Mike's Guide

A study guide for
Transport Canada
2nd Class Marine Engineer
Written Examination

Engineering Knowledge Motor
(EK Motors) Exam

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Martin's Marine Engineering Page
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Topics Covered:

1. Construction of marine machinery
2. Internal combustion engine systems
3. Construction of internal combustion engines
4. Starting and reversing systems
5. Operation and maintenance
6. Defects and remedies
7. Auxiliary boilers
8. Compressed air systems
9. Power transmission
10. Lubricating systems

Construction of marine machinery

1. Sketch and describe a heat exchanger for fresh water on a seagoing vessel. Explain how to prevent sea water contamination. (Craig, Diesel Duck x 2, Notes)
    1. A shell and tube type cooler is often used to cool jacket water
        1. It is often a double pass arrangement where the seawater makes two passes through the length of the cooler as the freshwater makes one pass
            1. Straight flow (one pass for seawater) is common in small coolers
        2. The seawater passes through the tubes and the freshwater circulates around and over them
        3. Heat will be transferred from the freshwater to the seawater and passed overboard
    2. When designing a heat exchanger, a balance must be held between size, cooling efficiency, weight and pressure drop, as well as cost
        1. The exchanger must be compact but allowance must be made for partial fouling of the heat exchange surfaces
        2. Access must be available for cleaning
    3. A divisional plate separates the top and bottom of the inlet end horizontally
        1. The water will enter on bottom and be forced to pass through the lower half of the tubes before turning around and passing through the upper half of tunes and then exiting
    4. The freshwater inlet and outlet are both on top of the shell but at different ends
        1. Baffles are fitted to direct freshwater over all the tubes to ensure uniform heat exchange over all the tubes
        2. The baffles also support the tubes
    5. The water boxes (end bells) at the ends of the cooler are large enough to reduce any turbulence, the interior surfaces being coated to prevent corrosion and erosion
    6. Materials:
        1. Tube plates and baffles are naval brass
        2. Aluminum brass for tubes, stress relieved and tested
            1. 76% copper, 22% zinc, 2% aluminum
            2. Tubes are expanded into the plates and metal bonded to the plate
        3. The shell can be cast iron since it is not in direct contact with sea water
        4. The water boxes are coated cast iron
            1. Sacrificial anodes are fitted to protect cooler materials
    7. The inlet tube plate end is secured rigidly between the shell flange and water box flange, with gaskets in between
    8. The opposite is floating on lantern ring o-ring seals sandwiched between the shell and water box
        1. This allows for expansion due to heat
        2. Holes are fitted in the lantern ring to show which o-ring is leaking and avoid cross contamination
    9. Also to avoid contamination, the freshwater is run at a higher pressure than the seawater side
        1. A leak would be noticed with losses in the expansion tank

2. Sketch some type of shell and tube type of lubricating oil cooler, indicating the direction of oil and coolant flow. Name the materials used for components. What major faults are likely to arise with this equipment and how are these faults inhibited?
    1. The materials used:
        1. Shell – close grained cast iron, gunmetal or fabricated steel
        2. Water boxes and covers – rubber coated cast iron or brass
        3. Tube plates – naval brass
        4. Tubes – aluminum brass
    2. The inclusion of a tell-tale hole on the floating tube plate is to show any leakage past neoprene sealing o-rings
    3. Faults likely to arise are:
        1. Tube failure – due to corrosion or erosion
        2. Water box or cover leaks – corrosion
        3. Leakage past seals – requires careful installation, wear
        4. Air lock
        5. Plugged tubes
    4. To inhibit these faults:
        1. Tube failure can be reduced by use of sacrificial anodes that slow down corrosion
        2. Regular cleaning will slow down erosion by getting rid of silt
        3. Seals must be installed properly and replaced during maintenance to prevent leaks
        4. Air locks can be prevented by installing purge cocks
            1. Also by fitting cooler in vertical manner
            2. Cooler water should enter from bottom to flow in natural way (upwards) when heated
        5. The jacket water used to cool the oil should be treated to prevent corrosion and deposits
3. Sketch and describe a water jet used on a high speed craft. (Craig)
    1. A jetboat is a boat propelled by a jet of water ejected from the back of the craft.
        1. Unlike a powerboat or motorboat that uses a propeller in the water below or behind the boat, a jetboat draws the water from under the boat into a pump inside the boat, then expels it through a nozzle at the stern.
        2. There is no engineering limit to the size of jetboats, though the validity of their use depends a lot on the type of application.
        3. Classic prop-drives are generally more efficient and economical at low speeds, up to about 20 knots (37 km/h; 23 mph), but as boat speed increases beyond this, the extra hull resistance generated by struts, rudders, shafts (etc.) means waterjets are more efficient in the 20-50 knot range (up to 90 km/h; 60 mph).
        4. Also, in situations with very large propellers turning at slow speeds (such as tug boats), the equivalent size waterjet would be too big to be practical.
        5. For these reasons, the vast majority of waterjet units are installed in high-speed vessels and in particular situations where shallow draught, maneuverability, and load flexibility are main concerns.
    2. A conventional screw propeller works within the body of water below a boat hull, effectively "screwing" through the water to drive a vessel forward by generating a difference in pressure between the forward and rear surfaces of the propeller blades and by accelerating a mass of water rearward.
        1. By contrast, a waterjet unit delivers a high-pressure "push" from the stern of a vessel by accelerating a volume of water as it passes through a specialised pump mounted above the waterline inside the boat hull.
        2. Both methods yield thrust due to Newton's third law— every action has an equal and opposite reaction.
        3. In a jetboat, the waterjet draws water from beneath the hull, where it passes through a series of impellers and stators - known as stages - which increase the velocity of the water flow.
        4. Most modern jets are single-stage, while older waterjets may have as many as three stages.
        5. The tail section of the waterjet unit extends out through the transom of the hull, above the waterline.
        6. This jetstream exits the unit through a small nozzle at high velocity to push the boat forward.
        7. Steering is accomplished by moving this nozzle to either side, or less commonly, by small gates on either side that deflect the jetstream.

        8. Because the jetboat relies on the flow of water through the nozzle for control, it is not possible to steer a conventional jetboat without the engine running.

4. Sketch and describe a self-cleaning purifier. (Dave)
    1. Self-cleaning purifiers are fitted with a sliding bowl bottom that is raised or lowered by a water operating system for self-cleaning
        1. Manual cleaning may be preferred so that the solids can be examined and also because use may be intermittent and extra expense not justified
5. Describe any centrifuge separator (oil) that you are familiar with. Describe its operation. (Diesel Duck, Notes)
    1. The stainless steel bowl of up to .6m diameter is mounted on a tapered spindle
        1. The lower part of which is fashioned into a sleeve that passes over a stationary spindle
    2. The stationary spindle carries two ball races that are provided for the rotating spindle
        1. The upper bearing serves as a thrust bearing
        2. These bearings provide a high degree of flexibility
    3. The suction and discharge pump may be driven by an electric motor or geared to the horizontal spindle through a shear pin
    4. The wheel and worm drive for the centrifuge bowl is driven by an electric motor
        1. The bowl rotates under operating conditions at 5000 to 8000 RPM depending upon size
    5. Stainless steel conical discs carried by splines on the distributor are fitted to reduce the settling distance
    6. To operate the centrifuge as a purifier, it is first brought up to operating speed
    7. It is then supplied with fresh water to form the water seal
        1. This water prevents oil escaping from the water outlet
    8. Then the oil to be purified is delivered to the distributor by the inlet pump
    9. As the oil passes down the distributor, it is rapidly brought up to rotational speed by the radial vanes provided for this purpose
    10. The oil from the distributor passes through the space between the bottom plate and bowl to the supply holes in the discs
    11. Separation and clarification takes place between the discs
    12. The solid particles and water present are thrown off the conical plates into the outer confines of the bowl where the heavier particles accumulate
        1. The water and lighter sludge is discarded through the water outlet
        2. Clean oil will remain closer to the center of the bowl and exit through the oil outlet
    13. This type of purifier will work properly until the sediment space is full of solid matter
    14. Oil with lower viscosity is easier to purify due to less drag on particles so heating aids in the cleaning process
    15. Throughput should be limited to maximize purification time inside the bowl
    16. If the centrifuge is to be used as a clarifier:
        1. No water seal is necessary = no paring disc
        2. No supply and distribution holes
6. State the importance of having clean fuel oil going to the engine. How is fuel cleaned aboard ships? How is clean fuel ensured? (Notes)
    1. When residual fuel is used for diesel engines, it is necessary for it to be subject to a higher degree of purification in order to remove the large quantity of ash forming impurities
    2. If these impurities were allowed to reach fuel pumps and injectors, damage to the fine working surfaces will occur and deposits will occur in the combustion chambers and injector nozzles
    3. Settling tanks are used to remove water and heavy particles that sink to the bottom of the fuel to the valves located at the bottom of the tanks, which are opened to allow flow to the dirty fuel tanks
    4. Coarse and fine filters are also fitted to catch any solids
    5. Centrifuges, both a purifier and a clarifier are used to remove water and impurities
        1. The oil when passing through the centrifuge is subject to a very high centrifugal force and is split up into fine layer between the rotating disc stack and any moisture or solids that are heavier than the oil are thrown outwards
        2. The water and solids gather here in the purifier inner bowl surface and are discharged out the water outlet while the lighter clean oil exits out the fuel outlet close to the center of the bowl
        3. A centrifugal clarifier is used in series and after the centrifugal purifier to further separate harmful particles
        4. The clarifier requires no water seal, therefore can subject a higher centrifugal force on the oil and increase the separation working surface

    5. The clarifier also has no holes in the lower discs which increases the amount of time exposed to centrifugal force since the oil must travel to the outside edge of the discs before it can move back to the center
    6. The smaller particles are therefore dealt with and discharged to waste
    7. As there is no water or sludge, there is only an oil outlet while the solids are retained in the bowl until cleaned manually
    8. The purifier may be self-cleaning using operating water pressure to split the bowl to flush away sediment and sludge

7. Describe any detuner you are familiar with. What is the purpose and how does it work? (Diesel Duck x 2, Notes)
    1. In diesel engines, during the firing stroke the flywheel is always slightly behind the crank and during the compression stroke, it is slightly ahead
    2. Should the firing impulses be in step with the natural vibrations of the shaft and allowed to continue, complete fracture may occur
    3. This condition may be detected by:
        1. A change in tune of the engine
        2. A low rumbling of the camshaft driving gears
        3. Waving of the chain drive
        4. A violent reversal of load on top and bottom end bolts
    4. If it is not possible to avoid this critical speed range, a detuner is fitted to reduce vibrations up to 60-80%
    5. By fitting this flexible flywheel, the node or point on which the shaft is undisturbed by vibration is shifted to the center of the crankshaft
    6. The detuner causes a variable stiffness with the torque vibration as the load changes
    7. Any tendency to build up torsional vibrations is reduced by frequency change and the amplitude settles down to a value below that of a rigid system
    8. It is essentially a flexible mass addition to the system that is self-adjusting
    9. The spring is supported over a long span at full load and a short span at overload
        1. The spring connects the drive to the driven mass which is thus floating
        2. This gives a variable natural frequency to the whole system and prevents synchronism from being established

8. Describe the construction and principle of operation of a diesel engine silencer. (Diesel Duck, Notes)
    1. Exhaust systems are fitted to an engine to carry away the exhaust gases and discharge them to atmosphere
        1. The gases leave the engine at about 40 psi and if led straight to the atmosphere, this could cause vibration and noise
    2. The silencer is fitted in the exhaust line to:
        1. Cool the exhaust gases
        2. Reduce their velocity
        3. Lessen the noise from the exhaust discharge
    3. A silencer normally takes the form of a cylindrical tank
    4. When water-cooled it is made of cast iron
    5. When not cooled, it is usually made of steel
    6. The exhaust pipes are attached to the end covers of the silencer at each end by means of expansion glands or bellows type joints
    7. Expansion may also be allowed for by supporting the silence on sliding feet
    8. Baffle plates are fitted that slow down the gases and allow heat to pass to the water jackets
        1. The baffles may be constructed of perforated plate or they may be solid and placed in such a way that the gases zigzag through the silence
        2. If the baffles are perforated, the holes are about 1 1/8" diameter
    9. Drains are fitted to the bottom of the silencer to drain away any accumulated water or oil
    10. Carbonized fuel and oil may cause an explosion and water may cause corrosion, especially if it mixes with sulfur content from fuel
    11. Low speeds cause condensation of water in exhaust gases
    12. Doors are fitted for inspection and cleaning
    13. Silencers are sometimes fitted in the funnel and are vertically orientated
    14. An exhaust gas boiler acts as a silencer when fitted

9. Sketch and describe a quick-closing valve as used on a fuel line. Explain fully how it works and the reasons why it is fitted. (Mike, Diesel Duck)
    1. A quick closing valve is often a gate valve
        1. This is a flat, tapered valve that can be fitted to a pipeline without disturbing the contour of the bore
        2. Quick closing valves can be worked by:
            1. Spring compression
            2. Hydraulic pressure
        3. Spring operated unit:
            1. Consists of gate valve, spindle, spring, side links, crossbar and wheel
            2. When the wheel is revolved in a counter clockwise direction, the valve rises on the threaded part of the spindle and the spring is compressed at the same time
            3. With the links vertical and the fork ended pull rod in position, this valve can be open or shut as required
10. Why are governors fitted to diesel engines? Describe a governor you are familiar with and explain its action. (Diesel Duck x 2, Notes)
    1. A governor automatically controls engine speed by regulating the fuel supply
        1. 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
        2. If it maintains the engine at a set speed, irrespective of load and power, it is said to be isochronous (generator)
        3. When fitted to main engines, there must be the facility to adjust the set speed on the governor, which is then said to be a variable speed type
    2. The electric governor, which operates without a flyweight, has proportional and reset action with added advantage of load sensing
    3. With this governor, a small permanent magnet alternator is used to obtain a speed signal from the engine
        1. The advantage of using a permanent magnet alternator is that there will be no slip rings or brushes to wear
        2. The alternator generates on AC voltage and the frequency of this voltage determines the speed signal
        3. This signal is converted into DC voltage by a rectifier and this is proportional to engine speed
    4. The DC voltage is then sent to the amplifier and controller which also receives a reference DC voltage of opposite polarity from the speed setting unit
        1. This voltage is representative of the desired operating speed
        2. These two voltages are the input of an electronic amplifier
        3. If the voltages are equal and opposite, they cancel each other out and there is no change in amplifier voltage output
        4. If the voltages are different, the amplifier sends a signal through the controller to the electro-hydraulic converter which via the servo motor will reposition the fuel rack to lower or increase speed as required
    5. In order that the system be isochronous, the amplifier controller has internal feedback
        1. The load sensing unit is included in the governor to correct the fuel supply to the prime mover before a speed change occurs
        2. The speed of response of the load sensing element must be better than that of the speed sensing element which would be used to correct small errors of fuel rack position
        3. In the example of the electronic governor, the electrical output of the main generator would be tapped and if a load alteration took place on the main generator this would be sensed and a signal fed into the controller to order the electro-hydraulic converter via the servo motor to increase or decrease engine speed by adjusting the fuel rack
11. Sketch and describe a centrifugal type governor. What is its purpose? (Diesel Duck)
    1. A mechanical hydraulic governor may be fitted to control the speed of an auxiliary diesel within close limits
        1. This type of governor allows a wide range in power output according to demand
        2. It may be used to control electric generators where fluctuations in demand occur
    2. The governor will automatically allow the engine fuel pump settings to regulate power output and return speed to the set value
    3. It should be fail safe so that the engine will stop in the event of failure
    4. By using a hydraulic system to operate the fuel control, greater power can be applied from the governor without loss in the sensitivity
        1. Oil pressure is either taken from the engine lubrication system or from a separate gear pump on the governor drive

5. The governor incorporates 2 systems:
    1. The mechanical ball head, which senses any change in speed of the engine
    2. The hydraulic piston valve and power piston that operates the fuel pump control setting to give the required change in power output
6. The ball head consists of 2 identical eccentrically pivoted flyweights mounted on opposite sides of a rotating sleeve
    1. 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
    2. A crank on each flyweight bears on a sliding compression plate that is held in equilibrium between forces from the flyweight and a compressive force from the helical governor spring
7. The sleeve is connected to a hydraulic piston valve and consequently any speed alteration automatically causes a corresponding change in sleeve and piston valve positions
    1. The piston valve controls oil pressure to operate the governor power piston
    2. If the engine speed slows, oil pressure passes to raise the power piston that is linked to increase the fuel setting
    3. The piston is spring loaded and when the engine speed increases, the oil pressure is released allowing the spring to force the piston down and decrease the fuel setting
8. Linkage from the power piston will also operate a governor speed droop lever
    1. This is pivoted to alter the ball head spring compression thus resulting the piston valve position in order to stabilize the governor action
    2. With this type of governor, a slight change in engine speed occurs with any change in load
    3. This can be corrected by the speed adjustment control that moves the droop lever pivot and corresponding governor setting
9. Maintenance of this type of governor is required to maintain the working parts in a free condition without undue wear
    1. Check the governor springs, oil tightness and cleanliness of hydraulic system
    2. Replenish and change oil as required

12. Describe the operation of a governor for an auxiliary engine. (Mike)
13. Describe a diesel electric propulsion system. Explain how it is controlled and reversed. (Diesel Duck)
    1. The electrical side of a diesel electric propulsion system will be based on a DC or AC motor coupled to the ship's propeller shaft
        1. Speed and direction of the propeller rotation is governed by electrical control of the motor itself or by alterations of the power supply
        2. An electric motor couple to a CPP is arranged for either constant or variable speed operation
    2. DC:
        1. The electrical power may be from one or more DC generators or it may be AC alternator derived and delivered through a rectifier as a DC supply
        2. The rectification scheme can incorporate speed control and the means of reversing
    3. AC:
        1. Power for an AC propulsion motor is supplied by an AC alternator
    4. Electric propulsion is used for specialized vessels such as dredgers, tugs, trawlers, lighthouse tenders, cable ships, ice breakers, research ships, floating cranes and vessels for the offshore industry
    5. Advantages:
        1. Flexibility of machinery layout
            1. Can give high propulsive power in restricted space
            2. Machinery spaces can be made smaller
            3. Propeller system and diesel are separated so less chance of torsional vibrations
        2. Can match generators in operation to the speed and power required
        3. Electric power can be diverted to cargo or dredge pump operation or for bow or stern thrusters or fire pumps
    6. Disadvantages:
        1. High installation costs
        2. Lower efficiency

Internal combustion engine systems

14. What is a timing diagram? Give an example of a single-acting 4-stroke and a single-acting 2-stroke timing diagram. How is timing set up? (Craig, Diesel Duck, Notes)
    1. A timing diagram will show the position of the piston when each phase of the engine cycle is carried out
    2. It will show the piston position in relation to:
        1. Fuel injection position
        2. Inlet and exhaust port or valve opening and closing
        3. Air start (optional)
    3. From the timing diagram, the exact timing of these sequences can be seen as well as any overlap of valves
        1. This makes it useful for timing an engine
        2. When timing an engine, it is first necessary to know the firing order of an engine
            1. The usual order for a 6 cylinder 4 stroke is 1, 5, 3, 6, 2, 4
        3. Timing marks are made on the flywheel as well as on the gear train gears when manufactured
        4. The camshaft is manufactured to correctly operate the valves and fuel pump in the proper sequence
            1. The gear wheel driving the camshaft has a mark on it
            2. This mark is lined up with the mark on the gear adjacent to it and each gear wheel lines up
            3. When the marks are lined up, the engine should be timed
            4. The timing of the fuel pump can be changed at the pump instead of changing these timing marks
    4. For a 4-stroke:
        1. Beginning at 0 degrees and moving in a clockwise direction, it will be seen that the inlet valve begins to open 20 degrees before TDC giving a total angular opening of 220 degrees
        2. After the air inlet valve closes, the air in the cylinder is compressed until 5 degrees before TDC is reached when injection of fuel commences
        3. Injection continues until the crank is 15 degrees past TDC giving total angular opening of 20 degrees
        4. During the next stage of the cycle, the high pressure gases expand and continue to force the piston downward until a point 45 degrees before BDC is reached
        5. When the exhaust valve opens and the products of combustion are released and then expelled by the next upward stroke of the piston, the exhaust valve closing 15 degrees past TDC by which time the inlet valve has already opened to begin the next cycle
        6. The overlap of inlet and exhaust in this case is 35 degrees
    5. For a 2-stroke:
        1. The admission of fuel begins at 10 degrees before TDC and finishes 10 degrees after TDC making a total angular opening of 20 degrees
        2. In most cases, the fuel injection period is slightly less than a 4-stroke because release of burned gases must take place earlier due to the use of ports
        3. In the case of a non-turbocharged engine, there will be symmetrical scavenge and exhaust periods would be acceptable
        4. Expansion of gases taken place until the crank reaches a point 50 degrees from BDC, where the piston uncovers the exhaust ports and the products of combustion are released
        5. About 15 degrees later, the scavenging air is admitted and the remaining burned gases are driven out of the cylinder
        6. The air trapped in the cylinder is trapped and eventually compressed
        7. At 35 degrees after BDC, the scavenge ports close and at 50 degrees after BDC the exhaust valve or ports close
        8. Compression begins and continues until 10 degrees before TDC when fuel is again injected to start the next cycle
        9. The reason for overlap between scavenge closing and exhaust port closing is to ensure that all the burnt gases, plus some of the cool scavenge air is expelled through the exhaust ports
            1. This cool air tends to cool down the exhaust valve or trunking
15. Sketch and describe a 4-stroke indicator diagram. How is this different from a 2 stroke? (Adam)
    1. Most medium speed engines utilize the 4-stroke cycle, that is divided into 4 distinct events
        1. Air inlet

    2. Compression
    3. Power
    4. Exhaust
2. These engines are fitted with exhaust and intake valves in the cylinder head to allow for the gas exchange process
    1. These valves are opened and closed by the action of the camshaft that is directly driven by the crankshaft
    2. The timing of opening and closing is determined by:
        1. The profile of the cam
        2. The position of the cam relative to the crank angle
3. Air inlet stroke:
    1. At some angle before TDC, the air inlet valve begins to open
    2. When the piston begins its downward stroke, the volume inside the cylinder is increasing, thus the pressure drops below atmospheric
        1. This pressure differential causes air to enter the cylinder
    3. The valve is opened slightly before TDC to allow time for it to be fully open and thus make more efficient use of the full intake stroke
    4. The air intake valve is closed at a slight angle after BDC
        1. This appears at first to be inefficient, since the piston has already commenced its upward stroke but it takes time to close the valve and it in fact increases the efficiency of the intake stroke
        2. The mass of air entering the cylinder has inertia and even though the piston is moving upward, air still continues to flow into the cylinder
4. Compression stroke:
    1. Commences as soon as the intake valve is fully closed
    2. The air trapped in the cylinder is compressed by the piston which is moving upwards reducing the volume of the cylinder
    3. The purpose of this stroke is to heat the air charge by rapid compression, allowing ignition of an injected quantity of atomized fuel
    4. The temperature and pressure of compression vary but an average would be 45 bar and 650C for a medium speed
5. Power stroke:
    1. At a slight angle before TDC, fuel is injected into the combustion chamber by the fuel pump and injector
    2. The fuel is at sufficient pressure to penetrate the dense air charge and is in atomized form to allow it to mix thoroughly with the air
    3. The fuel is injected before TDC because there is an ignition delay period between injection and ignition
    4. The entire fuel charge is injected over a period of crank angle, the length of the period depending on the amount of fuel which must be injected (engine load)
    5. The period of injection tends to maintain a near constant pressure in the cylinder during the first part of the power stroke
        1. This produces the characteristic high torque of the diesel engine
    6. As the piston moves downwards in the cylinder during the power stroke, the increasing volume causes the pressure to drop
    7. Firing pressures vary greatly but are generally from 40 to 50 bar with temperatures up to 1300C
6. Exhaust stroke:
    1. The exhaust stroke begins when the exhaust valve is opened at some angle before BDC
    2. Pressure in the cylinder will have fallen to about 3 bar at this point and his is referred to as the blow down period
    3. Pressure in the cylinder is allowed to fall to exhaust manifold pressure between the time the exhaust valve opens and BDC, thus reducing pumping losses during the exhaust stroke
    4. The piston decreases the volume of the cylinder as it moves upward creating a pressure higher than that in the exhaust manifold
    5. This causes exhaust gases to be expelled via the exhaust valve
    6. The exhaust valve is closed at some slight angle after TDC to allow the full exhaust stroke to be utilized

16. Sketch an indicator card and draw card for a 4-stroke single acting engine. How is indicated horsepower found? What does a draw card show you? (Andy, Notes)
    1. To find the indicated horsepower (IHP) of an engine, it is first necessary to take an indicator card
        1. This is done by attaching a pressure indicator to the indicator cock
        2. The indicator has a piston arrangement set up so the motion of the piston in the cylinder creates a pressure that is transmitted to a pencil
        3. This pencil records a reading on a drum of paper
        4. This diagram is known as an indicator diagram
        5. The diagram gives you the mean indicated pressure (MIP) by finding the area of the diagram in square inches by means of a planimeter and dividing the area by the length of the diagram in inches
        6. Then the mean height will be obtained
        7. Having found the MIP, the IHP can be obtained by the following formula:
            1. IHP = PLAN/75 x60 for 2-stroke and PLAN/75x60x2 for a 4-stroke
                1. P = MIP
                2. Length = length of stroke
                3. A = Area of piston
                4. N = RPM
        8. In the metric system, the unit of work is measured by the kg/m
        9. Therefore 1 HP = 75 kg/m
    2. The draw card is an extended scale picture of the combustion process
        1. Incorrect combustion details show readily on the draw card with increased fuel consumption
        2. The draw card can also indicate if valve timing and fuel timing are correct
        3. It is also an indication of firing and compression pressures
        4. Irregularities that can be found by a draw card:
            1. Fuel injection timing (early and late)
            2. Slow or late combustion
            3. Leaky fuel injector
            4. Partly choked injector or valve
            5. Low compression
            6. Exhaust valve opening
            7. Choked exhaust
17. Sketch and describe an indicator card for a 2-stroke diesel engine. Give temperatures and pressures. Show compression, expansion and fuel cut-off. Explain how you would find IHP from the card. (Notes)
    1. Indicator cards are created by indicators which measure and draw the pressure and volume relationships inside the cylinder on a rectangular axis
    2. The indicator pen moves a vertical distance proportional to the pressure inside the cylinder
    3. The pen bears against a drum that rotates a distance proportional to the change in cylinder volume
    4. The area within an indicator diagram represents the work done within the measure cylinder in one cycle
    5. The area can be measured by an instrument known as a planimeter or by used of the mid-ordinate rule
    6. The area is then divided by the length of the diagram in order to obtain a mean height
    7. This mean height, when multiplied by the spring scale of the indicator mechanism gives the indicated mean effective pressure of the cylinder
    8. This mean effective pressure can now be used to determine the work done in the cylinder:
        1. Work = mean effective pressure x area of piston x length of stroke
    9. To obtain a measure of power, it is necessary to determine the rate of doing work
        1. This can be done by multiplying by the number of power strokes in one second
        2. For a 4-stroke engine, this will be rev/sec/2
        3. For a 2-stroke engine, this will be rev/sec
    10. For a multi-cylinder engine it would be necessary to multiply by the number of cylinders

18. Describe the cycles with timing diagrams and values for opposed piston 2-stroke, slow speed 2-stroke, medium speed 4-stroke. (Jackson, Diesel Duck)
    1. 2-stroke:
        1. Downstroke
            1. With the cylinder full of compressed air at about 500 psi and 600C, the oil is forced in, ignites and combustion takes place, the expansion of the gases driving the piston down
            2. At about 7/8 stroke, the piston uncovers the exhaust belt port openings and the exhaust gases begin to pass away to the atmosphere
            3. At about 9/10 stroke, the scavenge ports are opened and low pressure air from the scavenge pump or turbocharger is forced into the cylinder, clearing out the remainder of the exhaust gases and at the same time filling up the cylinder with pure air in readiness for the next compression stroke
        2. Upstroke
            1. The air is admitted by the scavenge port and after the exhaust ports are close, is compressed to about 500 psi and temperature of 600C
            2. It will be seen that in the 2-stroke cycle, 3 operations are effected on the downstroke which in the 4-stroke cycle takes 3 separate strokes to perform
    2. 4-stroke:
        1. Downstroke
            1. Atmospheric air at engine room temperature is drawn into the cylinder through the suction silencer
            2. Air suction valve is open
        2. Upstroke
            1. The air is compressed to about 500 psi and 600C
            2. All valves closed
        3. Downstroke
            1. When the piston is near TDC, the fuel injector is opened by the fuel under pressure from the fuel pump
            2. Fuel at high pressure is forced through the atomising holes and sprayed into the hot compressed air in the engine cylinder
            3. The oil ignites, combustion takes place and expansion of the gases formed force the piston down
            4. This is the power stroke of the cycle
        4. Upstroke
            1. Just before BDC, the exhaust valve starts to open and the gases of combustion are forced out of the cylinder by the piston
            2. The exhaust valve opens full and does not close completely until shortly after TDC
    3. Opposed piston:
        1. It is a special case of the 2-stroke cycle
            1. This cycle is used in the Doxford engine, which is no longer manufactured although many are still in operation
        2. Beginning at the moment of fuel injection, both pistons are forced apart, one up, one down, by the expanding gases
        3. The upper piston opens the exhaust ports as it reaches the end of its travel
        4. The lower piston, a moment later, opens the scavenge ports to charge the cylinder with fresh air and remove the final traces of exhaust gas
        5. Once the pistons reach their extreme points, they begin to move inward
        6. This closes off the scavenge and exhaust ports for the compression stroke to take place prior to fuel injection and combustion
19. Why are burnt gases expelled from a 2-stroke earlier than a 4-stroke diesel engine? Sketch and describe timing diagrams for 2-stroke and 4-stroke engines. (Dave)
    1. The 4-stroke cycle is completed in four strokes of the piston, or two revolutions of the crankshaft
        1. In order to operate this cycle, the engine requires a mechanism to open and close the inlet and exhaust valves

        2. In a 4-stroke, the exhaust has a longer stroke to expel the exhaust gases because the piston acts as a pump to force the gas out of the exhaust valve
        3. There is a full stroke dedicated to ridding the cylinder of burnt gases while the 2-stroke must perform this during a portion of its downstroke
    2. For a 2-stroke, when the exhaust port is uncovered in the liner, the pressure in the cylinder is higher than if it was opened later in the stroke due to the position of the piston
        1. This higher pressure, when the port is opened, will drive the turbocharger harder than if the ports were opened later
        2. The cylinder must then be charged with a fresh load of air for combustion, also on the downstroke
    3. The fresh air must be forced in on a 2-stroke engine while a 4-stroke can rely on the reciprocating action of the piston to force out burnt gases

20. Sketch an indicator diagram and draw card for a naturally aspirated 4-stroke diesel engine. Show in a dotted line the effect if the engine were supercharged. Explain the advantages and effect, if any, of supercharging. (Diesel Duck)
    1. Naturally aspirated:
        1. Pressure at injection = 33 bar
        2. Pressure at firing = 44 bar
        3. Temperature at injection = 525C
        4. Temperature at firing = 1400C
        5. Temperature at exhaust = 400C
    2. Supercharged:
        1. Pressure at injection = 37 bar
        2. Pressure at firing = 48 bar
        3. Temperature at injection = 550C
        4. Temperature at firing = 1425C
        5. Temperature at exhaust = 425K
    3. Advantages of supercharging:
        1. Mass of fuel burned in the cylinder depends on the mass of air of air present in the cylinder at the end of compression
        2. Hence, by increasing the pressure of the scavenge air in a 2-stroke engine and by supplying air under slight pressure in a 4-stroke engine during the induction stroke instead of relying on drawing the air in by suction, a greater mass of air for compression can be supplied to the engine
        3. More fuel can then be burned without causing excessive temperature during combustion
        4. Burning more fuel creates more heat energy to be imparted to the piston, thereby increasing the power of the engine
    4. The draw card is taken 90 degrees out of phase or with the drum advanced 90 degrees to the main piston of the engine
        1. This allows the injection period to be spread out across the centre of the card so that the combustion process can be examined more closely
        2. The same spring is used for both the draw and power cards

21. Describe the valve arrangement on a 4-stroke engine. Describe in relation to the crank operation. Sketch a timing diagram. How do worn cam lobes affect timing and why is this bad? (Andy)
    1. A 4-stroke engine utilizes two complete revolutions of the crankshaft to complete its cycle (720 degrees)
        1. The camshaft that runs the valve and fuel injection timing must revolve at half the speed of the crankshaft so has a gear twice as large if gear driven
        2. The shape of the cam profile regulates the period of opening of a valve and this cannot be afterwards varied to any appreciable extent
        3. The actual angle during which a valve is understood to be open is equal to that through which the shaft turns from the instant the roller of the valve ever engages with its cam to the moment the contact finishes
        4. The cam roller clearance prevents contact at all other position
        5. When the camshaft is placed low, push rods connect the cams and the outer ends of the valve rocker levers, the cam rollers being pivoted on the lower ends of the push rods
    2. Air inlet and exhaust valves are kept shut by means of springs, which have to be overcome by the valve levers when operated by the cams and push rods

    3. Worn cam lobes increases the clearance between the distance to its roller or follower
        1. This causes the valve to open late and close early
        2. This will decrease the maximum lift and cause noisy operation
22. Sketch and describe the cam location of a 4-stroke diesel engine. What effects would cam wear have on engine performance? (Diesel Duck)
    1. The shape of the cam profile regulates the period of opening of a valve and this cannot be afterwards varied to any appreciable extent
23. Give the compression pressures and temperatures for a 2-stroke and 4-stroke diesel engine. Give the terminal pressures and temperatures for a 4-stroke and 2-stroke diesel engine by means of an indicator card. Explain the differences, if any. (Diesel Duck, Notes)
    1. For an average 2-stroke engine:
        1. Compression pressure = 500 psi
        2. Firing pressure = 550 psi
        3. Details at start of each cycle:
            1. Compression = 5 psi, 20C
            2. Firing = 500 psi, 600C
            3. Expansion = 550 psi, 1200C
            4. Exhaust = 40 psi, 330C
    2. For an average 4-stroke engine:
        1. Details at start of each cycle:
            1. Compression = 15 psi, 20C
            2. Firing = 500 psi, 560C
            3. Expansion = 550 psi, 1030C
            4. Exhaust = 40 psi, 410C
    3. In 2-stroke engines, the events described above are contrived to take place in only 2 strokes of the piston
        1. The exhaust gases are expelled from the cylinder and the cylinder is charged with air during the period that the crank is passing from around 45 degrees before BDC and 45 degrees after BDC.
        2. The remaining part of the cycle is identical with the compression, combustion and expansion phases in the 4-stroke engine
        3. To accomplish expulsion of the exhaust gases and the supply of air charge within 90 degrees of crank rotation requires the assistance of a low pressure air supply
24. Sketch and describe a fuel injector or valve. Explain how volume is delivered. (Craig, Notes)
    1. A common fuel injector is hydraulically operated by the system fuel
    2. It consists of a spring-loaded non-return needle valve operated by a fuel pressure pulse from the fuel pump to discharge fuel at high pressure through an atomizer
    3. The main components are:
        1. Valve body or nozzle holder
        2. Nozzle or atomizer
        3. Nozzle retaining nut
    4. The complete injector is fitted to a pocket in the cylinder head
    5. The retaining nut has a ground edge to take a gasket and make a gastight joint in the landing of the pocket to seal the combustion chamber
        1. The injector is secured in position by studs and nuts
        2. The ideal position is the center of the cylinder head
            1. This allows a symmetrical full spray pattern in the combustion chamber
    6. The valve body contains the spring, compression nut and an intermediate spindle
        1. There is a passage to convey fuel to the atomizer and in most cases there will be a cooling passage
        2. The lower end of the body is ground and lapped for an oil pressure tight face with the atomizer
        3. The atomizer top is ground and lapped in a similar manner
        4. This face will also include matching passages for fuel oil and cooling and a dowel is fitted for alignment

5. At the base of the atomizer, there are 2 chambers
    1. The upper chamber is charged with fuel from the fuel pump and is sealed by the needle valve
    2. At the lower end, the mitre seat is accurately ground and lapped to form a positive oil seal while at the top of the chamber the larger diameter of the needle valve above its shoulder also forms an effective oil seal
        1. The lower chamber, also sealed by the mitre seat of the needle valve has a number of small atomizer holes of correct size and pattern to atomize and distribute the fuel sprayed into the combustion chamber
6. Injector spring compression is set under test and a compression ring fitted
    1. It is set to allow the needle valve to lift under a predetermined pressure
7. The intermediate spindle conveys the spring tension to the needle valve and may be arrange to limit its lift
8. The valve will open when pressure from the fuel pump acting on the shoulder of the needle valve overcomes the spring compression
9. As the needle valve lifts, oil flows to the lower chamber in the atomizer
10. The additional area of the needle mitre now subject to pressure causes it to lift rapidly, allowing fuel at high pressure to pass through the atomizer holes into the combustion chamber
11. When the pump cuts off pressure, the valve will close under spring compression
    1. Since the full area of the needle is now exposed to pressure, closing will occur at a lower pressure than opening

25. Describe a fuel injector for a common rail fuel system. What are causes of failure? What sort of maintenance must be performed? (Dave, Diesel Duck)
    1. The injectors in a common rail system are often referred to a fuel valves
        1. It works on the same principle as an injector used in a jerk pump style system
    2. Construction and operation:
        1. The two basic parts:
            1. Nozzle holder or body
            2. Nozzle
        2. The high pressure fuel enters and travels down a passage in the nozzle, ending finally in a chamber surrounding the needle valve
        3. The needle valve is held closed on a mitred seat by an intermediate spindle and a spring in the injector body
        4. The spring pressure, and hence the injector opening pressure, can be set by a compression nut which acts on the spring
        5. The nozzle and injector body are manufactured as a matching pair and are accurately ground to give a good oil seal
        6. The two are joined by a nozzle nut
        7. The needle valve will open when the fuel pressure acting on the needle valve tapered face exerts a sufficient force to overcome the spring compression
        8. The fuel then flows into a lower chamber and is forced out through a series of tiny holes
        9. The small holes are sized and arranged to atomize, or break into tiny drops, all of the fuel oil, which will then readily burn
        10. Once the timing valve cuts off the high pressure fuel supply, the needle valve will shut quickly under the spring compression force
    3. Maintenance:
        1. Injectors must be overhauled at regular intervals to ensure correct operation and combustion
        2. The injector compression spring must be screwed back before slackening the retaining nut
        3. Parts are cleaned, inspected and renewed if necessary
            1. Lapped surfaces must be free of damage and correctly aligned
            2. Springs must be inspected for distortion
            3. Atomizer holes must be clear and unworn
        4. After assembly, the injector is tested with a test pump
            1. Operating pressure and fuel spray pattern are checked and there must be no leakages

        5. Defects in injectors while in use:
            1. Choking to dirt in the fuel or carbon building up in the atomizer
            2. A leaking needle valve will cause secondary burning and reduce combustion efficiency
            3. Worn springs

26. Describe a common rail injection system for a 2-stroke diesel engine. Explain what defects can be found with this system and what maintenance is required to keep it in good working condition. (Diesel Duck)
    1. The common rail system has one high pressure multiple plunger fuel pump
    2. The fuel is discharged into a manifold or rail which is maintained at high pressure
        1. The fuel pump or pumps supply at a constant pressure of 1500 to 10000 psi
    3. From this common rail, fuel is supplied to all the injectors in the various cylinders via a connecting line
    4. Between the rail and the injector or injectors for a particular cylinder is a timing valve that determines the timing and extent of fuel delivery
    5. The injectors in a common rail system are often referred to a fuel valves
        1. The injection valve is mechanically operated and timed to spray fuel into the combustion chamber exactly when needed
    6. Either by varying the lift of the injection valve or by varying the pressure in the common rail, the operator can change the amount of fuel which the engine received, thus controlling speed and power
    7. Spill valves are connected to the manifold or rail to release excess pressure
    8. Accumulator bottles will dampen out pump pressure pulses
    9. Timing valve
        1. The timing valve is operated by a cam and lever
        2. When the timing valve is lifted by the cam and lever, the high pressure fuel flows to the injector
        3. The timing valve operating lever is fixed to a sliding rod which is positioned according to the manoeuvering lever setting to provide the correct fuel quantity to the cylinder

27. State two good reasons why heavy residual fuel oil is heated before being injected into a diesel engine. What effect will excessive heating of the fuel have on the engine performance? What precautions must be taken before manoeuvring an engine that is operating on this heavy residual fuel and has to be changed to diesel oil? (TCMS)
    1. Two good reasons for heating residual fuel are:
        1. Reduce the viscosity for better atomization
        2. Reduce energy and time required to ignite and combust fuel
    2. Excessive heating will:
        1. Cause the fuel to burn too early causing:
            1. Diesel knock,
            2. Lower power,
            3. Lower exhaust temperature
            4. Higher temperature on head, piston, rings and liners
        2. This extra heat will case lube oil to burn and increase wear
        3. May cause fuel to gas off and cause vapor lock in fuel pumps or injectors, stopping the engine
    3. Precautions:
        1. Timing will depend on size but should be done before maneuvering.
        2. Temperature should be allowed to drop about 2 degrees C per minute to prevent gassing up.
            1. May take about an hour.
        3. Drain diesel tank slightly to ensure no water in it and ensure quick closing valve on tank is open.
        4. Ensure return valve to HFO tank is closed to avoid diesel returning there.
        5. Load should be reduced on engine to avoid changeover happening too quickly and heating up the diesel causing gassing up due to residual heat in heaters.
        6. Changeover the 3-way valve to diesel and monitor viscosity.
        7. Shut off trace heating and if fitted with return cooler for diesel, put this online.

28. What are the calorific value and the constituents of fuel as used in a diesel engine? How much is available to do work? Where are the losses and how to improve efficiency? What are the constituents of exhaust gas? (Craig, Diesel Duck)
    1. Calorific Value of diesel = 45 MJ/kg
        1. The value quoted is the higher calorific value that includes heat from water vapor formed as products of combustion are cooled
        2. Measured by bomb calorimeter
    2. The combustible elements in a fuel are:
        1. Carbon = 86.3%
        2. Hydrogen = 12.8%
        3. Sulfur = 0.9%
    3. These combustibles when supplied with oxygen from atmospheric air combust and liberate heat
        1. One kg of carbon requires 2.6 kg oxygen to burn completely
        2. One kg of hydrogen requires 8 kg of oxygen to burn completely
        3. Since air is not only oxygen, 14 kg of air are required for full combustion
            1. Certain amount of excess air is required in the cylinders to get the best combustion
    4. Simple heat balance:
        1. 100% input
            1. Indicated power = 40%
                1. Brake power = 35%
                2. Friction losses = 5%
            2. Exhaust = 35%
            3. Cooling = 22%
            4. Radiation = 3%
    5. How to improve efficiency:
        1. Exhaust gas boiler
        2. Turbochargers
        3. Coolant can be used as evaporator heat source (under vacuum)
    6. Constituents of exhaust gas:
        1. Nitrogen = 74%
        2. Oxygen = 11%
        3. CO2 = 11%
        4. Water vapor = 4%
        5. Sulfur dioxide = trace
        6. Nitrogen oxides = trace
29. State the composition and calorific value of diesel fuel oil, explain the meaning of the following giving a numerical example of diesel fuel oil. (Diesel Duck, Notes)
    1. Specific gravity = .87
        1. The ratio of the mass of that substance to the mass of an equal volume of pure water
        2. The ratio of density to that of pure water
    2. Closed flash point = 95C
        1. Minimum temperature at which the oil gives off flammable vapor, which on the application of a flame in a specified apparatus would cause momentary ignition
        2. The vapor ignites but does not maintain a flame
    3. Fire or Burning point
        1. The temperature at which volatile vapors given off from a heated fuel are ignitable by flame application and will burn continuously
        2. Can be anything up to 40C higher than the closed flashpoint for most fuels
    4. Pour Point (-40C)
        1. The lowest temperature at which oil will pour or flow

        2. This value is an important consideration for lube oils working under low temperature conditions such as refrigerant oils, telemotors, etc.
    5. Viscosity = 5 cSt @ 50C or 7 cSt @ 38C
        1. Defined as the resistance to change shape or flow
        2. Due to the internal molecular friction of fluid causing drag
        3. Important for combustion of fuels since it must be low enough to ensure proper atomization, this is often regulated by heat
    6. Cetane number = 60
        1. An indication of the ignition quality of the fuel
        2. Cetane is paraffin hydrocarbon of high ignition quality and is taken as the upper limit of 100
        3. Alpha-methyl-naphthalene is of low ignition quality and is given the lower limit of 0
        4. Cetane number is numerically the percentage volume of cetane in a mixture of cetane and alpha-methyl-naphthalene that matches a chosen fuel in ignition quality
        5. This will have an effect on cold starting characteristics between injection and firing, called ignition delay
    7. Constituents:
        1. Carbon – 86.3%
        2. Hydrogen – 12.8%
        3. Sulfur - .9%
    8. Calorific value – higher = 46 MJ/kg, lower = 43.3 MJ/kg
        1. Measure of the amount of heat released during complete combustion of a unit mass of fuel
        2. Determined by a bomb calorimeter
    9. Exhaust gas constituents:
        1. 75.8% Nitrogen
        2. 13.0% Oxygen
        3. 5.6% Carbon dioxide
        4. 5.35% Water
        5. Trace gases:
            1. 1500 ppm NOx
            2. 600 ppm SOx
            3. 60 ppm CO
            4. 180 ppm HC

30. What is meant by "Open" and "Closed" flash points? Describe the apparatus used for testing flash point. Give the approximate flash points of Paraffin, Diesel fuel, Boiler fuel and Gasoline. (Jackson, Diesel Duck)
    1. Flash point is the minimum temperature at which an oil gives off flammable vapors
        1. At this point there would be momentary ignition if a flame is brought into contact with the oil surface, but a flame is not maintained
        2. This figure is used mainly to indicate the maximum safe storage temperature
        3. Open flashpoint is for atmospheric heating
        4. Closed flashpoint is when the fuel is covered while heating
            1. Closed flashpoint is always lower than open flashpoint since the lid seal allows accumulation of volatile vapor above liquid surface
            2. Marine fuels have closed flashpoint above 66C (150F)
    2. The apparatus used for finding the closed flashpoint of marine fuels (above 45C) is the Pensky Marten unit.
        1. Carried out by heating a sample of oil in a metal dish that is resting on a frame and air jacket casing with a heating lamp below
        2. A stirring rod is fitted to stir the sample at 1 to 2 revs/sec
        3. A thermometer is immersed in oil.
        4. Heat should be applied to bring temp of oil up roughly 10 degrees F per min.
        5. When the operating handle is depressed the shutter uncovers the ports

6. The flame element is depressed through one port above the oil surface
7. Starting at temp 17C below the estimated flashpoint, the flame is depressed, left and quickly raised in a period of under 2 s, at 1C intervals.
8. Just before the flashpoint is reached, a blue halo occurs around the flame the flash observed just after, through the two observation ports, stirring being discontinued during flame depression
9. A fresh sample must be used for every test and care must be taken that no trace of cleaning solvents are present in the oil cup

3. Flashpoints:
    1. Paraffin = 25C
    2. Diesel = 95C
    3. Boiler fuel (Heavy fuel) = 100C
    4. Gasoline = -17C

31. Describe a fuel oil system for a Diesel-Electric propelled vessel. (Diesel Duck)
32. Make a line diagram of a complete fuel system from double bottom tanks to the main engine fuel injectors. Label all major components. Why is settling and purification necessary? (Notes)
    1. Components:
        1. Double bottom tank
        2. Fuel oil manifold
        3. Duplex strainers
        4. Heaters
        5. Transfer pump
        6. Settling tanks
        7. Purifier
        8. Day tank
        9. Tank level gauges
        10. Low level alarm
        11. Tank level gauges
        12. Main engine booster pump
        13. Main engine injection pumps
        14. Injectors
    2. Path:
        1. The fuel transfer pump draws fuel from the double bottom tanks via the fuel manifold and discharges it to the settling tanks
        2. For heavy fuels, one settling tank is used while the other is used for heating by means of a steam heating coil
            1. The temperature in these tanks should never exceed 65C because the vapours given off may be flammable
            2. Heating also promotes water settling out to the bottom the settling tank
        3. Drains are fitted at the bottom of the settling tanks to get rid of accumulated water and sediment to the dirty oil tank
        4. The oil, now free from most of its water is passed through a centrifugal purifier to remove any remaining water as well as solid impurities that are heavier than the oil
        5. The oil may then pass through a centrifugal clarifier to separate finer impurities
        6. Clean oil passes onto the day tank
        7. The day tank overflows to the settling tank and the settling tank overflows back to the double bottom
        8. The suction valves from the settling and day tanks are quick-closing or remotely operated in case of fire
        9. Save-all trays are fitted below the tanks with drains to the dirty oil tank
        10. The tanks are also fitted with pneumercator gauges to indicate the level of oil in the tanks and are fitted with low level alarms to alert the watch keeper of the situation
        11. Vent pipes are fitted to the highest area of the tank to allow air in when emptying and to expel air when filling
            1. This vent is fitted with wire mesh gauze on its gooseneck to prevent entry of spark and to dissipate flame
        12. The day tank feeds the engine by gravity through a set of duplex filters to the booster pump

        1. The fuel filters are fitted with a spring loaded bypass that will open to allow fuel to bypass clogged filters to prevent an inadvertent shut down
        2. The low lube oil pressure shut down may be fitted on the fuel inlet to shut off fuel to prevent engine damage
    13. Fuel is then delivered to the injection pumps through a distribution manifold that is fitted to each cylinder
    14. The fuel pumps and injectors are precision machined so clean oil is absolutely necessary to prevent blockage, excessive wear and poor combustion
    15. The fuel pumps deliver oil at about 3000 psi and the injectors operate at about 2400 psi
    16. Surplus fuel drained from injectors and pumps are drained away to the fuel trough and then to a fuel drip tank and then eventually the settling tank to be purified again

33. Sketch and describe a rotary blower for supercharging a 2-stroke diesel engine. Is cooling required? Explain how the blower operates when the engine is reversed. (Craig, Mike)
    1. Blowers of this type are driven by the engine either through gearing or by roller chains
    2. They may be driven at higher speeds than the engine
    3. They take up less space than the reciprocating pump but are much louder
    4. The moving parts consist of two rotors, each mounted on its own shaft and connected to each other by a gear
    5. The rotors normally have 3 lobes and they mesh during rotation but never make contact with each other
        1. The clearance between lobes in always very small, usually just greater than the gear tooth clearance or backlash
    6. The rotor shafts are parallel and are supported by bearings in the end covers
    7. Ball bearings are fitted at one end to locate the shaft axially and roller bearings at the other end to allow for expansion
    8. As there is no contact, the efficiency of the Roots blower is high
    9. The design of the casing depends on how many lobes are fitted
        1. Suction will be on one side of the casing and discharge on the other
    10. When the lobes are rotated, the volume of the space on the suction side between adjacent lobes and the casing increases, drawing air into the casing
    11. Continued rotation traps the air between the casing and the lobes
    12. This air is passed around with the rotor until it reaches the discharge side of the casing
    13. As the lobes mesh on the discharge side, the volume of space between adjacent lobes and the casing is reduced and the air is expelled into the casing
    14. If the direction of rotation is reversed, the air flow is also reversed
        1. This type of blower is used on reversible engines and a reversing arrangement must be fitted
        2. Changeover valves are used and activated by the reversing gear
        3. The valves are of the butterfly type, one on top and one bottom and will rotate open or closed to act as suction or discharge depending on engine direction
        4. They extend the full length of the blower and are fitted between the outer casing and inner casing
        5. In order to reduce the inertia shock of the parts, a spring loaded coupling is used on the blower drive and a damper coupling so that cycle variations are damped out and not transmitted to the blower

34. List methods of providing scavenging air on a slow speed 2-stroke engine. Describe one method in detail and give pressures and temperatures for inlet and exhaust manifold. (Jackson, Diesel Duck x 2)
    1. Scavenging refers to the removal of exhaust gas from the cylinder after combustion and its replacement with air for subsequent combustion
        1. Efficient scavenging is necessary for good combustion and is required for the very first working cycle of the engine
        2. The passage of scavenge air will also assist cooling of the cylinder, piston and valves
        3. 2-stroke engines rely on a charge of scavenge air under pressure sweeping through the cylinder and expelling the exhaust in front of it
        4. This process must take place while both scavenge and exhaust connections are open and the piston is near the bottom of the cylinder
        5. Scavenge air must be supplied at a higher pressure than that in the exhaust manifold
    2. 2-strokes have used the following for scavenging:
        1. Turbochargers

        1. Most modern engines use these with an electric blower for low speeds or low loads
    2. Reciprocating scavenge pumps
    3. Rotary blowers
        1. Driven by engine either through gearing or roller chains
        2. Can be driven at much higher speeds than engine
        3. Take up less space than reciprocating pumps
        4. Noisier
    4. Under piston scavenging
        1. Uses the compression of the piston on its down stroke
    5. Electrically driven fans for low loads

35. Describe fully the construction and operation of a scavenge pump for a 2-stroke diesel engine. Is cooling necessary and at what air pressure does the pump operate? (Diesel Duck)
    1. To obtain low pressure air for scavenge purposes, a pump or pumps are fitted
        1. Driven by:
            1. Crank extension
            2. Engine type levers
    2. Scavenge air pressure is about 1.5 to 2 psi
    3. Volume is usually 1.3 to 1.4 of the volume of the cylinders
    4. Scavenge pumps have been replaced by turbochargers
    5. The pump consists of a light weight piston working in a cylinder
    6. Each end of the cylinder has covers fitted with suction and delivery valves, with a baffle or division plate between the valve groups, making 2 separate spaces
    7. The suction valve space is open to the atmosphere and the delivery valve space is connected either directly or through air trunking to the scavenge trunk
    8. The valve plates are made from thin steel sheet and bend or deflect off the seat to open
    9. The valves have large opening areas so that only a small valve lift is necessary to accommodate air flow
    10. The pump piston and piston rod are attached to a crosshead that works in a set of guides
    11. The motion of the crosshead is obtained from rocking levers linked to an engine crosshead or from a separate crank and connecting rod
    12. Reciprocating scavenge pumps, when driven by a separate crank, are sometimes arranged with 2 scavenge pumps, one above the other in tandem
    13. For moderate amounts of pressure charging like a scavenge pump or blower provides, cooling of the charge air is not worthwhile
        1. For turbochargers that produce a higher pressure, therefore temperature, charge air cooling is necessary to provide cool dense air for scavenging and combustion

36. Describe the following and list the advantages and disadvantages: port scavenging, valve scavenging, supercharging (Dave, Diesel Duck x 2)
    1. Scavenging of an internal combustion engine consists of the removal of exhaust gas from the cylinder after combustion and its replenishment with air for subsequent combustion
        1. Efficient scavenging is necessary for good combustion and it is required for the very first working cycle of the engine
        2. The passage of scavenge air will also assist cooling of the cylinder and piston
        3. 2-stroke engines rely upon a charge of scavenge air under slight pressure sweeping through the cylinder and expelling the exhaust gases in front of it
        4. This process must take place while both scavenge and exhaust connections are open and the piston is near the bottom of the cylinder
        5. Some mixing of air and gas will occur but this must be kept to a minimum
            1. Scavenging can be improved by supplying a volume of air in excess of the cylinder volume, the excess passing to the exhaust system
        6. In the case of cross and loop scavenging, a piston skirt or exhaust timing valve will be necessary to prevent scavenge air leaking to exhaust while the piston is at the top of its stroke

        7. In all engines, the scavenging trunking must be kept drained, inspected regularly and maintained in a clean condition
    2. Port scavenging (cross)
        1. The method of scavenging where scavenge air is drawn in through ports on the liner and exhaust is expelled though similar ports in the liner
        2. The air enters and travels upwards due to the shape of the ports and then down the other side forcing the exhaust gas out of the exhaust ports on the opposite side
        3. The opening of the ports occurs when the piston moves downwards to a position near BDC and the ports become uncovered giving access into the cylinder space
        4. The ports are closed by upward movement of the piston blanking them off
        5. Advantages:
            1. Do not require exhaust valves or scavenge valves so are simpler than uniflow
            2. Permits large openings for air
        6. Disadvantages:
            1. Require complicated liner pattern that is more expensive
            2. The height of the ports extends relatively high in the cylinder liner and the effective stroke for expansion of gases is reduced
            3. Piston ring breakage is more common
            4. Lube oil is more easily lost by blowing through the ports
            5. Guide bars between ports are apt to distort and crack due to temperature differences
    3. Valve scavenging (uniflow)
        1. The type of scavenging where air enters the cylinder through ports at the lower end of the piston stroke and passes upward and out through the exhaust valves located in the cylinder head
            1. Used in most modern slow seed 2-stroke engines
            2. In this system, when the piston has travelled 80-85% of the expansion stroke, cam operated exhaust valves in the head are opened
            3. The exhaust gases are released and begin to escape from the cylinder
            4. The piston then begins to move downward, it uncovers the air inlet or scavenge ports
            5. Air enters these ports into the cylinder and forces the burned exhaust gases ahead of it
            6. This continues until the piston, on its upstroke, covers the scavenge ports
            7. After the scavenge ports close, the exhaust valve closes
            8. The swirl or direction of air is assisted by angled ports and by the shape of the piston crown and head
            9. Advantages:
                1. Uniflow gives the highest scavenge efficiency with the least mixing of air and gases
                2. It may also be used with greater stroke/bore ratio since the ports do not reach as high
                3. In opposed piston engines, it avoids the difficulty of high temperature gradient between adjacent scavenge and exhaust ports in loop scavenging
                4. Also avoids high temperature difference across piston in cross scavenged engines
                5. Absence of exhaust ports allows a simpler liner
                6. Long piston skirts are not required
                7. Cylinder lubrication is satisfactory and economical
                8. Less susceptible to damage from products of combustion from low quality heavy fuels
                9. The swirl imparted by the port edges causes the air to rotate as it rises through the cylinder
            10. Disadvantages:
                1. The disadvantage is the fitting of exhaust valve gear and its required maintenance
                2. Fuel injector must be offset to make room for valve

37. What is meant by cross scavenging, loop scavenging and uniflow scavenging? Use sketches to illustrate your answers. (Notes)
    1. Cross scavenging
        1. See port scavenging above
    2. Loop scavenging

        1. In the loop scavenge system, the scavenge air enters the cylinder and goes directly across to the other side and up to the top and then down the same side that it came in from
        2. Here it exits through the exhaust ports which are above the scavenge ports
        3. The angle of the ports and the shape of the head are very important in creating this type of gas flow
    3. Uniflow
        1. See valve scavenging above

38. What does supercharging as referred to a diesel engine mean? Describe a system of supercharging as fitted to a 4-stroke engine. (Diesel Duck)
    1. It is essential that each cylinder should be adequately scavenged of gas before a fresh charge of air is compressed
    2. Otherwise this fresh air charge is contaminated by residual exhaust gases from the previous cycle
    3. Further, the cycle temperature will be unnecessarily high if the air charge is heated by mixing with residual gases and by contact with hot cylinders and pistons
    4. Turbo charger:
        1. Necessary scavenging is obtained by supercharging, that is by providing pressurized scavenge air
        2. This provides a pressure difference between the air manifold and the exhaust manifold
        3. The air flow through the cylinder during the overlap period has a valuable cooling effect
        4. The excess air helps to increase the volumetric efficiency and to ensure a low cycle temperature
        5. The relatively cooler exhaust allows a higher engine output to be obtained before the exhaust temperature imposes a limitation on the satisfactory operation of the turbine blades

39. Describe how turbocharging and supercharging is obtained in a diesel engine. What are the advantages of turbocharging and supercharging? (Notes)
    1. Supercharging involves the provision of an excess of air that is pumped into the cylinder to help with getting rid of excess gases and providing fresh air under pressure for higher combustion efficiency and power
        1. The increase in air supply also cools the cylinder, piston and exhaust valve or port
        2. Can be achieved by:
            1. Under piston scavenging
            2. Pumps
            3. Engine driven blowers
            4. Exhaust drive blowers (turbocharger)
            5. Electrically driven fans for low loads
    2. Turbocharging
        1. Many 2-stroke and 4-stroke engines are now using a rotary air compressor driven by an exhaust turbine
        2. This makes use of the energy contained in the exhaust gases to enable a great increase in power to be obtained for a small increase in fuel consumption
            1. Only a relatively moderate increase in size, weight and initial cost
            2. Efficiency of system is increased by adding a charge air cooler after the compressor
        3. Consist essentially of two sections:
            1. The turbine
            2. The centrifugal air compressor
        4. Turbine:
            1. The impulse type uses high velocity and pressure of the exhaust gases to drive the compressor that is fitted on the same shaft
            2. Made in two parts cast in high quality heat resistant cast iron
            3. Turbine is shot blasted to remove loose material and give a smooth interior finish
            4. Inlet casing may have two to four inlet passages to facilitate correct grouping of inlet exhaust gas pulses
            5. Exhaust from engine is arranged so that the surge of gas from one cylinder does not interfere with the scavenging of another
                1. This requires multiple exhaust pipes

            6. The exhaust gas on its way through the casing passes through the nozzle vanes secured to the after ends of the casing
            7. The vanes direct the gas so that it impinges on the turbine blades at the correct angle to impact the maximum energy
            8. The vanes are secured by casting them into two concentric cast iron rings
                1. The outer ring is cut into segments so that the expansion of the metal may be allowed
            9. After passing through the turbine blades, the gas is exhausted to atmosphere
        5. Compressor
            1. Air slightly below atmospheric pressure and at atmospheric temperature is led to the impeller eye
            2. It is caught by the rapidly rotating impeller blades and discharges at high velocity into the compressor diffuser
            3. The diffuser forms a stationary passage of gradually increasing area and surrounds the impeller wheel
            4. The air gains in velocity as it passes from eye to the tip of the wheel and the pressure and temperature are increased
            5. The air is then discharged into the volute and led into the intercooler and then the engine via the inlet manifold
            6. The cooler will increase the efficiency of the unit by providing denser air for combustion
        6. By increasing the weight of air within the cylinder at the power stroke, more power can be produced form the same cylinder dimensions
            1. The mean effective pressure will be increased and the scavenge efficiency can be improved
            2. If the scavenge period is increased, more air can pass through the cylinder, sweeping out exhaust gases
            3. The temperature of the piston crown and cylinder head can be reduced by this cool air
            4. When the exhaust and inlet valves/ports closes, the air trapped in the cylinder is above atmospheric
            5. With this greater weight of air, the fuel can be burned efficiently and more power produced
        7. Advantages:
            1. Substantial increase in power for a given speed and size
            2. Better mass power ratio (reduced engine mass for given output)
            3. Higher mechanical assistance
            4. Increase in air supply has cooling effect leading to improved reliability and less exacting work conditions
        8. Two different types of turbocharge systems are:
            1. Pulse
                1. Gives a rapid buildup of turbine speed when starting or manoeuvering
            2. Constant pressure
                1. Gives best overall efficiency
    3. Supercharging:
        1. The positive displacement blower is a very simple and dependable method of providing extra air in order to increase the power of a diesel engine
        2. The blower may be driven from the crankshaft by a chain or gears
        3. One rotor shaft geared to the engine shaft acts as a driver for the two gear wheels that are external to the casing
        4. The blower normally operates at a speed of 2.5 to 4 times the engine speed
        5. The blower consists of 2 symmetrical rotors revolving within a casing and rotating in opposite directions
        6. The rotors are synchronized by the two gear wheels
            1. The gear wheels have to be very accurately made because all clearances, both axial and radial, have to be as fine as possible for efficiency
        7. This type of blower, having no out of balance forces can revolve at high speed and only requires to be rigidly supported in good alignment
        8. Unfortunately, the blower does absorb some power from the engine
        9. Volume of air delivered is controlled by speed of the engine, not by the load
        10. Change over valves must be fitted for this type of blower to be used on a reversible engine

40. State the reasons for the following turbocharger abnormalities and the steps taken to avoid such occurrence: (TCMS)

1. Unusually low discharge air pressure
    1. Dirty inlet filter – change or clean when pressure difference is too high
    2. Dirty compressor impeller or diffuser – clean with water wash
    3. Dirty turbine – deposits alter geometry of nozzles and blades and slow down turbine
    4. Turbine not running at proper speed – bearing wear
    5. Wear of compressor or turbine causing loss of pressure and efficiency
    6. Engine room fans not set properly
2. Unusually high discharge air pressure
    1. Surging
    2. Restriction in flow through turbocharger – cleaning required
        1. Blockage in exhaust system due to carbon or scavenge fire
    3. Dirty aftercooler on air side – restriction requires cleaning
    4. Dirty aftercooler on water side – causing temperature to rise and pressure with it
3. Excessive vibration when operating at normal speed
    1. This is a sign of imbalance and load should be reduced and engine stopped for investigation when safe to do so
    2. There may be damage to the rotor possibly due to a foreign body (piece of exhaust valve) passing through turbine
    3. Also, the aluminum alloy turbine is subject to creep failure and must be changed after a certain amount of hours
        1. If not changed, a piece may break off an cause imbalance
    4. Worn bearings, especially ball or roller – proper oil type must be used
        1. Ball and roller bearings are often housed in resilient mountings to dampen vibration – these can be checked
        2. If journal bearings are use, oil film is used as hydraulic dampener, oil system should be checked
        3. Bearings last 6000-8000 hours normally
        4. Axial clearances must be maintained and labyrinth seals in good condition
    5. Critical speed reached causing resonance – avoid these RPM's that cause excessive vibration

41. Using a proper line diagram, explain the jacket water cooling system for a large reversible turbocharged diesel engine. Note pressures and temperatures. How is the water temperature maintained at a proper temperature and what is the effect of running it too hot or too cold? What merits does it have as compared to cooling with seawater? (Diesel Duck, Notes)
    1. Engines use a closed feedwater system that utilizes the same treated freshwater over and over
        1. The cooling liquid is thus heated up and is in turn cooled by a seawater circulated cooler
        2. Without adequate cooling certain parts of the engine which are exposed to very high temperatures as a result of burning fuel, would soon fail
    2. A jacket water cooling system on a large engine is used to cool the internal passages within an engine:
        1. Cylinder liners
        2. Cylinder heads
        3. Turbochargers
        4. It may also be used to cool the pistons, with a separate system
    3. From the jacket water circulation pumps, it is pumped to the distribution manifold where it is pumped around the engine cylinder liners, heads and turbochargers
    4. It enters at the bottom of the cylinders and goes through the cooling water passages in the heads and exhaust valves and out through the outlets in the heads
    5. After leaving the engine, the cooling water passes through the thermostatic valve and either through the cooler or around it through a bypass
        1. If warm enough it flows through the sea water circulated cooler and then into the jacket water circulation pumps
        2. If cool, the bypass will be open to allow the water to heat up when starting
        3. This thermostatic valve will hold the best operating temperature and act to hold this temperature independent of load
    6. A header tank allows for expansion due to heat and water make-up in the system
        1. This tank is located at the highest point and maintains a constant head pressure in the system
        2. Vents are led from the engine to the header tank to release any air built up in the cooling water
        3. The expansion tank is fitted with a low level alarm, a sight glass and guard

            4. Also the tank contains a vent and a make-up valve for filling
    7. The cooling system also has an automatic backup pump that will start via pressure switch if the main pump fails to deliver
    8. The system includes a high temperature alarm and low pressure alarm
    9. Fresh water pressure is slightly higher than seawater pressure to avoid contamination in the event of a leak in the cooler tubes
        1. Normally around 1-2 bar
    10. The freshwater is treated with chemicals for anti-corrosion and to minimize effects of impurities
    11. Temperature:
        1. Thermometers are fitted in the system before and after the coolers to see if the cooler is working properly
            1. The water temperature exiting the engine is roughly 80-82C while it is roughly 74-76C prior to entry
        2. A heater in the circuit facilitates warming of the engine prior to starting
        3. Thermostatically controlled three way valve is provided in the circuit to enable the water to bypass the cooler if temperature is low
            1. A temperature regulator or controller can also be used to direct flow of jacket water to or around the cooler depending on its temperature
            2. When load increases, the valve opens more to allow more flow to the cooler and vice versa
        4. The cooler is provided with full flow seawater that is not controlled by the system
            1. If seawater was able to be throttled through a valve, this could also allow some control over jacket water temperature
    12. The piston cooling system employs similar components, except that a drain tank is used instead of a header tank and the vents are led to a high point in the machinery space
        1. A separate piston cooling system is used to limit any contamination from piston cooling glands to the piston system only
    13. The effects of running an engine with high jacket water temperature are:
        1. Excessive wear
        2. Scoring of piston rings in liner
        3. Burned piston and valves
        4. Lubrication failure
        5. Seizure of moving parts
        6. Loss of power
    14. The effects of running an engine too cold are:
        1. Excessive wear
        2. Loss of power
        3. Accumulation of water and sludge in crankcase
    15. Advantages over seawater cooled system:
        1. No danger of scale formation
        2. No danger of galvanic action due to seawater
        3. Better efficiency may be obtained since the engine can be kept at higher operating temperature
        4. Better control of engine temperature

42. Describe the treatment given to the main engine cooling water to maintain it in acceptable condition. Why is such treatment necessary? Name the chemicals most generally used and the manner in which they produce the desired effects. (TCMS, Notes)
    1. Water treatment is recognized as being an essential safeguard for expensive modern machinery
    2. It is well known practise to add chemicals called inhibitors to the cooling water in closed systems to prevent corrosion and scale formation
    3. Treated distilled water is used for cooling:
        1. Pistons
        2. Cylinders
        3. Combustion belts
        4. Fuel injector
    4. Water should be free of suspended solids and have a hardness as low as possible

    5. Distilled water itself is slightly acidic having pH of 6.5
        1. As the water circulates, it absorbs CO2 and this may cause corrosion
    6. Most inhibitors work by stifling the electro-chemical actions by providing conditions in which the corrosion products become insoluble in water
    7. These corrosion products then form a protective film on the metal
    8. Inhibitors are chosen to protect the wide variety of metals of which most systems are composed including cast iron, steel, copper, brass and solder
    9. They also must not attach rubber and non-metallic materials used for joints or seals
    10. Chemical treatments range by manufacturer:
        1. Potassium bichromate – toxicity has led to ban
        2. Aqua-clear – non-poisonous
        3. Maxigard – primarily nitrite-borate, forms passive oxide surface layer
        4. Sodium nitrite
    11. Water used to mix should be of high quality, ideally distilled or de-ionized but definitely of low hardness
    12. Inhibitors are mixed with the water depending on a formula given by the manufacturer and tested regularly

43. What is meant by "Compression Ratio?" What is average ratio for Diesel Engines? Would an increase in volume alter the compression Ratio? (Diesel Duck)
44. State the usual compression for 4-stroke gasoline engine, 4-stroke diesel engine, 2-stroke engine, and the semi-diesel engine. Give reasons for any difference. What pressure would you expect with a supercharged 2-stroke engine?
    1. Pressures and ratios:
        1. 4-stroke gasoline – 120 psi, 8.1 bar, Ratio = 8:1
        2. 4-stroke diesel (naturally aspirated) = 500 psi, 34 bar, Ratio = 15:1
        3. 2-stroke diesel (low supercharge) = 700 psi, 47 bar, Ratio = 15:1
        4. Semi-diesel = 185 psi, 12.5 bar, Ratio = 10:1
    2. Reasons for difference:
        1. Gasoline engines use a spark to ignite the fuel so only a low compression is needed
        2. In the semi-diesel, the fuel lights off from the hot metal in the pre-combustion chamber, so because there is no spark, the ratio must be slightly higher than gas engines
        3. In a 4-stroke diesel engine, no flame or hot spot is used, the fuel lights only in the high temperatures produced by compression, therefore high pressure is need to reach the temperatures required for combustion
        4. In the 2-stroke engine, the compression pressure must be again higher because the air must be heated in only one revolution of the crankshaft instead of two
            1. This means a higher compression pressure is required to produce the temperature needed for combustion
    3. In a highly supercharged 2-stroke engine, compression pressure could be between 55-60 bar
45. What is meant by mechanical clearance and volumetric clearance? How are they found? What effect does wear have on clearances and efficiency? (Notes)
    1. Mechanical clearance of a cylinder is the least distance between the piston and the head when the piston is at top dead center
        1. In a large crosshead engine, the piston is put at top dead center and a chisel mark is made on the edge of the guide shoe and a corresponding mark is made on the column
        2. The top end bearing is then let go and the piston rod and guide shoe is lifted with lifting gear until the piston touches the head and a mark made
        3. The distance between the two marks are measured and this is the mechanical clearance
    2. Volumetric clearance is the cubic capacity of the space defined by the mechanical clearance plus the capacities of any ports and passages
        1. To find the volumetric clearance
        2. The space above the piston at top dead center can be made water tight and filled with water and the quantity of water measured.
        3. The quantity of water is compared with the swept volume and is expressed as a percentage to give the volumetric clearance.

        4. The swept volume is the stroke volume of a cylinder
    3. The wear of moving parts will increase volumetric clearance and reduces the volumetric efficiency of the cylinder
        1. With a large clearance volume, the outward travel of the piston will be greater before the pressure is low enough within the cylinder to allow the suction valves to open (air compressor)
        2. In consequence, a large part of the suction stroke is made ineffective and the amount of air taken into the cylinder during each suction stroke is reduced

46. What is meant by thermodynamics, volumetric efficiency, mechanical efficiency and indicated and brake thermal efficiency? State where losses occur and give approximate percentage values. Describe methods of recovery of heat loss. (Notes)
    1. Thermodynamics
        1. Relates to physics including the relationship of heat with mechanical forms of energy
    2. Volumetric efficiency
        1. The ratio between the volume drawn into the cylinder during the suction stroke to the full stroke volume swept out by the piston
    3. Mechanical efficiency
        1. The ratio of brake horsepower to the indicated horsepower
    4. Thermal efficiency
        1. The relationship between the quantity of heat energy converted into work and the quantity of heat energy supplied
        2. Can be based on the heat energy supplied to develop 1 kW of indicated power in the cylinders or the heat energy supplied to obtain 1 kW of brake power at the shaft
        3. For indicated thermal efficiency:
            1. The specific fuel consumption is expressed as kg fuel per indicated kWh
            2. = 3.6 (MJ/kWh) / (kg fuel/ ind kWh x cal. value (MJ/kg))
        4. For brake thermal efficiency:
            1. The specific fuel consumption is expressed as kg fuel per brake kWh
            2. = 3.6 (MJ/kWh) / (kg fuel/ brake kWh x cal. value (MJ/kg))
            3. Also the product of the indicated thermal efficiency and the mechanical efficiency, therefore the overall efficiency of the engine
            4. Roughly 80%
        5. Losses:
            1. Heat converted into useful work (thermal efficiency) = 37%
            2. Heat carried off by exhaust gases = 35%
            3. Heat carried off by cooling water = 17%
            4. Heat used by turbocharger = 7%
            5. Friction and other losses = 4%
        6. Some heat may be recovered by use of an exhaust gas boiler
            1. The single pass composite Cochran boiler is one that uses such an arrangement
                1. Working pressure is nearly 8 bar
                2. There is two uptakes:
                    1. One for the oil fired system used when the engine is not running
                    2. One for the exhaust gases for when the engine is running
            2. A waste heat evaporator may also be fitted for freshwater production
                1. This may be connected to the jacket water system to create a heat source for water production

47. State the meaning of constant volume and constant pressure cycle. Show PV diagrams showing important points in both cycles. Give examples of engines using these cycles. (Mike, Diesel Duck)
    1. Constant volume cycle
        1. This occurs in a gasoline engine
        2. All heat is taken in at constant volume and all heat is rejected at constant volume
        3. This means that when combustion or exhaust takes place, there is no change in volume
        4. In the gas engine therefore, combustion occurs practically instantaneously and is in effect an explosion

        5. This cycle is also called the Otto cycle
    2. Constant pressure cycle
        1. Diesel engines work on the principal theoretically (but is actually the dual or mixed cycle)
        2. All heat is taken in and rejected at constant pressure
        3. When combustion or exhaust occurs, there is no appreciable pressure rise, as fuel is being injected and burned constantly
        4. Combustion takes place over a period of time and not an explosion
    3. The 3 reasons why the actual work done diagram differs from the ideal work diagram are:
        1. The manner and rate at which heat is added to the compressed air is a complex function of the hydraulics of fuel injection equipment and the characteristics of the operating mechanism
        2. The compression and expansion strokes are not truly adiabatic
        3. The exhaust and suction strokes create pressure differentials which the crankshaft feels as pumping work

48. Sketch and describe the construction and operation of a coil and battery ignition system for a gasoline engine. (Notes)
    1. The method of interrupting the primary current to induce an emf is used extensively in ignition systems for internal combustion engines
        1. The main benefit from using coil ignition is the intensity of the spark is the same irrespective of engine speed
        2. When starting the engine the speed is low but a good spark is obtained
    2. The ignition gear is made up of 4 separate and independent parts:
        1. Battery
            1. The battery has the negative terminal earthed to the body of the engine
            2. The positive terminal can be connected by the switch to the primary or low tension coil
            3. Normally a 12 volt battery
        2. Induction coil
            1. Consists of a primary coil of a few turns of relatively heavy wire would on an iron core
            2. Also fitted with a secondary coil of many turns of fine wire wound directly around but insulated from the primary coil and the core
            3. The other end of this coil is connected to the circuit breaker
        3. Contact maker
        4. Spark plug
    3. As the mechanically driven cam revolves to its peak, the contacts are broken
        1. These breaker points are connected in series with the primary coil and the battery are alternatively opened and closed
    4. When the points are closed, current from the battery flows through the primary coil establishing a flux that links both primary and secondary coils
        1. One end of the secondary winding is common with one end of the primary winding
        2. The other end is connected to the center terminal of the distributor
        3. This terminal bears on the center spring and brush connections of the rotor
    5. As the cam rotates and breaks the contacts, the low tension current is interrupted
        1. At the same time, the distributor arm connects the secondary coil to the proper spark plug
        2. This charge is induced in the soft iron core and is conveyed to the secondary winding and produces a high voltage charge
        3. The high voltage secondary winding is connected to the center terminal of the distributor and as the rotor turns, the brushes come in contact in turn and the high tension current jumps from the end of the rotor to the spark plug connections
            1. The high voltage induced is applied across the spark plug gap, causing an arc between the points that ignites the mixture in the cylinder
        4. These spark plug connections are connected by high tension wires to the plug in the cylinder head, so making the spark in the right cylinder at the right time
    6. The condenser (capacitor), which prevents the points from being destroyed by arcing, also assists in making a better and speedier break of the low tension current

        1. It may be thought of as a storage tank for electricity
        2. The capacitor momentarily provides a place for the current to flow
    7. This sequence of events is then repeated as the next lobe on the cam again breaks the points and the distributor arm advances to fire the next spark plug

49. Describe a cylinder relief valve. Why are they fitted to diesel engines? Where are the relief valves fitted to 2-stroke, 4-stroke and opposed piston engines? (Notes)
    1. The valve is made of stainless steel with a mitre seat and it is loaded by the compression of a helical spring
    2. The spring keep is secured head down into the valve housing and spring compression is adjusted by the thickness of the adjusting ring at its lower end
    3. The lower end of the valve spindle lands on the spindle seating disc allowing the valve to align itself in its seat
    4. Valve lift is limited by a collar at the upper end of the spindle
    5. The valve is fitted to protect the cylinder against excessive internal pressure and it should be set to lift at no more than 20% above the maximum designed pressure for the cylinder
    6. The discharge from the valve should be directed in such a way as not to harm personnel
    7. Valve maintenance will mainly consist of cleaning and inspection and should be carried out at similar intervals to cylinder overhauls
    8. The valve and seat must be examined and ground in if necessary
    9. The spring must be checked for warping and its free length measured
    10. The adjusting ring should be changed if necessary and the valve pressure tested
    11. This can be done by an adapter fitted to the fuel injector test pump
    12. When the valve lifts in service, it indicates incorrect conditions within the cylinder
    13. Theses must be ascertained and corrective action taken
    14. The most likely occasion in which relief valves may lift are starting, slow running or maneuvering of the engine
    15. This may be due to several causes:
        1. Excess pressure due to leakage of fuel in cylinder
        2. Incorrect fuel pump settings or timing
        3. Stuck air start valve
    16. In the event of a large leakage of water or oil, the relief valve may be insufficient to safe guard the cylinder upon starting
    17. That is why the indicator cocks should be opened and the engine blown through to get rid of any fluid and alert the engineer of a problem
    18. Location:
        1. In 2 and 4 stroke engines, the relief valve is fitted in the head
        2. In the opposed piston engine, the relief valve is fitted in the combustion chamber between pistons

Construction of internal combustion engines

50. Why is a fly wheel fitted to a diesel engine? What determines its weight and size? Describe its construction. How can a flywheel be made smaller/lighter? (Jackson, Craig)
    1. A flywheel is a wheel or disc of substantial mass that is attached to the crankshaft of an engine
    2. The major purpose is to stabilize crankshaft rotation
        1. The speed of the crankshaft increases momentarily when it receives a power impulse from a piston
        2. The speed decreases between power impulses
        3. The changes in speed would result in an undesirable instability in rotation
        4. The flywheel will absorb energy during power impulses and when the speed tends to decrease, the flywheel will give this energy up to the shaft in an effort to maintain uniform rotation speed
    3. This will help minimize speed variations at all loads and also to dampen speed changes due to loading
    4. The rotation will help a piston in the compression stroke at low speeds such as starting or idling
    5. In some engines, the flywheel is the point of attachment for such items as
        1. Starting ring gear

            1. In smaller engines, the teeth engage with starter motor pinion to rotate engine to starting RPM
        2. Turning gear
            1. Used during maintenance to position crank
        3. Over-speed safety mechanism
    6. The rim of the flywheel may be marked in degrees
        1. With a stationary pointer attached to the engine, the degree markings can be used to determine the position of the crankshaft when the engine is being timed
    7. Flywheels are generally constructed of cast steel or rolled steel
        1. Strength is important for material due to stresses created during engine operation
    8. The size of the flywheel, meaning its mass and effective diameter, is determined by its inertia
        1. The kinetic energy that the flywheel builds up during rotation and stores depends on its inertia
        2. The flywheel can be made lighter by the addition of counterweights to the crankshaft
        3. These counterweights add to the inertia effect so that the flywheel does not have to absorb so much energy
        4. This would require a vibration dampener on the front of the engine to compensate for harmonics
        5. A heavier, denser material would allow a smaller flywheel since it will do the same work as a larger flywheel made of lighter materials

51. Explain the construction and materials of piston rings on a large diesel engine. How are rings fitted to the piston? What are the typical side and butt clearances and how do they differ with respect to position on the piston? Give possible causes for defective rings in service and the effects on operation of the engine.(Craig, Diesel Duck, Notes)
    1. Purpose
        1. Act as gas seal between the piston and liner
            1. Must be free to follow the liner surface irrespective of transverse movement
            2. Outward pressure initially spring pressure but will be increases by gas pressure on the back of the ring
            3. Pressure and temperature is highest on top rings and they will have highest wear rates
        2. Convey heat to the liner
        3. Build up oil wedge on liner to reduce wear and spread cylinder lubrication
    2. Materials for piston rings must possess:
        1. Good strength
            1. Must not break easily
        2. Good elasticity
            1. Must at all times retain its tension to give a good gas seal
        3. Wear resistance
        4. Low friction
            1. Self-lubricating
        5. Must maintain properties at high working temperatures
        6. Resist corrosion
        7. Readily transfer heat
        8. Have thermal expansion compatible with piston in order to maintain groove clearances
        9. Be compatible with liner material
    3. Construction:
        1. For large 2 stroke engines, most rings are cast and machined from pearlitic grey cast iron
        2. The alloys may include chromium, molybdenum, vanadium, titanium, nickel and copper
        3. Spheroid graphite iron may be used, which has greater hardness and tensile strength
        4. It is possible to improve the properties by treatment
            1. In the case of the cast irons with suitable composition, they can be treated by quenching or tempering
            2. This gives strength and hardness without affecting the graphite
        5. The cross section of rings is rectangular with small radii on all edges
            1. This allows and oil wedge to build up on outer surface and prevents sticking at the back of the ring groove
            2. The section may vary adjacent to ring butts

        3. Rings are machined either circular or to a cam shape from which they expand to form a circle at working temperatures and to avoid port chipping
        4. A radial cut is made and the shape of ring joint ends may be butt (vertical), which gives a robust joint for top rings
        5. They may be scarfed (diagonal) giving better gas seal but less robust
        6. They may have a form of lap or bayonet joint to give a good gas seal but vulnerable to breakage and is only used in some lower rings
    4. Fitting:
        1. Compression rings are fitted in corresponding ring grooves machined in the piston
        2. They will bear heavily on the lower surface known as the land of the grooves during the power stroke
            1. The lands must remain true or rings will distort
            2. To reduce wear, theses may be chromium plated or heat treated or have wear rings fitted
        3. Rings will spring outwards with a spreading tool to pass over the piston and released into the grooves that have been oiled
            1. This tool will give an even bending moment without twisting ring section
        4. The rings should then float freely within the whole depth of the grooves
    5. Clearances:
        1. Ring clearances are necessary to allow movement and thermal expansion
        2. Due to ring and groove wear being uneven, rings should not be moved from one groove to another during overhaul
            1. New rings should be fitted when clearance or wear becomes excessive
        3. Axial clearance must be gauged
            1. This will allow gas pressure to pass to and from the back of the rings
            2. This clearance will increase with wear and must not be allowed to taper
            3. Clearances vary with engine size and rating but for a large engine will be roughly 0.4mm for the top ring to 0.2mm for lower rings
        4. Circumferential clearance at the ring joint is necessary to allow for thermal expansion but should not allow excess blow-by of gas
            1. It is measured before fitting the ring into the least worn (lower) part of the liner bore
            2. This clearance will also vary with the shape of joint, engine size and rating but for large engines, approximate figures may be from .5% of cylinder diameter for moderate ratings to 1% for higher ratings
                1. An amount equal to about 2/1000" per every inch of diameter could also be considered
            3. Wear can be measured by reduction in the width of the ring section and an increase in joint clearance at the corresponding liner bore
            4. Excessive wear will allow rings to distort and eventually break and will reduce engine efficiency
            5. It will reduce compression causing poor combustion and will allow blow-by, which will increase wear rates of rings, grooves and liner
                1. Lubrication will be removed, pistons and liners will be burned and damaged

52. Sketch and describe a trunk type piston including the piston ring bushing. What materials are they made of? How is the gudgeon pin prevented from gouging liner? (Andy, Diesel Duck)
    1. Trunk pistons are fitted to practically all modern 4-stroke engines and may vary in size from small high speed engines up to cylinder bores of about 600mm in the medium speed range
    2. The piston in a trunk engine serves the additional function of a crosshead and the side thrust is taken up by the cylinder wall
    3. Materials used for pistons requires similar properties to those for cylinder liners and heads
        1. The crown must withstand the high gas load and transmit the force from this to the piston rod
        2. It must have a long fatigue life to survive the fluctuating mechanical and thermal stresses
            1. Its surface is exposed to very hot combustion gases followed rapidly by cool scavenge air during each cycle
        3. The metal must resist high temperature creep, corrosion and erosion and readily conduct heat for cooling but have limited thermal expansion so that working clearances are maintained with the liner and piston rings
        4. Material and design will depend on the engine rating, size, speed and fuel

        5. Medium speed engines of modern design have composite pistons that comprise a thin-sectioned alloy steel piston crown supported by an aluminum alloy skirt
        6. This gives a strong, light structure capable of resisting high temperatures and corrosion with low inertial losses
        7. The steel crown may be cast or forged and is shaped to give adequate cooling spaces
        8. Small engines may have cast iron pistons and skirts manufactured from either grey iron or spheroidal graphite iron giving strength and wear resistance with low thermal expansion
        9. Aluminum alloy pistons have been used and can be cast integral with the skirt for economy
            1. They have low inertia and give good strength and wear under moderate conditions
            2. The material work hardens to give low ring groove wear although an insert may be required for top ring due to high temperature and corrosion
            3. Aluminum crown will not be used for heavy fuel as their strength, corrosion and abrasion resistance is reduced at high temperatures
    4. Inner surfaces are cooled by the shaker method in which oil from the gudgeon pin bearing passes to the piston and relies on the reciprocating motion to splash it against hot surfaces and to force it through passages where necessary
    5. The oil drains down inside the skirt to the crankcase
    6. Piston compression rings are fitted in grooves in the cylindrical part of the steel crown
    7. Landings of grooves may be plated or surface hardened to reduce wear
    8. The top surface of the crown may be recessed to allow clearance for inlet and exhaust valves which will be open during the overlap period of the engine cycle
    9. A number of pre-stressed bolts are screwed into the crown to secure it to the skirt
    10. The skirt of silicon-aluminum alloy will contain the gudgeon pin bearing and its outer diameter may be oval to allow for thermal expansion
    11. It must be of sufficient length to dissipate the side thrust to the liner
    12. Oil control rings may be fitted at the top of the skirt to remove excess lube oil splashed from the crankcase
    13. The gudgeon pin is prevented from gouging the liner by securing its ends with circlips to limit axial movement

53. Sketch a piston for a large 2-stroke engine. How is cooling carried out and why is it the preferred method? (Andy, Diesel Duck)
    1. In large engines, a piston rod and crosshead are fitted so that the side thrust is taken up by the crosshead guide shoes on the guides
    2. Pistons will be subjected to rigorous conditions due to the large-bore cylinders and heavy fuels
    3. The piston crown must be supported against bending while allowing cooling of its underside
    4. The shape is concave to give an effective combustion space
    5. Materials
        1. Pistons are cast in chrome-molybdenum alloy steel and machined on all surfaces
        2. Ring grooves are cut into the wall
            1. To reduce wear and fretting of groove surfaces, they are chromium plated and ground
        3. The piston may have a small taper inwards above the top ring position to allow for small changes in its geometry due to high temperatures and stresses
        4. In some case, to give extra protection from high temperature corrosion, part of the piston crown may have a thin layer of protective alloy welded on
    6. Cooling of pistons is necessary to remove excess heat from combustion and to limit thermal stressing
        1. It also limits thermal expansion to maintain correct clearances between piston and liner and between ring grooves and rings
        2. Cooling is carried out by circulating internal passages in pistons with a coolant
        3. This may either be oil or fresh water
        4. Oil cooling:
            1. Oil cooled pistons are used in most engines currently in production
            2. Oil has a slightly lower thermal capacity than water and an adequate supply is necessary
            3. It has a lower maximum safe temperature of 56C to prevent formation of carbon or lacquer on hot internal surfaces

1. This layer will cause reduction of heat transfer, choking of small oil passages
2. Piston cooling oil forms part of the engine crankcase lubrication system and this will require an increased capacity to accommodate it
3. There may be a slight increase in oil deterioration due to the increased thermal cycling
4. Cooling oil is supplied under pressure to the crosshead via either telescopic pipes or swinging links with glands
5. From the crosshead it passes through holes bored in the piston rod to the cooling spaces in the piston
6. 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

5. Water cooling:
    1. Freshwater has the advantage of a higher thermal capacity than oil and a higher outlet temperature of 70C may be sustained
    2. There are a number of disadvantages:
        1. Water is led to and from the pistons by means of telescopic piping
            1. This consists of 2 pipes fixed to each piston, one for supply and one for return
            2. These pipes oscillate in trombone fashion in larger diameter stationary pipes that are fitted with glands to prevent loss
            3. Must be carefully maintained and aligned to prevent contamination of crankcase
        2. Inhibitors are necessary to prevent corrosion and adequate venting must be maintained
        3. A separate piston cooling water system including pumps and heat exchanger, etc. will be necessary
    3. A sight glass is included on return piping so that the flow of water can be observed
    4. A mean of temperature measurement is incorporated in supply and return pipes
    5. Temperature is controlled by passing it through a cooler, usually circulated by seawater, before returning it to the reservoir
    6. The quantity of water in the reservoir must be noted regularly as a check against leakages in system

54. What major stresses would you expect to occur in an IC engine piston and what are the causes of these stresses? Explain why large IC engine pistons must be cooled, state the various cooling mediums and give the advantages and disadvantages of each. (Notes)
    1. Piston stresses:
        1. Compression from combustion forces forcing piston down (gas pressure)
            1. Upper surface under compression
            2. Lower surface under tension
        2. Expansion due to high heat
        3. Thermal stresses due to varying temperatures in upper and lower part of piston
        4. Inertia stresses from reciprocating motion
            1. Same direction as those caused by gas pressure
                1. Crown tends to bow upwards at TDC
                2. Crown tends to bow downwards at BDC
    2. Pistons must be cooled due to:
        1. The heat liberated by combustion is quite high and may deform materials due to loss of strength
        2. Lubrication of rings would be affected if pistons were too hot – oil would flash off and oil film would fail
        3. By circulating coolant on the underside of crown, the temperature of the cool side of the piston is reduced
        4. This increases the heat transmission rate across the piston and prevents ho side from getting too hot
    3. Cooling mediums:
        1. Water
            1. Advantages:
                1. Cheap, easily obtainable
                2. Can remove more heat than lube oil and at higher temperatures

            1. Specific heat is twice that of oil
        2. Disadvantages:
            1. Could contain hardness salts and be acidic, needing water treatment
            2. Separate cooling system required to minimize risk of oil contamination
                1. Additional expense of pumps, coolers, filters, buffers to prevent hammering, etc.
            3. Risk of contamination of crankcase oil
    2. Oil
        1. Advantages:
            1. Part of lube oil system – same pumps, coolers and pipework
            2. Simpler arrangement
            3. No risk of contamination
        2. Disadvantages:
            1. Larger pumps and coolers required
            2. Larger charge of oil in system (cost)
            3. Longer period of cooling down after engine is stopped required to prevent coking of piston

55. Explain why pressure on the cross heads vary. Ignore centrifugal and inertia forces. Where is the maximum pressure? (Andy)
    1. The crosshead bearing transmits the full gas load from the piston to the connecting rod and crankshaft
    2. The load fluctuates throughout the engine cycle
    3. The force acting on crosshead guides may be quite large and causes or tends to cause the engine to rock or vibrate in a transverse direction
    4. The thrust from the guides acting on the engine frames is found from the triangle of forces drawn up from the force acting downwards from the piston, along the line of the piston stroke and the reaction from the upper part of the connecting rod
    5. The force acting in the horizontal direction represents the guide and slipper load
    6. This force completes the triangle and represents the magnitude of the equilibrium or resultant of the forces from the piston rod and the connecting rod reaction
    7. When the line of the connecting rod is identical with the line of stroke, the load on the guides is zero as there is no side component of thrust.
        1. At these points in the piston stroke at TDC and BDC, the direction of the load on the side of the liner or guides is reversed
    8. However as the piston starts to move downwards and the angle the connecting rod makes with the vertical increases, so the component of side thrust increases.
    9. Although as a percentage of piston force, the guide force is at a maximum at 90° ATDC, the gas force on the piston at this point is relatively low.
    10. The point at which it is a maximum will depend on a number of factors, primarily crank angle at which max cylinder pressure occurs, and con rod/crank length ratio, but is usually between 20 - 25° ATDC.

56. Sketch and describe a bottom end bolt as fitted on a large IC engine. State the material it is made of and show how the bolt is held position. What arrangements are made to prevent the nut from becoming slack? (Notes)
    1. Bottom end bolts require constant attention and careful fittings
    2. The bolts are made from good quality steel of about 500 Mpa
    3. Design and manufacture must be of highest quality with fine finish
    4. The head of the bolt must be dead square to the shank
    5. Generous fillets or slow tapers should be used to prevent stress points
    6. When the bolt is tightened, test the head with feelers, at no point should there be clearance
    7. Some makers use a milled flat across the heat fitting on a projection on the housing
    8. When tightening up, be sure not to over tighten and stretch the bolts
    9. Bolts should be checked with trammel at overhaul to see if length OK
        1. Should be replaced at about 12000 hours to be safe
    10. In many cases, hydraulic means are used to loosen and tighten to ensure correct tension

57. Sketch and describe a high pressure fuel pump. Explain fully its operation and the material it is made of. (Adam, Diesel Duck)

1. The Bosch pump has a constant stroke, the quantity of fuel delivered to the cylinder being varied by allowing the fuel to spill port at some point of the delivery stroke
2. The plunger has a vertical groove and a helix (curved slope) cut down the side
3. For inlet, the plunger uncovers both the inlet and spill ports, allowing oil to fill the space between the delivery valve and the shoulder formed on the plunger below the vertical groove
4. At the beginning of delivery, the plunger has covered the inlet and spill ports
5. The pressure builds up rapidly and the oil is forced into the cylinder
6. As the plunger moves up, the edge of the helix uncovers the spill port
7. The pressure suddenly drops and the injection valve snaps shut
8. If the plunger is turned clockwise (looking on top), the spill port remains closed longer allowing more fuel to be delivered to the cylinder
9. If the plunger is turned anti-clockwise, the reverse action will take place
10. Turning of the plunger is effected by means of the fuel control rod either by hand or by the governor

58. Sketch and describe the construction and function of a plunger helical release type of Bosh type fuel pump. Explain how the pump is timed and how the amount of fuel pumped is regulated. (Diesel Duck, Notes)
    1. A widely used pump is the Bosch type pump
        1. This pump is of the constant volume, variable delivery type
        2. This pump consists of a cam operated, single acting plunger of fixed stroke
        3. Helical springs are fitted to return the plunger on its down stroke and to maintain contact of follower on the cam
        4. Fuel delivery takes place at a fixed point on the upward stroke when the top edge of the plunger blocks off suction ports
        5. A helix is machined on the plunger and delivery of fuel ceases when this helix uncovers the suction ports
        6. This allows fuel pressure above the plunger to fall to the suction pressure through a vertical slot
        7. Injector nozzle and pump delivery valve close when the pressure is release and the cycle repeated
        8. The amount of fuel injected depends on how long it takes for the helix to uncover the suction port
            1. This in turn depends on the plunger angular position, which is controlled by the fuel rack linkage to the governor
    2. To time and set an injection pump, the following steps are carried out:
        1. Close fuel to pump on supply line
        2. Turn #1 cylinder to TDC on compression stroke, put a mark on the casing and on the flywheel
        3. From the engine manufacturers data sheet, find out the # of degrees before TDC at which injection should start
        4. Calculate what this represents in inches on the circumference of the flywheel and put a mark to represent "injection start"
        5. Turn the engine astern so that the mark "injection starts" is well beyond the datum line, then slowly move ahead until the marks almost coincide
        6. Disconnect and remove the fuel pipe from pump to injector
        7. Take out delivery valve and spring from the connection on top of the fuel pump and replace connection
        8. Place control lever in running position
        9. Open fuel to pump valve a very little and move the engine ahead slowly and watch when fuel ceases to flow
        10. Close fuel to pump valve
        11. If the pump setting is correct, the marks on the casing and the flywheel "injection starts" should coincide. If not, lock the pump in this position and prevent engine from being moved
        12. Open fuel pump gear-case and take out of of the timing wheels
        13. Now move the engine ahead or astern until the casing and flywheel marks coincide. When the marks coincide, replace the timing wheel
        14. Remove the locking device from the fuel pump and open the fuel pump valve and carefully check again
        15. Close fuel to pump valve, replace spring, and delivery valve in connection
        16. Replace connection and open fuel to pump valve
        17. Close up timing gear-case

3. The quantity of fuel delivered is regulated by the vertical length of the helix where it is in line with the suction ports
    1. This setting may be regulated by rotating the plunger
        1. A rack is fitted to the pump to engage with a pinion machine on the outside of the sleeve
        2. The sleeve fits over the plunger and has slots engaging with keys
        3. In this way, the plunger may be rotated by moving the rack
        4. The fuel cam is designed to raise the plunger at the rate required to build up fuel pressure and maintain the pressure for the corresponding period to operate the fuel injector
        5. The pump only discharges on its upward stroke
        6. One flank of the cam operates the timing and the trailing flank of the cam returns the plunger to the bottom of its stroke to allow the chamber to refill
        7. Timing is controlled by the relative angular position of the cam peak to the crankshaft
            1. It can be adjusted by moving the cam with respect to the crank
        8. Further adjustment is made by raising or lowering the pump plunger with respect to the cam follower
        9. The fuel pump casing itself may be raised or lowered on its mounting by the use of shims to give corresponding effect
        10. Fuel supply to the pump suction is by means of a supply booster pump or by gravity from a day tank of higher elevation
            1. This causes flooding of the pump chambers as soon as suction ports are uncovered
            2. An air vent is fitted on the discharge side of the pump to remove it quickly

59. Describe with the aid of a sketch a high-pressure jerk type of fuel pump suitable for a slow speed diesel engine. How the beginning and end of injection is controlled in this pump. (TCMS)
    1. Helix-type:
        1. This type of pump with small variations is used in many diesel engines
            1. One is fitted for each cylinder
            2. The pump consists of a cam operated single acting plunger of fixed stroke
            3. Usually operated once every cycle by a cam on the camshaft
            4. The barrel and plunger are dimensioned to suit the engine fuel requirements
        2. Helical springs are fitted to return the plunger on its down stroke and to maintain contact of follower on the cam
        3. No timing valves are required and fuel delivery commences at a fixed point on the up stroke when the top edge of the plunger blanks off the suction port
        4. A helix or scroll is machined on the plunger and delivery of fuel ceases on the up stroke when the curved surface of the helix uncovers the suction port
        5. This allows fuel pressure above the plunger to fall to the suction pressure trough a vertical slot or hole
        6. The quantity of fuel delivered is regulated by the vertical length of the helix where it is line with the suction port
        7. This setting may be altered by rotating the plunger
        8. A rack is fitted to the pump to engage with a pinion machined on the outside of a sleeve
        9. The sleeve fits over the plunger and has slots engaging it with keys
        10. In this way, the plunger may be rotated by movements of the rack
        11. The fuel cam is designed to raise the plunger at the rate required to build up fuel pressure and maintain this for the corresponding period to operate the fuel injector
            1. The needle valve in the injector will lift at a pre-set pressure which ensures that the fuel will atomize once it enters the cylinder
        12. Since the pump only discharges on its up stroke, only one flank of the cam operates the timing
        13. The trailing flank of the cam returns the plunger to the bottom of its stroke to allow the chamber to refill
        14. Timing:
            1. Timing is controlled by the relative angular motion of the cam peak to the crankshaft
            2. Further adjustment is made by raising or lowering the pump plunger with respect to its follower
            3. Raising the plunger will make cut off of the fuel suction port and corresponding fuel injection early, while lowering will make these later

            4. Alternatively the fuel pump casing may be raised or lowered on its mounting to give a corresponding effect
            5. Plunger must maintain clearance at the top of its stroke
        15. Oil supply to the pump suction is by means of a continuously operating supply or surcharge pump that causes flooding of the fuel pump chamber as soon as the suction port is uncovered by the plunger
        16. In some pumps a non-return spring-loaded discharge valve is fitted
            1. This is arranged to reduce pressure on its discharge side as it closes
            2. This ensures positive seating of the fuel injector needle and reducing cavitation within the pump
        17. A priming or vent plug is fitted to the discharge
    2. Valve controlled pump
        1. In the variable injection timing pump used in MAN B&W engines, the governor output shaft is the controlling parameter
            1. Two linkages are actuated by the regulating shaft of the governor
            2. The upper control linkage changes the injection timing by raising or lowering the plunger in relation to the cam
            3. The lower linkage rotates the pump plunger and thus the helix in order to vary the pump output
        2. In the Sulzer variable injection timing system, the governor output is connected to a suction valve and a spill valve
            1. The closing of the pump suction valve determines the beginning of injection
            2. Operation of the spill valve will control the end of injection by releasing fuel pressure
            3. No helix is therefore present on the pump plunger

60. What materials are used in the manufacture of diesel engine crankshafts? What physical tests are the materials subjected to? What properties must this material possess? (Notes)
    1. There are 3 main types of crankshafts:
        1. Fully built
            1. Webs are shrunk onto journals and crank pins
            2. Large engines
        2. Semi-built
            1. Webs and crankpin as one unit shrunk onto the journals
            2. Medium speed and large engines
        3. One piece
            1. One piece of material wither cast or forged
            2. High speed diesels
    2. Material:
        1. When these parts are made separate from the webs, the crankpins and journals used good quality mild steel
            1. Steel with around .2% carbon and UTS of approx. 425 MPa
        2. Webs:
            1. May be open hearth steel and machined out of rolled or forged slabs
            2. To try and lessen machining, some manufacturers have used cast steel for webs
    3. Tests:
        1. Chemical analysis – necessary to ensure that the specification is being adhered to and that sulfur and phosphorous content is not too high
        2. Magnetic particle test – detects surface and subsurface defects
        3. Ultrasonic test – detects defects with the material
        4. Dye-penetrant test – detects slight surface defects
        5. Destructive tests:
            1. Tensile
            2. Fatigue resistance
            3. Bend test
            4. Hardness test
    4. Properties:
        1. Toughness

        2. Strength
        3. Hardness
        4. High fatigue strength – most important since loads imposed on a crankshaft are fluctuating in nature
        5. Form good bearing surfaces
    5. Defects and causes
        1. Misalignment
            1. If we assume alignment was correct when assembled, reasons for misalignment occurring are:
                1. Worn main bearings caused by incorrect bearing adjustment leading to overloading
                    1. May be caused by broken, badly connected or choked lube oil passages causing starvation or contamination
                2. Excessive bending of engine framework
                    1. Could be caused by improper cargo distribution or vessel grounding
                    2. All bearing clearances must be checked and deflections taken after any accident
            2. Vibration
                1. Can be caused by incorrect power balance or prolonged running at critical speeds
                2. Can also be caused by slipped crank webs or journals
                3. Light ship conditions may lead to impulsive forces from the propeller
                4. Excessive wear down of propeller shaft which can lead to shaft whip
                5. Damage due to vibration can be severe since parts can work loose or seize

61. Describe a method of constructing a diesel engine crankshaft. Why is the crankshaft of heavier construction than that used with a steam engine of the same horsepower? How is the angular spacing of the cranks determined? Sketch a crankshaft showing the crank angles. (Notes)
    1. The crank webs, pins and shaft lengths are usually forged separately but in diesel practise, the crank webs and pins are often machined out of one solid ingot
        1. Mild annealed steel with 28 to 32 ton/in2 and elongation of 25-29% is used
    2. If loose, the webs are shrunk onto the crank pins and shaft length
        1. Webs are sometimes cast steel
        2. The shrinkage allowance should be 1/625 of the diameter of the shaft if no dowel pins are used
        3. Visible reference marks must be made on the outer ends of the journals and crankpins and on the adjoining webs
    3. The crankshaft is not subjected to axial thrust, this being absorbed by the thrust block
    4. For equal power development, the crankshaft of diesel engines is heavier than that of a steam engine due to the bending and shearing stresses are more one-sided and act on the down stroke only
        1. Higher inertial load is created on piston due to combustion (550 psi vs. 180 psi)
    5. For 6 or 8 cylinder engines, the crankshaft is usually made up of two separate sections which are bolted together with 6 or 8 coupling bolts
        1. The spur gear or chain sprocket wheel for transmitting motion to the camshaft is generally mounted on the coupling connecting two sections
    6. Passages are bored through the journals, webs and crankpins to allow lube oil under about 20 psi admitted at the main bearings to pass through to the crankpin bearings
        1. After the big end bearings, the oil passes through a hole bored in the connecting rod and lubricates the crosshead bearings and guides
    7. A flywheel is bolted on the end to ensure a uniform turning moment
        1. If crankshaft is balance, a flywheel may not be required
    8. The order of firing, together with the sequence of crank angles is arranged for good balancing, with equal load per cylinder

62. Sketch and describe a 2-stroke cylinder liner. Show and explain the sealing arrangement. What material and how is it made? How is it secured? (Dave, Notes)
    1. Cylinder liners are designed to give an extended working life with long periods between overhauls
        1. They must maintain low rates and friction losses from the sliding motion of the piston rings under fluctuating pressures and temperatures

2. Materials for liners must provide:
    1. Characteristics:
        1. Adequate strength and fatigue life
        2. Readily transfer heat
        3. Resist abrasion and corrosion
        4. Be able to retain an oil film on working surfaces
        5. Have a rate of thermal expansion compatible to adjacent parts
    2. A cylinder liner for a 2-stroke is manufactured with pearlitic grey cast iron with vanadium and titanium
    3. These alloys refine the structure while increasing strength, wear resistance and corrosion resistance from sulfur in fuel
    4. Actual specifications depend upon the engine type, its rating and fuel type
    5. Liners are centrifugal cast
    6. Chromium plating of the internal surface can be carried out to further reduce wear and corrosion
        1. The chrome must be porous or etched to retain lubrication
        2. Chromium plated rings must not be used with plated liners
3. The upper end of the liner forms a flange of sufficient strength to support it
    1. This flange is secure between the cylinder head and jacket or entablature
    2. The cylinder head lands on top of the liner and is secured to the jacket by a number of studs and these ensure a water tight seal between liner, flange and jacket via a gasket
    3. The liner being fixed at this position, tie bolts pass from the top of the jacket to the transverse members of the engine bedplate
        1. These transmit the gas load
    4. The liner is free to expand downwards
4. The thickness of the liner must give adequate strength to resist gas loads but thickness is limited by the necessity to transfer heat rapidly and limit thermal stress
    1. The outer surface of cylinder liners are always tapered downwards to a smaller diameter because:
        1. The bursting pressure at the lower end is less that the upper end
        2. Much of the heat from the upper end is conducted to the lower and cooler end
            1. This thin wall will allow better heat transfer to the cooling water
5. The portion of the liner encased in the scavenge space has a row of scavenge port, which are uncovered by the piston on the bottom of its downward stroke
        1. These ports will be cut or cast into the liner in the lower end
        2. Engines using loop or cross scavenging require exhaust ports as well
        3. All ports are shaped to direct flow
    2. Above and below the ports, grooves are cut in the liner to receive copper rings
        1. 2 rings are rolled into these grooves, one above and one below the ports
        2. These rings ensure a gas-tight joint when the liner is inserted in the jacket
6. A water seal is made at the bottom end of the water jacket by two silicone rubber o-rings fitted in grooves cast in the liner
7. There is a space fitted between the jacket and scavenge trunk and any leakage can be detected there
8. A similar gland with two more seals is fitted between the oil lubricating holes and the scavenge ports
9. Lubricator connections are fitted in the access space

63. Sketch and describe a liner for a 2-stroke diesel engine. How is it sealed at the top exhaust ports from the cooling water? What is its composition and why is it made of this? (Diesel Duck)
64. How are liners fitted and retained in position? Describe the cooling water seals. How do you know if these are leaking? Illustrate your answers with line sketches. (Diesel Duck)
    1. 4-stroke:
        1. The upper end of the liner is formed in the shape of a flange which is cast integral with the liner
        2. The underside of this flange rests on and is supported by the cylinder beam or jacket
        3. The cylinder head holds the liner in place at its upper end when the cover studs are hardened down

        4. At the lower end of the liner, one section is made thicker to form a belt, this thicker section being located in the lower part of the cylinder beam or jacket that holds it in place
        5. This is where the lower sealing rings are located
    2. 2-stroke:
        1. The upper part of the liner is held in place in the same way as in a 4-stroke engine
        2. The ported section of the 2-stroke liner fits into the lower part of the cylinder beam which also forms the jacket in many 2-stroke loop and cross scavenged engines
        3. In many uniflow engines, the thickened section of the liner is formed about halfway down its length and fits into the lower part of the cylinder beam which also forms the jacket
        4. This thickened section houses the scavenge ports through which the scavenge air passes
    3. Often, leakage from the liner sealing rings can be found only by visual inspection when the engine is stopped
        1. The cooling spaces should be kept under pressure during the examination
        2. The usual places are the bottom of the liner and crankcase in trunk type engines and the scavenge space in crosshead engines
        3. Some engines are fitted with leakages tell-tale holes so that when leakage occurs in inaccessible places, it is indicated by leakage at these holes

65. Describe the construction of a cylinder including the head and liner. (Diesel Duck)
66. Describe the construction of a large 2-stroke cylinder head. State the materials used and list the valves housed in the head. How is the head secured to the liner?
    1. The head (or cover) from the top part of the combustion space and must be of sufficient strength to withstand gas load at maximum pressure
    2. The head must also locate and support all the valves required to operate the engine
        1. For a large 2-stroke:
            1. Central exhaust valve and cage
            2. 2-3 fuel injectors
            3. Starting air valve
            4. Relief valve
            5. Indicator cock
    3. Design must:
        1. Transfer heat readily
        2. Resist bending
        3. Be symmetrical in shape
        4. Coefficient of thermal expansion similar to liner
    4. For a large 2-stroke:
        1. Machined from solid steel forgings drilled to give bore cooling
        2. Circulated with fresh water to maintain moderate temperatures and allow intensive cooling of exhaust valve seat
    5. Securing:
        1. The head lands on the top of the cylinder liner flange and is secured to the block by a number of cover studs and nuts
            1. These are tightened hydraulically to maintain a gas tight seal under the arduous fluctuating pressure and temperature conditions
67. Sketch and describe the construction of a 4-stroke cylinder head, include hold down arrangement and common defects of a cylinder head. (Adam, Jackson, Mike)
    1. The cylinder head of a 4-stroke diesel engine is usually made of cast iron
        1. They can either be square or circular in shape
        2. They are made by casting to the particular shape or size required
        3. Any surfaces of the head must be machined perfectly true to a smooth finish
    2. The majority of heads are water cooled with passages cast in
        1. Passages are tested hydraulically to 30 psi

3. In designing depth, the chief factor in the case of a 4-stroke engine is the exhaust passage from the valve pocket to the outer wall
    1. The area of the passage must be sufficient to allow unrestricted flow of the gases
    2. Cooling water must also flow around this passage to avoid undesirable heat stresses
4. The strength of the cylinder head is not entirely dependent upon the thickness of the lower wall or flame plate
    1. The upper wall enclosing the cooling water spaces assists greatly in resisting the gas pressure inside the cylinder, the load being transmitted through the side or outer vertical walls
5. The head flame plates are perforated to accept valves and fittings:
    1. Inlet valves
    2. Exhaust valves
    3. Injector
    4. Relief valve
    5. Indicator cock
    6. Air start valve
6. The head is held to the engine by a large number of studs screwed into the block and nuts equally spaced around the periphery of the head
    1. When securing the head, each nut is torqued down to a pre-determined value set by the manufacturer
    2. A particular pattern is followed to even the stresses in the head and studs or bolts
    3. A metallic gasket is fitted to seal the head against the block
7. When heads fail, it is often from cracking in the flame plate starting from the corner of an opening
    1. Typically this crack extends between the exhaust valves or between the exhaust valve and injector pocket or inlet valve
    2. To eliminate this weakness, the injector is often offset to increase this space
    3. Cold starting air also causes stress cracks when administer to a hot engine during maneuvering
    4. Lower ends of all pockets should be well rounded and any cracks should be removed by chipping and filing, otherwise they will extend into water space possibly
    5. Heads should be regularly checked for cracks before they become major faults
        1. Can be checked by dye penetrant to find cracks too small for the naked eye

68. Sketch and describe a cylinder head for a 4-stroke diesel engine, name material and all valve fittings, reasons if cracked. (Diesel Duck)
    1. Cracks may be caused by:
        1. Heat stresses due to temperature difference on each side of metal thickness
        2. Intense heat of exhaust gases, which often cause cracks between exhaust valve and injector pocket
        3. Deposits of scale in water jackets
        4. If atmospheric temperature is low, starting up engines from cold without warming up passages
        5. Cracks tend to form around openings of any size cut into head
69. How do you measure exhaust temperatures? Sketch and describe one type. (Adam)
    1. Thermocouple
        1. A pyrometer can be a millivolt meter calibrated in temperature units, which is attached to individual cylinder exhaust thermocouples
        2. The thermocouple is made of 2 rods of different metals that are welded together at one end
        3. When heated at the welded junction, an electromotive force is produced between the terminals
            1. The other end is termed the cold end
        4. Formed from 2 junctions:
            1. The indicator, that is remote from the source where temperature is to be measured
            2. The dissimilar metal inside the exhaust pipe form the second junction
        5. The greater the temperature difference between the 2 junctions, the greater the emf (in millivolts) that will be produced
        6. The temperature reading on a pyrometer is usually a direct interpretation of the amount of power being developed in a cylinder
        7. The greater the pyrometer reading, the higher the cylinder mean effective pressure except in the cases of faulty injection, incorrect timing or leaky valves

8. A very high pyrometer reading means overload and a very low reading means that the particular cylinder is not carrying its required load
9. When used to indicate exhaust gas temperature, the metals used are:
    1. Positive end = iron
    2. Negative end of couple = constantan
    3. Protective sheath = iron
    4. Insulating material = porcelain
10. Advantages:
    1. Simplicity
    2. Compactness
    3. No external power required
    4. Quick to respond to changes in temperature
    5. Relatively cheap
11. Disadvantages:
    1. Small changes in voltage for large changes in temperatures
    2. Needs good insulation
    3. Signals would require amplification if they were to be used in a control system

2. Thermistor
    1. Uses variation of resistance to measure variation of temperature
    2. Temperature sensing resistance would be incorporated into a Wheatstone bridge circuit whose balance would be upset if the temperature being measured varied
    3. In most metals, electrical resistance increases with temperature increase
        1. The semi-conducting thermistor has its resistance markedly decreased with temperature increase
        2. Hence the thermistor, because of the bug change in bridge potential for small change in temperature is becoming increasingly popular
    4. The leads of the temperature sensing resistance could be of considerable length and could pass through compartments at various temperature so they are arranged to compensate each other

70. Describe an exhaust valve unit of 4-stroke engine. Describe the valve seating arrangement, guide, spring and keeper assembly. State materials from which each is made. (Diesel Duck)
    1. One or more exhaust valves are fitted to each cylinder with the cylinder head and are of the poppet type with their valve lid and spindle of inverted mushroom shape
    2. They are arranged to open inwards in order to maintain positive closing under pressure in the cylinder and ensure their non-return action
    3. Gas pressure will act on the area of the valve lid to hold it against the seat and supplement the closing action of the springs
    4. This positive contact of valve and seat removes carbon or other deposits on the valve seat, which is allowed to build up, causes blow-by of hot gases and burning of valves and seats
    5. The shape of the lid protects the seat from the flame and hot gases during combustion
    6. 4-stroke engines have their exhaust valves mechanically actuated from the camshaft, the shape of the cam controlling the timing and lift of the valve
    7. 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 the valve to open
    8. During opening, the valve springs are compressed and these force the valve closed as the cam peak leaves the follower
    9. Helical coiled steel valve springs are used, designed to have sufficient compressive strength while avoiding vibrations
        1. Valve springs and operating mechanism can be of moderate proportions, reducing inertia of parts and power demand
        2. To facilitate valves without lifting the cylinder head, each valve together with its springs may be fitted in a separate cage
    10. Materials:
        1. Exhaust valves may be manufactured from heat-resistant alloy steels but to prevent corrosion when burning heavy fuels, Stellite is welded to the valve landing surface

        1. Stellite is a very hard alloy of cobalt, chromium, tungsten with some iron and carbon
        2. It resists impact, wear and corrosion at high temperature
    2. Large exhaust valves may be austenitic alloy steel and have the underside of the valve protected by a sintered layer of Inconel or Nimonic
        1. Alternatively, the whole valve and spindle may be forged in Nimonic, which is a high nickel alloy
11. Cooling of exhaust valves will prolong the useful life of valves, seats and bushes
12. It will maintain temperature low enough to prevent burning and rapid wear and also allow lubrication of the spindle bushes, reducing wear and maintaining valve alignment
13. When burning heavy fuels containing vanadium and sodium compounds, valve temperatures must be kept below 530C to avoid hot corrosion and deposits
14. Cooling is by circulating the valve cage and seat with fresh water
15. In some case, the valve itself may be cooled by cooling passages with flexible external connections
16. Valves and seat should be made of materials that readily conduct heat from the valve lid
17. Valve cages must be a good fit in the cylinder head in order to transfer heat to the head
18. Rotation of valves during operation will assist in removal of deposits between seat and landing
    1. It will also ensure an even temperature and wear around the valve
    2. Rotation may be carried out mechanically by fitting a ratchet or friction device at the top spring compression plate (termed a Rotocap)
    3. Alternatively, angle guide vanes may be fitted to the spindle causing the gas stream passing through the valve to rotate it while in the open position
19. Tappet clearances are necessary to allow for thermal expansion of the valve spindle length at working temperatures and to ensure that positive closing of the valve continues as it wears or seats during use
20. Clearances should normally be set with the engine cold and the cam follower is off the peak
21. Wear in parts of the valve operating gear will tend to increase clearances
22. Excessive tappet clearance will cause the valve to open late and close early in the cycle and will reduce maximum lift
23. It will also cause noise and eventually damage from the impact of working surfaces
24. Insufficient clearance will cause the valve to open early and close late with increased maximum lift
    1. In extreme cases it may prevent the valve from closing completely as it expands or beds in
    2. This in turn will cause hot gases to blow past valve faces, causing valve burning, low compression, etc.

71. Describe the construction of an opposed piston engine and name the materials. Give the advantages over a single acting piston 2-stroke engine. (Diesel Duck x 2, Notes)
    1. Fairbanks-Morse:
        1. Operated on the 2-stroke principle
            1. The cycle begins with pistons at the outer end of their stroke and a fresh charge of air in the cylinder
            2. As the pistons move inward, the air charge is compressed resulting in the air reaching a high temperature
            3. At approximately 9 degrees before the lower piston reaches TDC injection begins
            4. The high temperature of the air cause the fuel to ignite and combustion takes place as the pistons pass their inner dead center
            5. The resulting pressure causes the pistons to be forced apart, delivering power to the crankshafts
            6. The expansion continues allowing the burned gases to pass to the atmosphere through the exhaust ports and then through trunking
            7. When the pressure in the cylinder has dropped to nearly atmospheric, the upper piston begins to uncover the inlet ports
            8. Scavenge air, under pressure from the engine driven blower, rushes into the cylinder sweeping out remaining exhaust gases and filling it with fresh air for the next compression stroke
            9. Maximum firing pressure is about 1200 psi with compression pressure of about 510 to 550 psi
        2. Advantages:
            1. Light weight per HP
            2. Absence of complicated casting cylinder heads, valves and valve operating gear

        3. Convenience and ease of overhaul, repair and inspection due to accessibility and fewer parts
2. Doxford:
    1. Advantages:
        1. Greater power per unit so engine length may be reduced, however height is increased
        2. More easily dynamically balanced.
            1. Two piston moving in opposite directions give good primary balance to the engine
        3. Since both pistons are connected to crankshaft, all gas loads are transmitted to working parts, eliminating need for tie bolts and allowing lighter bedplate construction
        4. Lower piston will uncover scavenge ports while upper piston uncovers exhaust port so engine has a rapid, large exhaust opening with no requirement of an exhaust valve or cylinder head
        5. During overhaul, removal of two pistons for each unit opened gives economy of time
        6. Troubles due to cracked cylinder heads eliminated
        7. Piston rod is subjected to compressive stress only while side rods are subject to tensile stress only
        8. Heat developed is absorbed by piston crown so that efficiency is increased and a lower compression pressure is found sufficient
        9. The ideal uniflow scavenge system can be employed
    2. The lower piston is oil cooled by telescopic pipe to the crosshead
    3. The upper piston which runs hotter, is cooled by water with telescopic connections made clear of the crankcase
    4. The upper piston is connected to the crankshaft by side rods, crossheads and guides and thus 3 times the amount of bearings per unit, thus more maintenance required
    5. Engine crankshafts must also be more complex design
        1. By advancing the cranks of the upper pistons compared with the lower piston cranks, the exhaust timing is adjusted to reduce the post scavenge loss, while increasing the blow down period
        2. This will be less efficient however when the engine is reversed and for this reason, the angle of load between cranks is limited
    6. To restore balance of the engine, the stroke of the upper piston is reduced
    7. The engine may be turbocharged on the pulse system and have an auxiliary blower for idle speeds and manoeuvering
    8. The fuel system operates on the common rail system with camshaft operated, mechanical timing valves passing fuel to operate two injectors per cylinder
    9. This allows very simple direct reversing, being controlled by an air start distributor only
    10. The fuel pumps are connected to a chain driven crankshaft and discharge to the common rail at high pressure
    11. The cylinder consists of 3 parts:
        1. The upper and lower liners, each of which are bolted to a central cast steel combustion chamber
        2. The chamber has cooling water passages and contains radial pockets to accommodate fuel injectors, an air start valve, and a relief valve
        3. Cast steel pockets reinforce the liners and allow water cooling
        4. The lower jacket is attached to the engine and thus secures the cylinder
        5. The upper liner jacket contains the exhaust belt with bore cooled exhaust port bars
        6. The liners are free to expand both up and down from the central combustion space
            1. Rubber seal rings are fitted at each end of the jacket
    12. Materials:
        1. Liners – pearlitic gray cast iron
        2. Piston crown – cast or forged steel
        3. Connecting rod – forged steel
        4. Frame – fabricated cast steel
        5. Combustion belt – cast steel
        6. Side rods – cast steel

72. Describe in detail the construction of a 4-stroke and 2-stroke diesel engine and name the materials used. (Diesel Duck)
    1. Engine materials:

1. Frames - cast iron or steel
2. Liners – close grained cast iron
3. Pistons – cast iron or aluminum alloys
4. Connecting rods – forged steel
5. Camshafts – cast or forged steel
6. Valves – nickel chrome steel or alloys
7. Valve springs – spring steel
8. Bearings
    1. Shell – cast iron, cast steel or bronze
    2. Surface – Babbitt or copper nickel alloys
    3. Bushings – bronze and brass

2. 4-stroke:
    1. The engine is made up of a piston that moves up and down in a cylinder that is covered by a cylinder head
    2. The fuel injector, through which fuel enters the cylinder, is located in the cylinder head
    3. The inlet and exhaust valves are also housed in the cylinder head and held shut by springs
    4. The piston is joined to the connecting rod by a gudgeon pin
    5. The bottom end or big end of the connecting rod is joined to the crankpin which forms part of the crankshaft
    6. With this assembly, the up and down movement of the piston is converted into rotary movement of the crankshaft
    7. The crankshaft is arranged to drive through gears, the camshaft, which either directly or through pushrods operates rocker arms that open the inlet and exhaust valves
    8. The camshaft is timed to open the valves at the correct point in the cycle
    9. The crankshaft is surrounded by the crankcase and the engine framework which supports the cylinders and houses the crankshaft bearings
    10. The cylinder and head are arranged with water cooling passages around them
3. 2-stroke:
    1. The piston is solidly connected to a piston rod which is attached to a crosshead bearing at the other end
    2. The top end of the connecting rod is also joined to the crosshead bearing
    3. Ports are arranged in the cylinder liner for air inlet and a valve in the cylinder head enables the release of exhaust gases
    4. The incoming air is pressurized by a turbocharger that is driven by exhaust gases
    5. The crankshaft is supported within the engine bedplate and house guides in which the crosshead travels up and down
    6. The entablature is mounted above the frames and is made up of the cylinders, cylinder heads and scavenge trunking
4. Comparison:
    1. The main difference between the two cycles is the power developed
    2. The 2-stroke engine, with one working or power stroke every revolution will theoretically develop twice the power of a 4-stroke engine of the same swept volume
    3. Inefficient scavenging however and other losses limit the power advantage to about 1.8
    4. For a particular engine power, the 2-stroke engine will be considerably lighter – an important consideration for ships
    5. The 2-stroke engine also does not require the complicated valve operating mechanism of the 4-stroke
    6. The 4-stroke engine can operate efficiently at high speeds which offsets its power disadvantage
        1. It also consumes less lube oil

73. Describe a semi diesel engine and explain fully its function. What would be the compression and firing pressures? Describe the cycle of events (Diesel Duck, Notes)
    1. The semi diesel is a 2-stroke engine
    2. The cycle of events in a semi-diesel are as follows:
        1. On the downward stroke, above the piston:
            1. Ignition of fuel, combustion, expansion of gases, uncovering of exhaust ports and scavenge ports near the bottom
        2. On the downward stroke, below the piston:

        1. Compression of the crankcase suction air to about 3 psi
    3. On the upward stroke, above the piston:
        1. Compression of scavenge air to about 200 psi, injection of fuel near TDC
    4. On the upward stroke, below the piston:
        1. The suction air enters the crankcase through the inlet valves
3. Firing is obtained by the ambient effects of moderate compression and the hot bulb or uncooled part of the head against which the liquid fuel is injected by the fuel pump
4. Before the engine can be started, the ignition chamber must be heated by a heating lamp
5. When the piston has reached its upper portion, a certain amount of fuel is injected into the injection chamber through the nozzle and the fuel charge explodes, the expanding gas driving the piston down towards the shaft
6. During the downward stroke of the piston, the air in the crank housing is compressed
7. As the piston nears the end of the stroke, the exhaust port opens and immediately after, the inlet port opens
8. The burned gases escape by the exhaust port while the compressed air in the crank housing enters the cylinder scavenging the cylinder and furnishing air for the next full charge
9. The injection chamber has two ports, by this it means it is blown with fresh air every revolution, an important feature for securing a rapid and effective ignition
    1. Air enters the port near the injector and leaves by the other port
10. The piston is now on the upward stroke again and the cycle is completed

74. Name the types of internal combustion engines which are fitted respectively with carburetors, vaporizers. What is the purpose of this fitting? Give the type of fuel diesel in each case and describe the system of ignition for each. (Diesel Duck)
    1. Gasoline engine are fitted with carburetors
        1. The carburetor is a small chamber employed to vaporize the gasoline and at the same time mix it with proper proportions of air
        2. The openings are arranged to give from 8 to 20 parts of air to 1 part of gasoline but this varies with running conditions
        3. A throttle valve is also fitted on the carburetor to regulate the amount of vapor admitted to the engine
        4. A float and needle valve regulates the oil supply to the mixing chamber of the carburetor
        5. A single carburetor is sufficient for any number of cylinder, as by suitable pipe connections the vapor can flow into each as required
    2. A hot-bulb or semi-diesel engine has an uncooled chamber, called a vaporizer, connected to the cylinder by a restricted passage
        1. This chamber contains most of the clearance volume
        2. The chamber has a hot surface on which fuel is sprayed
            1. Ignition of fuel will result when air is compressed at end of compression stroke
        3. For starting purposes, the surface of the chamber is heated by an electric plug
        4. After starting the heat of combustion keeps the surface of the chamber hot enough to ignite the fuel, except in case of very low load
        5. This type of engine has a low compression pressure of 180 to 250 psi
75. In large heavy fuel engines, what kind of stresses act on top and bottom and bolts of a single acting 4-stroke engine and a double acting engine. Would the design of the bolts be affected? (Diesel Duck)
76. Describe a bedplate for a large reciprocating engine. How is the ship's hull strengthened around the bedplate? Show by a sketch how the hold-down bolts are fitted to the double bottom tanks. (Notes)
    1. The bedplate is one of the most important parts of a marine engine
        1. The alignment of the crankshaft and other moving parts depend on the rigidity of the bedplate
        2. It must carry the weight of the engine
        3. Must resist torque forces caused from the propeller
        4. Must resist the stresses and strains produced due to rolling and pitching
    2. The two main types of bedplate are the trestle and the box types
        1. The box type can be bolted directly to the top of the double bottom tank which eliminates the necessity to build an elevated seating as with the trestle type
    3. The bedplate supports the rest of the engine and the crankshaft and is made up of transverse sections running throughout

    4. These sections house each bearing throughout the length of the crankshaft
    5. Spaces are cut through these sections for oil flow
    6. Inspection doors are placed on each side of the bedplate, these doors being located between each section are secured to the bedplate by studs and nuts
    7. The transverse vertical girder center sections contain the main bearing saddles and the tie bolt connectors, which are castings that are welded in
    8. They are fitted between each throw of the crankshaft, as close as the engine design will allow
    9. They are secured by substantial butt welds to complete the rigid structure of the bedplate
    10. Flanges are machined for handling on support chocks and for assembly of other parts
    11. Regular inspection must be made for fatigue cracks, particularly the girders
    12. The hull around the bedplate is strengthened by using heavier plating, usually double the thickness that is used elsewhere or by fitting a doubler plate on the tank tops
    13. Solid floors are fitted on every frame and are increased in depth and thickness
    14. The bedplate sits on cast iron chocks that are machined to proper thickness after the shaft is line dup
    15. The fitted stud then passes through the tank top making sure it is sealed in the event that the stud should break, the tank would still be watertight

77. Sketch and describe a tie-rod for a large diesel. What would happen if they became slack? How is an engine secured without tie-rods? (Notes)
    1. Tie-rods are fitted to bond the entablature, columns and bed plates firmly together
    2. One such rod is located on each side of the crank bearing at equal distance apart
    3. The tie-rods are made of mild steel threaded at each end to take nuts
        1. The portion between is reduced in diameter
    4. The lower nut is square and sits in a similar shape in the bedplate to prevent turning when tightening
    5. The diameter of the bolts and the thickness of the column is proportional so that when the bolts are tightened, they stretch and the cast iron column compresses
        1. The object being that when full working pressure is reached in the cylinder, the long ties stretch and the cast iron expands and maintains a firm contact with the nut on each tie-rod
    6. The operation of tightening these rods must be carried out with extreme caution, otherwise parts will become strained or distorted
        1. If tightened too much, the crank bearing may be pulled out of line by a few thousandths
        2. The athwartships bolts are slacked off and tightened together to create an even stress in each
        3. The stress should match manufacturer specs
        4. Normally tightened by hydraulic wrench in proper sequence
    7. Seals are fitted if tie-bolts pass through air passages to prevent oil entry and air escape
    8. If an engine is run with slack tie-rods:
        1. The cylinder beam flexes and lifts at the location of the slack tie-rod
        2. In time, the landing faces of the tie-rod upper and lower nuts and the landing faces fret and the machined faces are eventually destroyed
        3. The fitted bracing bolts between the cylinder jackets will also slacken and the fit of the bolts will be lost
        4. If fretting has occurred in an uneven pattern where the cylinder beam lands, and the tie-rods are tightened, the alignment of the cylinders to the line of the piston stroke is destroyed
        5. A bending moment will be induced in the tie-bolt which can lead to early fatigue failure

Starting and reversing systems

78. List procedure for starting and manoeuvring a large two stroke engine on heavy fuel. (Jackson)
    1. Pre-start:
        1. Warming through
            1. Most engines are warmed through prior to starting

            1. This makes starting easier
            2. Minimizes wear
            3. Minimizes thermal shock and damage due to unequal expansion
         2. Warming through is done by heating the cooling systems
            1. Steam is often used to heat the water gradually to about 70C while it is circulated through the engine (cylinder jackets, pistons, heads, etc.) by an independent pump
         3. In engines burning heavy fuel, the fuel injectors and pipelines are also warmed through prior to starting
            1. The final warming through temperature depends on the oil viscosity required
            2. The cooling circuit for the injectors is separate from the cylinder jacket system and may use water or fine mineral oil as the cooling medium
               1. This circuit is fitted with a heating element
            3. Some oil pipes may be steam jacketed or have a small bore heating line wrapped spirally around them to heat the cold fuel oil standing in the pipes
            4. A small auxiliary pump may be used to circulate part of the fuel system with pre-heated oil
            5. Failure to pre-heat the heavy oil and system could result in the engine failing to start
      2. The various supply tanks, filters, valves and drains are all to be checked
      3. Open indicator cocks and run the turning gear or turn engine by hand to see if it is clear for running
         1. Any water which may have collected in the cylinders will be forced out
         2. Close cocks and remove turning gear when satisfied
      4. Start pre-lube pump to ensure oil will get to all bearing surfaces
      5. Pump fuel system up to ensure it is primed and free of air
      6. Open stop valves in starting air line
      7. Give cylinder lubricators a number of turns by hand to get some oil onto the piston rings
      8. Start jacket water cooling pump
      9. Auxiliary scavenge blowers, if manually operated, should be started
      10. All control equipment and alarms should be examined for correct operation
      11. See that propellers are clear
   2. Starting
      1. The direction handle is positioned ahead or astern
         1. This handle may be built into the telegraph reply lever
         2. The camshaft is thus positioned relative to the crankshaft to operate the various cams for fuel injection, valve operation, etc.
      2. The manoeuvering handle is moved to Start
         1. This will admit compressed air into the cylinders in the correct sequence to turn the engine in the desired direction
         2. A separate air start button may be used
      3. When the engine reaches its firing speed, the maneuvering handle is moved to the running position
      4. Fuel is admitted and the combustion process will accelerate the engine and starting air admission will cease

79. Describe with the aid of a sketch the arrangements used to ensure that the engine cannot be operated in contradiction of the bridge telegraph order. Some engines may continue to operate in the ahead direction after the controls have been placed in the astern position. Describe the arrangements fitted to prevent such an occurrence. (TCMS)
80. What checks would you make before starting a small diesel engine and a large direct drive diesel? Explain how the two systems differ and why?
   1. Small diesel:
      1. If it were an engine that was new to you, read the directions that are furnished with each engine for preparing the engine for starting and follow the instructions
      2. Make sure there are no tools, materials, or waste lying around on the engine
         1. They may be caught up in the moving parts or thrown into them by vibration

        3. Make sure that all tanks have sufficient fuel, lubricating oil, air and that all equipment and parts are intact and working properly.
        4. Check all levels in engine, lube oil, cooling water, gearbox oil level
            1. Ensure no water/fuel in sump
        5. Any points requiring hand lubrication should be lubricated
        6. Fill any external lubricators
        7. Pre-lube engine if pump fitted
        8. Prime all fuel pumps and injectors
        9. Bar the engine to starting position if this is necessary
            1. Engines with 6 or more cylinders normally start from any position
        10. Open all necessary valves
            1. This includes cooling water and fuel valves
        11. Drain starting air receivers and pump up to full again
        12. Proceed to start
        13. Gradually bring up speed
        14. Watch lube oil pressures
            1. Should show pressure above normal since cold and high viscosity
        15. Check other gauges, tachometer, governor
    2. Large direct drive diesel
        1. The instruction book should be read and understood if you are unfamiliar with the engine
        2. Since the ship will move as soon as the engine is started with a fixed pitch propeller, the deck department must be consulted to ensure enough mooring lines are out to secure the vessel and that none are too close to the propeller
        3. The engine must be warmed through by circulating hot jacket through the cooling passages
        4. The various supply tanks, filters, valves and drains are all to be checked
        5. The standby lube oil pump and jacket water pumps are to be started and all variable returns observed
        6. The control and alarm equipment should be checked for correct position
        7. The indicator cocks are then opened and the turning gear engaged, turning the engine through several complete revolutions
        8. The fuel system is then checked
        9. The turning gear is disengaged and if possible, the engine should be rolled over by air before closing the cocks
        10. The engine is now available for starting
    3. The two systems differ in that the small engine aboard will most likely be an auxiliary engine for a generator or pumping system
        1. Usually started by an electric DC starter from battery packs or small air motor
    4. A large direct drive diesel will be for propulsion
        1. Must be started by direct injection of air
81. How is starting and reversing achieved in a large direct reversing engine? Name the type of engine. (Notes, Mike)
    1. For a Sulzer RD:
        1. Starting:
            1. Air from starting receiver at 30 bar max flows to the pre-start valve via the open turning gear blocking valve and then to the automatic valve
            2. At the automatic valve, air passes through the small drilled passage to the back of the piston and this together with the spring, keeps this valve shut
            3. The pilot valve is shut with air pressure on top and atmospheric vent below
            4. If the air starting lever is operated with control interlocks free, the opening of the pre-starting valve allows air to lift the pilot valve and vent the bottom of the automatic valve and cause it to open
            5. This allows air to pass to the cylinder valve via non-return and relief valves and also to the distributor
            6. The distributor will allow air to pass to the appropriate cylinder valve causing it to open due to air pressure on the piston top

        7. In this design, when the piston top of the cylinder valve is connected to the atmosphere for venting, the bottom of the valve is connected to air pressure, this ensures a rapid closing action
    2. Reversing:
        1. For reversing of a two stroke direct reversing engine, it is usually necessary to reposition the fuel cams on the camshaft
        2. So that reversing can use the same camshaft, this adds to the complication of moving the shaft axially
        3. This means it is necessary to use a lost motion clutch on the camshaft
        4. The design, which is based on older Sulzer engines, has a lost motion on the fuel pump camshaft of about 30 degrees
        5. When reversal is required, oil pressure and drain connections are reversed
        6. Oil flowing laterally along the housing moves to the center section to the new position
        7. Oil pressure is maintained on the clutch during running so that mating clutch faces are kept firmly in contact with no chatter

Operation and maintenance

82. Why do you change main bearings on main engines? Explain how it is done. (Adam)
    1. Worn main bearings will lower compression due to the fact that the top clearance is increased
    2. The gear teeth mesh will also be affected
        1. They will not fully mesh and may cause excessive strain and possible breakage of the teeth
    3. Main bearings are normally made of cast steel, lined with white metal
    4. Crankshaft deflections should be taken before removal for reference
    5. Various means are adopted to facilitate removal of the lower half of the bearing
        1. A common method is to fit a special clamp on the crank web adjacent to the bearing that has to be removed
        2. The engine is then turned slowly with the turning gear and the bearing is pushed round out of its pocket by a projection on the clamp
        3. When the bearing has been turned for a half revolution it will be sitting on the top of the journal free of the pocket
        4. It is then lifted off the journal and swung clear of the crank webs with a set of chain blocks rigged above the bearing and another set rigged near the crankcase door
        5. Some engines have pocket under the main bearing so that oil can be pumped in to lift it slightly and facilitate its removal
83. Describe all the precautions you would take for entry into a fuel tank. (Adam)
    1. A fuel tank is an enclosed space with many dangers that must be taken into account prior to entry and while inside.
    2. The atmosphere inside such a tank is likely deficient in oxygen and will not sustain life
        1. The small manhole for entry at the top of the tank will not give much assistance in ventilating the compartment
        2. Fatal accidents have resulted from entry to tanks that have not been properly ventilated
        3. Normal oxygen of air is about 21%
        4. Where a test shows that there is a lower value in an enclosed space, ventilation should be continued until the correct level is reached and also while inside tank
        5. The air changes necessary to improve the oxygen level will have the beneficial effect of lessening the possible presence of harmful gas or vapor
        6. A lack of oxygen will cause a loss of consciousness resulting in a fall with serious or fatal injury
    3. Petroleum vapors when mixed with air can be ignited provided that the mixture limits are about 1% to 10% of hydrocarbon vapor with the balance being air
        1. Below 1% is too weak and above 10% too rich
        2. These are known as the lower and upper flammable limits
        3. Oxygen would also have to be more than 11% by volume
            1. Class A petroleum gives off a lot of vapor
                1. This type is dangerous since it is made readily flammable by dilution during loading, discharge or tank cleaning
            2. Class B petroleum give off less vapor but may be within flammable range

            3. Class C petroleum give off little vapor unless heated to above flash point
        4. In a tanker, the inert gas used to produce a safe condition in tanks will reduce oxygen as will steam cleaning of the tank
        5. Many liquid cargoes are toxic by absorption through the skin or swallowing
    4. Liquids in bottoms of tanks should be drained as far as possible since it may give off vapor
        1. Tanks should be cleaned
        2. Valves into tank must be isolated and locked out to avoid inadvertent pumping
    5. Protective clothing and breathing apparatus must be worn
    6. Any portable lights must be gastight and safe
    7. Tools must be spark-proof
    8. There must be a second person attending at the entrance and others should be made aware
        1. A rescue method and plan must be in effect
            1. Location of rescue and first aid equipment should be close by
        2. Communication to the person entering the tank must be established and to the bridge
        3. A lifeline should be attached to the person entering the tank with signals arranged in advance
    9. A gas-free certificate must be attained before any hot work in the tank

84. State how explosions are prevented in fuel tanks. What gases are you likely to find in empty fuel tanks? (Diesel Duck)
    1. Gases present in empty fuel tanks:
        1. Hydrogen sulfide
            1. Toxic gas that is produced by bacteria in the water
        2. Carbon dioxide
            1. May be given off due to chemicals in tank or tank coatings
        3. Volatile vapors from fuel and cargo

85. Describe an engine room fire suppression system. How are engines shut down when the engine room has been evacuated? (Dave)
    1. CO2 is colorless, odorless and heavier than air
    2. It fights fire in the following three ways:
        1. Displaces the atmosphere
        2. Lowering the oxygen level
        3. Smothering the fire
    3. Gas is normally stored in 50 pound bottles at a pressure of around 50 bar (750 psi)
    4. Each bottle is fitted with a combined seal and bursting disc that will rupture at 177 bar which occurs at 63C
        1. Bottles are made with solid drawn steel
        2. Hydraulically tested to 228 bar, retested every 7 years
        3. Fitted with syphon tubes
            1. If tube was not fitted, the CO2 would evaporate on discharge removing latent heat and causing the remaining CO2 to freeze
    5. When the control cabinet is opened, an alarm is triggered that is audible and visual in the machinery space warning personnel that the release of CO2 is imminent and that they must vacate the space immediately
        1. Opening this cabinet also stops ventilation to that space
        2. The doors, hatches and dampers to the space must be closed to seal off the space to contain the CO2
        3. Pumps and machines must also be stopped and quick closing valves for oil and fuel closed
    6. Can be automatically set off by temperature sensors
    7. The lever for releasing the CO2 is then operated, which in turn operates the starting bottles
    8. The gas from these bottles will drive a piston via a safety valve, and this piston releases the main battery of CO2 bottles through a pulley system
        1. Delay is normally around 30 seconds to ensure personnel have a chance to evacuate – however only one or two people are authorized to pull CO2 releases
    9. Main bank of bottles sometimes protect more than one compartment
        1. Master valves are fitted at the discharge line to permit the desired compartment to be selected

10. The CO2 then discharges to the machinery space through multi-jet nozzles designed to discharge large volumes of gas at a fast rate
11. The system incorporates a stop valve on the discharge line and also a pressure alarm to indicate any leakage from the CO2 battery that will be vented off to atmosphere via a relief valve
12. The system must give a 40% saturation of the whole compartment in which 85% must be discharged into the compartment in the first two minutes
    1. CO2 will expand 450 times its liquid volume
13. The use of check valves in the discharge line allows for saving part of the bank for second attempts or for the flexibility in the number of cylinders discharged to compartments of different volumes
14. This system requires regular maintenance and testing:
    1. Ensure that all moving parts are kept clean, free and well lubricated
    2. Wires must be checked for tightness
    3. Toggles and pulleys must be greased
    4. The distribution pipes must be blown through with compressed air periodically
        1. These pipes are solid drawn steel and galvanized to protect from corrosion
    5. CO2 bottles must be weighed yearly to check contents or use of an ultrasonic or other type of level detector may be used
    6. Bottles are hydrostatically tested to 228 bar
    7. Contents must be topped up if there is more than 10% loss
15. Advantages:
    1. Quick operation
    2. Rapid filling of space with CO2
    3. No power required to use system
    4. Non-conductor of electricity
    5. Does no damage, clean
    6. Relatively inexpensive
16. Disadvantages:
    1. Space has to be evacuated before use
    2. Does not sustain life – deadly since it blocks a body's ability to absorb oxygen
    3. Fires may reignite after use
    4. Must wait before re-entering space
17. Engines are shut down remotely via emergency stops
    1. Anything consuming fuel or pumping fuel such as transfer pumps, boilers, purifiers, generators can all be shut down via electric stops located outside the engine room

86. Explain possible causes of a crankcase explosion and explain how they may be prevented or the severity lessened. (Mike, Diesel Duck, Notes)
    1. Three things are required:
        1. Fuel = lube oil mist
        2. Air = always present
        3. Source of ignition = hotspot
    2. The cause of a crankcase explosion is a hotspot or overheated part within or adjacent to the crankcase of an operating engine
    3. Under normal conditions, the air in a crankcase will contain oil droplets formed by lube oil splashing from bearings and impinging on moving surfaces
    4. This mixture will not readily burn or explode since it has a flashpoint of around 230C, unless these is fuel contamination that will lower the flashpoint to a dangerous level
    5. Local hotspots may arise due to overheating of bearings, piston rod gland, timing chain, hot combustion gas or sparks from blow-by in engines where no diaphragm is fitted
    6. Heat could also come from scavenge fires

7. Such sources can be eliminated by proper maintenance, correct lubrication and oil condition, cleanliness and by avoiding engine overload
8. The general use of white metal bearing materials that have moderate softening and melting temperatures will also help to avoid a rapid rise in temperature
9. If a hotspot exists, oil will come into contact with it and be evaporated
10. The evaporated oil circulates to cooler parts of the engine and condenses into a mist consisting of finely divided oil particles mixed with air
11. At certain concentrations, this mist is combustible
12. If this mist circulates back to the hotspot in a combustible strength, it will be ignited and a primary or minor crankcase explosion will occur
13. This explosion causes a flame front and pressure wave to move through the crankcase, evaporating further oil mist in its path
14. This pressure wave may build up sufficiently to rupture crankcase doors unless otherwise relieved
15. If a hole is created, the low pressure area following an explosion will draw air back in to the crankcase to mix with oil mist and create a secondary or major explosion that will cause major damage
16. It may start fires in the vicinity and injure personnel severely
17. To prevent crankcase explosions, close watch must be kept on the engine
    1. Watch must be kept for irregular running or noise, bearing temperatures, and by appearance or smell of a dense white oil mist
    2. Detection by instruments may be temperature probes near possible hotspot locations or in bearing oil returns or by crankcase oil mist detectors
        1. This operates visual and audible alarms in the event of mist formation well below that which could allow combustion
    3. The engine should be immediately slowed down and stopped as soon as possible to allow hotspot to cool.
        1. Oil pumps must be kept on to avoid seizure of hot parts and allow cooling
        2. The turning gear should also be engaged with indicator cocks open
    4. Personnel should avoid vicinity of relief valves
    5. On no account should crankcase be opened until parts have cooled to avoid allowing air in that may cause an explosion
    6. Subdivision of crankcase will prevent any buildup of high velocities and pressures of flame propagation from a primary explosion
    7. Internal crankcase lighting must be flameproof
    8. Vent pipes must not be too large and led to a safe place remote from engine and covered with gauze
    9. Oil drain connections must dip below oil levels in storage tank to prevent air entry
    10. There must not be connection between crankcases of multiple engines
    11. If fixed fire-fighting systems are fitted to the crankshafts, they must be fully ventilated before entry
    12. Crankcase explosion relief valves are fitted to all but the smallest engines
        1. The valves open automatically at low pressure allowing primary explosion pressure to be dissipate and preventing rupture of the crankcase
        2. The valve instantly closes when the pressure drops and thus prevents ingress of air that may lead to major explosion
        3. Valves are fitted with wire gauze to prevent the emission of flames and may have external deflectors to aim hot gases in directions that they will do least amount of damage
        4. The valve consists of a light spring loaded non-return disc valve of simple construction
        5. The disc is made of aluminum alloy that reduces its mass and inertia that it must overcome to open and close rapidly
        6. Large diameter spring will give sensitivity and allow the valve to float
        7. The absence of a valve spindle eliminates the valve sticking
        8. The valve landing must form a gas and oil tight seal when closed and a non-stick oil and heat resisting rubber ring is fitted to the disc face

9. An external aluminum valve cover secures the valve spring and acts as a deflector to direct any gas emitted over an arc of 120 degrees in the direction of least damage
10. Inside the crankcase is a dome shaped flame trap made of several layers of woven mild steel wire gauze
11. This projects into the crankcase where it will become wetted with oil mist or splash from adjacent bearings
12. When wet with oil, the gauze dissipates greater heat and becomes more effective as a flame trap
13. Free area of gauze must be at least equal to open valve
14. The valve assembly is secured to an aperture cut in the crankcase by a number of cross studs and distance spacers that also act as a guide for the valve disc
15. The valve spring is set for an opening of around 5 kPa
16. Regulations determine the size of crankcase relief valves

87. Describe how alignment of a diesel engine crankshaft may be checked and recorded. Why are such tests performed and what are may be the result of misalignment? What steps would you take if you discovered a main bearing that was abnormally worn down? (Notes)
    1. The alignment of the shafting with the cylinders is checked by means of a dial indicator, otherwise known as a clock gauge or deflection gauge
    2. If the crankshaft bearings are worn unevenly, the crankshaft will not be in true alignment with the cylinders
        1. This will results in uneven wear of the top and bottom ends
        2. Will also cause the piston to be off center in the cylinder causing liner to wear oval.
        3. Due to the crankshaft tending to follow the line of bearings, bending stresses will be induced in it in addition to the normal stresses
        4. Due to low bearings, the crank webs tend to open out or spread when the crank is at TDC and close in at BDC
        5. The dial indicator measures the amount of movement between the webs
            1. All the webs should be checked and compared to see which are low
            2. The gauge is sprung into two punch marks on opposite webs
            3. The measuring starts with piston just on one side of BDC
            4. The gauge is zeroed and turned to 90 degrees where the reading is taken
            5. Positive and negative results will show the webs opening or closing, these are recorded and tabulated to compare to manufacturer specs
            6. Causes of misalignment:
                1. Wiped bearings
                2. Faulty workmanship
                3. Bearings lined with different materials
                4. Distortion of tank tops due to weather or grounding
                5. Slack hold down bolts
                6. Slack bearing caps
                7. Uneven power distribution in a line of cylinders
        6. If the journal is not sitting in the main bearing, the results will not be a true indication
            1. If this is the case, the shaft must jacked down by special gear and the amount of movement measured

88. State the reason for explosions taking place in the following and in each case, the precautions necessary to prevent their occurring: starting airline, air compressor and main engine crankcase (Diesel Duck)
    1. Start air explosion
        1. The main cause for excess of pressure might be a leaky air start valve or this valve jamming partly open and filling the cylinder with pressurized air while the piston is starting its upstroke
            1. This air could be compressed as the piston is swept up to TDC and reach an excessive pressure
            2. A non-return valve is fitted to the starting air pipe to prevent an air start explosion reaching the reservoir
            3. Under normal operation, some lube oil mist may be discharged from the air compressor to the air start system
                1. This oil may be discharged from the air compressor to the air start system
                2. This oil may be from :
                    1. Excess compressor cylinder lubrication

            2. Faulty oil scraper rings
            3. Suspended oil vapor contaminating the engine room atmosphere and drawn in the compressor suction
         3. Oil discharge is kept to a minimum by draining the after cooler, air receiver and starting system
         4. If small quantities do get passed into the start air system, they will deposit as a thin moist film over internal pipe surfaces but are not readily combustible
      4. If a cylinder non-return valve should leak while the engine is in operation, some hot gas, possibly with unburned fuel and cylinder lube oil may be blown through the valve to the adjacent air manifold
         1. With further heating from this leaky valve, this together with the already deposited oil film, will carbonize and from incandescent carbon
         2. If starting air is applied to the system while still hot, the high pressure air coming into contact with the burning carbon may cause an explosion
         3. Such an explosion will cause a flame to pass back through the air start pipe system, evaporating the deposited oil film and igniting it in the presence of air
         4. Very high velocities and shockwaves are generated that may rupture pipes and fittings
   2. Another cause of an explosion occurring when starting a diesel engine is most likely to arise from an excess of fuel having been admitted to the cylinder due to either a leaky injector or failed start
      1. Any accumulation of fuel in a cylinder would ignite due to the heat of compression when the initial start was made, resulting in a dangerously high temperature and pressure in the cylinder
      2. It is advisable, after the fuel system has been primed, to make the initial start with indicator cocks open
         1. This has the effect of clearing all cylinders thoroughly and avoid high pressures building up
         2. After one or two revolutions, the cocks can be closed and a regular start made on fuel
   3. Precautions to prevent an air start explosion:
      1. Use a good quality, high flashpoint lube oil
      2. Avoid over lubrication of compressor cylinders
      3. Use of a non-explosive medium for preserving the receiver internals
      4. Cleaning of cooler tubes regularly to allow for efficient cooling of air
      5. Proper maintenance of compressor suction and delivery valves and rings
      6. Non-return valves provided to prevent blowback from cylinders to lines to be kept in good condition
      7. Bursting discs provided to prevent excess pressure in line and tanks
      8. Pressure gauges fitted on tanks and between pressure stages to allow observation of compressor
   4. To minimize the effects of such explosions, the air start manifold to each cylinder valve must be fitted with a flame trap and ample relief valves
      1. Bursting caps or discs must be fitted to relieve excess pressure
      2. An isolating non-return valve is fitted at the outlet from the main control valve
   5. A leaking air start valve may be detected while the engine is operating by local overheating of the pipe adjacent to the valve
      1. The engine should be stopped at the first opportunity and the valve replaced
      2. As a temporary measure, a blank may be fitted to isolate the valve but the engine ma not readily start
2. Air compressor
   1. In the event of overheating of the discharge from the air compressor to the filling line, an explosion would be possible between the compressor and the air reservoir
      1. Overheating may be caused by failure of compressor intercooler and circulating water
      2. In this case, the high temperature within the HP stage will make operation of the compressor and its cylinder lubrication difficult
      3. Excess discharge temperature is detected either by an alarm system or a fusible plug that will melt at 121C to give warning

89. A large reciprocating engine has just been installed in your ship, but there are no markings on the flywheel, describe in detail how you would find TDC in relation to one cylinder and how you would make a trammel for future use. (Lawson, Dave on General exam, Diesel Duck, Notes)
    1. The rim of a flywheel is usually marked into 360 degrees, showing the top and bottom positions of the various cranks
    2. This is for convenience of setting the various valve timings
    3. A stationary index arrow points at the flywheel
    4. If the flywheel was not marked, the following procedure can be used:
    5. First turn the engine up to near the top for that cylinder and mark the guide and shoe
    6. Then with a trammel fixed on the column and long enough to reach the crank, mark the top of the crank
    7. Now turn the engine over the center until the marks on the crosshead guide and show come together and again mark the crank top with the trammel
    8. Find the center between the two marks on the top of crank and make a center mark
    9. Then turn the engine until this mark comes into line with the trammel point, the engine will now be at top dead center for that cylinder
90. Discuss each of the following factors in relation to scavenge-space fires: (TCMS, Notes)
    1. Primary cause of such fires
        1. Ignition of unburned oil and carbon that has blown from the cylinder into the scavenge spaces
            1. This may include unburned fuel or cylinder lube oil cause by:
                1. Incorrect combustion
                2. Defective injector
                3. Faulty fuel pump or timing
                4. Lack of scavenge air
                5. Damaged air inlet filters
                6. Partially choked exhaust
                7. Worn or broken rings
                8. Uneven cylinder liner wear
                9. Cracked oil-cooled pistons
            2. Excessive cylinder lubrication
        2. The oil will build up in the scavenge space where it will become carbonized by further heating in which it can burn in the presence of air
        3. It may be ignited by piston ring blow-by or hot exhaust gases from combustion that blows into the scavenge trunking
    2. Effect upon the engine operation
        1. Normally local to one cylinder
            1. Excessive black smoke
            2. Loss of power
            3. High temperatures in scavenge trunk
            4. Surging of turbocharger
            5. Paint blistering and peeling from trunking
    3. Manner in which the fire may be dealt with
        1. Slow engine down in case of a small fire it may burn out
        2. Fuel from suspect cylinders should be cut out to reduce temperature
        3. Lubrication increased to cylinder to prevent seizure
            1. If the engine is stopped suddenly, overheated parts may become distorted and seizure may result or fire may spread
        4. Scavenge drains shut
        5. The fire will probably burn itself out
            1. After fire has gone out and conditions return to normal, the effected unit can then be run on reduced power until inspection of scavenge trunking can be carried out at the earliest opportunity
        6. Should a fire persist, the engine must be stopped and normal cooling maintained

            1. A fire extinguishing medium should be used as a last resort
            2. CO2, dry powder or steam smothering are injected into the scavenge trunk through nozzles
        7. The space should not be opened up while hot since air entry may cause explosion
    4. Manner in which such fires may be avoided
        1. Good maintenance is required and correct adjustment of fuel and lube oil to the cylinders must be provided
        2. The scavenge ports and spaces should be regularly inspected and cleaned of oil and carbon
        3. Temperature sensors in the scavenge spaces will alert the engineer of a hot area or fire, thereby offer a degree of safety
            1. These should be checked regularly as well and replaced after fire
        4. After a fire, the cylinder liner and water seal, piston and rings, piston skirt, piston rod and gland must be inspected

91. Describe how you would take over a watch of a large diesel engine vessel. (Diesel Duck)
92. List all the auxiliary machinery for a safe and efficient operation of a large motor ship. State the size and type of ship. (Diesel Duck, Notes)
    1. Auxiliary machinery covers everything aboard except main engines and boilers
        1. This includes all the pipes and fittings as well as many items of equipment providing the following functions:
            1. Supply the requirements of the main engine and boilers – circulating water, forced lubrication, feed water, feed heating, coolers, condensers, air compressors, fuel oil separators, transfer and treatment
            2. Keep the ship dry and trim – bilge and ballast systems
            3. Supply the domestic requirements – fresh, salt, sanitary and sewage systems, refrigeration, heating and ventilating
            4. Supply the main power for propulsion and maneuvering, shafting, propellers, steering gear and bow thrusters, stabilizers
            5. Supply the ship with electric power and lighting, steam and diesel generating engines
            6. Look after cargo winches, windlass, capstans and pumps
            7. Provide for safety, fire detection and lighting, lifeboat engines and launching gear and water-tight doors
            8. Provide for data-logging, remote control and automatic action, pneumatic and self-regulating apparatus
            9. Incinerator, water distiller, sewage treatment, fresh water treatment
        2. Auxiliaries found in single screw motor ships of 7500 ton cargo ships of 10000 HP:
            1. Main lube oil pumps – 2
            2. Main seawater pumps – 2
            3. Main Jacket water cooling pumps – 2
            4. Main piston cooling pumps – 2
            5. Heavy fuel transfer pump – 1
            6. Diesel transfer pump – 1
            7. Heavy fuel purifier – 1
            8. Lube oil purifier – 1
            9. Sludge pumps – 2
            10. Boiler feed pumps – 2
            11. Fire and wash deck pump – 1
            12. General service pump -1
            13. Ballast pump – 2
            14. Bilge pump – 1
            15. Refrigeration cooling pump – 2
            16. Freshwater pumps – 2
            17. Sanitary pumps – 1
            18. Air Compressors – 2
            19. Starting air receiver – 2
            20. Main lube oil coolers – 1
            21. Main jacket water coolers – 2
            22. Main piston water cooler – 1

        23. Generating engines – 4
        24. Storage, drains, sludge and dirty oil tanks – 1 each

93. Describe the procedure of servicing a fuel injector, stating what must be carried out during testing. (Diesel Duck)
    1. Maintenance:
        1. Injectors must be overhauled at regular intervals to ensure correct operation and combustion
        2. The injector compression spring must be screwed back before slackening the retaining nut
        3. Parts are cleaned, inspected and renewed if necessary
            1. Lapped surfaces must be free of damage and correctly aligned
            2. Springs must be inspected for distortion
            3. Atomizer holes must be clear and unworn
        4. After assembly, the injector is tested with a test pump
            1. Operating pressure and fuel spray pattern are checked and there must be no leakages
            2. A good spray pattern with a sharp cut-off should be obtained at each stroke of the pump with no dribble
        5. Defects in injectors while in use:
            1. Choking to dirt in the fuel or carbon building up in the atomizer
            2. A leaking needle valve will cause secondary burning and reduce combustion efficiency
        6. Never dismantle more than one injector at a time
            1. These particular parts are high-precision units and each nozzle is made to suit its own needle valve
            2. All parts are so highly finished that should they accidentally be mixed up, trouble is almost certain to follow

Defects and remedies

94. One cylinder exhaust temperature is in excess compared to the others, state causes why and how you can remedy it and prevent it. (Andy, Adam, Diesel Duck)
    1. This cylinder may be getting more fuel than the others
        1. The cylinder getting more fuel would be overloaded and would smoke and knock and soon carbon up
            1. This could cause the rings to stick and possibly break
        2. The exhaust valve would become overheated and warp due to the carbon
        3. This will cause faulty compression, incomplete combustion and loss of power
        4. The fuel system would have to be adjusted to distribute load equally to all cylinders
            1. May be injector setting
    2. This cylinder may also have a leaking exhaust valve
        1. If allowed to continue, damage to the exhaust valve and seat will increase due to burning by high velocity, very hot gases
        2. Partly burned fuel may pass to exhaust grids, turbochargers, silencers and uptakes causing:
            1. Fouling
            2. Loss in efficiency
            3. Surging of turbocharger
            4. Uptake fires or explosions
        3. The compression pressure and peak firing pressure will also be reduced
        4. The valve must be changed at the first opportunity and until then fuel should be shut off to that cylinder
        5. To prevent such leakages, exhaust valves must be changed and overhauled at regular intervals and valve tappet clearances checked
            1. Excessive powers must be avoided and combustion efficient maintained
    3. Early opening of exhaust
    4. After burning
95. List and describe reasons for smoky exhaust. What is needed for efficient combustion? (Dave, Diesel Duck, Notes)
    1. Black smoke exhaust indicates incomplete combustion from one or more cylinder
        1. This can be checked by shutting off fuel from one cylinder at a time and witnessing any change in exhaust

        2. Diagnosis can also be helped by looking at exhaust temperatures, use of combustion monitoring and taking indicator diagrams
    2. Causes of smoky exhaust (normally fuel related)
        1. Injector
            1. Leaky fuel injector
            2. Choked injector nozzle holes
            3. Broken or incorrectly set injector spring
            4. Incorrect fuel temperature or viscosity
        2. Fuel pump
            1. Insufficient fuel supply
            2. Incorrect timing
                1. Late or early injection
            3. Worn plunger
            4. Worn, slack or wrongly positioned cam
        3. Compression pressure low
            1. Worn liner
            2. Worn or broken rings
            3. Faulty valve timing
            4. Leaky valves
        4. Air:
            1. Low scavenge air pressure in a 2 stroke
            2. Choked scavenge ports
            3. Faulty air inlet valve on 4-stroke
            4. Inadequate air supply – fouled turbocharger, air cooler or intake filter
            5. High air temperature – means a decrease in density of air supplied
        5. Overload or too high an acceleration rate
        6. High resistance in exhaust
            1. An exhaust gas pressure may be caused at waste heat boiler
    3. For the ideal combustion of fuel, constituents are:
            1. Carbon = 83.3 %
            2. Hydrogen = 12.4%
            3. Oxygen = 3.8%
            4. Sulfur = .5%
        2. This composition will ideally convert all carbon to CO2
            1. Ideal combustion requires CO2 at 14%
        3. To make this possible, the amount of air required is approximately 1.5 times greater than the theoretical amount
        4. Theoretically about 14.5 pounds of air is required for the combustion of 1 pound of fuel
        5. However, under such conditions, some particles of oxygen diluted by nitrogen and products of combustion will not be able to participate in the process of combustion due to the short time in which combustion must take place
        6. This means that some carbon monoxide will be formed or carbon particles left unburned
        7. So, to ensure complete combustion of the fuel, and to avoid heat loss due to carbon monoxide or unburned carbon, an excess of air must be present in the cylinder
        8. During the process of combustion, the fuel particles are split in their respective elements
            1. Carbon and hydrogen are each combined with oxygen separately
            2. Nitrogen is an inert gas and does not take part in the combustion process
        9. Must also have proper compression
        10. Fuel injection must be at correct time

96. A 4-stroke diesel engine has a leaky fuel injector. Give the symptoms you would look for; explain the dangers involved and the action you would take to continue the safe operations of the engine. (Mike, Diesel Duck x 2)

1. A leaky injector will cause a cylinder to fire ahead of time
    1. Early fuel injection causes oil to ignite too soon causing a backpressure on the piston and a resultant loss in power
    2. Pre-ignition may cause damage to cylinder, head or even a bent rod
2. Late ignition causes a smoky exhaust, loss of power and incomplete combustion
    1. Incomplete combustion results in carbon accumulation that affects piston rings and valve stems
    2. These deposits will carbonize silencer, which may lead to a fire
3. Causes of leaky injectors are:
    1. Pitting, grooving or scoring of the valve seat or nozzle
    2. A leaky gasket
    3. A weak or broken spring

97. State the reasons for a cylinder liner overheating. What would you do to prevent such an occurrence and give the results of your failure to do so? (Diesel Duck)
    1. Reasons for cylinder liner overheating:
        1. Friction
            1. Takes place between the sliding surface of liner and rings and will increase dramatically with loss of proper lubrication
        2. Cooling
            1. If cooling water is lost or reduced, the liner will heat up accordingly since combustion heat will not be transferred away
        3. Overloading
            1. If the engine is overloaded, it is not designed to deal with the heat produced by the burning of extra fuel
98. What would cause cracks in cylinder heads? How would you detect them? (Notes)
    1. Cylinder head cracks are often caused by:
        1. Stresses produced during manufacture
        2. Stresses created by tightening
        3. Unequal working temperatures
        4. Cracks can also start when cold starting air is admitted to a hot cylinder during maneuvering
        5. Cracks can also occur when an accumulation of foreign matter such as scale deposit on the heat transfer surfaces that restrict proper cooling
    2. When subjected to abnormal stresses, heads generally crack at the bottom plate between the valve pockets
    3. The area in vicinity of the injector is subjected to the greatest temperature stresses due to:
        1. Location between air inlet and exhaust valves that work at different temperatures
        2. The most intense heat is created by combustion here
        3. Limited space available here for cooling water passages
            1. Some makers offset the injector to give better circulation of water at the center of the head or give extra water at base of injector hole
    4. Signs that signify a cracked head:
        1. Loss of water from expansion tank in a closed cooling system
        2. Gas bubbles rising to top of expansion tank
        3. Cooling pump pressure drops because of gas bubbles and air pockets formed
        4. If water exits indicator cock when engine is blown through prior to starting
        5. If the leaks is serious, a knock will be heard in that cylinder and white smoke will be visible in exhaust
        6. When removed, head can be inspected visually or by non-destructive testing such as magnetic or dye penetrant testing
99. Describe how wear is measured in cylinder and on piston. What causes wear? What is considered a normal amount of wear over a given period of running? (Diesel Duck)
    1. Cylinder liners should be gauges internally at fixed intervals during overhaul (6000–8000 hours) to measure accurately the increase in bore
    2. Continuous records of gaugings should be kept for each cylinder
        1. The liner must be cleaned and inspected

        1. General appearance of the surface may show whether lubrication has been adequate
        2. A careful examination must be made for surface cracks, particularly around the combustion space
    2. The liner is now gauged with a micrometer and extension bar that has been calibrated against a master gauge
    3. The liner should be preferably cold but if not possible, the gauge must also be at the same temperature to counter effects of expansion
    4. Gaugings are taken at a number of vertical positions (4 to 6) over the area swept by the piston rings
    5. Readings are taken fore and aft and athwartships
    6. To ensure readings are taken at proper points a template may be used
    7. Gauging figures are noted as total wear from original and mean rate of wear since the last recording was made
    8. Pattern of wear tends to be greatest at top of stroke adjacent t combustion space where pressure and temperature are greatest
    9. This reduces toward the lower end of the stroke but will increase at the exhaust and scavenge ports when relative pressure on port bars is increases and blow-by may remove lube oil film
3. A normal wear rate for a large cylinder would be 0.1mm per 1000 hours or 1.5/1000" to 3/1000"
    1. Maximum wear before renewal is usually limited to 0.6 to 0.8% of original bore diameter
4. Wear in a cylinder liner is caused mainly by friction, abrasion and corrosion
    1. In severe conditions, adhesion may also occur
5. Friction
    1. Takes place between sliding surface of cylinder liner and piston rings
    2. It will depend on:
        1. Materials involved
        2. Surface conditions
        3. Efficiency of lubrication
        4. Piston speed
        5. Engine loading with corresponding pressures and temperatures
        6. Maintenance of piston rings
        7. Combustion efficiency
        8. Contamination of air or fuel
6. Corrosion
    1. Occurs mainly in engines burning heavy fuels, particularly with high sulfur content
    2. It is caused by acids formed during combustion and these must be neutralized by the use of alkaline cylinder oil
    3. Sulfuric acid corrosion may be cause in the lower part of the liner if the jacket cooling temperature is too low
        1. This may allow vapor present after combustion to condense
        2. The moisture will absorb any sulfur present and form sulfuric acid
        3. This can be prevented by maintaining jacket water temperatures above the corresponding dew point
    4. Water vapor will be present from the combustion of hydrogen together with any water in the fuel
        1. It may be increased if water passes from the charge air cooler
7. Abrasion
    1. May take place from the products of mechanical wear, corrosion and combustion – all of which form hard particles
    2. Ash may be present in some heavy fuels as well as fines (aluminum compounds added as a catalyst during the refining process and not fully removed from the residual fuel) which may act as abrasives
8. Adhesion or scuffing
    1. Is a form of local welding between particles of the piston ring and the liner rubbing surface, resulting in very rapid wear
    2. It may occur if the lube oil film between ring and liner is removed due to excessive temperature, insufficient oil supply or incorrect oil distribution, piston blow-by
    3. Engines operating on some low sulfur grades of fuel may be prone to scuffing
9. Excessive liner will cause:
    1. Rate of wear to rapidly increase
    2. Blow-by may remove lube oil film causing piston rings to distort and break

        3. Piston slap may cause scuffing
        4. Compression is reduced causing incorrect combustion with fouling of exhaust system
        5. Unburned oil may be blown into scavenge spaces giving rise to scavenge fires

100. List several causes of engine failing to start, tell how you would identify and correct these faults. (Diesel Duck)
    1. If starting air were suspected:
        1. Check to see if there is sufficient air pressure
        2. Check starting valve – it may be stuck
        3. Check timing of air distribution
        4. Too great of a clearance between starting valve roller and cam
    2. Fuel:
        1. No fuel
        2. Fuel filter blocked
        3. Air in fuel line or in fuel pump
        4. Injection nozzles not working
        5. Viscosity of fuel too high
        6. Injection timing wrong
        7. Water in fuel
    3. Cylinder too cold
    4. Check to see if turning gear is disengaged
    5. Defective governor
    6. Compression low

101. Explain how the power developed by an engine is effected by the following conditions: (TCMS)
    1. Worn piston rings and cylinder liners
        1. Compression reduced – combustion will be at lower temp and some fuel will not be burnt
            1. Causes fuel carryover into exhaust which may lead to fire
            2. Loss of power
        2. Excessive blow-by may cause hot spots in scavenge space or crankcase – possible fire/explosion
        3. Rings may twist in place and break causing liner and piston damage and possible turbocharger damage if pieces entered exhaust
        4. Excessive lube oil consumption since oil will not be properly scraped away
        5. Excessive wear due to burning lube oil film
    2. Insufficient clearance between the cylinder valve cams and their followers
        1. Valves open too early and close too late
        2. The scavenge period will be affected
        3. Worst case is that the open valve will contact the piston crown and break off causing a lot of damage to cylinder, head and possibly connecting rod and crankshaft
        4. For an intake valve, this means that excessive air may be brought into cylinder, causing cylinder to run cool with possible thermal stressing causing cracks
            1. The valve may remain open during power stroke, causing loss of pressure and power
        5. For an exhaust valve, this means that the valve will open early on power stroke, lowering the pressure in the cylinder, robbing power of the engine
            1. The scavenge air will keep flowing out of the exhaust valve if it remains open too long, causing less fresh air in cylinder for combustion
    3. Leaking fuel pump spill valves
        1. Injection pressure doesn't reach full potential or duration
        2. This means less fuel will be injected into cylinder during fuel injection period
        3. This will cause a loss of power
        4. May enter cylinder at wrong period of cycle, causing afterburning
            1. Some heat and unburned fuel will exit into exhaust causing fire hazard and exhaust restriction

    2. Exhaust valves may be burned
    3. High exhaust temperature
  5. Turbo may surge

Auxiliary boilers

102. How do you bring an oil fired boiler up to pressure from cold? (Andy)
    1. If the boiler has been opened up for cleaning or repairs check that all work has been completed and carried out in a satisfactory manner
    2. Ensure that all tools and materials have been removed
    3. Examine all internal pipe and fittings to see that they are in place and properly fitted
    4. Check that the blow down valve is clear
    5. Fit the lower manhole door
    6. Check external boiler fittings to see they are in order
    7. See that all blanks are removed from safety valves, blow down line, etc.
    8. Fill boiler with water to about ¼ of water level gauge glass
        1. If possible, hot water heated by means of a feed heater should be used
        2. The initial dose of feed treatment chemicals, mixed with water can be poured in the top manhole door at this stage
    9. Fit top manhole door
    10. Ensure air vent is open
    11. Set one fire away at lowest possible rate
        1. Use the smallest burner tip available
        2. Bypass air heater if fitted
        3. Change furnaces over every 20 minutes
    12. After about an hour, start to circulate the boiler by means of an auxiliary feed pump and blow down valve connection
        1. If no means of circulation is provided, continue firing at lowest rate until the boiler is well warmed through, especially below the furnaces
        2. Running or blowing out a small amount of water at this stage will assist in promoting natural circulation if no other means is available
        3. Continue circulating for about 4 hours, raisin the temperature at a rate of about 6-7C per hour
        4. Water drawn off the salinometer cock can be used to check water temperatures below 100C
    13. At the end of this time, set fires away in all furnace, still at the lowest rate
    14. Close the air vent
    15. Nuts on manhole doors, and any new joints should be nipped up
    16. Circulating the boiler can now be stopped and steam pressure slowly raises during the next 7-8 hours to within 100kPa of the working pressure
    17. Test the water gauge
    18. The boiler is now ready to be put into service
        1. About 12 hours should be allowed for the complete operation provided some means of circulating the boiler is provided
        2. If circulation cannot be carried out, the steam raising procedure must be carried out more slowly, taking about 18-24 hours for the complete operation
        3. This due to the fact that water is a very poor conductor of heat and heat from the furnace will be carried up by convection currents leaving the water below the furnace cold
        4. This will lead to severe stresses being set up in the lower sections of the circumferential joints of the boiler shell if steam raising is carried out too rapidly and can lead to leakage and grooving of the end plate flanging
        5. If steam is being raised simultaneously on more than one boiler, use the feed pump to circulate each boiler in turn for about 10 minutes each
103. Sketch and describe a boiler suitable for auxiliary purposes and all of its mountings. (Jackson, Adam)
    1. For many years, the most common boiler in use at sea was the tank type boiler known as the multi-tubular cylindrical or Scotch boiler
    2. Scotch:

1. The main components of a Scotch boiler consists of:
    1. Cylindrical shell containing the furnaces
        1. These are about 1m in diameter, the number depending upon the boiler diameter
        2. Two furnaces are usually fitted for boiler shell diameters up to 4m while 3 furnaces are fitted diameters greater than this
    2. The fuel is burnt in these water cooled furnaces, constructed in the form of corrugated cylinders, which due to their relatively large diameter have to be fairly thick and so are liable to overheating problems
    3. Care must be taken to ensure undue deposits of scale are not allowed to build up on the water side of the furnace as this would lead to overheating of the furnace metal
2. After leaving the furnace, the hot gases enter the combustion chamber
    1. This is also surrounded by water and so again provided for the generation of stem
    2. The top of this chamber is close to the water level in the boiler and if this is allowed to fall below a certain value, overheating may occur leading to distortion and possible failure
3. From the combustion chamber, the gases pass through smoke tubes, which consists of plain and stay tubes
    1. Stay tubes are necessary to support the flat tube plates
    2. After leaving the tubes, the gases enter the smoke box and then the uptakes
    3. In many cases gas/air heaters are fitted to increase boiler efficiency
4. As the boiler has a considerable amount of flat surface subjected to pressure, an elaborate system of stays is required
    1. Large steam space stays support the upper parts of the flat end plates while stay tubes and combustion chamber stays support the mid-section of the back plate, the tube plates and combustion chamber
    2. Through stays again are used to support the top of the combustion chamber, transmitting the bending stresses from the top wrapper plate onto the vertical tube plate and back plate of the chamber
    3. Internal access to the boiler is provided by means of a top manhole in the shell and by lower manholes in the front end plate
    4. At one time this type of boiler was of riveted construction but it is now common to find a composite form of construction
        1. The internal and end plate joints are welded
        2. The shell circumferential and longitudinal joints are riveted
    5. All welded Scotch boilers are built but, as this entails the use of a large furnace in which to stress-relieve the completed boilers, their numbers are limited
    6. The rate of steam generation is limited by the poor circulation of water in the boiler
    7. To assist the circulation, the sides and back of the combustion chamber are tapered in towards the top and the smoke tubes arranged in vertical rows so as to offer as little resistance as possible to the heated water and steam bubbles rising to the surface
    8. The Scotch boiler is a strong, robust type of boiler capable of operating with poor quality feed water and only requires an open feed system
    9. It contains large amounts of water and provides a reservoir of steam, which makes it suitable for the supply of considerable amounts of steam for auxiliary purposes
    10. However, the large quantity of steam and water contained in the boiler introduces a hazard in that, in the event of tube failure, etc., large amounts of steam and water can enter the boiler room

3. Another type of donkey or auxiliary boiler is the Cochran Spheroid boiler:
    1. This auxiliary boiler is all welded
    2. The furnace is spherically shaped and seamless
    3. The small bore tubes are expanded at their ends into flat tube plates
    4. Advantages:
        1. Increased steam output for same size as earlier designs
        2. Spherical furnace gives increased radiant heating surface and is the ideal shape for withstanding pressure
        3. Efficient (up to 80%0 and robust
        4. Easier to maintain

        5. No furnace brickwork apart from burner quarls
        6. With small tubes fitted with retarders, gas velocity and turbulence are increased
            1. This gives better heat transfer and cleaner tubes
    5. It can be supplied in a range of sizes from 1.5 to 2.6m diameter with height just over twice the diameter
    6. Working pressure 10-17 bar
4. Boiler mountings:
    1. Main steam stop – connecting boiler with main services
    2. Auxiliary stop – connecting boiler with auxiliary systems
    3. Main feed check – connecting main feed pumps and boiler
    4. Auxiliary feed check – connecting auxiliary feed pump with main boilers
    5. Blow down valve – connecting bottom of boiler with valve on ship's side
    6. Scum valve – connecting surface of boiler with ship's side or bilges
    7. Salinometer cock – for testing boiler water density
    8. Safety valve – with connection to waste steam pipe
    9. Whistle valve – with steam to ship's whistle
    10. Pressure gauge
    11. Test cocks on column
    12. Water gauge cocks to ascertain water level

104. You are in port and have an 850 kPa fire tube boiler that is due for overhaul and inspection. Describe how and what you would overhaul and what inspections need to be done for annual inspection. What fire extinguishing equipment is suitable for this boiler? (Dave, Diesel Duck)
    1. Empty the boiler, preferably by allowing the boiler to cool down and then running or pumping out
    2. If there is not sufficient time for this, allow boiler pressure to fall to 300-400 kPa and blow down
    3. When pressure is off the boiler, open the air vent and allow the boiler to cool down
    4. When the boiler is cool, make sure there is no vacuum on the boiler by opening the drain cock on the gauge glass in case the air vent is choked
    5. Commence to open up the boiler by first removing the top manhole door
        1. To do this, slacken back the nuts holding the dogs but do not remove them until first breaking the joint
        2. This precaution should be taken in the event of pressure or vacuum existing in the boiler
        3. The nuts and dogs can then be removed and the door itself
        4. Depending on the weight of the door, it may be necessary to rig a lifting block to the door in order to do this
    6. The opening should now by roped off with a warning for personnel to keep clear
    7. The bottom door can now be removed again taking care when breaking the joint in case water is still above the sill of the door
        1. If this should be the case, pump out before removing door
        2. It is important that this sequence be followed as when the lower door is removed, it allows a through draught and hot vapor rising through the top door may scald anyone standing over the hole
        3. Hot vapor can remain in a Scotch boiler even after a considerable period of time allowed for cooling down
    8. With the doors removed, allow the boiler to ventilate before attempting to enter
        1. Do not allow naked lights near the boiler until it has ventilate due to the danger of explosive gas in the boiler
        2. Use a gas analyzer to determine if atmosphere is OK for entry and follow all other confined space entry guidelines
    9. A preliminary internal inspection should be carried out before cleaning is commenced to check the general condition
        1. Note scale deposits and any special points
    10. Plug the orifice to the blow down valve to ensure it does not get choked during cleaning operations and place guards over the manhole landings to ensure they are not damaged
    11. The boiler can now be cleaned and any internal work carried out
    12. When all work has been completed, a full internal examination must be carried out
    13. It is advisable to keep a record of the boiler, consisting of a drawing on which any troubles, repairs, etc., can be shown and a book in which remarks regarding scale formation, corrosion, deformation, etc. can be kept
    14. Check to see all cleaning has been carried out efficiently, especially where the tubes enter the tube plate

15. See that all tools and other articles have been removed from the boiler
    1. Pay special attention to combustion chamber top, tube nests and bottom of boiler
    2. Make sure all openings are clear, taking special care with the water level gauge glass connections to ensure they are clear and free from deposits
    3. Make sure all internal pipes and fittings have been replaced correctly and are securely attached
    4. The guards can be removed, and the faces of the manhole doors and landings inspected to see they are clean and undamaged
16. Remove the plug from the blow down valve orifice
17. Replace the lower manhole doors using new gasket
18. Operate all boiler mountings and see they work correctly
19. Leave in a closed position, except for water level gauge steam and water cocks and air vents
20. The boiler can now be filled to ¼ level in the gauge glass if steam is to be raised or filled completely if a hydraulic test is to be carried out

105. Describe how you would blow down one of two donkey boilers, clean it and prepare it for inspection. (Notes)
    1. The boiler would first have to be locked out by isolating its breakers and fuel supply
    2. The boiler would then have to isolated from the other boiler and allowed time to cool down
    3. Blow sight glass to check water level
    4. Make sure drain valve on ships side is open before you open boiler drain
    5. Open drain slowly at first making sure piping is not leaking so that personnel are not injured
    6. Then open drain valve fully
    7. The vent valve and sight glass drain can then be opened
    8. When the boiler is cool, make sure there is no vacuum in the boiler
    9. Commence to open up the boiler by first removing the top hand-hole door
        1. To do this, slacken back the nuts holding the dogs but do not remove them until first breaking the joint
        2. This precaution should be taken in case pressure or vacuum exists in boiler
        3. The nuts and dogs can then be removed and door taken off
        4. This should be done for the other doors, with particular attention to the lowest door, which may have water above it
            1. It water is present, this must be pumped out before removing door
    10. To clean the opened up boiler:
        1. Before cleaning, the blow down valves should be plugged to avoid scale deposits getting in and blocking the valves
        2. The tube stack should be cleaned of the scale forming deposits that have gathered on them
            1. A manufacturer recommended chemical is mixed into a solution and sprayed onto the tubes to soften scale deposits
            2. Safety gear should be worn and ventilation provided
            3. Enclosed entry permits must be filed to ensure procedures are followed for proper safety
            4. A wire brush can be used to clean the inside of the tubes
        3. An inspection should be carried out to see if heating surfaces have been sufficiently cleaned
        4. It is advisable to keep a record of boilers to show any repairs or trouble which may have accrued including scale formation, corrosion and deformation

106. Describe a fuel oil system for a Scotch marine boiler. Describe all fittings and system maintenance. (Diesel Duck x 2)
    1. The fuel is first pumped into the ships storage tanks by means of large diameter filling pipes
        1. These usually consist of side tanks, deep tanks or double bottoms
        2. Allowance is made for the expansion of the fuel due to rise of temperature by filling up the tanks to only about 95%
        3. A transfer pump draws the cold oil from the storage tanks and discharges it into the settling tanks, usually 2 in number
        4. The oil is then heated in the settling tanks by steam coils to perhaps 110F to 115F to produce separation of the water
        5. Heated oil is next drawn off by the oil service pump through the cold filters of coarse mesh and is discharged through one of two heaters
            1. The temperature is raised to near the flashpoint by steam

        6. After leaving the heater, the oil is forced through the hot filter of fine mesh and then passes direct to the boiler distribution header to the various burners of the furnace
        7. The hot oil is atomized into a fine mist on leaving the burner nozzle and enters the furnace in the form of a hollow cone

107. Describe a feed water system for an auxiliary boiler. Name all the fittings in the system and the reasons for using these fittings. (Diesel Duck)
108. Sketch and describe the construction of a waste heat boiler including the boiler mountings and name the boiler selected. (Diesel Duck, Notes)
    1. Single-pass composite Cochran boiler
        1. With diesel engines, the amount of heat carried away by the exhaust gases varies between 20-25%
        2. Recovery of some of this heat loss to the extent of 30-50% is possible by means of an exhaust gas boiler
        3. The amount of heat recovered from the exhaust gas depends on various factors:
            1. Steam pressure and temperature
            2. Evaporative rate required
            3. Exhaust gas inlet temperature
            4. Mass flow of gas
            5. Condition of heat exchange surfaces
        4. Composite boilers are often used so that steam can still be created when the engine is not running or running at low load
            1. An oil fired furnace is included, hence "composite"
        5. Working pressure is roughly 7-8 bar and is available in various types and arrangement
        6. There are two uptakes:
            1. One for main engine exhaust gases
            2. One for oil fired burner exhaust
        7. Construction:
            1. Good quality, low carbon steel
            2. Furnace is pressed out of a single plate and is seamless
            3. A seamless ogee ring connects the bottom of the furnace to the boiler shell plating
                1. This ring is pressed out of thicker material than the furnace
                2. The greater thickness is necessary since circulation in the vicinity is not as good as elsewhere in the boiler and deposits can accumulate between it and the boiler shell plating
                3. Hand hole cleaning doors are provided around the circumference of the boiler in the region of the ogee ring
            4. The tube plates are supported by means of the tubes and gusset stays
                1. The gusset stays support the flat top of the tube plating
                2. The wave formation of the tubes lies in a horizontal plane, thus ensuring no troughs are available for collection of dirt or moisture
                3. The tubes are baffled to increase heat transfer by altering the path of the gas
            5. Refractor is fitted in brick form to line boilers and furnaces
                1. Must resist high temperatures
        8. The fittings found on a boiler are:
            1. Main and auxiliary steam stops – isolates steam from systems
            2. Safety valve – Most important since it prevents damage due to excess pressure, fitted in pairs
            3. Feed valve – provides make-up water to boiler
            4. Vent valve – prevents boiler from going into vacuum when shut down and also expels air during start-up
            5. Pressure gauge – For observation of internal steam pressure
            6. Inspection manhole doors – provide access for inspection and cleaning
            7. Scum and blow down valves – Take the scum off surface of boiler water and sludge at bottom of water level
            8. Chemical feed valve – Will allow injection of treatment chemicals into the feed line for anti-corrosion, anti-foaming, etc.

9. Sampling valve – fitted to allow a representative water sample to be drawn
10. Gauge glass – allows operator to see water level in boiler
11. Low level alarm and cut-out – fitted to prevent boiler from going dry
12. Low and high steam pressure alarms and high water level cut-out – fitted to prevent water carryover with steam

109. The boiler used to supply the heating steam for a motor ship is found to show no water level in the gauge glass. Describe the action you would take to rectify this situation. Describe any fault you may have discovered in the automatic boiler control system which may have precipitated the problem and how it was rectified. (TCMS)
    1. The gauge glass may be reading incorrectly so should be blown down as soon as possible
    2. If no water appears after proving the gauge, the boiler is in a potentially dangerous situation
    3. Reduce boiler load and rate of firing and as long as the water covers the combustion chamber tops, the feed supply should be increased and if necessary, the standby feed pump and auxiliary feed check should be put into operation
    4. If the water does not appear quickly or IF ANY DOUBT, take the boiler out of operation
    5. Shut off the fuel and if it is suspected that overheating has occurred, operate the easing gear on the safety valves to release boiler pressure
    6. If the water in a Scotch boiler became dangerously low, the fusible plug would melt out
        1. If this happened, the burner must be stopped right away as well as feedwater
        2. The main and auxiliary steam stops must then be closed and the safety valve lifted with easing gear
        3. The air should then be shut off to furnace and allow the boiler to cool gradually
        4. The Chief should be called
        5. When the boiler has cooled, the boiler must be inspected for signs of overheating (distortion)
        6. If no damage is found, renew the fusible plug and get up steam again
        7. A report must be submitted to the inspectors in the next port where there is an inspector
        8. If damage was done by overheating, the inspector must approve any necessary repairs
110. Why are lime and soda used in boiler water? What is meant by acidity of boiler water? What are causes and remedies of this acidity? If the boiler water were left in an acidic condition, what effect would it have? (Adam on General exam, Diesel Duck x 2, Notes)
    1. Make up fresh water that does not come an evaporator contains salts which would precipitate and form a scale or acid when heated in in the feed heater, economizer or boiler
    2. The combination of lime and soda gives zero hardness and alkaline feedwater, therefore feed water should be treated prior to its entry into boiler
    3. Lime (calcium hydroxide) and soda ash (sodium carbonate) are used in boilers to deal with the calcium and magnesium compounds in boiler water
    4. Lime is used to react with magnesium compounds and alkaline hardness salts
    5. Soda is used to react with calcium compounds in the boiler feed, including those formed by employing lime
    6. It is an alkaline substance and reacts with any non-alkaline hardness salts
    7. Any excess soda will remain in solution, providing the reserve alkalinity required to reduce corrosion
    8. As water temp increases, hydrogen concentration increases and there is a decrease in alkalinity
    9. PH should be around 10.5 to 11.
        1. Can be tested with litmus paper.
        2. Litmus paper will turn blue if alkaline and red if acidic
        3. The degree of coloration is an indication of the pH
        4. Also 10 drops of methyl-orange can be used
        5. The sample will turn yellow for alkaline or pink for acidic
        6. Also a few drops of phenolphthalein can be used:
        7. If the water turn bluish pink, the water is alkaline
        8. If no change takes place, the water is acidic
    10. When there is an excess of hydrogen ions, the water is referred to acidic
    11. When there is an excess of hydroxyl ions, the water is referred to as basic or alkaline
    12. Measured by pH on a scale of 0 to 14 with 7 being neutral at atmospheric pressure, between 9 and 10 under boiler pressure

13. Acidic water will also cause erosion/pitting or corrosion
14. A protective layer over the steel, magnetite, is best maintained around pH of 9 and 11, anything too high or low will cause corrosion
15. If acidic, it will cause scale formation which can:
    1. Reduce thermal efficiency
    2. Reduce flow and cause hot spots
16. However, if alkalinity is too high, then foaming can take place in drum and possible caustic attack

Compressed air systems

111. Sketch and describe a pressure relief valve for a starting air compressor. (Craig)
112. Sketch and describe a relief valve for a starting air receiver. What material is it made from? What would you check on inspecting the valve and how is it adjusted? When the receiver is at maximum pressure how many starts is it required to be capable of for the main engine? (Diesel Duck, Notes)
    1. Safety or relief valves are most important of pressure vessel fittings
    2. They are fitted to air reservoirs to automatically release excess air pressure to prevent damage to the tank which could harm personnel or the ship
    3. These valves are fitted normally on top of the tank in a vertical position
    4. The pressure at which these valves open are closely regulated and are adjusted by spring pressure
    5. The regulating adjustment permits roughly a 10% increase of decrease in setting in comparison with its manufactured pressure setting
    6. A common type in use is the full-lift type
        1. This type will remain fully open until a specified pressure drop has occurred
        2. It will close without chattering and remain tightly seated
        3. To set spring pressure, the adjusting nut is tightened or loosened to regulate spring tension
        4. Valves are sealed to prevent tampering after survey
        5. Operation:
            1. When valve lifts due to over pressure, a small amount of escaping air acts on the full area of the valve
            2. This increases the lift until the lower edge of the valve just enters the guide
            3. This reaction causes the valve to lift further until it is fully open since the valve acts as a piston in a cylinder
            4. When the valve is fully open, the escape air is said to be equal to the area of supply through the seating
            5. When the system over pressure has been relieved, the valve begins to close and as the face of the valve disc emerges from the guide sleeve, the reaction effect ceases and the valve closes sharply to prevent chatter
    7. Materials
        1. Valve, seat, spindles, compression screw and bushes must be non-corrodible such as bronze, brass, or Monel
        2. The material of the body is usually brass
        3. The lifting lever is iron or steel and the spring, washer and stem are steel
    8. When checking the valve, it should be opened manually with the lifting lever to clean the seating surfaces or any corrosion
    9. For safety, the valve outlet should be installed in opposite direction of operation
    10. Tanks should be periodically pumped up to max pressure to ensure valve pops at proper pressure
    11. Fusible plugs are also fitted on receivers in case a fire creates a rapid pressure increase that the relief valve is not designed to handle
        1. This will prevent the receiver from bursting
    12. There are at least 2 receivers, the total capacity of which must be capable of:
        1. Starting a reversible engine 12 times
        2. Starting a non-reversible engine 6 times
113. Describe the construction of an intercooler. Why are air compressors fitted with intercoolers? Which compressors are fitted with intercoolers? What safety devices are fitted to the intercoolers? How do you examine and test an intercooler? (Andy, Diesel Duck x 2, Notes)

1. Intercoolers are heat exchangers fitted between stages in a multi-stage air compressor
2. They are used for cooling the air down between each stage as the air pressure is increased
3. Intercoolers allow for relatively high pressures to be reached while keeping the temperature of the air from reaching too high
4. As air is discharged through each stage of compression, it passes through the intercooler, where it is cooled at constant pressure, causing a reduction in temperature and volume
5. The lower temperature air in the high pressure stages allows lubrication of the liners by oil that may otherwise not be effective if hotter
    1. This adds generally to the safety of the system
6. Intercoolers return the air to its original temperature and due to an increase in density, later stages may be reduced in volume
7. An intercooler generally consists of copper tubes through which the air passes
    1. These are expanded into brass tube plates and header, which allows for expansion
    2. Cast iron casing permits circulation with cooling water
    3. Intercoolers are fitted with pockets and drain valves which allow removal of moisture condensed during cooling together with any excess lube oil carried over in the air
    4. A relief valve should be fitted to the air connection ad a bursting disc will relieve excess pressure in the water casing in the event of failure of an air tube
    5. Leaky cooler tubes would be indicated by a falling off of air pressure and a rise in the circulating water pressure of the intercooler
    6. If the tubes actually burst, a serious explosion may occur in the casing and result in fracture if the bursting disc was not fitted
8. Correct temperatures and adequate cooling water must be maintained and drains opened when starting and stopping the compressor and at frequent intervals during operation
9. The problems associated with intercoolers are:
    1. If seawater is used as cooling medium, scale may form on tube surfaces
        1. Oil and scale deposits will prevent proper heat transfer, affecting efficiency
        2. Oil deposits on tubes due to excess lubrication
        3. Must be kept clean, all surfaces and checked for corrosion
    2. Thinning of tubes due to erosion
    3. Bursting of tubes due to explosion of air and oil vapors at high temperature, also caused by over lubrication
10. Maintenance:
    1. Cleaning and inspection of tubes
    2. Scale removal by chemical bath
    3. Hydrostatic testing and leak testing

114. Why are intercoolers fitted to air compressors? List common defects and corrective action for air compressors. (Jackson)
115. Describe the construction of an intercooler for compressor. State why drainage of the cooler is essential. What means is provided to prevent overpressure in the cooler?
    1. An air compressor intercooler generally consists of a number of small diameter copper tubes contained in a cast iron chamber forming a water jacket
    2. The air passes through the tubes and the cooling water circulates around them
    3. Sometimes, a single long copper coil takes the place of the nest of straight tubes
    4. Each intercooler is fitted with purge-pots
        1. The purpose of which is to collect and drain off water and oil that finds its way into all intercoolers
    5. Intercoolers are fitted after each stage of compression and arranged as close to the cylinder as conveniently possible, to reduce the length of hot delivery pipes
    6. Automatic water valves are fitted to intercoolers to admit cooling water when the machine is in operation and to shut it off when the compressor is not
        1. This prevents overcooling and the formation of condensation on internal working surfaces
    7. Safety devices:
        1. A fusible plug is fitted on the HP intercooler discharge head to protect against overheating

            1. Overheating sufficient to melt the alloy material of the plug can be the result of carbon buildup around the discharge valve
            2. The air discharge temperature should not exceed 93C
        2. Relief valves are fitted to the air outlets of each stage and are set to lift at 10% above normal stage pressure
        3. To protect the water side against overpressure in the event of a cooler tube failure, a spring loaded relief valve or bursting disc is fitted on the cylinder jacket

116. What affects air compressor efficiency? How do the following problems affect efficiency? Leaking LP valve, low cooling water, and high clearance volume. (Adam)
    1. The factors that affect efficiency of an air compressor are:
        1. The clearance between the cylinder head and the end of the piston at TDC
            1. The larger the clearance, the less air is discharged per stroke
            2. The outward travel of the piston will be greater before the pressure is low enough to open the suction valve
                1. This makes part of the stroke ineffective and the amount of air brought in on suction stroke will be reduced
        2. Sluggish opening and closing of suction and delivery valves
            1. If a suction valve does not reseat promptly at the end of the suction stroke due to a weak spring or to carbon deposit, part of the air drawn into the cylinder will be returned through the defective suction valve during the first part of the delivery stroke
            2. If a delivery valve is slow in reseating, part of the air compressed and delivered during the delivery stroke will return to the cylinder during the first part of the suction stroke
        3. Leakage past compressor piston rings
            1. If air is leaking past rings, the amount of air delivered will drop thereby dropping the efficiency
        4. Insufficient cooling water or the cooling water inlet temperature too high
            1. With air cooled compressors an insufficient number of air changes into the cooling space or the cooling air temperature is too high
        5. Inlet temperature of the air to the LP stage is too high
            1. The higher the temperature of the air drawn into the LP cylinder, the less will be the weight of air discharged by the compressor in a given time
            2. Hot air is less dense than cooler air
            3. This would also leave deposits on cooler surfaces
        6. Throttling of air supply to LP suction – e.g. dirty air inlet strainer or insufficient suction valve lift
            1. If the inlet passage to the LP cylinder is restricted, the air will be prevented from following up the piston at the correct rate during the suction stroke
            2. When the piston begins the delivery stroke, there will be a partial vacuum in the cylinder and less air will be discharged during each delivery stroke
    2. Leaking LP valve
        1. Suction
            1. Reduced air delivery, increased running time and reduced pressure in the suction to the HP stage
            2. If the suction valve leaks badly, it may completely unload the compressor
        2. Discharge
            1. With high pressure air leaking back into the cylinder, less air can be drawn in
            2. This means reduced delivery and increased discharge temperature
    3. Low cooling water
        1. This will lead to excessive temperature of the air, which can lead to:
            1. Loss of lubrication causing severe wear
            2. High discharge air temperature which may cause fire or explosion when in contact with carbon
            3. Rapid valve deterioration due to carbon deposits
            4. Drop in volumetric efficiency since air will be less dense
    4. High clearance volume

        1. The pressure would be lowered

117. Sketch and describe a 2-stage air compressor and give the materials it is made of. How would a leaky HP delivery valve be indicated and how would you prove it? What effect would a leaking HP suction valve have and how would it be proved to be leaking? (Notes)
    1. Pressures and temperatures:
        1. First stage: delivery pressure 4 bar, air temp before cooler 130C, air temp after cooler 35C
        2. Second stage: delivery pressure 26 bar, air temp before cooler 130C, air temp after cooler 35C
    2. With a leaking HP delivery valve, air will be drawn back in during the suction stroke
        1. Air will be heated up and cylinder temperature will rise
        2. There will be less room for fresh air from LP side and delivery pressure will be reduced
    3. With a leaking HP suction valve, air will be blown back from the second stage into the first stage
        1. This would be indicated by a high pressure in the LP cylinder due to this back pressure
    4. Operation:
        1. Pressure can reach 350 to 400 psi
        2. Air is drawn in on the suction stroke of the first stage through a filter
        3. The piston compresses the air on its upstroke and forces it out of the delivery valve by overcoming its spring pressure to open the valve
        4. The air then passes through the first stage cooler where its temperature is lowered
        5. The air flows into the second stage suction valve on its down stroke
        6. The air is compressed to a much higher degree due to the smaller cylinder volume
        7. After the air is compressed on the upstroke, the air passes through the HP delivery valve and into the second stage intercooler and onto the storage receiver
        8. A non-return valve is fitted to prevent back pressure from the tank to the compressor
        9. An unloader is fitted to relieve the pressure form the discharge so that the compressor can easily get up to speed
    5. Construction
        1. The machine has a rigid crankcase that supports crankshaft bearings
        2. The cylinder block is fitted above the crankcase and contains replaceable liners
        3. The running gear consists of pistons, connecting rods and crankshaft
        4. The first stage head is located on the block and the second stage is mounted on the first
        5. Each head contains suction and delivery valves
        6. A chain driven rotary gear pump provides lubrication to the main bearings and through internally drilled passages in the crankshaft to both connecting rod bearings
        7. Cooling water is supplied either from an integral pump or the machinery space system
            1. The water passes into the block that contains the intercoolers and then into the cylinder heads
            2. A water jacket safety valve prevents a build-up of pressure should a cooler tube burst and compressed air escape
            3. Relief valves are fitted in the first and second stage air outlets
            4. A fusible plug is fitted after the second stage cooler to limit the delivery temperature and thus protect the receiver
            5. Drains are fitted to the coolers to drain any moisture that may have built up in the system
    6. Materials:
        1. Casing – cast iron
        2. Crankshaft – spheroidal graphite cast iron
        3. Bearings – white metal
        4. Piston – aluminum alloy
        5. Rings – cast iron
        6. Valve seat – low carbon hardened steel, polished working surfaces
        7. Valve – nickel steel, chrome vanadium steel or stainless steel, hardened and ground and finally polished to a mirror finish
        8. Spring – hardened steel

7. The HP delivery valve can be tried by taking out the HP suction valve, then putting air back from the receiver to the compressor
    1. If the HP delivery valve is tight, no air will leak out of the suction valve hole

118. Describe a 3-stage air compressor. Give the temperature and pressure of each stage. What would be the effect of over lubrication? (Diesel Duck, Notes)
    1. The 3-stage reciprocating air compressor is commonly used at sea for developing high pressure air for shipboard use
    2. Air is used for:
        1. Starting main and auxiliary diesels
        2. Operating whistles
        3. Testing pipe lines
        4. General workshop service
        5. For blast fuel injection on old engines
    3. Air is cooled between stages by intercoolers to reduce its temperature and volume while increasing its density mass
    4. Cycle:
        1. Air is drawn through a filter into the first stage of the compressor on the downward stroke of the piston and compressed on the upward stroke
        2. This pressurized air overcomes the spring tension of the first stage discharge valve and it discharges into the first stage intercooler
            1. Temperature reduces from 110C to 35C
        3. Moisture given up by the air in the intercooler an collects here, therefore a drain is fitted so it can be removed
        4. From the intercooler, the air travels to the second stage suction and enters the compressor on the upward stroke of the piston
        5. It is compressed on the pistons downward stroke to approximately 16 bar and it is discharged to the second stage intercooler where it is again reduced in temperature
        6. From here it travels to the suction on the third stage and is drawn in on the down stroke of the piston
        7. Here it is compressed for the final time to a pressure of about 40 bar and discharged from the compressor
        8. It passes through an intercooler where it is reduced in temperature and then to the air receiver for storage
    5. An intercooler usually consists of copper tube through which the air passes
        1. These are expanded into brass tube plates and headers which allows for expansion
        2. Cast iron casing permits circulation with cooling water
        3. The effects of the intercooler is as follows:
            1. First stage – 4 bar delivery pressure, air temp before 110C, air temp after 35C
            2. Second stage – 16 bar delivery pressure, air temp before 110C, air temp after 35C
            3. Third stage – 40 bar, delivery pressure, air temp before 70C, air temp after 25C
    6. The compressor may be driven by an auxiliary diesel engine or an electric motor
    7. Materials:
        1. Compressor casing is cast iron for water cooled
            1. Cast aluminum alloy for air cooled
        2. Crankshaft is nodular cast iron or forged low carbon steel
        3. Connecting rods are forged mild steel
        4. Wrist pins are surface hardened steel
            1. Top end bearings are bronze
        5. Bearings are white metal or Babbitt
            1. May now be ball or roller bearings on new machines
        6. Piston is aluminum alloy
            1. White cast iron compression and oil control rings
        7. Heads are constructed from cast iron or cast aluminum alloy
        8. Valves:
            1. Valve seat is hardened low carbon steel and polished working surfaces

        2. Valve is nickel steel, chrome vanadium steel or stainless steel, hardened and ground and polished to mirror finish
        3. Valve spring is hardened steel
8. There is a gear driven lube oil pump which supplies lube oil under pressure to the bearings and the lower cylinder walls by splash lubrication
9. An air filter is attached to the inlet to prevent entry of foreign matter suspended in the air such as dust
10. After each stage, a relief valve is fitted to protect the compressor from overpressure
11. The intercooler water side is also fitted with a bursting disc or relief valve
12. Suction and discharge valves are fitted for each stage
13. Over lubrication:
    1. Can cause serious effects on the operation of compressor and is quite dangerous
    2. An excess of oil will be carried with the oil throughout the intercoolers and compressor, as well as the system piping
    3. The oil will collect on surfaces and form a film that blocks heat transfer surfaces and acts as insulator, preventing proper cooling
    4. Excess oil will collect on the valves, particularly the HP delivery valve
        1. This will impair operation of the valve as the oil carbons it
    5. The most serious effect of over lubrication is explosion due to the thin flammable film that may reach starting air system
        1. If combustion flames reached this film through a faulty non-return valve or leaky air start valve, an explosion may occur
        2. Drains are fitted to remove oil and condensation regularly from low points to prevent damage

119. Describe a 3-stage air compressor and give the advantages over a single stage. (Diesel Duck)
    1. The number of stages used is governed by the required final pressure of the compressed air
    2. As the pressure increases, more stages are required
    3. Advantages of multi-stage:
        1. It is easier to control the temperature of the air and to hold it at lower temperatures during its passage through the air compressor
            1. This is accomplished by water jacketing the cylinders and passing the air through intercoolers between stages
            2. This lowers the work done in compressing the air and prevents a lot of the mechanical problems that could arise if the air temperature were uncontrolled
        2. By keeping the air temperatures low, less difficulty is experienced with the lubrication of the pistons and cylinders
            1. The suction and delivery valves remain in a cleaner condition without becoming fouled with carbonized oil
        3. Multistage requires less energy or work input than a single stage compressor for the same resultant air pressure

120. Describe a 3-stage air compressor. State the pressures and temperatures of each stage. Where are drains fitted? What type of lubricating oil is used and why? What provisions are made for overheating and excessive pressure? (Diesel Duck)
    1. Drains are fitted in the intercoolers to get rid of water from condensation and oil emulsions from cylinder lubrication
    2. Air compressor lubricating should be:
        1. High grade blended oil
            1. Straight mineral oil will be washed off the internal surfaces by moisture
            2. This will lead to wear and rusting
            3. A rust inhibitor should be added to blend to prevent corrosion
        2. High flashpoint
        3. Thermal stability
            1. Have high temperature anti-oxidants for long service life
        4. Low viscosity
        5. Non-emulsifying
        6. Have low carbon forming tendencies for less chance of fire and explosions
        7. Low volatility

            1. For reduced oil carryover
        8. Compatibility with seal materials
        9. Good resistance to foaming
        10. High film strength to ensure oil film between piston rings and cylinder walls
    3. Provisions for overheating and excessive pressure:
        1. Water side of intercooler fitted with bursting disc or relief valve to blow out if an air tube burst
            1. This will prevent damage to intercooler casing
        2. Relief valves are fitted between stages to prevent overpressure
        3. Fusible plug is fitted to HP discharge to melt if discharge air temperature is excessive

121. How is a 3-stage air compressor protected from overload? State any common problems with air compressors and their remedies. (Diesel Duck, Notes)
    1. Main preventions for compressor accidents:
        1. Prevent oil deposits on coolers
        2. Observe air temperature closely
            1. It is possible for excessive temperatures beyond the HP stage to ignite the vaporized oil that is always present
        3. Drain moisture periodically
    2. Common problems:
        1. High pressure in LP stages
            1. Delivery valves leaking or hung up.
            2. High pressure valves leaky or piston rings leaking
            3. Remedy is to examine valves and rings
        2. Air compressor falls off
            1. Air inlet filter is choked
            2. Compressor valves leaking or sticking
            3. Too much play in top end of LP cylinder
            4. Leaky piston rings
            5. Leaky cylinder head
            6. Leaky drain or safety valve or pressure gauge fittings
            7. Leaky intercoolers
        3. Buildup of oil from cylinders and water from moisture, precipitated in coolers
            1. This emulsion must be drained regularly to prevent any large quantity of water and oil reaching a subsequent compression stage and causing damage to a further stage
            2. Also, this must be drained to reduce amount carried over to the air receivers and starting air lines
            3. Moisture leads to corrosion of system components and parts seizing
122. Sketch and describe an air compressor for starting a main engine. Show piping from the relief valve to the starting air valve. (Diesel Duck)
123. With reference to air compressors why is air compressed in two or more stages in preference to one stage? What are the common faults with air compressors and how are the remedied? (Diesel Duck, Notes)
    1. Air is compressed in multiple stages for the following reasons:
        1. The strength of a cylinder varies inversely as the diameter so the walls of a single cylinder compressor large enough to handle the large volume of low pressure air would have to be made very thick to handle the pressure stress
            1. The thick walls would prevent effective cooling of the hot compressed air
        2. When multi-stage compression is used, the hot air can be cooled between stages
            1. This reduces volume of air and also means better working conditions of engine or motor driving compressor
            2. Cooling is necessary to prevent high temperature, high pressure air explosions
            3. If hot air cools in the receivers, the pressure would fall and this would cause frequent starting of the compressor
        3. Reduction in gas temperatures simplifies lubrication requirements and reduces the risk of overheating the compressor

124. State the considerations essential for the operation of air compressors. What actions can be taken to prevent accidents or unsafe operating conditions? (Notes)
    1. Considerations essential for proper operation of air compressors:
        1. Make sure air filter is clean
            1. Any obstruction in air passages can seriously affect efficiency of compressor
        2. Oil level must be checked to ensure proper amount of lube oil is in sump
        3. The compressor should be locked out and turned manually a few revolutions before starting after maintenance to ensure all parts are moving freely
        4. The cooling water valves must be open and system leak checked if water cooled or cooling fins clear and clean if air cooled
        5. The compressor should be started slowly and unloaded in order to build up lubrication of all surfaces
        6. The operation of the lube oil pump and cooling pump, if fitted, must be checked
        7. Relief valves should be checked to see if they are free to open if required
        8. The compressor should be stopped and a check of bearings completed for abnormal temperatures
        9. Temperatures should also be checked for air before and after intercooler and also between stages, and then compared to manufacturer specs
    2. Actions taken to prevent accidents or unsafe operating conditions:
        1. Make sure all guards are in place to protect personnel from rotating machinery
        2. Ensure proper oil level and pressure at all times
            1. Ensure correct lube oil is used at the proper high flashpoint
            2. Avoid over lubrication of cylinders since oil will coat system components and provide fire material
        3. Ensure proper cooling at all times
            1. Drain coolers regularly
            2. Check relief valves regularly
            3. Cooler tubes should be cleaned regularly
        4. Non-return valves must be checked and cleaned to prevent backpressure from receivers
        5. Suction and delivery valves must be maintained as well as piston rings
        6. Pressure gauges should be fitted and calibrated
        7. Bursting discs must be fitted to prevent excess pressure in lines and tanks
125. Describe the different types of air starting and the full details and operations of one system with which you are familiar. (Diesel Duck)
    1. Diesel engines are started by supplying compressed air into the cylinders in the appropriate sequence for the required direction
    2. A supply of compressed air is stored in air reservoirs or bottles ready for immediate use
    3. Up to 12 starts are possible with the stored quantity of compressed air
    4. The starting air system usually has interlocks to prevent starting if everything is not in order
    5. Compressed air is supplied by compressors to the air receivers
    6. The compressed air is then supplied by large bore pipe to a remote operating non-return or automatic valve and then to the cylinder air start valve
    7. Opening of the cylinder air start valve will admit compressed air into the cylinder
    8. The opening of the cylinder valve and the remote operating valve is controlled by a pilot air system
    9. The pilot air is drawn from the large pipe and passes to a pilot air control valve which is operated by the engine start lever
    10. When the air start lever is operated, a supply of pilot air enables the remote valve to open
    11. Pilot air for the appropriate direction of operation is also supplied to an air distributor
    12. This device is usually driven by the engine camshaft and supplies pilot air to the control cylinders of the cylinder air start valves
    13. The pilot air is then supplied in the appropriate sequence for the direction of operation required
    14. The cylinder air start valves are held closed by springs when not in use and opened by the pilot air enabling the compressed air direct from the receivers to enter the engine cylinder
    15. Safety:
        1. Lube oil from the compressor will under normal operation pass along the air lines and deposit on them
        2. In the event of a cylinder air start valve leaking, hot gases would pass into the air pipes and ignite the lube oil

3. If starting air is supplied to the engine, this would further feed the fire and could lead to an explosion in the pipelines
4. In order to prevent such an occurrence, cylinder starting valves should be properly maintained and pipelines regularly drained
5. Also oil discharged from compressors should be kept to a minimum by careful maintenance
6. In an attempt to reduce the effects of an explosion, flame traps, relief valves and bursting caps or discs are fitted to the pipelines
7. In addition, an isolating non-return valve (automatic valve) is fitted to the system

126. Sketch an air starting system for a large diesel engine. What is meant by overlap and what is its purpose? (Diesel Duck)
    1. In an air starting system for a main engine, a multi-stage air compressor compresses air and stores it in air receivers under pressure until needed
        1. Receiver pressure 350-600 psi
    2. The system normally incorporates several receivers so that they can be individually isolated by shut-off valves for maintenance
    3. To start an engine, air is admitted through the main air starting valve
    4. Interlocks or blocking devices may be fitted to prevent operation of this valve in the event of:
        1. Turning gear engaged
        2. Direction controls incorrectly set
        3. Fuel control wrongly positioned
        4. Failure of essential engine systems
    5. The air will now take 2 directions:
        1. Air will pass through a non-return valve to the main air start valve manifold
        2. Air will also pass to the distributor or timing valves
    6. These are synchronized with the engine position in order to pass air to operate each cylinder air start valve in the correct order as the engine rotates
    7. Timing is controlled by cams or gear drive from the engine camshaft
    8. The distributor is set up and timed so that pilot air will enter the air start valve and open it as the piston passes TDC
    9. In the air operated air start valve, pilot air along with pressure of starting air is used to open the valve and allow starting air into the cylinder
    10. Materials
        1. Internal parts of non-corrodible materials such as bronze or stainless steel in order to avoid jamming as a result of the moist air causing corrosion
    11. The cylinder air start valves are normally held closed by a compression spring together with cylinder pressure acting over the valve lid
    12. Air start valves are normally of the mushroom type and are contained in cast iron or bronze housings and open into the cylinder
    13. Air from the manifold enters these valves where it forms a pressure balance with the underside of the valve lid and a balance piston of equal area on the valve spindle, consequently this does not cause the valve to open
    14. Cylinder valves are opened when pilot air transmitted from the distributor applies pressure to the larger operating piston on the valve spindle
    15. As the valve is forced open, starting air from the manifold enters the cylinder applying pressure on the piston and causing the engine to rotate in the corresponding direction
    16. To close the cylinder valves, the connection from the distributor is open to the atmosphere allowing the spring to close the valve and return the operating piston
    17. For a 2-stroke,starting air is admitted to the engines for a period equal to the angle between cranks plus some overlap
        1. During overlap, starting air is admitted to 2 cylinders at the same time in order to ensure starting no matter the position of the crankshaft
        2. The amount of overlap necessary depends upon the speed with which the admission valve in the cylinder opens and to a certain extent, when the admission of starting air begins
        3. Overlap of 15-25 degrees is sufficient
    18. Safety devices:
        1. Non-return valves

        2. A relief valve fitted to the air manifold designed to rapidly release any pressure buildup
        3. A flame arrestor and bursting disc must be fitted to the air start connection to dissipate a backpressure from the air start system and prevent and explosion
        4. Drain valves must be fitted to keep lines free from oil
    19. Maintenance:
        1. Total use time is very small so little attention is normally required
        2. All moving parts should be checked for freeness
        3. The valve should seat with required pressure
            1. Occasional grinding will help this and avoid gas escape which could lead to air start explosion
            2. Should be regularly cleaned
        4. Receivers will be subject to condensation and should be drained regularly to prevent carryover

127. How many degrees of the cycle is the starting air valve open? What is meant by overlap in the air starting valves and illustrate with an example? Has this any advantage? (Notes)
    1. For a 2-stroke, the air start valve is open for 115 degrees
    2. For a 4-stroke, the air start valve is open for 125 degrees
        1. Opens 15 degrees after TDC and 10 degrees before exhaust begins
    3. Some overlap of the timing of air start valves has to be provided, so that as one cylinder is closing, another one is opening
        1. This is essential to ensure that no angular position of the crankshaft will have insufficient air in order to give a positive start
        2. The usual minimum amount of overlap in practise is 15 degrees
    4. Starting air is admitted on the working stroke and the period of opening is governed by practical considerations with 3 main factors to consider:
        1. Firing interval of the engine
            1. = # of degrees in engine cycle / # of cylinders
            2. With a 4 cylinder 2 stroke Doxford, the firing interval is 90 degrees (360/4)
            3. If each cylinder valve covered 90 degrees of the cycle, then the engine would not start if it had come to rest in the critical position with one valve just a fraction from closing and another just starting to open
            4. With a 6 cylinder 4 stroke = 720/6 = 120 degrees
        2. The intake valve must close before the exhaust commences
            1. It would be pointless blowing high pressure air straight to exhaust and it could also be dangerous
        3. The cylinder air starting valve should open after firing dead center to give a positive turning moment in the correct direction
        4. Some valves are arranged to start to open as much as 10 degrees before TDC because the engine is past this position before the valve is actually open
        5. The reversing effect is near impossible as the turning pressure on a crank near dead centre is very small anyway

128. What are the characteristics of lubricating oil used with air compressors? How is this flash point of lubricating oil found? (Diesel Duck)
    1. Characteristics:
        1. The lubricant must provide an oil film over the rubbing surfaces to effect piston seal, thereby preventing leakage of air past the piston rings and reducing wear
        2. If oil is too light in body, effective sealing will not be maintained
        3. If it is too heavy, it will not spread properly and cause drag and friction
            1. Impurities will also cling readily and assist in formation of undesirable deposits
        4. The oil must have considerable oil film strength to avoid rupture due to high pressures involved
        5. Lubricant must resist oxidizing effect of air at high temperatures reached in compression
        6. Must also be suitably compounded to resist washing off effect of excessive moisture
        7. Flash point is important and should be as high as possible to prevent fire damage
            1. Found with Pensky Marten Apparatus for Closed Flashpoint
    2. The oil is inclined to emulsify and should be changed at regular intervals

129. Describe a starting receiver, stating materials of construction and operating pressure. List all fittings and where found on receiver. How is it protected from corrosion? (Diesel Duck, Notes)
    1. Starting air at pressures of 350-600 psi is stored in cylindrical receivers of capacity sufficient to provide 12 starts for a reversible engine and 6 starts for a non-reversible engine
    2. An air receiver is constructed of good quality low carbon steel, similar to that used for boilers
        1. Length is normally several times greater than diameter
        2. 0.2% Carbon max, 500 MPa
        3. They are welded or riveted in construction, modern are welded
        4. Welding must be done to Class, over 35 bar regulations are more strict
        5. They are welded longitudinally and circumferentially for strength
        6. Welding must be radiographed
        7. Steel must be annealed to 600C
        8. Test piece must be subject to bend, impact and tensile tests
        9. The ends are dished convex for strength
    3. The safety valve is set to go off at 10% over working pressure
    4. The receiver is pressure tested to 1.5 times working pressure
    5. Piping to air start system must be protected from explosion
    6. The mountings and purpose of each are:
        1. Inlet valve – allow air into storage in receiver from compressor
            1. Valves will allow slow opening to avoid rapid pressurizing of system
        2. Outlet valve – allow air out of tank to compressed air systems
        3. Pressure gauge – give an indication of air pressure inside tank
        4. Inspection door – allow for inspection and cleaning
        5. Drain valve - to drain off accumulated moisture to prevent corrosion, blockage and poor operation of compressed air system
            1. Also to drain any accumulated oil in receiver
            2. The receiver is normally slightly inclined to facilitate draining
        6. Fusible plug – Melts in case of a fire at 150C so that tank won't explode
            1. If CO2 is used to fight fires, the air should be vented through piping to atmosphere outside of engine room
    7. Receiver is protected from corrosion by:
        1. Frequent draining of condensation through drain valve
        2. Coated inside with a non-spirit based varnish to prevent fire

Power transmission

130. Describe a reversible reduction gear for a single direction engine. How are thrust bearings incorporated and how is changing direction carried out? (Andy, Diesel Duck)
    1. The Hindmaich MWD oil operated ahead and astern gear consists in its simplest form of 5 wheels:
        1. Two on the input shaft
        2. One on an idler shaft
        3. Two on the output shaft to which they are keyed
    2. The two on the output shaft, one for ahead and one for astern, are hollow and contain the clutch plates
        1. The wheels are free to revolve on the hubs of the plates
    3. The 5 wheel are in constant mesh
    4. The phosphor bronze clutch plates, two in each wheel, can slide on splines on the shaft
    5. Each ahead and astern wheel is made from two steel forgings machined all over and recessed to accept the clutch plates
        1. The inner faces are serrated
        2. The two pieces are now secured together and the teeth cut on the rim
        3. When all parts are assemble, this forms the drive from the clutch plates to the output shaft

6. The clutch plates are serrated on their outer faces and the inner faces to form a chamber
    1. The inlet and outlet to which are through passages on the shaft
7. The lubricating and operating oil is obtained from the gear's own supply pump
    1. The oil pump is attached to the input shaft so as soon as the engine is started provides oil at around 65 psi to the system
    2. The pump draws the oil from the gearbox sump through a suction strainer, then forces it through a delivery filter and a cooler
    3. From the cooler, it enters the internal pipes and passages in the gearbox and points where required
    4. The lube oil passes through a reducing valve prior to going to the bearings, gear sprayers, etc.
8. Operating oil has two paths:
    1. One direct from main supply line
    2. The other through a hollow cock called the control cock
        1. If the control cock is in the "stop" position, oil goes direct from supply line to the "disconnect " passage in the output shaft
        2. This oil will act on the serrated faces of bot gear wheels and the clutch plates, so preventing any connection with the shaft
        3. If the cock is moved to "ahead", the operating oil will pass through the control cock into the ahead passage in the output shaft and enter the control chamber formed by the two clutch plates
        4. The plates will be forced apart, sliding on the splines and making contact with the serrated faces of the ahead wheel
        5. This will lock the ahead wheel to the output shaft and the vessel will move ahead
        6. A Mitchell thrust collar and pads absorb the propeller thrust and transmit it to the hull
        7. The movement of the input shaft is transmitted by two wheels, the main input wheel and the one on the output shaft
        8. Should the control cock be moved to the "astern" position, it must first pass through the "stop" position
        9. The "ahead" oil will be cut off and the "disconnect" oil opens simultaneously
        10. Operating oil to the astern clutch passage in the shaft and the astern plates will move apart and lock the astern wheel to the output shaft which will start to revolve
        11. The input shaft movement is now via the idler wheel to the output shaft, three wheels being used

131. Sketch and describe a flexible coupling you are familiar with. (Notes)
    1. Flexible Vulcan couplings are used between engine and gearbox to:
        1. Dampen torque fluctuations
        2. Reduce effect of shock
        3. Reduce loading on gears and engine
        4. Allow slight misalignment
        5. Minimize vibration
        6. Reduce noise levels
    2. Since oil will attack natural rubber, these couplings are usually made of reinforced synthetic rubber that is oil resistant
    3. Before the coupling is installed, all parts must be thoroughly cleaned and free from grease and oil
    4. The coupling disc is held in place by nuts and bolts
    5. A steel ring fitted on the side opposite of the control side when in position will even torque on the coupling disc
    6. Marks on the coupling will change form if the coupling starts to wear and lose strength
    7. Another indication of wear may be rubber dust particles around the coupling area
    8. These couplings may be used for different machinery so size and shape will vary for each unit

132. Define torsional vibration and state the chief cause in a diesel engine. When is an engine said to be operating at a critical speed? Why are torsional dampeners fitted to diesel engines? Explain briefly how they operate. (Notes)
    1. Critical speed
        1. The speed at which the firing impulses of the engine cylinders coincide with the natural torsional vibrations of the shaft due to inertia forces

2. At critical speed, the shaft is in serious danger of being fractured by the abnormal stresses set up
3. The action of the propeller blades working in water at varying depths also produces variations in the turning movements of the shafting
4. Critical speed also depends on the weight and elasticity of the revolving parts and the position of them along the crank length
5. Engines must be run at speeds either below or above critical speeds to avoid damage
    1. These speeds are normally marked on a plate fixed to the controls
6. It should be noted that the critical speed is independent of engine load and may occur at low or high speed

2. Torsional vibration
    1. Have been a source of considerable damage in past
    2. During the firing stroke of diesels, the flywheel is always slightly behind the crank
        1. During the compression stroke it is ahead of the crank
    3. If the firing impulses are in step with the natural vibrations of the shaft, the effect will be cumulative and if allowed to continue, may cause complete fracture
    4. This condition may be detected by a change in tune of the engine, a low rumble in the driving gears of the camshaft, or if chain driven, waving of the chain and consequent rubbing in the guides
    5. This will cause violent reversal of the load on the top and bottom end bearing bolts
    6. Design engineers endeavour by various means to ensure these conditions do not occur within ordinary speed of engine
        1. If this is not possible, a detuner is often fitted
        2. Has effect of reducing vibration by 60-80%
        3. Object of detuner is to provide a connection between groups of masses which alters its stiffness with the swing
        4. The construction of the detuner allows an elastic connection to a floating mass to be used in such a manner that as the vibration torque increases, the spring automatically stiffens
            1. This increases the natural frequency of the system so that there is no stable frequency which may cause resonance
        5. When under light vibration loads, the detuner spring is very elastic, which means a low frequency
        6. The system when fitted with a detuner becomes an unstable resonant system that has minimum vibration

Lubricating systems

133. Sketch and describe a lube oil system for a large marine engine with oil cooled pistons. (Jackson, Diesel Duck, Mike)
    1. Trunk engine:
        1. This type of force fed lube oil system uses the same oil to lubricate all engine components and cool the piston
        2. The lube oil is drawn through a coarse strainer from the sump by an engine driven pump that discharges to the thermostatic valve and oil cooler to the fie filters
        3. From the filters, it passes to the oil gallery where pipes or drilled passages in the engine block distribute it to the main bearings
        4. A little of the oil is used to lubricate the bearings, the remainder passes to the connecting rod journals through holes drilled in the crankpins and journals
        5. Here again, a little is used to lubricate the bearings, the remainder passing through a hole bored the length of the connecting rod to lubricate the gudgeon pin bearing
        6. The excess oil is sprayed on the underside of the piston crown through a sprayer nozzle located on top of the connecting rod
        7. The oil cools the piston and some oil passes through holes in the oil control ring of the piston, thus lubricating the walls of the liner
        8. The remainder of the oil falls back to the engine sump where the same cycle is continuously repeated
        9. A common practise is to fit a non-return valve at the bottom of the connecting rod to prevent oil from draining back to the sump when the engine is stopped, thus ensuring a full charge of oil when starting

    10. The holes in the crankshaft and the annular grooves in the bearings are large in order to allow a sufficient quantity of oil to reach the pistons

134. Sketch and describe an oil cooled piston. State the advantages over fresh and seawater systems. Why is it necessary to have the oil analyzed periodically? (Diesel Duck, Notes)
    1. Piston cooling:
        1. The operating temperature of the lube oil out of the piston is 55C as compared to 80C for cooling water
        2. With cooling water as medium, there is the threat of contamination of engine lube oil
            1. Cooling water has to be distilled and treated to prevent corrosion and scale build-up
                1. Lube oil requires no such treatment
            2. No extra pumping system required with oil cooled system since same oil is used for cooling and lubricating
            3. Leakage is more manageable since contamination is not a factor
                1. Provided it is small and does not cause other parts of the system to starve
    2. Oil analysis:
        1. A periodic laboratory analysis of the crankcase oil provides an accurate estimate of the condition and suitability for further service
        2. It also affords a valuable indication of the condition of the engine
        3. Physical, chemical and mechanical tests have been developed by detect the changes that have taken place in the oil due to the engine operating conditions
        4. From a study of the changes, an oil technician can estimate the conditions of operation inside the engine
        5. The sample must be representative of oil in circulation while in operation
        6. Contaminants that can be found are:
            1. Water or fuel dilution
            2. Oxidation products
            3. Carbonaceous material
            4. Foreign mineral mater
            5. Metal particles indicative of bearing wear

135. Describe a lubricating oil system for a large diesel engine, and explain how the oil is kept in good condition. (Diesel Duck)
    1. Pressure pumps, strainers and fine filters are in duplicate, one set being used while the other acts as a standby
    2. Fine filters should be capable of being cleaned without interruption of oil flow
        1. Mesh size will depend on bearing materials and clearances, in most large engines it is 50 microns
    3. Capacity of the system must be adequate for the type of installation
        1. If the engine has oil cooled pistons, the capacity and throughput will be increased accordingly
    4. Lube oil pressure pumps draw oil from the engine drain tank through suction strainers
        1. The tank suction is clear of the bottom of the tank to avoid picking up any water or sludge that may have settled
    5. The pumps discharge at pressure through the oil cooler, ensuring that seawater or jacket water is at a lower pressure to avoid contamination due to leakages in the cooler
    6. The oil then passes through fine filters to the engine
    7. It will be distributed to:
        1. All bearings
        2. Piston cooling
        3. Sprayers
        4. Exhaust valve actuators
        5. Control systems
    8. Various sections of the system may require different pressures and to accommodate this, engine driven booster pumps may raise the supply pressure
        1. Pressure reducing valves and restricted orifices may reduce pressure or flow to other parts
    9. Used oil drains to the bottom of the crankcase and passes through strainers by gravity to the drain tank
    10. Drain returns are kept remote from the pump suction and must be submerged to avoid aeration and make a safe seal

11. With oil cooled pistons, each piston return has its temperature monitored and then passes through a sight glass before returning to the crankcase
12. The oil drain tank is normally built into the ship's double bottom but it must be surrounded by a cofferdam to prevent any contamination from leakages
    1. It is fitted with an air vent, level measuring gauge and sounding pipe
    2. Central positioning of the level gauge will reduce fluctuation in readings due to pitching and rolling
    3. The tank must be sufficient size to accommodate the full charge of oil
    4. Its interior surfaces may be coated to prevent rusting due to condensation on its non-flooded surfaces
13. The system should also have low pressure, high temperature and low tank level alarms fitted
14. A bypass centrifuge system is fitted to purify oil from the drain tank to remove water, sludge and insoluble
    1. This should be operated continuously at sea with a slow throughput, the oil being preheated to 70-90C to assist separation
    2. When the engine is not in use batch purification of the whole charge may be carried out
    3. It is most important that water content in the oil is eliminated or kept to a minimum

136. Sketch and describe the lube oil system on a diesel engine having a dry sump showing the filter by-pass system. How many pumps are employed and what is their function? (Diesel Duck, Notes)
    1. In this system, the lube oil pump may be and engine driven pump or an electric motor driven pump
        1. In either case, a standby pump must be available
    2. The main lube oil pump takes its suction from the drain tank and pumps it to the duplex filters
    3. On the pump, a combined safety and pressure regulating valve is fitted which will direct excess oil back to the pump suction
    4. The duplex filters receive full oil flow and are equipped with a bypass valve that is pressure operated and will open if the filter becomes plugged
        1. This allows lubrication pressure at all times
    5. Oil then flows on to the cooler that is equipped with a thermostatically operated bypass valve then on to the engine
    6. Another pressure regulating valve is fitted before the engine to divert excess pressure back to the drain tank
    7. Another line is fitted for offline filtration with an orifice plate to another set of duplex filters and then back to the drain tank
        1. Thus there is a continuous restricted bypass system in operation and a large quantity of oil is always in circulation in the system
        2. This allows oil to be readily available in the event of a pressure drop for any reason
    8. When the oil reaches the engine, separate leads are taken to each main bearing and also to the thrust shafts
    9. A pipe is also connected to supply oil to the camshaft and the gearing for driving it
    10. When the oil enters the main bearing it is directed through drilled passages in the crankshaft to the bottom end bearings
    11. The connecting rod has a passage bored in it from the bottom palm to the top end eye
    12. The oil from the bottom end bearing enters this passage going through a non-return valve situated in the bottom end
        1. This valve prevents the oil from draining away when the engine is stopped, so ensuring an ample supply of oil when the engine is started
    13. Once the oil has been used in the engine, it drains back down to the base from where it is pumped by a scavenge pump back to the drain tank
    14. The line from the base to the drain tank is usually equipped with a sight glass so that the engineer can usually check that the scavenge pump is transferring the oil
    15. Two pumps are in use:
        1. Pressure pump – engine driven or electric
        2. Scavenge pump – used to draw oil from the base back to the drain tank or to an operating tank
137. Describe how diesel engine cylinder liner walls are lubricated. Tell how the main bearing journals, bottom end bearings and wrist pin are lubricated. (Notes)
    1. There are two methods of lubricating cylinder liners and it depends on the engine type:
        1. Trunk type
            1. With medium and medium speed trunk type engines, splash lubrication is used
            2. Oil is picked up by the rotating engine parts and is splashed on the cylinder walls

        3. As the piston moves up, the oil control ring spreads the oil over the liner and in its downward stroke, the oil is scraped off by the same ring
        4. The edge of this ring is shaped to facilitate spreading and scraping
        5. There are small radial holes in the piston in the control ring groove that allows drainage of oil back to the sump
        6. This ring is located below the bottom compression ring
    2. Crosshead type
        1. A mechanical lubricator is used
        2. This oil may be of different viscosity than that of the crankcase oil
        3. A pump is fitted for each cylinder and it injects oil into the rings of the piston as it passes by in a regulated manner
        4. At a low RPM, lubrication requirement is not as great as a higher speed
        5. Timing is very important for the lubricator to avoid oil being sprayed above the piston and into the combustion area
            1. For this reason, it is sprayed when the piston is going up
        6. The oil travels from the lubricator to quills situated around the liner
        7. This ensures that the oil gets all around the liner
        8. This oil is not retrieved
        9. The lubricators are fitted with non-return valves so that they always have oil in the line for start-up and prevent any back pressure from extending back to the pump
        10. The lubricator also has a cranking handle to manually inject some oil before start-up
    3. Trunk type:
        1. Oil pressure is supplied for the main lube oil system via an engine driven pump or electric pump
        2. From the supply piping, oil is distributed to each main bearing
        3. When oil enters a main bearing, it is directed through drilled passages in the crankshaft to the bottom end bearings
        4. The connecting rod has a passage bored in it from the bottom end to the top end
        5. The oil goes through this passage, going through a non-return valve situated at the bottom end
            1. This prevents oil from draining back when the engine is stopped
            2. The top end bushing, which is a force fit into the connecting rod eye has oil grooves cut longitudinal in it to spread the oil on the working surface
    4. Crosshead:
        1. Pressurized oil is piped to the crosshead and down the connecting rod to the bottom end bearing
        2. Main bearings are supplied by a separate piping system
        3. In this system, there is no requirement for drilled passages in the crankshaft

138. How is cylinder liner lubrication carried out in crosshead type engines and trunk type engines? What are the effects of insufficient or excessive lubrication? (Notes)
    1. Cylinder liners require adequate lubrication in order to reduce piston ring friction and wear
        1. The oil film also acts a gas seal between liner and rings and as a corrosion inhibitor
    2. Crosshead:
        1. The cylinder liner is isolated from the crankcase and a separate lubrication system is fitted
        2. This system supplies a measured quantity of oil to each liner
        3. Special, highly alkaline oil is used when burning heavy fuel
        4. Properties are expended during use so oil is not reused
        5. Oil is injected though a number of holes drilled in the liner, usually 6 or 8 displaced circumferentially around the liner at a vertical position within the piston stroke
        6. Oil is supplied by pressure pulse from mechanical lubricators driven from the engine camshaft and regulated to deliver at the required rate
        7. By linking the pump drive to the engine throttle setting levers, the oil quantity can be related to power produced

8. Lubricator quills are connected to the oil holes
    1. These contain non-return valves to prevent hot gases from the cylinder blowing back into the system
    2. They may pass through the jacket cooling space, in which case seals must be fitted
        1. These should be checked periodically
9. The vertical position of the lubrication points will depend on the engine design
    1. They should be clear of the combustion space with its high pressures and temperatures
    2. They should also be clear of exhaust or scavenge ports since unused oil may be lost
10. Distribution of oil may be aided by oil gutters adjacent to the lubricator points and angled downwards to assist flow by gravity while reducing piston ring chipping effect
11. Some engines are fitted with an oil spreading ring in the piston
12. Lube oil is spread over the length of the liner by the piston rings as they pass
13. Mechanical lubricators should be operated by hand before starting the engine to ensure priming of the connections and injection of oil for first movements
14. The supply should be increased for run-in periods after overhaul or repair
15. In opposed piston engines, two sets are fitted, one for each piston
    1. The upper piston runs hotter so has greater quantity injected
16. Trunk type:
    1. Majority of engines are splash lubricated but cylinder lubricators may be fitted
    2. Since most of these are 4-stoke, there will be no ports to lose oil in
    3. Oil is splashed from the crankcase into the lower end of the liner
        1. This could cause excessive lubrication so oil control or scraper rings are fitted to the piston skirt to reduce this and return excess oil to the crankcase
        2. Used oil from the cylinders will also drain into the crankcase and consequently a common oil is used for both
17. Operation of an engine with insufficient liner lubrication will cause high wear rates to liner and piston rings
    1. Corrosion of the liner may increase when burning heavy fuel
    2. Loss of oil seal around the rings will cause ring blow-by of hot gases causing local overheating, rapid breakdown of surfaces and possibly piston seizure
        1. This could also lead to crankcase explosion
18. Excessive lubrication will cause carbon deposits, piston rings sticking in grooves allowing possible breakage or blow-by
    1. There will be fouling of the exhaust system including turbocharger and contamination of scavenge spaces leading to a fire hazard

139. Describe with the aid of a sketch the operation of a mechanical lubricator used for supplying oil to the piston rings of a diesel engine. What is the usual arrangement adopted for conveying the oil supply through the cooling water spaces? (Notes)
    1. The principal purposes of cylinder lubrication are:
        1. To separate sliding surfaces with an unbroken oil film
        2. To form an effective seal between piston rings and liner surface to prevent blow-by of gases
        3. To neutralize corrosive combustion products and thus protect liner, piston and rings from corrosive attack
        4. To soften deposits and thus prevent wear
        5. To remove, dissipate and cause the loss of deposits to exhaust, hence preventing seizure of rings and keeping the engine clean
        6. To cool hot surfaces without burning
    2. The actual amount of lube oil to be delivered into a cylinder per unit time depends upon:
        1. Stroke and bore
        2. Speed of engine
        3. Engine load
        4. Cylinder temperature
        5. Type of engine
        6. Position of lubricators

        7. Type of fuel
    3. Position of lubricators for injection of oil has to be correct. The following points are important:
        1. They must not be situated too near the ports as oil can be scraped over the edge of ports and be blown away
        2. They should not be situated too near the high temperature zone (combustion chamber) as the oil will burn easily
        3. There must be sufficient points to ensure even and as complete a coverage as possible
        4. Ideally, the air is timed injection of lubricant delivering the correct measured quantity to a specific surface area at the correct time in the cycle
    4. There are many forms of cylinder lubricator pumps of the mechanical type
        1. The design that is mostly favored is the differential plunger type
        2. The advantage of this type of plunger over the simple ram is that small quantities of oil can be discharged per stroke with a relatively large plunger bore
    5. Some essential conditions for a lubricator:
        1. Must be capable of delivering a minute quantity of oil regularly every stroke against moderate pressure
        2. Must have a wide range of adjustment and maintain consistent delivery when the feed is cut down to as low as one bubble per minute
        3. Must operate equally well with shaft rotation in either direction
        4. Must be capable of being easily operated by hand prior to starting
        5. The quantity of oil discharged per stroke should be clearly visible
        6. The pump should be able to be easily removable and replaced with another

140. Draw a line diagram of a complete lubricating oil system for a 2-stroke medium speed Main Engine. Explain why a large quantity of oil is kept in reserve. Explain why both lubricating oil filters and centrifugal purifiers are fitted. (TCMS)
    1. The lubrication system of an engine provides a supply of lube oil to the various moving parts of an engine
        1. Its main function is to enable the formation of a film of oil between the moving parts, which reduces friction and wear
        2. The lube oil is also used as a cleaner and coolant
    2. Lube oil for an engine is stored in the bottom of the crankcase, known as the sump, or in a drain tank beneath the engine
    3. The oil is drawn from this tank through a strainer through one of a pair of pumps into one of a pair of fine filters
    4. It is then passed through a cooler before entering the engine and being distributed to the various branch pipes
    5. The branch pipe for a particular cylinder may feed the main bearing for instance
    6. Some of this oil will pass along a drilled passage in the crankshaft to the bottom end bearing and then up a drilled passage in the connecting rod to the gudgeon pin or crosshead bearing
    7. An alarm at the end of the distribution pipe ensures that adequate pressure is maintained by the pump
    8. Pumps and fine filters are arranged in duplicate with one as standby
    9. The fine filters will be arranged so that one can be cleaned while the other is operating
    10. After use in the engine, the lube oil drains back to the sump or drain tank for re-use
    11. A level gauge gives a local read-out of the drain tank contents
    12. A centrifuge is arranged for cleaning the lube oil in the system and clean oil can be provided from a storage tank
    13. The oil cooler is circulated by seawater or jacket water which is at a lower pressure than the oil
        1. As a result, any leak in the cooler will mean a loss of oil and not contamination of the oil by seawater
    14. Where the engine has oil-cooled pistons, they will be supplied from the lube oil system, possibly at a higher pressure produced by booster pumps
        1. An appropriate type of lube oil must be used for oil-lubricated pistons in order to avoid carbon deposits on the hotter parts of the system
    15. A large quantity of oil is kept in reserve because:
        1. There should be make-up for oil consumed in cylinders and leaks
        2. Allows time for the oil to cool before being re-used in engine
        3. Oil is pumped around the engine during use and drains down when stopped so a reserve is required for this lower operating level
    16. Lube oil filters and purifiers are used because:
        1. Filters are inline and trap sediment before reaching engine

        2. Purifiers remove water and sludge and also operate in parallel (bypass) with the engine oil system

141. What impurities are found in lubricating and fuel oils? What effects do these impurities have on a diesel engine? (Diesel Duck, Notes)
    1. Fuel:
        1. Impurities in diesel must be kept as low as possible and be removed in the pre-treatment system to minimize wear and corrosion or engine components
        2. Impurities derive from the crude oil itself from refinery processes and from handling and storage
        3. Some impurities such as sulfur and vanadium are oil soluble and therefor impossible to remove in a conventional mechanical treatment system
        4. The amount of water and solid impurities can be reduced by centrifuging and filtration
        5. Sand, rust, metal oxides, and catalyst particles can be found in fuel
        6. These can cause wear and chemically induced corrosion
        7. Combustion caused impurities, known as ash, can also cause wear, especially catalyst particles, silicon, aluminum oxides, carbonates and sulfates
        8. The corrosive and aggressive vanadium sodium ash can lead to high temperature corrosion on exhaust valves and turbocharger blades
        9. The sulfur content can lead to low temperature corrosion of combustion chamber components and form deposits
            1. The corrosive effect is due to the formation of sulfuric acid
                1. Tends to induce pitting of exhaust valves
            2. Water, especially salt water in fuel will lead to mechanical and corrosive wear as well as fouling
    2. Lube oil:
        1. In service, oils can be contaminated by the following:
            1. Water – from condensation or leakage
            2. Fuel – due to faulty injectors or incomplete combustion when starting
            3. Carbon – due to overheating or blow by
            4. Weak acids – from combustion products
    3. Water in fuel would lower efficiency of combustion and cause the engine to misfire or stop firing altogether
    4. Air or vapour in fuel would result in air lock with the result that the engine might stop by lacking fuel
    5. Carbon deposits would cause excessive wear in the liner at position of upper rings
    6. Tarry deposits might result in the piston rings becoming gummed up in piston grooves with resultant blow-by and heating of the liner
    7. Water in lube oil might lead to emulsification, in which condition the oil would lose most of its lubricating properties

142. Discuss the importance of preventing fuel oil from entering the crankcase of a diesel engine. Where are such leaks likely to occur? What dangers occur with the contamination of lube oil with fuel? What information can be gained by the analysis of a sample of crankcase oil? (Notes)
    1. The presence of diesel has several adverse effects on crankcase oil
    2. With fuel contamination, the oil viscosity will be reduced
        1. With low viscosity, lubricating properties are decreased and may lead to metal to metal contact and wear since the oil film will be too thin to carry the prevailing loads
        2. Engine parts may be damaged or seized due to over heating
    3. The flashpoint of the oil will also be reduced with fuel contamination
        1. Lube oil has a higher flashpoint than diesel (230C vs. 95C), therefore a mixture will be somewhere in a more dangerous range
            1. There will be an increase in a risk for crankcase explosion
        2. The sulfur in fuel may also mix with water in lube oil to form corrosive sulfuric acid which will attack steel parts
        3. Causes:
            1. Fuel dilution usually results from poor atomization of the fuel, which permits liquid fuel to run down cylinder walls into the crankcase
            2. Another cause is back leakage from fuel pump plungers

        1. Suitable trays should ensure that waste fuel is drained to the fuel drain tank and not into the oil sump
    3. A leaky fuel line or nut could cause the oil to drain down through rocker arms
4. Prevention:
    1. Careful maintenance of fuel pumps, injectors and pipe unions will reduce the trouble to a minimum
    2. A periodic lab analysis of the oil should be made as this provides an accurate observation of the condition of the engine and suitability for further use
        1. Physical, chemical and mechanical tests have been developed that measure the changes that have taken place in the oil due to engine operating conditions
        2. The test sample should be representative of the rest of the oil so should be taken from the circulation system and not the bottom of the sump
        3. Some variables that the testing looks at:
            1. Water dilution
            2. Fuel dilution
            3. Oxidation products
            4. Carbon material
            5. Foreign mineral matter
            6. Metal content including excessive wear of any engine component

143. Describe the construction of an oil filter as used for a diesel engine. State the materials used and what the filtering action is. Explain the procedure for cleaning an oil filter used on a running engine. (Diesel Duck)
144. What is a magnetic filter, where would you find it in the lubrication system and what information would you derive when you open it up for inspection? (Notes)
    1. A magnetic filter is a device fitted in a lube oil system to extract small particles of ferrous metal
    2. These particles are caused by the wear of bearings and interior engine parts or by the meshing of gear teeth
    3. This filter would be found in the suction line from the sump of the engine to the lube oil pump
        1. They would be in line with full flow
        2. They could also be fitted in gearbox oil circuits so that the lube oil passes though the filter before the sprayers and bearings
    4. When opened up for inspection, it would give an indication of the rate of wear taking place within the engine
    5. This could be a means of alerting the engineers of a fault or possible future fault
    6. As the oil passes through the filter, any ferrous particles are subjected to a magnetic pull during its flow through the filter
    7. These particles stick to the magnetic elements until cleaned off
    8. Non-ferrous particles such as brass, bronze, copper and aluminum are not subjected to the pull and will not be picked up by the magnetic elements
145. What would cause breakdown of a lube oil system? State what precautions you would take if you observed fuel oil in the lube oil. What steps would you take if you discovered your oil temperature increase to a dangerous level? (Notes)
    1. As oil breaks down, lubrication is decreased and parts such as bearings heat up and wear excessively, causing severe damage to the machinery
    2. Breakdown of a lubrication oil could be caused by:
        1. Oxidation and contamination with corrosive products from the cylinders
        2. There may be contamination with water or fuel and wear debris
        3. Water could come from condensation when running the engine cold or leaks in cooling circuit
            1. Water will emulsify and cause loss of lubrication qualities
        4. High temperature will cause carbon to form and oil to breakdown
        5. Using poor quality or improper lube oil may cause breakdown
    3. Precautions to take if fuel was found in the lube oil would be to watch the oil pressure closely and try to increase pressure and flow if possible
    4. Since viscosity of fuel is much lower than lube oil, the pressure will drop, which may cause loss of lubricating film and major damage or seizure of moving parts

5. There is also a much higher chance of a crankcase fire or explosion since the flashpoint of fuel is much lower than oil
    1. This means that the temperature of bearings and the oil must be closely monitored
6. As soon as possible, the engine should be shut down, fault found and rectified and then the oil changed
7. Causes are often leaky injectors or bad rings causing blow-by
8. The Chief should be made aware
9. Steps to take if your oil temp increased to a dangerous level would be to shut down the engine but leave the lube oil pumps running to prevent seizure of moving parts
10. The source of the problem may be a faulty pump, low oil level, fouled cooler or continued running in an overload condition
11. If it is not possible to shut down, engine speed and load should be decreased and cooling increased until correct action can be taken
12. Lube oil temperature is typically controlled by thermostatic valve, if able this should be made fully open to direct all oil flow to the cooler
13. Engine room ventilation should be put on high to air cool engine

146. Sketch and describe a gear driven lube oil pump. Show rotation of the gear wheels. How does the pump operate when the engine is reversed? (Notes)
    1. A reversible gear type oil pump has a cast iron body which holds the gear wheel and delivery valves as well as a spring-loaded relief valve
    2. The gears are case hardened steel run inside the body with very tight tolerances between themselves and the pump casing
    3. The gears are keyed to their own shafts with one being driven by the engine gearing and the other being run by this gear
    4. The pump contains two suction and two delivery valves, depending on the rotation of the engine
        1. The valves are non-return type and are opened by the pressure or vacuum of the oil on the underside of the valve
        2. The discharge valves are larger than the suction valves
        3. One suction and one discharge valve both work on the same spindle extending into the pump and protruding through one side of the casing
        4. The spindle is held in position by a nut where it protrudes through the pump casing
        5. On the other side of the spindle is a large plug that can be removed for valve maintenance access
    5. The relief valve is of the simple ball and spring construction
        1. Oil pressure is adjusted by turning an adjustment screw at the end of the relief valve which will change the compression of the spring
        2. Excess oil will flow back from the relief valve outlet to the suction side of the pump
        3. This will prevent damage since the pump is positive displacement
    6. An inlet and outlet are located on opposite sides of the pump
    7. Oil is drawn through the inlet and into the outside periphery of the gears where it is trapped between the teeth and the casing
        1. The close tolerance is necessary here to create a high pressure without the oil leaking back
        2. As the teeth begin to mesh, the oil is forced out through the delivery valve and through the outlet
        3. If the engine is reversed the other set of valves will be used