cam for each bank of cylinders.
- Rotates at half engine speed for 4 stroke, same speed for 2 stroke.
- Also, they have fewer cams since they do not require air inlet valves and loop or cross scavenge engines do not need exhaust cams.

Automation and alarms:

General understanding of the basic operation of automatic controls, particularly with regard to definitions

139. Sketch and describe a cascade type controller used in the jacket water cooling system in a diesel engine. List 5 other types of controller systems associated with diesel engines. (2008 Exam, Pacific Region Sample)

- Reed's Deck p. 176
- Cascade type control is used when something large is to be controlled such as a high volume of water or a large thermal capacity.
- The two controllers are used in series.
- When used for controlling cooling fresh water (FW) in an engine, two variables are involved:
  - Engine load
  - Seawater (SW) Temperature
- First, consider fixed engine load, then controller B senses changes in temperature of FW and adjusts the SW flow through the cooler to keep cooling water inlet temperature at the engine to a desired value.
- Now, if the engine load changes, inlet water temp should change or the engine may become overheated or overcooled.
- If we assume the engine load decreases, then the FW outlet would decrease.
- Controller A would sense this change and alter the desired value of Controller B to a higher temperature setting.
- Controller A is the master and B is the slave.
- Five other types of controller systems associated with diesel engines are:
  - Fuel rack / speed governor
  - Data logger for alarm system
  - Piston cooling control
  - Lube oil control
  - Overspeed and safety cutouts
  - Automatic rundown to half speed for certain parameters such as high jacket water temp.

140. Define the following and draw a simple logging scanner circuit. (Diesel Duck)

- Reed's GEK p. 453, Reed's Deck p. 188, Taylor p. 318
- The term data logger is loosely used nowadays to describe a broad range of electronic systems that automatically collect and process data.
- Can also be defined as the production of measured variable information either automatically at set intervals or on demand.
  - Transducer
    - Used with sensors to detect system conditions in the plant such as pressure, temperature, flow, level, speed, power, and position.
    - Converts the small sensing signal into a readily amplified DC output, usually in a different form.
    - Designs can generally be simplified into 3 basic reversible types but the electrical output is the most common:
      i. Mechanical displacement – pneumatic
      ii. Mechanical displacement – electrical
      iii. Pneumatic - electrical
  - Scanner
    - Scans measuring points in a data logging circuit to collect information
    - Each measuring point is selected in turn by automatically connecting the input terminals for presentation to the measuring circuit
    - Can normally scan about 200 points at 2 points per second
    - Receives the DC outputs from the sensor transducers, which are analogues of the physical functions,
  - Feedback
    - Data fed from amplifier to analogue to digital converter and then the display unit, alarm system and controller to allow system control.
    - The controller would be programmed to process this information and give early indication of any possible malfunctions.
  - Tele-metering
    - The process of long distance control transmission.
    - The device at the measure point is the transmitter with the receiver located at the recording or control centre.
    - May be involved with centralized instrumentation such as display, alarm scanning, data logging, etc. or with remote control devices.

141. Explain with reference to a diesel engine the following control terms: (TCMS Sample)

- Reed's Deck p. 167, Reed's GEK p. 458, Taylor p. 298, Reed's MEK p. 121
- To control a device or system is to be able to adjust or vary the parameters that affect it.
- All forms of control can be considered to act in a loop.
- The basic elements present in a loop are:
    - A detector
        i. Obtains a signal related to the output and feeds it to the transmitter
        ii. From the transmitter, it is fed to the comparator
    - A comparator
        i. Will contain some set or desired value of the controlled condition that is compared to the measured value signal.
        ii. Any deviation will result in an output signal to a correcting unit
        iii. Normally built into the controller.
    - A controller
        i. Will then take action in a manner related to the deviation and provide a signal to a correcting unit.
    - A correcting unit
        i. Will increase or decrease its effect on the system to achieve the desired value of the system variable.
- Closed loop
    i. A system in which the control action is dependent on the output
    ii. The system may be manually controlled or automatic
    iii. Example: steering gear, boiler control, engine control, cargo control
    iv. The measured value of the output is being fed back to the controller, which compares this value with the desired value for the controlled condition if there is any deviation.
- Feed back
    i. The transmission of a signal that represents the controlled condition for comparison with a signal preset by the operator. This is used to determine the value of the controlled condition.
    ii. Feedback will increase accuracy and reduce sensitivity
- Desired value
    i. The value of the controlled condition that the operator desires to obtain
    ii. Examples: 2 rev/s, 25° of helm, 55 bar, -5°C