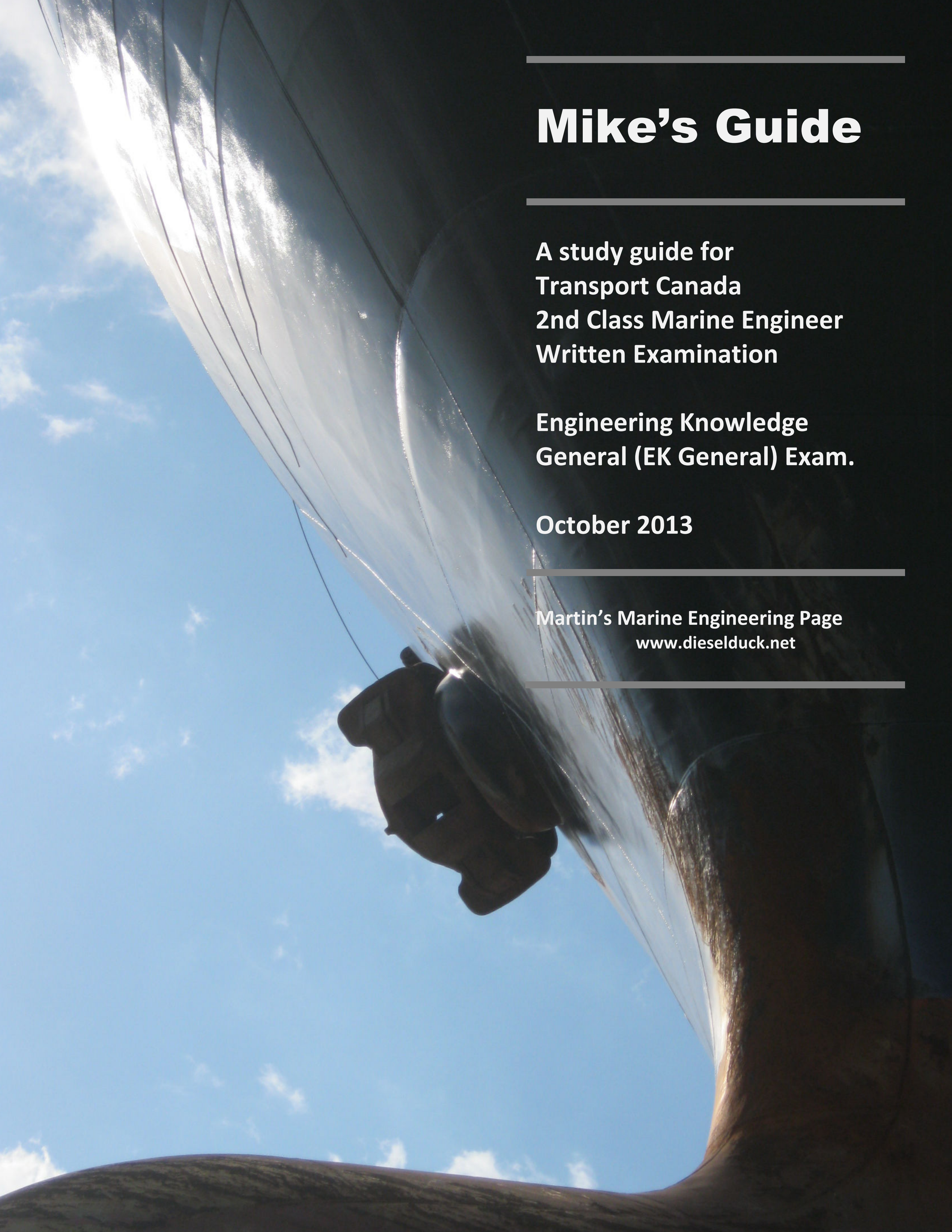

Mike's Guide

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

Engineering Knowledge
General (EK General) Exam.

October 2013

Martin's Marine Engineering Page
www.dieselduck.net

Twenty-one topics:

1. Materials (16 questions)
2. Heat and combustion (4 questions)
3. Instruments (2 questions)
4. Water treatment (7 questions)
5. Principles of marine engines (5 questions)
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8. Auxiliary machinery (20 questions)
9. Power transmission (12 questions)
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13. Safe working practices (1 question)
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15. Control systems (3 questions)
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19. Damage control (0 questions)
20. Electrical safety (0 questions)
21. Non-destructive testing (0 questions)

Materials

The general effects of various treatments on the physical and chemical properties of materials commonly used in the construction of marine engines and boilers, and the physical tests to which these materials are normally subjected.

1. In reference to metals, define the terms: (Craig, Diesel Duck)
    a. Tenacity:
        1. Same as toughness – a combination of strength and the ability to absorb energy or deform plastically
        2. Tenacity is the measure of resistance that a material offers to breaking, crushing, bending, cutting, or other acts of destruction.
        3. Very important since it shows how material will react under load in service.
        4. A condition between brittleness and softness
        5. Results from the attraction that exists between particles
        6. Determined by forming material into wire and hanging weights to see breaking force required
        7. For metals, steel has highest tenacity, lead the lowest
    b. Ductility
        1. Ability for a metal to deform under tensile stress (be drawn into wire form)
        2. Percentage elongation and contraction of area, as determined by a tensile test, are good practical measures of ductility
        3. When tested by stretching, the greater the percentage reduction in the specimen's cross section area at rupture, the greater the material's ductility
        4. Can also be tested with bend test with a plate being bent through 180 degrees
        5. Platinum has highest ductility, cast iron has very low ductility
    c. Malleability
        1. A material's ability to deform under compressive stress
        2. This is often characterized by the material's ability to form a thin sheet by hammering or rolling.
        3. Gold is the most malleable metal
    d. Hardness
        1. A measure of how resistant the material is to various kinds of permanent shape change when a force is applied.
        2. A material's resistance to erosion, wear, denting, scratching or bending
        3. Value can be modified by heat treatment
        4. Measured often by ability to resist plastic deformation by indentation.

    e. Brittleness
        1. Generally applied to materials that fail with little or no evidence of plastic deformation
        2. Opposite of ductility
        3. A brittle metal may break quickly with low stress applied to it.
        4. A strong material may also be brittle
    f. Compressibility
        1. A measure of the relative volume change of a material in response to a pressure or stress change.
        2. A gas is compressible, a solid is less compressible and liquids are not normally compressible.
        3. A metal's compressibility is important to know so we can see if and when it will deform under service loads
    g. Elasticity
        1. Ability of solid materials to return to their original shape after being deformed or loaded
        2. Solid objects will deform when enough force is applied on them.
        3. If the material is elastic enough, the object will return to its initial shape and size when these forces are removed.
        4. Gases, solids and liquids work the same as with compressibility
2. Describe the following stresses in relation to metals: tensile, compressive, shear and torsion. Give an example of each for ship's machinery. (Mike)
3. Describe how cast iron is made/properties. What parts in the machinery space can it be used for and why, and what is the density, tensile and compressive strength of cast iron? (Paul)
    a. Cast iron is made from iron ore, which has been smelted in a blast furnace.
        1. The blast furnace is a large, slightly conical structure lined with refractory
        2. The ore is put into a blast furnace along with coke or coal and heated to a very high temperature which causes the iron to become molten.
        3. Limestone is used to take out non-iron elements such as silica, by making the slag fluid so it can be drawn off
        4. Air necessary for combustion is blown in through a ring of holes near the bottom
        5. The coke, ore and limestone are charged through the top of the furnace in rotation
        6. Owing to its density, molten metal falls to the bottom of the furnace while the slag or waste floats on the surface.
        7. The furnace is tapered at the bottom and the molten metal is guided into a sand box which forms what are called pigs.
        8. The resultant pig iron is 92-97% pure iron
        9. The percentage of carbon ranges from 2 to 5% and the rest is silicon, manganese, sulfur and phosphorous
    b. Used in nearly all castings aboard ship, cast iron is easily shaped into complex forms by the usual method of making wooden patterns and casting the pig iron after reheating
        1. Reheating takes place in a smaller furnace called a cupola wherein the composition of iron is suitably adjusted.
    c. The fluidity of cast iron makes it:
        1. Easy to cast
        2. Easy to machine
    d. Other advantages:
        1. Inexpensive
        2. Wear resistant
        3. High compressive strength
        4. Low melting point
        5. High rigidity
    e. Engine parts where cast iron is used are:
        1. Cylinders
        2. Valve casings
        3. Sole plates and columns
        4. Valve chests that may be difficult to forge
    f. Pig iron is of various qualities depending on ore:
        1. White cast iron is clear and crystalline and hard.
            1. Used is manufacture of steel.
            2. Undesirable because it is brittle and gives poor machining characteristics
            3. Silicon content is low
        2. Grey cast iron is more open or granular and soft and crumbly.
            1. Silicon aids the formation of graphite and is used for the process of producing a soft cast iron
        3. Mottled cast iron is intermediate quality.
    g. The fracture of cast iron is a good index of its quality, it should show a close crystalline fracture
    h. Grey and mottled are used in marine use since white is too brittle for machining
    i. Density is around 7200kg/m3

   j. Tensile strength is low – about 300Mpa – used where tensile loads are very low
   k. Compressive strength is higher – 900Mpa

4. What are the differences between Cast Steel and Cast Iron? Explain how you would cast something small. How would you determine whether a certain machinery part was made from cast iron or cast steel? (Andy, Diesel Duck, 1982)
   a. Both have good physical characteristics for marine machinery such as wear and heat resistance.
   b. Cast iron:
      1. Cast iron is a continuation from the smelting of pure iron.
      2. It is made by re-melting pig iron, often along with substantial quantities of scrap iron, scrap steel, limestone, carbon (coke) and taking various steps to remove undesirable contaminants.
      3. Phosphorus and sulfur may be burnt out of the molten iron, but this also burns out the carbon, which must be replaced.
      4. Depending on the application, carbon content is adjusted to the desired levels, which may be anywhere from 2–3.5%
      5. Other elements are then added to the melt before the final form is produced by casting.
      6. The heating takes place in a special type of blast furnace known as a cupola, or often in electric furnaces.
      7. After melting is complete, the molten iron is poured into a holding furnace or ladle and then into its cast shape
      8. It requires little additional work and is very durable.
      9. Has higher carbon content than cast steel, this makes it:
         1. Very brittle, or easily breakable
         2. Less ductile
         3. Harder to make into shapes
         4. Very heavy
         5. Tensile strength around 300 Mpa
         6. Elongation around 1%
   c. Cast Steel
      1. Steel is iron with carbon added to it, but in smaller quantities than with cast iron, usually less than 1 percent of the overall weight.
      2. Cast steel is created by heating iron using a crucible container and often called crucible steel
      3. Iron is a soft metal, so not ideal for many marine purposes.
      4. The creation of steel removes many of the impurities in iron, which allows steel to be harder and more durable.
      5. The better the steel, the more iron impurities that are removed.
      6. By heating blister steel in a clay crucible placed directly into a fire, the metal reached up to 1600°C
      7. Melting allowed other elements, such as nickel, to be mixed into the metal, thus strengthening the steel.
      8. Like cast iron, it is poured in its molten state into molds so the object comes out as one piece and requires little additional work
      9. Since steel is a more useful material, cast steel can be used more widely:
         1. Less brittle
         2. Easier to shape
         3. Lighter
         4. It can also be mixed with other substances, for example with chromium to make stainless steel.
         5. Tensile strength around 900 Mpa
         6. Elongation around 16%
   d. To cast something small, a mold is formed in high refractory sand by a wooden pattern whose dimensions are slightly greater than the casting to allow for shrinkage.
      1. Molten pig iron or steel is poured into the mold and allowed to cool to form the desired shape.
      2. When the mold is opened, the item comes out in one piece.
      3. To ensure a sound casting, risers have to be carefully positioned to give good ventilation

5. Describe the manufacture of cast steel. Where would it be used in conjunction with boilers? Give figures for: (Diesel Duck, Notes)
   a. Tensile strength = 900 Mpa
   b. % Elongation = 16%
   c. % Reduction in area
   d. Yield point for a propeller shaft around 235 MN/m2
   e. Cast steel is manufactured in an electric furnace, open hearth or oxygen process, similar to that used to produce mild steel
   f. The furnace is charged with cast iron and pig iron of the white variety and the contents heated by gas flame until molten
   g. In order to reduce carbon content to the desired .4 to .5%, scrap wrought iron and iron oxide is added and samples of the molten metal are taken at intervals and tested
   h. Once the correct analysis is attained, the metal is run through prepared beds to solidify and form ingots
   i. These ingots are used in the foundry for the production of steel castings
   j. They are melted in a cupola furnace and the molten metal is poured into molds of the part that is to be casted

k. After casting, a heat treatment (annealing, normalizing or tempering) is required to reduce brittleness
l. Owing to its great strength and toughness, it is used on parts subject to sudden shock or heavy loads and where great rigidity is required
m. Hardness will defend against scouring action of superheated steam
n. Stern tubes, rudder frames, spectacle frames or other structural components may be produced as castings

6. Explain the process of arc welding. Where can you weld in a boiler? What metals can be welded? (Andy, Diesel Duck, 1982)
    a. Welding is a fabrication process that joins metals by causing coalescence.
        1. This is often done by melting the work pieces and adding a filler material to form a pool of molten material (the weld pool) that cools to become a strong joint.
        2. This is in contrast with soldering and brazing, which involve melting a lower-melting-point material between the work pieces to form a bond between them, without melting the work pieces.
    b. In electric arc welding, an arc is struck between the electrode, which may serve as the filler metal, and the metal to be welded.
        1. The electric current can be direct or alternating with a voltage of 80-100 V
        2. The metal being joined is connected to one pole of the current supply, while a coated electrode is connected to the other pole
    c. The generated heat from the arc causes the electrode to melt and the molten metal is transferred from the electrode to the plate.
        1. If the electrode is bare, the arc tends to wander and is therefore difficult to control.
        2. Also the arc stream is open to contamination from the atmosphere and this will result in a porous, brittle weld.
        3. To avoid these defects, flux coated electrodes are generally used.
        4. The flux coating melts at a higher temperature than the electrode metal, thus the coating protrudes beyond the core during welding.
        5. This gives better stability, control and concentration of the arc.
        6. The coating also shields the arc and molten metal pool from the atmosphere by means of the inert gases given off as it vaporizes.
        7. Silicates, formed from the coating, form a slag upon the surface of the hot metal and tis protects the hot metal from the atmosphere as it cools.
        8. Also, due to larger contraction of the slag than the metal as it cools, the slag is easily removed.
    d. The electrode is moved along with a series of small sideways movements, the metal in the pool furthest from the arc cools and solidifies
    e. The electrode is held at approximately 30 degrees from vertical with the hand in advance of the electrode tip in direction of movement along the joint
    f. May be done using DC or AC supply.
        1. DC requires at least 50 V
        2. AC requires at least 80 V
        3. AC is more popular because:
            1. More compact plant
            2. Less plant maintenance required
            3. Higher efficiency than DC
            4. Initial cost is less
        4. Disadvantages of AC are:
            1. Higher voltage, hence greater shock risk
            2. More difficult to weld cast iron and non ferrous metals
    g. The types of metals that can be welded are all ferrous metals including steel, cast iron, wrought iron, nickel steel, mild steel and cast steel. Non-ferrous metals such as aluminum, magnesium and copper may be welded with argon arc welding.
    h. Many parts of new boilers that were formerly riveted are now welded.
        1. Strict rules govern the parts which may be welded including the quality and dimension of the weld
        2. Classification societies will want radiographic, micrographic/macrographic and tensile, bending, impact tests as well as annealing after hot work
        3. Welding on boilers is best used on parts of boilers under compressive stresses such as furnaces and combustion chambers since the weld will be kept closed by the compressive stress.
        4. Parts of a boiler subject to tensile stress such as boiler stays and shell plates are not as suitable, however, can be welded if permission is gathered by the certifying authority. Parts include:
            1. Combustion chamber wrapper plates are welded to the back plate and the tube plate
            2. Combustion chamber girders that support top of chamber
            3. End plates are welded to the cylinder shell plates
            4. Manhole compensating rings (doublers)
            5. Mountings on a multi-tubular boiler are seated on a mild steel pad which is welded to the shell plates

            6. Mountings are also welded to the drum of a water tube boiler
            7. Standpipes are also welded to the shell plates and drums of boilers

7. Explain the process of case hardening. What are the properties of a metal that is case hardened? Where are they found in machinery? (Andy)
    a. Case hardening is sometimes referred to as pack carburizing.
    b. It involves heating the steel component until it is 30-50C above upper critical temp range (850-950C), followed by rapid quenching
    c. The hardest possible condition for the steel is produced and the tensile strength is increased
    d. The steel component is packed in a box which may be made of fire clay, cast iron, or a heat resistant nickel iron alloy.
    e. Carbon rich material such as charred leather, charcoal, crushed bone and horn is the packing medium, which would encompass the component.
    f. The box is then placed in a furnace and raised in temperature to above 900C.
    g. The surface of the component will then absorb the carbon, forming an extremely hard case.
    h. Depth of case depends on length of time and carbon material used.
    i. May vary between .8mm to 3mm requiring 2 to 12 hours.
    j. Examples of materials that are case hardened are:
        1. Gudgeon pins
        2. Bearing pins
        3. Cam lobes
        4. Journals
        5. Valve seats
        6. Valves
        7. Gears
    k. Case hardened materials possess a hard outer case with good wearing resistance and a relatively soft inner core, which retains the ductility and toughness necessary for such components.

8. Describe the Annealing and Tempering process. Why would you want to anneal a piece of machinery after it is been repaired? (Lawson, Dave, Diesel Duck)
    a. Annealing is the process of heating a part uniformly to a high temperature and allowing it to cool gradually at a controlled rate
        1. This is done to relieve stresses that are set up during manufacturing.
        2. Temperature normally 30 to 40 C above upper critical temperature (850 to 950C).
        3. Takes place in furnace while normalizing takes place outside of furnace.
        4. A softer, more ductile steel than that or normalized condition is produced
        5. Also to grain refine
        6. Castings, forgings, sheets, wires, and welded materials can be subjected to annealing.
        7. Does not increase the tensile strength but has the effect of allowing the molecules of the structure to contract uniformly and so leave a uniform stress throughout the part
        8. Parts made this way include:
            1. Boiler plates
            2. Connecting rods and piston rods
            3. Turbine rotors, etc.
    b. Tempering is the process of heating the metal to between 300C and 650C (lower critical temperature range), retaining this temperature for a prescribed period of time and then cooling in air, or quenching in water or oil.
        1. Used to restore ductility, relieve stress and brittleness of a metal after it has been hardened.
        2. Will accomplish without losing hardness or toughness
        3. Amount of time at temp will affect degree of toughness
        4. The higher the tempering temperature, the lower the tensile properties of the material
        5. Metal will take color that denotes hardness.
            1. Light grey is very hard
            2. Light blue is medium
            3. Dark blue is a soft temper
        6. Engine parts that are tempered:
            1. Coupling bolts, bearing bolts and parts subjected to alternating stress to increase strength and resistance to fatigue failure
            2. Also used for drills, chisels, punches, saws, reamers and other tools
    c. A piece of machinery that has been repaired often has local stresses in it set up by either the cold working or hot working (welding, etc.) on the part
        1. This could cause a localized failure during operation

        2. Since annealing has the effect of allowing the molecules of the structure to contract uniformly and so leave a uniform stress throughout the part, this lowers the risk of a local failure

9. Define the following processes and state what purpose each would have aboard ship: (Diesel Duck)
    a. Tempering **See above**
    b. Annealing **See above**
    c. Case Hardening **See above**
    d. Brazing
        1. Brazing is hard soldering and consists of the joining together of copper or brass parts such as a brass flange to a copper pipe
        2. The pieces are carefully cleaned then fitted in place and clamped together in the required position
        3. After they are covered with spelter (one part copper and one part zinc), heat is applied and the spelter runs into the spaces of the joint
        4. Borax is sprinkled over the parts as a flux to make the spelter run easily
        5. After cooling, the spelter sets hard and the parts are then firmly soldered together
    e. Welding **See above**
10. What is Monel metal? How is it made and where is it used? What engine parts are made from Monel? (Adam)
    a. Monel is perhaps the most useful marine copper alloy natural alloy consisting of approximately 2/3 nickel and 1/3 copper with a small percentage of iron and manganese.
    b. While the metal is generally a manmade alloy today, it is found both in its natural state and in the production of commercial metal.
        1. It was created by Robert Crooks Stanley for INCO in 1901, and named for company president Ambrose Monell
        2. It is made by direct reduction from ore in which the constituent metals occur in these proportions
        3. Eliminating the impurities is accomplished without separation of its contingent metals.
        4. Produced in:
            1. Cast
            2. Drawn
            3. Hot-rolled
            4. Cold-rolled in billets, bars, wire, plate, sheet, strip, tubing
    c. Metal characteristics are:
        1. High resistance to seawater corrosion and erosion
            1. Rust proof and highly resistant to corrosive liquids such as ammonia.
        2. Easy to machine but must be worked at low speeds
            1. Can be worked on much like steel
        3. Great physical strength when subject to high temps
            1. Low coefficient of expansion
        4. Quite ductile and malleable
        5. High fatigue resistance
        6. Has a glass like polish and is highly resistant to wear and abrasion
        7. Tensile strength of 400-700 MPa depending on treatment.
        8. Primary drawback is added cost
            1. Monel is typically much more expensive than stainless steel.
    d. Uses are where high heat and pressures typically exist:
        1. Turbine blades
        2. Condenser tubes
        3. Pump rods
        4. Impellers
        5. Scavenge valves
        6. Super heat steam valves
        7. Piping
        8. Strainer baskets
    e. With 2-4% aluminum, a material called K monel is created that can be temper hardened to increase its strength still further without detracting from its other properties
11. Describe the defects that occur to anchor/mooring cables and steering chains. How are they tested and how are the defects rectified? (Paul, Diesel Duck x 2)
    a. Anchor chains are under various stresses:
        1. Tensile stress
            1. Weight of anchor, anchor dragging, etc.

        2. Compressive stress
            1. When piled on top of each other, the weight causes compression
        3. Shock loads
            1. When anchor chain is taut and weather is causing the ship to pull sharply on chain
        4. Erosion
            1. Sitting in sand or rough bottom
        5. Corrosion
            1. Seawater oxidation
        6. Forging and casting defects
        7. Fatigue stresses the metal after long service and becomes brittle
            1. Alternating stresses can cause failure below normal stress failure points
    b. Tests are carried out by Class on cables over 12.5mm (1/2") diameter
        1. Every shot (90 feet) are tested
        2. Three lengths are taken from each shot and tested for tensile breaking stress
        3. Then the entire length is checked for tensile strength
        4. Then there is an inspection for flaws, weakness and material deformation
        5. Shackles and accessories are subject to same testing
            1. Should be opened, inspected and well lubed regularly
        6. If the chain passes, it receives a certificate with information such as type and grade chain, diameter, total length, total weight, dimensions of links, loads used in tests, serial #, testing facility, and certifying body.
        7. Full length should be checked for wear down, with a 10% diameter decrease being the maximum tolerable
        8. Every link should be hammer tested
    c. Required maintenance:
        1. Cable in a locker kept idle for a long time becomes brittle
            1. To remedy the brittleness, the chain is annealed – heated to a red heat in an annealing furnace and cooled slowly to help restore ductility
        2. Anchors should be used alternatively where possible
            1. Should also be flipped end for end regularly
        3. Chain lockers should be kept painted and clean of moisture
        4. Chain should be rinsed with fresh water to reduce salt water corrosion

12. Describe the construction materials and tests that are completed on materials for a water tube boiler. (Paul, Adam, Diesel Duck)
    a. Classification societies require analysis of materials in order to maintain an approved quality and factor of safety
    b. Destructive tests:
        1. Tensile tests
            1. This test is carried out to ascertain the strength and ductility of a material.
            2. Completed for shell plates, drums, headers, tubes and stays.
            3. Test pieces are machined to standard sizes depending on the thickness of the metal in question
                1. Normally length is 5 times diameter
            4. When a material is tested under tensile load, it changes shape by elongating
            5. A machine stretches the material and measures its extension
                1. This extension will be uniform until the yield point is reached
                2. Up to the yield point, the removal of load would result in specimen returning to original size
                3. If testing continues past yield point, the specimen will "neck" or reduce in cross section
            6. A yield stress, ultimate tensile stress and elongation must be attained
        2. Bend test
            1. Consists of bending a straight specimen of a plate through 180 degrees around a former to see if any cracks appear on the outer surfaces of the plate.
            2. Former is 3 x thickness of test piece
            3. If no cracks show, the material passes this test
            4. Used to asses ductility
            5. Completed for boiler plates, corrugated furnaces and rivets.
        3. Impact test
            1. This test is useful for determining differences in material due to heat treatment, working and casting that would not otherwise be indicated by the tensile test
            2. This is a toughness test – its ability to withstand fracture under shock loading
                1. Measures energy absorbed when it is fractured
            3. A beam type test piece is used in the Charpy v-notch test

4. Test piece is laid across the supports with the notch on the opposite side from the impact pointer of the striker
5. The striker is released and the swing of the pendulum after striking the test is used as an indication of impact strength
6. Energy absorbed in fracturing the specimen is automatically recorded by the machine
7. The greater the toughness, the lower the extent of the swing after it has been fractured

4. Hardness test
    1. The hardness test of a material basically determines the wear resistance of that material by measuring the resistance to indentation
    2. The Brinell test is used which measures the deformation of a hardened steel ball
    3. Consists of a cylinder into which oil is forced by a pump
    4. Oil pressure is raised until the top piston that supports a weight is floating
    5. The bottom piston holds the hardened steel ball, which is pressed into the metal beneath it to a load of 3000 kg
    6. The load is held for 15 seconds to ensure plastic flow occurs
    7. Surface indentation is measured with a microscope and results can be measured against a chart
    8. The load is reduced for softer metals
5. Flattening tests – Completed for rivet heads and boiler tubes
    1. Otherwise known as a dump test
    2. The specimen is compressed to half its original length and if it does not crack, it passes
    3. Also the head must withstand flattening until it's diameter is 2.5 times the diameter of shank
6. Hydraulic test – Pressure testing to 1.5 x working pressure for at least 30 minutes.
    1. Also called the fatigue test.
    2. Can wrap a tape around tubes to check for expansion.
7. Creep test
    1. May be defined as the slow plastic deformation of a material under prolonged loading.
    2. Plain carbon steels when used at temperatures above 400C tend to deform under stress, which is important for boiler and engine materials
    3. Can occur in metals like lead and tin at room temperatures
    4. Creep temperatures coincide with recrystallization temperatures
    5. A material may fail under creep condition at a much lower stress and elongation than would be ascertained in a straight tensile test.
    6. Hence, tests have to be conducted to determine a limiting creep stress with small creep rate.
    7. Alloys such as molybdenum or chrome and vanadium can be added to improve creep strength
    8. Tested at controlled temperature over an extended period of time in the order of 10000 hours
    9. Similar machined specimen to the tensile tests
    10. Piece is gradually brought up higher in temperature by furnace as a steady load is applied
    11. Extension of piece is graphed
8. Fatigue testing
    1. Fatigue failure results from a repeatedly applied fluctuating stress which may be a lower value than the tensile strength of the material
    2. A specially shaped specimen is gripped at one end and rotated by a fast revolving electric motor
    3. The free end has a load suspended from it and a ball race is fitted to prevent the load from turning
    4. The specimen as it turns is subjected to an alternating tensile ad compressive stress
    5. The stress reversals are counted and the machine is run until the specimen breaks
    6. The results will provide a limiting fatigue stress for the material
9. All welded parts are also given hammer test to see if they are sound. Completed for smoke and water tubes.

c. Nondestructive testing:
1. Non-destructive tests are carried out on components, not test pieces
    1. They are used to detect flaws or imperfections during manufacture or during surface
    2. The tests do not give indication of mechanical properties
    3. Internal testing:
        1. Radiographic / X-ray
        2. Ultrasonic
    4. Surface testing for cracks:
        1. Penetrant
        2. Magnetic crack detection

2. Welded parts of pressure vessels are subject to:
    1. Radiographic examination for the detection of cracks or faults in the metal
        1. Uses an x-ray to penetrate the steel to impinge on a photographic plate/paper to give a negative
        2. Faults in the metal affect the intensity of rays passing through the material, hence showing shadow picture of material
        3. Defects such as porosity, slag inclusions, lack of fusion, poor penetration, cracks and under cuttings are shown in the film
        4. Limits are placed on the extent of defect by the different inspecting bodies
    2. Ultrasonic examination
        1. Uses high frequency sound waves to reflect on the tested metal, similar to radar
        2. A probe can be passed down a piece of metal and it will show a readout on a portable, hand held display
        3. This probe emits high frequency sound waves that are reflected back by any flaws in the object
        4. The waves are displayed on a screen where the size and position of a defect can be seen
        5. Can also be used to detect thickness of a material
        6. Can be used to find leaks of air pressure or vacuum in pressure vessels
    3. Penetrant testing
        1. Low viscosity fluid is smeared over the surface of a metal and then wiped clean after allowing time for penetration
        2. A whitewash or chalk is applied as dust over the metal, which will discolor if it comes in contact with any fluid that remains in any small cracks
        3. Also, a fluorescent penetrant dye can be used and then inspected under ultraviolet light
        4. A developer may be used to act as a blotter to bring the penetrant to the surface and better show any cracks or faults by staining along the crack
        5. After testing, the fluids can be cleaned off by solvent or water spray, depending on manufacturer
    4. Magnetic crack detection
        1. Suitable for materials that can be magnetized
        2. After the test, the component is normally de-magnetized
        3. Metallic material is applied to the surface of the metal
            1. Normally a black oxide held in suspension in thin oil
            2. Can also be magnetic ink in aerosols
            3. Or just dry powder
        4. A magnetic field is applied to the component by an electric current or permanent magnet
        5. Wherever there is a fault, flux leakage will occur
        6. The powder will accumulate at the defect to try and establish continuity of the magnetic field
3. Microscope examination for a picture of the structure of the metal

13. Describe the open hearth process of manufacturing mild steel. What is meant by acid and basic mild steel? What parts of a boiler and engine are made of mild steel? (Diesel Duck)
    a. Capable of producing large quantities of steel (150 – 300 tons) in a single melt
    b. Instead of using solid fuels such as coal and coke, the open hearth process uses the outgoing hot burnt furnace gas to preheat an incoming gaseous fuel
    c. This results in a sufficiently high temperature to treat large quantities of metal and keep it molten throughout the process
    d. The molten metal lies in a shallow pool, roofed in, on the furnace bottom or hearth, which has 2 brick lined heating chambers
    e. At the end are openings for heated air and fuel (gas or oil), known as a heat regeneration chamber
    f. The outgoing hot gases are channeled through this heat regeneration chamber
    g. The gases heat the brick work of the channels
    h. In the meantime, the gaseous fuel mixture are being passed separately through the other regenerator that has been heated previously
    i. The direction of the mixture is reversed at intervals of about 20 minutes to maintain a high temperature of combustion
    j. Usually, scrap steel is previously charged and heated in the furnace and liquid pig iron is added to it
    k. This allows the impurities of the pig iron to be deleted and the refining process does not take as long
    l. Iron oxide is added and combined with oxygen, oxidizes the impurities
    m. The carbon is removed as carbon monoxide
    n. Silicon and manganese are also changed into their oxides which react with sand and lime to form slag
    o. At the end of the process, silicon and manganese are added to bring the steel to its correct composition
    p. Later, a small addition of aluminum is added to further deoxidize the metal
    q. Acid steel is when the slag produced is siliceous

1. Process is used to refine pig iron low in phosphorous and sulfur which are rich in silicon
2. Oxidation takes place in the presence of oxides of non-metals
3. Certain amounts of silicon, manganese and carbon are removed but sulfur and phosphorous remain
4. Converter is lined with an acidic material to prevent a reaction with the slag and assist in removing impurities

r. Basic steel is when the lime content is high
1. Inferior grades of cheap pig iron can be used containing phosphorous and low in silicon
2. Oxidation takes place in the presence of oxides of metals
3. Sulfur and phosphorous are removed by addition of limestone, which is basic
4. Converter is lined with dolomite that absorbs the phosphorous and is quite basic
5. Majority of steel is basic since modern techniques allow it to be completed more economically with inferior ores

14. What is the term "Factor of Safety" and how is it determined? How is it used in regards to a) boiler b) connecting rod c) propeller shaft d) piston, e) cylinder liner, and why do they differ between these items? Also what do the terms dead load, live load, and alternating load mean and how are they used in relation to the Factor of Safety. Which type of load would you allow the greatest factor of safety? (Paul, Dave, Lawson, Diesel Duck)
   a. Given that failure of a marine machinery or materials cannot be totally avoided, it is important that risk of failure be kept within an acceptable range of possibility
   b. To meet this need a factor of safety can be prescribed to effectively separate the likelihood of loading to the likelihood of failure by a prescribed amount
   c. In other words, the safety factor indicates how much greater the strength of material must be than the force that normally acts on it. (capability vs. demand)
   d. Factor of safety is defined as the ratio of working stress allowed in relation to ultimate (breaking) stress
      1. Stress is the force acting on a unit area of material
      2. If a material is stressed beyond the elastic limit, it will be permanently deformed
      3. Ultimate Tensile Strength = Maximum load / Original Cross Sectional Area
      4. Factor of Safety = Ultimate Tensile Stress / Working Stress
      5. Safety factor cast iron is roughly 6 to 20 depending where it is used
      6. Safety factor of hard steel varies from 5 to 15.
   e. Dead load is defined as a stress producing load that is applied statically or very gradually
      1. Boiler stays are around 7 to 8 F of S but could be as low as 4.5 to 6 since these are dead loads
   f. Dynamic/live load is defined as a variable applied load, such as a weight hung quickly on a bar
      1. Initial effect is to produce a much higher stress than a dead load
      2. Connecting rods are built to around 9 to 14 due to the live loads (similar to piston rods and main bearing bolts)
   g. An alternating load is defined as a load that is applied in motion to a material
      1. The stress and deformation is highest on these loads, increasing with the velocity of the load
      2. May result in fatigue failures so these components have the highest factor of safety
      3. A cyclic load well below a material's yield strength can cause failure if it is repeated through enough cycles.
      4. Tail shafts are 12 or above
      5. Where there are shock loads such as in the drive chain for a camshaft, the F of S may be as high as 25
15. List the material and physical properties (include typical values) for the following: (Jackson, Diesel Duck)
   a. Hold down bolts
      1. Heat treated mild steel
         1. Should possess properties of strength and toughness and ductility
   b. Crankshaft
      1. Medium carbon steel is used
         1. It is harder and stronger than mild steel but less ductile
         2. More difficult to weld and machine
         3. Has tensile strength up to 700 N/mm2 and elongation up to 12%
   c. Tail shaft
      1. Ingot steel
         1. Should possess properties of high tensile strength and ductility
         2. Ability to resist torsional stresses
         3. Around 470 MN/m2 for tail shaft and elongation around 22%
   d. Surface of engine bearings
      1. White metal
         1. Tin based (88%), antimony (8%), copper (4%)
   e. Boiler tubes
      1. Mild steel alloyed with molybdenum and vanadium for strength and fatigue resistance at high temperatures

f. Boiler shell plate
   1. Uses mild steel
   2. May be riveted or welded
   3. It welds easily and has good machining properties
   4. Tensile strength ranges up to 430-560 MPa and elongation of 25%
   5. Should be ductile to mold into shape
g. Boiler stays:
   1. Tensile strength of 430-560 MPa
   2. % elongation of not less than 20%
h. Stern tube bearings
   1. Used to be lignum vitae (hard wood), now normally a polymer resin or hard rubber for water cooled
   2. White metal for oil cooled stern tubes
i. Centrifugal pump casing
   1. Centrifugal pumps impart a high velocity to the liquid pumped
   2. This high velocity is largely converted to static pressure in the pump casing
   3. Made of gunmetal or cast iron but will depend on the pump application
j. Cylinder liner
   1. Cast iron
      1. Contains carbon (2%), silicon (1%), manganese (1.5%), phosphorous (.25%), sulfur (.1%)
   2. Should possess properties of hardness, tensile strength, capability of forming a smooth running surface
   3. Ability to resist distortion or cracking from severe heat stresses
   4. Tensile strength: not less than 14 ton/in2
   5. Transverse strength: not less than 2500 ton/in2
   6. Brinell hardness: not less than 200
k. Connecting rods:
   1. Ingot mild steel is used
      1. 3-4% nickel for strength and erosion resistance
   2. Tensile strength: 28-32 ton/in2
   3. Elongation: 25-29%
l. Fuel lines:
   1. Solid drawn seamless high pressure steel
   2. Thickness can be varies depending in working pressure

16. What is stress when referring to engineering materials? Name the types of stresses acting on the following? (Diesel Duck x 2)
   a. Stress is defined as the state that the particles of a body are put in when put under load
   b. The term refers to the load per unit area and the units are commonly ton/m2 or N/m2
   c. Common stress are:
      1. Compressive – a load tying to decrease the length of something
      2. Tensile – a load trying to increase length of something
      3. Bending
      4. Shearing
      5. Torsional
   d. Cylinder cover stud
      1. The pressure set up by the combustion inside the cylinder cause and upward force on the cylinder head causing a tensile (stretching) stress on these studs
   e. Crank web
      1. A bending stress is created when the crank turns resulting from the tensile stress in the upper side of the web and a compressive stress in the lower side of web
      2. Where piston connects with the web, a shearing stress is created
   f. Connecting rod on down stroke
      1. On compression and power strokes, a compression stress would be set up in connecting rod
      2. A bending stress would be present due to piston forcing straight down on con rod and the crank web forcing up on the con rod at a certain angle
   g. Thrust shaft forward of thrust collar
      1. This would be torsional stress due to the twisting moment caused by the downward force of the connecting rod acting on the length of the crank web
   h. Propeller shaft aft of stern tube
      1. There would be bending stress due to weight of propeller and racing in heavy seas

        2. There would be torsional stress in turning the propeller
        3. Compressive forces in ahead
        4. Tensile forces in astern
    i. Piston on down stroke
        1. Compressive force of combustion, downward forces cause tensile stress and shearing stress in the piston pin
    j. Safety valve spring

17. Define the following and give expected values for each with regards to a mild steel tail shaft: (Notes)
    a. Ultimate strength
        1. Is a measure of a material's strength
        2. Can be found by using the following relationship:
            1. Maximum load/original cross sectional area
        3. Around 470 MPa for tail shaft
    b. Yield point
        1. Stress which will produce permanent change in material
        2. Found by using
            1. Yield load/original cross sectional area
        3. Around 235 MPa
    c. Elongation:
        1. Measure of a material's ductility
        2. Can be found by using:
            1. (Final length – original length)/original area = %
        3. Around 22% for tail shaft

Heat and combustion

The properties of steam, fuel, lubricants and other liquids, gases and vapours used in machinery onboard ship.

18. Define the following terms: (Lawson, Dave, Diesel Duck x 3)
    a. Quantity of heat expressed in joules
        1. Joule is the SI unit for work done and also for energy, including heat
        2. Dr. Joule demonstrated that heat was a form of energy, using apparatus that generated heat by the expenditure of mechanical work
        3. Equivalent to force of 1 N for 1 m.
            1. Also the heat required to raise the temperature of 1 g of water by 0.24 K
            2. 778 foot lbs. of work = 1 Joule of heat
    b. Latent heat
        1. Latent heat is the heat which supplies the energy necessary to overcome the forces of attraction between the molecules of a substance,
        2. Is responsible for it changing its physical state from a solid into a liquid or from a liquid into a vapor, the change taking place without any change in temperature.
    c. Temperature
        1. The degree of hotness and coldness of a substance relative to some zero value – not to be confused with heat or heat energy
        2. The fact that one body has a higher temp than the other does not mean that the hotter body necessarily contains more heat.
        3. Heat will always flow from a hotter body to a colder body in contact with it, however this does not mean that a rise in temperature of the colder body will equal to the fall in the temp of the hotter body even if the mass in each case is equal and the transfer takes place without loss.
    d. Specific heat capacity
        1. The quantity of heat required to vary the temperature of unit mass of the substance by 1 degree
        2. Water is used as the standard substance because it has a greater capacity for heat than any other known liquid, as well as most solids.
        3. Gases have two different specific heats according to whether heat is applied at constant volume or constant pressure.
        4. Specific heat is measured in British Thermal Unit or BTU. SI is J/kg.K
    e. Calorific value
        1. The heat energy given off during complete combustion on a unit mass of fuel

        2. Expressed as KJ/Kg
    f. Spontaneous combustion
        1. The self-ignition of an explosive gas, oil waste or coal (without being ignited by some outside source)
        2. Gases are given off by the substance during slow oxidation that gradually increases temperature until kindling temperature is reached and the gases catch fire or explode
        3. Careful storage of materials is an ever present fact in the prevention of fire by spontaneous combustion.
        4. Requires a closed space and still air to occur.
        5. This prevents the heat generated within the oxidizing material to be carries away.
        6. If the speed of oxidation is increased so that the heat is generated faster than it is dissipated, the ignition temperature of the substance will be reached.
        7. Ignition often occurs through the chemical interaction of two or more substances, one of which is often air or water.
            1. Sodium and potassium react with water.
            2. Magnesium, titanium, calcium, and zirconium oxide rapidly in the presence of air.
    g. Specific enthalpy of vaporization of steam
        1. Enthalpy of evaporation of steam is equal to the latent heat of evaporation.
        2. The process of changing the physical state of a substance from a liquid into a vapor is called boiling or evaporation, and the quantity of heat to bring about change at a constant temp to unit mass is the latent heat of evaporation.
    h. Describe how you would find the specific heat capacity of a piece of metal, such as copper tubing.
        1. In order to determine the specific heat of a solid such as a piece of copper: take 10lbs of water at 60F and place 1 lb. of copper into it, noting the temperature of the copper before mixing.
        2. Say it was 200F; now note the resultant temperature after mixing. Say it should be 61.6 F, now make an equation where (x) is the specific heat of copper.

BTU before mixing = BTU after mixing
Heat in water + heat in copper = heat in water + heat in copper
(10lbx60Fx1)+(1lbx200F+x) = (10lbs x 61.6F x1) + (1lbx61.6Fx (x))
600 + 200 x = 616 + 61.6 x
200 x - 61.6 x = 616 - 600
138.4 x = 16
X = 16/138.4
X = 0.115 BTU

19. Define the following and state where each would occur in a boiler: (Diesel Duck x 2)
    a. Latent heat
        1. The heat that supplies the energy necessary to overcome the binding forces of attraction between the molecules of a substance
        2. Heat that is responsible for changing the physical state from a solid to liquid or liquid to vapor without any change in temp
        3. In a boiler, this can be seen at the point when the water is heated enough to form steam but remain at the same temperature temporarily
    b. Sensible heat
        1. Heat resulting from a change in temperature of a substance but not change in state
        2. In a boiler, the heat given to the water before it reaches its boiling point is sensible heat
    c. Conduction
        1. Transfer of heat from one body to another by contact
        2. A movement of energy through a material with no displacement of the material
        3. Takes place due to difference in temp between the two bodies
        4. Can occur in fluid, most common in solids
        5. Materials with low values of thermal conductivity are referred to as insulators, those with high conductivity are conductors
        6. Natural path of heat is from warmer body to colder body
        7. In a boiler, heat is conducted from the heating surface to the water due to direct contact through the material between them
    d. Convection
        1. Transfer of heat through a fluid through the movement of heated particles inside that fluid
        2. Two types of convection:

        1. Free Convection - heated particles become less dense and rise while denser particles take their place
        2. Forced Convection – pump of fan is used to cause motion of fluid
      3. This causes a convection current that will aid in heating fluid evenly
      4. Takes place by movement of the heated material itself
      5. In a water tube boiler, the tubes are arranged to take full advantage of convection currents to aid in the creation of steam
   e. Radiation
      1. Transfer of heat energy from on body to another through space by rays of electromagnetic waves
      2. Unlike convection and conduction, there is no need for contact for heat transfer
      3. The rays of heat travel in straight lines in all directions at approx. speed of light
      4. In a boiler, heat from combustion of fuel passes off in rays in all directions striking the furnace walls, tubes and other surfaces, raising their temps
      5. Loss of heat through radiation is prevented by the use of water walls and the lagging of all exposed parts such as shell, end plates, steam and water drums, steam pipe, and stop valve.

20. What are the principal combustibles in petroleum and diesel? Give an approximate analysis of each of these fuels. In what proportions do these combustibles combine with air to produce heat? Give an exact definition of combustion. (Diesel Duck)
   a. Desirable constituents of fuel oil are:
      1. Hydrogen
      2. Oxygen
      3. Nitrogen
      4. Carbon
   b. Undesirable constituents of fuel oil are:
      1. Coke
      2. Sulfur
      3. Ash
      4. Water
      5. Earthly matter
      6. Hard asphalt
   c. Calorific value of fuel is 42 NJ/kg
21. What is meant by thermo dynamic, volumetric efficiency, mechanical efficiency, and thermal efficiency? (Diesel Duck)
   a. THERMO DYNAMIC:
      1. Physics, including the relationship of heat with mechanical forms of energy
   b. VOLUMETRIC EFFICENCY
      1. The ratio between the volume drawn into the cylinder during the suction stroke and the full stroke volume swept out by piston is the volumetric efficiency of compression
   c. MECHINICAL EFFICIENCY
      1. The mechanical efficiency is the ratio of the brake power to the indicated power
   d. THERMAL EFFICIENCY
      1. The thermal efficiency of an engine is the relationship between the quantity of heat energy converted into work and the quantity of heat energy supplied.

Instruments

The use, construction details and principals involved in the action of the pressure gauge, thermometer, pyrometer, barometer, salinometer, hydrometer and other meters commonly used by engineers on board ship.

22. Describe and explain the operation of a pneumercator. Does the density of the fluid have an effect on the reading? (Craig, Adam, Diesel Duck x 3)
   a. The pneumercator gauge is a simple and reliable apparatus used to measure the quantity of liquid in a tank.
   b. It gives a direct reading of the contents of a tank at a remote location, such as a control room.
   c. The primary uses aboard ships are ballast tanks, fuel tank, oil and fresh water storage tanks.
   d. One gauge can be connected to multiple tanks with a selector valve used to check the level of each tank individually, one at a time.
   e. It consists of these main parts:
      1. Graduated mercury gauge column.
      2. balance chamber (hemispherical bell) fixed to the bottom of the tank

      3. control valve attached to the indicator and connected to the top of the balance chamber
      4. hand operated air pump or pressurized air supply from a compressor
   f. The balance chamber is a cast iron bell shaped chamber having an orifice out on its side, near the bottom as possible.
   g. The top is attached a copper tube to the air supply with a branch leading off to the mercury gauge.
   h. The liquid in the tank, upon entering the orifice in the side of the balance chamber, traps the air contained in the chamber and tubing and compresses it against the mercury column
   i. This causes the mercury to rise in proportion to the head of pressure
   j. If left for a time, fluid enters the bell, causing the gauge to read inaccurately
   k. To get rid of any inaccuracy, the air valve is opened temporarily, to allow the air pressure from the pump or supply to displace the liquid from the chamber until the level is steady to the level of the orifice.
   l. When the level is steady, the air can escape passing upward through the liquid to the atmosphere via the vent pipe.
   m. When the air has displaced the liquid in the chamber, the liquid in the balance chamber is restored to the zero level
   n. The cock is switched over to stop the air pressure and open to the mercury gauge and the height of the mercury can be read off the graduated scale.
   o. When the system is idle, the selector valve should be placed in the vent position.
   p. Since mercury has a different relative density to various fluids, the column will react differently – for example since water is heavier than oil it will pressurize the system air more and force the column of mercury higher than would the same head pressure of oil
   q. Therefore, the scale must be calibrated against a certain fluid, otherwise a correction chart can be used to ascertain the tank depths
23. Sketch and describe a mercurial barometer. What graduations is the pressure usually measured in and what is the average reading in kPa? What other instrument can be used in its place? (Paul, Mike Diesel Duck x 2)
   a. Mercurial barometer works on principle of atmospheric pressure supporting a column of mercury.
   b. The simplest is constructed with a glass tube about 800mm long, closed at one end and open on the other.
   c. The tube is filled with mercury so that all air is excluded and open end plugged temporarily
   d. The tube is inverted and its open end submerged into a vessel containing mercury.
   e. The plug is removed and the level of mercury in the tube falls, leaving a perfect vacuum between mercury level and the sealed end.
   f. The vertical column of mercury left in the tube is supported by atmospheric pressure, therefore is a measure of atmospheric pressure.
   g. As the atmospheric pressure rises and falls, the level of the supported column of mercury rises and follows accordingly.
   h. Graduated in mm or inches of Hg. Average sea level pressure is 101.3 kPa, which equals 760mm of mercury.
   i. The barometer is fitted with a level adjustment screw for adjusting the mercury level to zero
      1. The screw simply raises the level of mercury in the leather cup by pushing the cup bottom upwards
      2. The barometer is also fitted with an adjustable vernier scale
   j. The aneroid barometer is sometimes used in lieu of the mercurial barometer.
      1. Consists of a thin cylinder with the surface corrugated.
      2. The space within the cylinder is evacuated so that falling atmospheric pressure will tend to collapse it.
      3. An attached spring will lift the cylinder if atmospheric pressure rises.
      4. A series of linkages transfer the movement to a pointer moving over a scale, typically measured in kPa.
      5. The cylinder is made of phosphor bronze or cupro nickel, the remainder of components either brass or steel

Water treatment

The causes, effects and usual remedies for encrustation and corrosion; feed-water, blow densities and electrolysis.

22. In terms of boiler feed water; describe the following terms and the tests that are carried out for each and the test results you would expect to find for each. (Lawson, Andy, Dave)
   a. Hardness
      1. Refers to those dissolved solids in the water that can lead to the formation of scale
      2. May be:
         1. Alkaline hardness – sometimes referred to as temporary hardness
            1. Due to bicarbonates of calcium and magnesium that are slightly alkaline in nature
            2. Rapidly decompose upon heating which forms a soft scale or sludge
         2. Non-alkaline Hardness – sometimes referred to as permanent hardness
            1. Due mainly to sulfates and chlorides of calcium and magnesium, which are acidic in nature

2. Can deposit under certain boiler conditions to form scales of varying degrees of hardness
3. Non-hardness salts
    1. Consist mostly of sodium salts that remain in solution and do not normally deposit
3. Tested by means of a soap test but there is the more accurate EDTA test
    1. A high reading points to contamination or to the phosphate reserve being too low, thus giving the possibility of scale formation
4. Test details:
    1. A water's ability to form a lather with soap depends on the hardness salts that are present
    2. Take 100 ml boiler water sample
    3. Ass 2ml at a time of a standard soap solution
    4. Shake vigorously after each soap addition until a lather persists for at least 5 minutes
    5. Calculation: ml of soap solution used x 10 = ppm $CaCO_3$
    6. Typical value: max 5ppm ppm $CaCO_3$

b. Alkalinity
1. Alkalinity is the name given to the quantitative capacity of an aqueous solution to neutralize an acid
2. If alkalinity is too high, then foaming can take place in drum and possible caustic attack
3. If alkalinity is too low, it can cause corrosion
4. When there is an excess of hydrogen ions, the water is referred to acidic
5. When there is an excess of hydroxyl ions, the water is referred to as basic or alkaline
6. Measured by pH on a scale of 0 to 14 with 7 being neutral at atmospheric pressure, between 9 and 10 under boiler pressure
7. Keeping the water slightly alkaline reduces corrosion so it should be between 10.5 and 11 for safety
8. A protective layer over the steel, magnetite, is best maintained around pH of 9 and 11, anything too high or low will cause corrosion
9. Tested with a phenolphthalein test that measures the amounts of hydroxides and carbonates in the sample:
    1. Pour 100 ml of filtered water into a porcelain dish
    2. Add 1ml phenolphthalein solution and if the sample has pH higher than 8.4, it will turn pink
    3. Add drops of sulfuric acid stirring continuously until the pink color disappears
    4. 1 ml of .02N sulfuric acid will precipitate 10 ppm of $CaCo_3$
    5. Thus #ml of .02N sulfuric acid used x 10 = alkalinity to phenolphthalein in terms of ppm $CaCO_3$
    6. Typical value = 150-300 ppm $CaCO_3$
10. Bicarbonates do not show up in the phenolphthalein test as they have pH less than 8.4 and do not cause it to turn pink
    1. If their presence is suspected, a methyl orange test is required
    2. Take the last sample and add 1ml of methyl orange
    3. If the sample turn red, no bicarbonates are present
    4. If sample turns yellow, it indicates bicarbonates are present
    5. Drops of sulfuric acid should be dropped in until it turns red
    6. This means that ml.02N sulfuric acid used in both tests = total alkalinity in terms of ppm $CaCo_3$
11. Caustic alkalinity test can be done the same way except with 10 ml of barium chloride mixed and stirred for 2 minutes
    1. 1 ml phenolphthalein can be added to turn it pink and show hydroxides only
    2. Added drops of sulfuric acid until this pink disappears
    3. 1ml .02N sulfuric acid used x 10 = caustic alkalinity in terms of $CaCo_3$
12. Can also be tested inaccurately with a strip of litmus paper immersed into the water sample.
    1. If the sample turns red, the water is acidic
    2. If the sample turns blue, the water is alkaline

c. Density
1. Density is a measure of how heavy the boiler water is which will give a good idea of how much dissolved solids are present
2. In boiler water, this is important since if the water becomes too dense, it can cause scaling or corrosion on heating surfaces
3. A salinometer is an instrument used for measuring the density of water – not necessarily the amount of salt, however it is calibrated for boiler water
4. It is made of glass or silvered brass.
5. It consists of a stem with a hollow bulb 1/3 of its length from the lower weighted end so that it floats upright
6. Varying portions of the graduated stem become submerged depending on the density of the sample measured.
7. To find the density of boiler water a sample is drawn through the test cock into the salinometer pot.
8. The salinometer is placed in the pot when the temperature is 200F where it floats upright in the sample of water.

9. If the water cools down below this, the salinometer will show more density in proportion to the drop in temperature since water contracts when cooling down to 39.4F (critical temp)
10. The salinometer sinks according with the density of the water and is measured off the scale on stem at the water level.
11. The graduations on the upper stem are in 1/32 from 0/32 to 5/32
12. For a water tube boiler, I would expect a reading of roughly 2/32, maximum 3/32 to avoid scaling

23. Describe how you would carry out any these of the following tests in a sample of boiler water. (Diesel Duck)
    a. hardness
    b. alkalinity
    c. chlorides
    d. excess phosphate
    e. excess sulfites
    f. pH
    g. dissolved oxygen
        1. **Avoid this question due to length of answer required**
24. What is the average density of seawater? How would you find density of water in a boiler? List forming salts that are normally present in fresh water and sea water. At approx. what temperature do calcium sulfate and calcium carbonate deposit? (Craig, Diesel Duck x 2)
    a. Boiler water should be as free from corrosive or scale forming salts as possible.
    b. This purity can be measured as density by a salinometer.
        1. A salinometer is an instrument used for measuring the density of water – not necessarily the amount of salt, however it is calibrated for boiler water
        2. It is made of glass or silvered brass.
        3. It consists of a stem with a hollow bulb 1/3 of its length from the lower weighted end so that it floats upright
        4. Varying portions of the graduated stem become submerged depending on the density of the sample measured.
        5. To find the density of boiler water a sample is drawn through the test cock into the salinometer pot.
        6. The salinometer is placed in the pot when the temperature is 200F where it floats upright in the sample of water.
        7. If the water cools down below this, the salinometer will show more density in proportion to the drop in temperature since water contracts when cooling down to 39.4F (critical temp)
        8. The salinometer sinks according with the density of the water and is measured off the scale on stem at the water level.
        9. The graduations on the upper stem are in 1/32 from 0/32 to 5/32:
            1. If the salinometer is floating in pure water at 200F, the salinometer reading is 0/32 since it will have a relative density at that temperature of unity
            2. If we take 32lbs of seawater and boil off all the water, about 1 pound of solid matter will remain.
            3. Thus, the salinometer reading is 1/32 (approx. 32000 ppm)
            4. 32000 ppm is equivalent to roughly 1030 kg/m3
    c. Scale forming salts in salt water are:
        1. sodium chloride 25000 ppm (79% common salt)
            1. Sodium chloride (salts) deposits at 7/32 in either a high pressure boiler or evaporator.
        2. Magnesium chloride 3300 ppm (10%)
            1. Breaks up at a temperature of 360 F and 140 psi into magnesia and chlorine the chlorine combining with the hydrogen and oxygen of the steam to form hydrochloric acid corrosion.
            2. In addition magnesium hydroxide which may form a hard scale will be produced.
            3. In a evaporator the magnesium chloride will decompose at a density of 5/32
        3. magnesium sulfate 2000 ppm (6% Epsom salts)
            1. Too soluble to deposit under normal boiler operating temp but if too high a density is carried it may deposit.
        4. Calcium sulfate 1200 ppm (4%)
            1. Deposits at a temp of 267F in a boiler and at a density of 5/32 in an evaporator.
        5. Calcium bicarbonate 200 ppm (1%)
        6. Total = approximately 32000 ppm
    d. Scale forming salts in fresh water are
        1. calcium carbonate 200 ppm (carbonate of lime)
            1. Deposits at a temp of 212F at atmospheric pressure in a high pressure boiler and evaporator
        2. calcium sulfate 90 ppm
        3. sodium chloride 50 ppm
        4. sodium nitrate 35 ppm
        5. sodium sulfate 30 ppm
        6. Total = approximately 400 ppm

27. Sketch and describe a salinometer. How is it graduated? Why is it graduated for a specific temperature? How would you test water density of a multi-tubular boiler? (Diesel Duck x 2)
    a. A salinometer is a device designed to measure the salinity, or dissolved salt content, of a solution.
    b. I will explain the hydrometer, that is used for total dissolved solids above 2000 ppm
        1. A sample of water is drawn from the boiler into a jar
        2. The hydrometer is held by the top of its stem and lowered gently into the sample
        3. The density can be read from the hydrometer stem at the underside of the meniscus, making sure the instrument is floating freely and not touching the side of the jar
        4. The temperature must be taken of the sample, and if it does not correspond to the hydrometer scale, the density reading must be corrected by the appropriate formula or conversion table
            1. This is due to the fact that water contracts when cooling so will show higher density in lower temps
        5. Great care must be taken to ensure the hydrometer and jar are kept clean and free of grease
    c. Electric version:
        1. Since the salinity affects both the electrical conductivity and the specific gravity of a solution, a salinometer often consist of an etc. meter or hydrometer and some means of converting those readings to a salinity reading.
        2. A salinometer may be calibrated in either micromhos, a unit of electrical conductivity, (usually 0-22) or else directly calibrated for salt in 'grains per gallon' (0-0.5).
        3. A typical reading on-board ship would be 2 micromhos or 0.05 grains per gallon. A reading of twice this may trigger a warning light or alarm.
        4. Fresh water generators (Evaporators) use salinometers on the distillate discharge in order to gauge the quality of the water.
        5. Water from the evaporator can be destined for potable water supplies, so salty water is not desirable for human consumption.
        6. In some ships, extremely high quality distillate is required for use in water-tube boilers, where salt water would be disastrous.
        7. In these ships, a salinometer is also installed on the feed system where it would alert the engineer to any salt contamination.
        8. The salinometer may switch the evaporator's output from fresh-water to feed-water tanks automatically, depending on the water quality.
        9. The higher quality (lower salinity) is required for the boiler feedwater, not for drinking.
28. What are the constituents of sea water? How do they effect boiler feed water? At what density would a boiler be operated at if sea water was used as makeup and what would be the result? (Jackson, Diesel Duck x 2)
    a. Sea water is denser than fresh water due to the presence of dissolved solids, mainly salts.
    b. Relative density is 1.025 for sea water, meaning it is 2.5% denser than pure water.
    c. Sea water contains approximately 32000 ppm of dissolved solids.
    d. The principal solids in sea water are:
        1. Sodium chloride (79%)
            1. Most common salt
            2. Can create foaming and priming
            3. Solubility is variable depending on pressure and temp
        2. Magnesium chloride (10%)
            1. Is soluble under normal boiler conditions but can be broken down into hydrochloric acid which causes corrosion and magnesium hydroxides which can form scale
            2. Decomposes at 360F
            3. Also forms magnesia that deposits as mud or slime
        3. Magnesium sulfate (6%)
            1. May cause deposits and scale
        4. Calcium sulfate (4%)
            1. Most dangerous scale former in boiler feed water
            2. Can deposit as hard tenacious scale that greatly affects heat transfer
            3. Solubility decreases with rising temperature, deposits at temps over 267F
            4. Similar to plaster of Paris and marble (gypsum)
        5. Calcium bicarbonate (less than 1%)
            1. Can form scale but is soft and porous
            2. Heat drives off CO_2 and calcium carbonate is left, depositing a scale
            3. Similar to common chalk
            4. Deposits at temps above 212F

   e. Scale consists chiefly of calcium sulfate (about 85%) and calcium carbonate (about 1%)
      1. Scale is caused by the action of heat on sea water feed.
      2. The heat concentrates the calcium carbonate and calcium sulfate and results in deposits on the tubes, furnaces, etc.
      3. Scale increases with pressure, because temperature is higher in proportion.
      4. Only salt contained in feedwater after 3/32 will deposit, under this amount it should remain in solution.
   f. When sea water is used for makeup feed it is recommended that the boiler density should maintain as close as possible to 4/32 (125000 ppm).
      1. The use of sea water as make up for boiler should be avoided as far as possible but if it has to be used a certain amount of protection for the boiler can be provided by using soda ash.
      2. This would be attained by resorting to blow down.
      3. Blowing down a boiler reduces density but increases scale since more feedwater will need to be pumped in

29. What could be the cause of a gradual increase in boiler water density? How is the boiler water tested for density, alkalinity and acidity? What is the maximum density you would operate the following boiler at and why? (Diesel Duck)
      1. scotch marine boiler
      2. water tube boiler
   b. Feed water employed for boilers is usually, un-evaporator fresh water or evaporated salt water.
   c. The first and third of these are normally employed as feed for low pressure boilers such as the scotch boiler.
   d. Evaporated fresh water and evaporated salt water is employed with water tube boilers.
   e. All of this water can contain salts which could be harmful to the boiler from the point of view of scale forming and corrosion.
   f. However, feed systems can become contaminated with salt water, leaky condenser or an evaporator priming could be the cause.
   g. Testing for density, acidity and alkalinity
      1. Density-use the salinometer
      2. Acidity and alkalinity- litmus paper can be used turning blue for alkalinity and red for acidity.
         1. However methyl-orange or phenolphthalein are more reliable and sensitive as testing agents.
         2. One or two drops of methyl-orange will turn yellowish to indicate alkalinity and pink to indicate acidity.
         3. In the phenolphthalein test the sample will turn purplish for alkalinity and cloudy white for acidity.
   h. Scotch boilers
      1. Maximum density would be 2.5/32 - 3/32 but if the feed consist entirely of sea water then a convenient density would be 4/32.
   i. Water tube boilers
      1. Only distilled water should be used, but 3/32 would be the maximum scale on tubes causing overheating and failure.

30. 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, Diesel Duck x 2)
   a. 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
   b. The combination of lime and soda gives zero hardness and alkaline feedwater, therefore feed water should be treated prior to its entry into boiler
   c. Lime (calcium hydroxide) and soda ash (sodium carbonate) are used in boilers to deal with the calcium and magnesium compounds in boiler water
   d. Lime is used to react with magnesium compounds and alkaline hardness salts
   e. Soda is used to react with calcium compounds in the boiler feed, including those formed by employing lime
      1. It is an alkaline substance and reacts with any non-alkaline hardness salts
      2. Any excess soda will remain in solution, providing the reserve alkalinity required to reduce corrosion
   f. PH should be around 10.5 to 11.
      1. Can be tested with litmus paper.
         1. Litmus paper will turn blue if alkaline and red if acidic
         2. The degree of coloration is an indication of the pH
      2. Also 10 drops of methyl-orange can be used
         1. The sample will turn yellow for alkaline or pink for acidic
      3. Also a few drops of phenolphthalein can be used:
         1. If the water turn bluish pink, the water is alkaline
         2. If no change takes place, the water is acidic
   g. When there is an excess of hydrogen ions, the water is referred to acidic
   h. When there is an excess of hydroxyl ions, the water is referred to as basic or alkaline
   i. Measured by pH on a scale of 0 to 14 with 7 being neutral at atmospheric pressure, between 9 and 10 under boiler pressure
   j. Acidic water will also cause erosion/pitting or corrosion

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

31. Describe a modern feed water treatment system for a high pressure water tube boiler. Why treatment used and what is the importance to the boilers operation? (Paul, Diesel Duck)
    a. System:
        1. With modern water tube boilers, the feed water circuit from the regenerative condenser to the boiler is completely closed.
        2. The essential function of this closed feed system is to prevent the condensate, from which mist of the air has been extracted in the condenser, from coming into contact with the atmospheric air before being returned as feed water to the boilers
        3. The de-aerated water would otherwise absorb air if any part of the circuit was open to the air
        4. The air is extracted by a steam jet ejector, usually of two or three stage type which discharges air into the atmosphere
        5. The water is taken out by a condensate pump and discharged along the feed circuit into the boiler
        6. Along the feed water path, water passes around the outside of the tubes of the air ejector to condense the steam from the steam jets
        7. It also passes through the drain cooler where it cools the drains from the feed heaters
        8. Then it is discharged by the feed pump through surface feed heaters into the boilers
        9. Drains and make-up feed water are led to the condenser where the water is de-aerated before passing into the feed range
        10. The level of the condensate in the bottom of the condenser is kept constant by a float operated control valve (closed feed controller) that allows make-up water to be drawn into the condenser from the feed tank, or to be discharged into the feed tank from the condenser
    b. Treatment:
        1. Modern high pressure boilers require careful monitoring and control of the type and quantity of impurities found in boiler water
        2. Incorrect or inadequate treatment can result in failure of tubes, headers and drum and result in costly unscheduled shutdowns
        3. High corrosion rates can result from improper water pH or failure to remove dissolved oxygen from the water
        4. Scale formation on the inside of the boiler tubes due to impurities such as calcium sulfate can result in tubes overheating
        5. High levels of dissolved and suspended solids can also result in carryover, causing problems in the super heater and turbines
        6. A program of regular boiler testing, chemical addition and blow down is necessary to avoid such problems and obtain service life from the boiler
        7. Feedwater treatment deals with the various scale and corrosion causing salts and entrained gases by suitable chemical treatment.
        8. This is achieved as follows:
            1. By keeping the hardness salts in a suspension in the solution to prevent scale formation
            2. By stopping any suspended salts and impurities from sticking to the heat transfer surfaces
            3. By providing anti-foam protection to stop water carry-over
            4. By eliminating dissolved gases and providing some degree of alkalinity to prevent corrosion
        9. The treatment consists of adding various chemicals into the feedwater system and then sampling the water with a test kit
        10. The test kit is provided by chemical manufacturer with simple instructions for use
        11. For high pressure water-tube boilers various phosphate salts are used such as trisodium phosphate, disodium phosphate and sodium metaphosphate
        12. Coagulants are also used to combine with scale forming salts into a sludge and stop it from sticking to boiler surfaces
            1. Sodium aluminate, starch and tannin are used as coagulants
        13. Finals de-aeration of the boiler water is achieved by chemicals such as hydrazine that combines with any oxygen present
        14. Treatment chemicals regulate the following:
            1. pH
            2. Alkalinity

        3. Phosphates
        4. Sulfite
        5. Hydrazine
    15. Blow down controls the following:
        1. Total solids
        2. Conductivity
        3. Chlorides

Principles of marine engines

Constructional details and working principles of marine engines; methods of determining their kilowatt power; the principles of working and methods of calibration of dynamometers and torsion meters mounted on ships.

32. Describe a multi-cylinder four stroke engine suitable for driving a shipboard alternator. How would you change all injectors, and get it ready for running. (Andy)
33. 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, Diesel Duck)
    a. The rim of a flywheel is usually marked into 360 degrees, showing the top and bottom positions of the various cranks
    b. This is for convenience of setting the various valve timings
    c. A stationary index arrow points at the flywheel
    d. If the flywheel was not marked, the following procedure can be used:
        1. First turn the engine up to near the top for that cylinder and mark the guide and shoe
        2. Then with a trammel fixed on the column and long enough to reach the crank, mark the top of the crank
        3. 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
        4. Find the center between the two marks on the top of crank and make a center mark
        5. 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
34. How would you test the alignment of the piston, piston rod and crosshead guides of a large reciprocating engine? (Diesel Duck, 1982)
35. Describe an engine indicator, how and why it is used. State how the mean effective pressure is obtained and how indicated power is calculated. Give an illustrated example. (Mike, Diesel Duck)
36. Define indicated power and brake power. Describe how you would find the IHP and BHP of an engine using indicator cards and a dynamometer. (Diesel Duck x 2, 1982)
    a. The burning of fuel in an engine cylinder will result in the production of power at the output shaft
    b. Some of the power produced in the cylinder will be used to drive the rotating mass of the engine
    c. The power produced in the cylinder can be measured by an engine indicator mechanism.
    d. This is termed as IHP
    e. The power left to drive the shaft after friction/heat losses is termed BHP since it used to be measured on smaller engines by applying a type of brake to the shaft
    f. The area within the indicator diagram represents the work done within the cylinder in one cycle.
    g. The area can be measured with a planimeter or by the use of the mid-ordinate rule
    h. The area is then divided by the length of the diagram to obtain a mean height.
    i. The mean height, when multiplied by the spring scale of the indicator mechanism, gives the indicated mean effective pressure of the cylinder
    j. Mean effective pressure can be used to determine work in cylinder by multiplying it by the swept volume of the cylinder:
        1. W = Pm x A(piston) x L(stroke)
    k. To obtain power, you would find out how much work is done per second:
        1. P = W x RPM/60
    l. You would have to multiply this by the number of cylinders
    m. Example:
        1. Two stroke
        2. 6 cylinders
        3. Spring Constant = 65 kpa/mm
        4. Engine stroke = 1100mm
        5. Bore = 410mm

6. 120 RPM
    1. Divide diagram into 10 parts and for each find a mid-ordinate
    2. Mean height of diagram = sum of mid-ordinates/# of parts in diagram
        1. =3+4+5+7+8+9+11+14+26+42/10= 12.9mm
    3. Mean Effective pressure = 12.9 x 65 = 838.5 kPa
    4. IHP = 835.5 x 1.100 x (.205^2 x π) x (120/60) x 6 = 1460kW

37. Describe the type of engine usually installed as a lifeboat motor. Describe the cycles and how reversing of the propeller is executed. How is it started from cold? What fuel is used? (Diesel Duck x 3)
    a. Shall be a compression ignition engine
    b. Shall be provided with enough fuel to run for 24 hrs.
    c. Shall be capable of starting readily and reliably in cold weather and bad weather conditions
    d. Shall run properly under conditions of 10 degree trim and 10 degree list
    e. Shall have self-priming circulating water pumps if engine is water cooled. If air cooled it should have the proper amount of air supplied to the position where it is most needed.
    f. Adequate protection of engine and fuel tanks and accessories from bad weather
    g. The engine casing shall be of fire proof material
    h. The engine should be able to be started remotely – not just hand crank
    i. The engine should be using lightweight materials
    j. There shall be sufficient ventilation of the engine
    k. The fuel tank must be capable of withstanding 15 foot head water.
        1. It should have intake fitting and relief arrangement and if steel constructed it should be galvanized externally.
    l. Starting procedure:
        1. Before starting the engine the oil level in the base should be checked.
        2. Fuel oil level should be checked. Then, levels should be maintained at all times.
        3. Turn-on the fuel and prime the fuel filter with the fuel left on and lift the decompression lever to facilitate the turning of the engine.
        4. Turn the engine with the starting handle and move the decompression lever back to the run position and as the engine picks up speed, as the engine fires remove the turning handle
        5. Slowly turns the control level back to run position and the engine is running.
        6. Some lifeboat engines may be started by means of a 12 volt battery and starting motor system or a hydraulic cranking system.
    m. The engine is reversed with a gearbox which incorporates a cone type ahead clutch and a reverse gear.
    n. It is not necessary to fit a thrust block since the gear box is capable of absorbing the end thrust.
    o. The engine should always at idle when changing gears.
        1. engine shaft running in one direction only
        2. bevel wheel solid on engine shaft
        3. propeller shaft
        4. loose bevel wheel on propeller shaft
        5. feather on propeller shaft (keyway)
        6. clutch
        7. free bevel wheel fixed to floor
    p. In the ahead position the clutch dog (6) locks into the solid wheel (2) of the engine drive shaft (1) and by means of the feather (5) both shafts (1) and (3) turns in the same direction while wheels (4) and (7) running idle. in the astern position the clutch (6) is moved by means of the lever of the reversing gear by a yoke the clutch dog (6) now locks in the loose bevel wheel (4) and the drive is moved from the freewheel with ( ) propeller shaft (3) and revolves in the reverse position direction of the engine shaft, the feather (5) again acts as the drive.
    q. Another method of reversing is the reversible propeller blades of which can be rotated to any angle by movement of suitable gear contained in the hollow boss and actuated by a lever and rod, the rod passing through the hollow tail shaft.

Practice

The methods of dealing with wear and tear of machinery and boilers; the alignment of machinery parts; the correction of defects due to flaws in material or accident; temporary or permanent repairs in the event of derangement or total breakdown; detection of machinery malfunction; location of faults and actions to prevent damage.

38. What is a bridge gauge? If one is not available, what other means are available to measure crankshaft bearing wear or crankshaft deflections? (Craig, Mike, Diesel Duck x 2)
    a. The bridge gauge is also called the Lloyds gauge is reliable method in checking the wear down of the main bearings of an engine.
    b. Each bearing is loaded by its adjacent units and wear rates may not be equal
    c. Main bearing wear must be checked and recorded regularly to prevent misalignment that could cause crankshaft failure
    d. Main bearing clearances should be zero at bottom, if not the crankshaft is out of alignment
    e. The bridge gauge is of steel construction with machined faces which will rest on the machined faces of the bedplate.
    f. The bridge gauge is especially designed for the engine in question and cannot be interchanged between engines.
    g. To check for the wear down using these method top halves of the bearing can be removed and the halves of each journal relative to the machine uppermost face of the bedplate is measured.
    h. This is done by placing the bridge gauge across the crank journal in the place of the top half of the bearing.
    i. If the bearing has worn or the crank sagged, there will be a clearance between the bridge gauge and the top journal.
    j. This clearance is then measured using feeler gauges.
    k. The value is compared with the value stamped on the bridge gauge for that journal, which are the manufacturer's specifications.
    l. A number of readings should be recorded and attached to the engine, as a permanent record.
    m. If the original gauge reading is subtracted from the new reading the result is the combined wear down of the bearing and journal.
    n. However as the wear down on the journal usually very small, the bridge gauge readings are usually accepted as the bearing wear down.
    o. In some cases where the shaft has not sagged, but the bearing are suspected of wearing a hydraulic jack is used to jack the crank down on to the bearing.
    p. The bridge gauge is then fitted in place and the clearance recorded, thus giving the bearing wear down.
    q. There are several sources of error involved with using a bridge gauge.
        1. The feet of the bridge gauge may have been placed on dirt, or there may be small burrs on or under the feet.
        2. These faults will result in high readings. To reduce the chances of error, the surface below the bridge gauge feet and the feet themselves as well as the journal should be thoroughly cleaned.
        3. In some engines a specific location is scraped up for taking the readings so that the reading is the same throughout the engine when it is new. If the bridge gauge is moved from this especially scraped area, errors in readings will result.
    r. Instead of using the bridge gauge to measure wear down a dial indicator gauge can be used.
        1. A dial indicator is used in the same manner as a bridge gauge, except it records the readings instead of having to use feeler gauges.
    s. There are several factors which contribute to bearing wear down such as:
        1. Unequal power distribution in the cylinders
        2. Impurities in the oil such as debris
        3. Interruption in the flow of lube oil, which would cause overheating and possible melting of the bearing metal
        4. If different bearing are lined with different anti-friction material, then different rates of wear would occur
39. Sketch and describe how a high pressure cylinder liner is bored. How is the liner changed? (Triple expansion steam engine.) (Adam)
    a. **Avoid this question due to lack of study material**
40. Explain the procedures for dry docking a vessel for a full survey. What precautions are taken before, during and after undocking? (Diesel Duck x 2)
    a. **Avoid this question due to length or response required**
41. Describe a machinery breakdown you have experienced at sea. How were repairs carried out? (Diesel Duck x 2)

Pumps and systems

Constructional details and principles of action of pumps fitted in ships; general requirements concerning feed, fuel, bilge and ballast pumping systems.

42. Describe a centrifugal type of salt water circulating pump and illustrate answer with sketch. Under what conditions would the pump fail to function? (Diesel Duck)
    a. This is a rotary pump which works on the principal of centrifugal force, that is, that outward radial force set up by a mass rotated in a circular path due to its natural tendency to fly off at a tangent to the circular path and travel in a straight line.
    b. The pump consists of a rotating impeller within a stationary casing.
    c. The impeller is like a hollow disc wheel with internal curved vanes, mounted on a shaft which is driven by an electric motor, steam engine or turbine, or other prime mover.
    d. Openings in the sides of the impeller near the shaft communicate with the suction branch

e. Water or oil enters the rotating impeller through these ports, and due to the circular motion given to the water it is thrown by centrifugal force to the open periphery of the impeller and the casing and directed to the outlet branch.
f. The centrifugal pump does not have a positive suction action and must be primed by flooding before it will draw water from a lower level.
    1. Therefore it is employed mainly where the suction is submerged of the lift is very small.
    2. If used as a bilge/ballast/fire pump, it must be self-priming – having some means of removing air from the suction pipe
g. Centrifugal pumps will only pump in one direction of rotation.
h. The drive for these pumps is most often directly from an electric motor but can be from an auxiliary turbine.
i. In the latter case the prefix turbo is adopted for exam; " turbo feed pump"
j. Fluid enters the impeller axially through the eye, then by centrifugal force/action continues radically and discharges around the entire circumference. The fluid in passing through the impeller receives energy from the vanes giving an increase in pressure and velocity.
k. The kinetic energy (velocity) of the discharging fluid is partly converted to pressure energy by the design of the vanes and casing.
l. In some types a diffuser is used, which consist of a ring of stationary guides' vanes surrounding the impeller, the passage through the diffuser is designed to change more kinetic energy to pressure energy.
m. The sealing arrangement may be a packing gland of a mechanical seal depending on the type of service the pump is used for.
n. Materials:
    1. casing: gunmetal, bronze or cast iron
    2. impeller: aluminum bronze
    3. shaft: stainless steel
    4. bearing seals: leaded bronze
    5. wear rings: aluminum bronze

43. Sketch and describe a boiler feed pump including all materials of construction and how it operates. (Craig, Diesel Duck)
    a. Boiler feed pumps must be capable of raising the feed water to a pressure high enough for delivery to the boiler as required
    b. A common example of a boiler feed pump is a double acting piston pump
    c. There are two types of displacement pumps, both are self-priming:
        1. Direct acting
        2. Reciprocating
    d. Benefits of these pumps:
        1. Will accept high suction lifts
        2. Can handle large amounts of vapor and entrained gases
    e. Disadvantages:
        1. Complicate din construction with a number of moving parts requiring attention and maintenance
    f. Materials:
        1. For direct acting:
            1. Cast steel cylinder with cast iron liner
            2. Cast steel piston for steam side with cast iron rings
            3. Forged steel piston rod
            4. Cast iron slide valve
        2. For both types:
            1. Gunmetal bucket with ebonite (highly vulcanized rubber) rings
            2. Gunmetal pump casing
            3. Steel bucket rod
            4. Stainless steel, spring loaded plates are used for suction and discharge valves
    g. Direct Acting:
        1. To distinguish between the steam and water cylinders of the pump, it is usual to refer to the water cylinder as the pump chamber and the water piston as the bucket
        2. There is a specially designed slide and/or piston actuated by the movement of the crosshead, which drives a linkage
        3. This slide distributes steam alternatively to the top and bottom side of the steam piston to give it a reciprocating motion.
        4. Steam is supplied to the pump at boiler pressure and since the bucket's area is smaller, it allows a higher pressure to be delivered to feed water
        5. The boiler feed water regulator can be used to operate a control valve in the steam supply line to the pump, so varying its speed as necessary
        6. The steam piston is connected directly to the water piston by piston rod, crosshead and pump rod
        7. Since it is a double acting pump, water is discharged from both the top and bottom of the bucket, i.e. on every stroke
        8. Each end of the water cylinder has its own set of suction and delivery valves

9. The two sets of suction and delivery valves are housed side by side in one casting
10. One set of valves is connected by a port leading to the top of the chamber and one is connected to a port leading to the bottom of the chamber
11. On the upstroke of the bucket, water is drawn into the bottom of the chamber through the bottom suction valve and at the same time, the water on the top side of the bucket is forced out of the top of the chamber through the top delivery valves
12. On the down stroke, water is drawn into the top of the chamber through the top suction valve while the water on the bottom side of the bucket is forced out through the bottom discharge valve.

h. Reciprocating:
   1. Commonly a double acting pump ran by an electric motor through a worm gear/wheel
   2. The worm drive enables relatively large speed reductions without producing undue noise
   3. The gearing is enclosed and runs in an oil bath
   4. Similar materials to direct acting pump except bucket rings on smaller units will be rubber or neoprene instead of ebonite (highly vulcanized rubber)
   5. The feed water regulator controls amount of feed entering boiler, the remainder is sent back to the pump suction through a relief valve on the discharge side
   6. This may be replaced with float switches that turn the pump on and off depending on boiler water level.
   7. Routine maintenance includes:
      1. Keeping valves and bucket rings in good condition
      2. Liner and bucket must also be inspected since ridges will develop at limits of bucket travel
      3. Adjusting glands at frequent intervals, renewing packing as necessary
   8. To operate:
      1. Suction and discharge valves open
      2. Must be a relief valve to prevent pump damage in case of blockage or closed valve
      3. Should flood pump to reduce wear and risk of seizure

44. Describe the construction and operation of a duplex double acting feed pump. Describe how the steam slide valves are set. (Diesel Duck)
   a. To set the steam valves:
      1. Put the piston of #1 cylinder at exactly half stroke
      2. To do this, force the piston to the right into the cylinder until it strikes the cover
      3. Mark the piston rod with a pencil close up to the gland
      4. Now force the piston to the left until it strikes the bottom cover, again make a mark on the rod close to the gland
      5. Bisect the distance and make a third mark
      6. Move the piston until the new mark is close up to the gland and it is now at dead center
      7. Take the valve cover off on #2 cylinder and set the valve as shown, that is, cutting off steam at each end and with the lost motion divided between the jaws of the valve
      8. This must be done carefully and the lost motion is normally between ¼" and ½" according to the size of the pump
      9. The valve spindle may have to be screwed in or out between the jaws to get this setting correct
      10. Connect up the gear by inserting the pin or locking the nuts, whichever method is used
      11. Repeat the process by putting # 2 piston at half stroke and set the valve on @1 cylinder as described
      12. Again connect up the gear
      13. In some cases, the lost motion is arranged on the valve gear outside the valve but in either case, the lost motion must be equally spaced on each side
      14. The valve travel is normally about ¼ of the piston travel

45. Sketch and describe an Edwards type air pump and explain how it differs from a single acting type of air pump. (Paul)

   1. A certain amount of air and non-condensable vapor unavoidably enters the condenser
   2. This air is at below atmospheric pressure and must be compressed to remove it
   3. Air pumps are designed to handle the condensate or air, or a combination of both, from a condenser and also to create a vacuum in the condenser
      1. The Edwards Air pump design is one of the more successful designs for air pumps
      2. It is considered a wet pump, as opposed to dry, since it handles both condensate and air
      3. It is normally driven by the low pressure crosshead of the main engine
   4. It is a simple design with only two moving parts; it makes use of the fact that water contains momentum and at the same time compressing the water to prevent it from flashing into steam (remember at 29" Hg water will boil at about 25C).
   5. The design at first looks like it wouldn't work, however once you understand the principle of the mechanism, it makes a lot of sense.
   6. In a piston pump like this, the bucket moves down, forming a vacuum.

        1. As it approaches the bottom it open up ports around the cylinder.
        2. This allows the water to fill the void (vacuum) in the cylinder.
        3. By doing this, water vapour and steam is generated because of the rapid expansion of the water, taking up valuable space in the cylinder which could otherwise be filled with water.
    7. An Edwards pump is designed as above, except with the following improvement:
        1. To help fill the cylinder with water and air instead of steam, when the piston has reached the bottom of its travel it forces a jet of water from the very bottom of the air pump into the cylinder.
        2. By compressing the water into the cylinder instead of "sucking" the water in, no steam is created, and most which was created before is forced back to water.
    8. The piston is then raised shutting off the inlet ports and forcing all air and water through the top valve.
    9. This top valve, often a simple flat ring over a series of holes, is held shut only due to the vacuum within the cylinder.
    10. The only downsides to an Edward's air pump design is:
        1. They don't operate to their design at very low speeds,
        2. They have a tendency to clank.
    11. These are often small factors compared to the benefits of having a decent vacuum.

46. What types of valves are fitted to double bottom tanks for fuel or ballast? How do you ballast and de-ballast a double bottom tank. Why are these valves fitted? How does air escape when filling. Where are sounding tubes fitted on the tank? (Andy, Mike, Diesel Duck x 2)
    1. Water ballast is used to distribute water around the vessel in various tanks in order to properly set the vessel's trim and list
    2. Double bottom and water ballast tanks are fitted with screw lift valves in order to pump in and out thus the same valve.
    3. Once opened they stay opened until closed manually.
    4. Screw down non-return valves are not used normally since they only allow flow in one direction, but if there is a designated suction pipe they can be fitted there
    5. To empty a tank, the appropriate valve for the tank on the distribution chest in the engine room is opened, next the tank suction valve to pump distribution chest is opened.
    6. The discharge overboard valve on the discharge chest and ships side is opened and the pump started up. All other valves should be shut.
    7. To fill a tank, open appropriate tank valve in distribution chest in engine room. Open sea suction valve and close overboard discharge.
    8. Open discharge valve to main tank line on discharge chest and start the pump.
    9. Air pipes (vents) are fitted at the forward end of each tank. This end is the highest point of the tank while under normal trim; therefore all air will be expelled.
    10. Otherwise, air pockets might be formed which would result in damage being done to the tank by movement of water; also the ship is inclined to list more readily.
    11. Sounding pipes are fitted at the aft end of each tank, usually port and starboard this end being the lower end under normal trim.
    12. Sounding pipes are fitted so the level of the liquid in the tanks can be ensured.
    13. These pipes may also serve as vent pipes when filling tanks, but it should be noted that it is still essential to also have vent pipes.
    14. If they are fitted low in ER, they must be fitted with self-closing weighted cocks to prevent spills and also vapor accumulation.

47. Sketch and describe a fuel system for a propulsion or auxiliary boiler, settling tank to burner. Show all safety features and include pressures and temperatures (Jackson, Diesel Duck, 1982)
    a. Fuel is stored in double bottom tanks and pumped from there as required into settling tanks by means of a transfer pump.
        1. There are normally two settling tanks, each with a capacity for about 12 hours supply.
        2. One tank is in use while the oil in the other is being heated by means of steam coils in the tanks or by other means.
        3. This allows the water and sediment in the oil time to settle to the bottom and be drained off to the dirty oil tank before use.
        4. The temp of the oil in these tanks should never exceed 150F (66C)
        5. There are high and low suction valves, and the system should be on high suction to get the best fuel
        6. These suction valves are quick closing so they can be isolated remotely in a fire
    b. Fuel is drawn from the settling tank through duplex cold filters into the fuel pressure pump that discharges it at a pressure of 5.5 bar or higher
        1. Here dirt and other solid contaminants are caught before damaging pump or other system components
        2. The pump is a positive displacement with a relief valve that will send oil back to its suction side in the event of overpressure
        3. The pump is fitted with a remote stop in case of fire

c. The oil may be transferred to the main service tanks direct or may be passed through a second heating system and from there to any of the centrifugal separator and then to the main service tanks.
d. The fuel then flows through a steam operated heater where it is heated to roughly 90C (depending on oil type/density)
    1. The heaters are used to raise the viscosity of the fuel for proper flow and atomization at the burner
e. The fuel then flows through hot filters into the supply line into burners in the furnace
    1. These filters further stop contaminants that may cause damage or blockage in the burner
    2. Thermostats are provided to regulate the temperature of the oil by the amount of steam passing through the heater
    3. Control valves are fitted before the burners to control the pressure of oil to the burners
    4. In some systems, a steam activated shut off valve will close off fuel to the burner if feed water supply is lost
    5. There is also a flame failure alarm to alert engineers of problems
f. There is a fuel circulating valve on the furnace distribution valve that allows the fuel to be returned to the pump suction so that cold oil can be heated quickly up to the proper temperature and maintained there
g. The transfer pump, pressure pump, heater and filters are in duplicate so that either can be used while the other is on standby
h. The burners are fitted in the furnace front and protrude into the furnace
i. The burner is a hollow tube with a diaphragm and nozzle in the end
j. The diaphragm has small holes in it, drilled through at an angle so that the oil is broken up into a film of fine particles and acquires a spiral motion to mix readily with the air supplied over the burner as it enters the furnace
k. System consists of:
    1. Double bottom fuel oil tank
    2. F/O transfer pump
    3. Cold filter
    4. Settling tank
    5. Overflow to DB tank
    6. Heater
    7. Centrifugal oil purifier
    8. Main service tank
    9. Gauge glass
    10. Float control cock
    11. Engine service tank has overflow to DB tank, also low level alarm
    12. Quick shut off valve controlled from deck
    13. Change cock
    14. Filter in duplicate
    15. Settling tank vent
    16. Main service tank vents
    17. Overflow to double bottom tank
    18. Fuel for boiler
l. Vent pipes of at least 2" diameter are fitted in the highest part of the tank and the open ends, with a gauze diaphragm over the outlets, are let to some place where there is no danger of vapor from oil being ignited.
m. Flat type gauge glass, not tubular, or a pneumercator may be used to ascertain the depth of oil in the tank type of sounding apparatus may be used.
n. If gauge glasses are used then they must have self-closing cocks or valves.

48. Describe how you would proceed to clean the lubricating oil of a turbine. What principle is involved in this process? (Diesel Duck)
    a. The oil use in connection with the turbine is a special grade of pure mineral oil.
    b. Even a small quantity of another type of oil might ruin the whole charge of oil in the system.
    c. In all modern installations an oil separator of the centrifugal type is provided and full advantage can be taken of this unit to maintain the oil in a proper condition.
    d. Despite all precautions a certain amount of moisture will find its way into the system.
    e. There is usually a certain amount of solid material present in a very finely divided state, and there may be a certain amount of sludge formation.
    f. The use of the separator will remove these impurities so that it should be in use 3 or 4 hours each day and periodically when the opportunity occurs, when the vessel is in port a few days, the whole oil in the system should be centrifuged.
    g. If the centrifuging is not carried out in proper manner the desired results may not be obtained.
    h. Care should be taken to follow the instructions issue by the manufacture of the particular machine concern.
    i. Any time when the vessel is in port and the oil allowed settling, advantage should be taken of this fact that most of the impurities in the oil such as water, sludge and particles of metal having a higher specific gravity than the oil will settle to the bottom of the containing vessel.

j. If these impurities are drawn off from the bottom of the drain tank by means of a hand pump better results will be obtained with the separator.
k. The efficiency of the clarification will be increased if the oil being passed through the separator.
l. In addition, about 2% by volume of hot distilled water should be added the oil at the separator.
m. This helps to dissolve out the acids of a corrosive nature which are sometimes formed and also sea water which may have found its way into the oil.
n. The salts tend to promote the formation of these acids and must therefore be eliminated.
o. Care should be taken that the gravity disc used in the separator includes within the range of the specific gravity of the oil being treated.
p. It is also essential that the separator must be run above its specific capacity in order to get the work done more quickly.

49. Describe a bilge chest suitable for use with forward bilge wells on a cargo ship. State the materials of the different parts. Sketch and describe a valve that would be used in a bilge system. Describe some methods of passing pipes through a watertight bulkhead. (Lawson, Dave, Adam, Diesel Duck x 2)
    a. Bilge pipes used to drain cargo and machinery spaces are led to valve chests or manifolds that allow an engineer to direct which areas get pumped out and to where
    b. Discharge will be overboard during emergency flooding but must be led to an oily water separator system for normal operations to avoid pollution
    c. A bilge chest will always be fitted with screw down non-return valves so that back flooding of a compartment is impossible
    d. Only two pipes are permitted to pass through the forward collision bulkhead below the bulkhead deck and a screw down valve operated from above the bulkhead deck is provided for each pipe in a chest on the forward side of the bulkhead
        1. An indicator must be provided to show whether the valve is open or closed
    e. The materials used in a bilge suction manifold are:
        1. Manifold casing and hand wheels – cast iron
        2. Gaskets on flanges – rubber
        3. Bolts and nuts – mild steel
        4. Valves, guides, spindles and seats – bronze
        5. Identifying tags – brass
    f. There are three main methods of passing a pipe through watertight bulkheads:
        1. Welding with a doubler flange
        2. Screwed double flange – studs must be welded or bulkhead tapped and caulking used
        3. Fitting a spectacle flange that is flanged on both sides. This is bolted on one side of the bulkhead

50. Describe an emergency bilge pump. What are some rules for its use in relation to a passenger ship? How is it controlled? (Diesel Duck x 2)

    1. This pumps function is to drain compartments adjacent to damaged compartments.
    2. The pump is capable of working when fully submerged.
    3. The pump is a standard centrifugal pump with twin reciprocating air pumps or rotary air pumps
    4. The motor is enclosed in air bell as that even with the compartment full of water the compressed air in the bell will prevent water coming into contact with the motor.
    5. The air bell is tested to withstand a water pressure equivalent to 70 feet head.
    6. The motor is usually DC operated by a remote controlled electric circuit which is part of the vessels emergency power.
    7. The pump is designed to operate for long periods without attention and is also suitable for an emergency fire pump.
    8. This design is particular suited for use in large passenger vessels giving outputs of 60 kg/sec.
    9. In the ordinary centrifugal pump, priming usually required to facilitate good pumping.
        1. In the emergency bilge pump, this process is taken care of by properly designed reciprocating twin air pumps geared to the pump motor and sucking the air from the pump chamber.
        2. The air when mixed with water rises to the top of the suction chamber where it is withdrawn by the twin air pumps through a float operated valve.
        3. When the air is extracted from the suction chamber the chamber becomes full of water causing the bell float to rise and close the valve between the suction chamber and the air pumps.
        4. This permits the pump a continuous flow of suction and discharge.
    10. The pump consists of:
        1. PUMP CASING:
            1. Unless otherwise stated the pump casing is made of cast iron, with renewable impeller clearance rings made of brass.
            2. The casing is of the divided type with suction and discharge branches arranged in the back portion so that the front part can be removed and the impeller and spindle can be taken out without breaking any pipe joints.
            3. An extension is provided for taking the driving motor.

        4. This pump casing is provided with a hand hole giving access to the impeller eye.
    2. IMPELLER:
        1. The impeller is made of bronze, so arranged as to pass any solid material which can come through the suction strainers and mud boxes.
        2. The impeller is of the sided type so designed that the upward thrust tends to balance the weight of the rotating parts of the pump and motor but in addition a double thrust bearing is provided in the motor, capable of taking charge of any unbalance thrust and weight of those rotating parts.
    3. SPINDLE:
        1. This is usually a very large diameter, fitted with an impeller of special hard bronze finished by grinding.
        2. An external bearing is provided of suitable dimensions and of the divided type for case of overhauling. A grease lubricator is fitted to this bearing.
    4. STUFFING BOX:
        1. This is fitted with special metallic packing rings, and is pressure sealed from the pump through a central cock. Where specified a filter may be fitted
    5. AIR PUMP:
        1. The air pump has a cast iron crank case with detachable top arrangement for bolting to facing on the pump casing to cylinders, valve plates and piston are of highest quality gunmetal alloy,
        2. The latter being fitted with special piston rings and stainless steel gudgeon pins.
        3. Reversible Monel metal discharge valves with phosphor bronze spindle and cast iron valves covers are incorporated, so design as to give ready access to the valves for cleaning and overhauling.
        4. The air pump pistons are driven from a high tensile steel crankshaft carried in two split gunmetal main bearing. The crankshaft is driven through worm reduction gearing (case hardened steel worm and phosphate bronze worm wheel) by the main pump spindle.
        5. The air pump has no suction valves, the pistons uncovering the inlet ports during their travel.
        6. The air pump has been found in service to give satisfactory results over long periods without wear or adjustment.
        7. The air pump can be removed from the main unit for overhaul by the removal of four nuts and is divided in place to ensure correct alignment of gearing.
        8. Lubricating of air pump bearings is by a mechanical pump feeding the drips in proportion to the speed of the pump, from a box of ample capacity.
    6. AIR BELL:
        1. The air bell is of the best quality welded steel painted with bitumastic solution, and is water tested to a pressure equivalent of 70 ft. head.
        2. A hand hole with an air tight joint is fitted near the top of the air bell so that the commutators and bushing of the motor can receive attention, without breaking the seal of the air bell.
        3. Suitable handles are fitted for convenience of removing or turning the air bell.
    7. ELECTRIC MOTOR
        1. The electric motor is of the vertical spindle mica insulated, shunt wound type fitted with series stability windings.
        2. All windings are thoroughly impregnated to withstand dampness.
        3. The thrust bearings are of the roller type and the double thrust bearing of the heavily rated ball type.
        4. When the motor is running non-submerged fresh air is drawn in around the motor and discharged again by an air fan mounted on the armature shaft of the motor.
        5. When the motor is submerged, this fan causes the entrapped air to impinging on the sides of the air bell which is kept cool by the surrounding water.
        6. The rating of the motor is such that it can be run continuously if the water rises sufficiently high to seal the bottom of the bell but not submerge it.
        7. To facilitate rapid charging a non-return valve is fitted on the delivery side of the pump.

51. Tanks that are used to carry fuel oil and ballast alternatively have an arrangement so that the correct tank gets pumped out. Sketch and describe this arrangement. (Diesel Duck x 3)
    a. An interchangeable oil/water ballast chest is required in order to change the fluid system that will be pumped with this type of arrangement.
    b. This water-oil ballast chest is a standard fitting on many cargo vessels, on the double piping systems.
    c. This chest utilizes a dome that can be alternated with a flat blank.
    d. The dome allows fluid to pass while the blank stops any flow.
    e. If the dome is on the ballast side, then ballast can be freely pumped and vice versa.

f. Normally all chest are open to oil and blanked to water ballast.
g. Care must be taken when changing the dome to ensure all valves are closed and sealing properly to prevent flooding or contaminating other tanks.
h. The housing of this chest is cast steel
i. Valves, seats and spindles are bronze.
j. Great care is necessary to avoid any mistakes being made, and a rigid routine is advised
k. Clear explanatory instructions should be posted to avoid mistakes when changing over the chest to the other fluid.
l. Valves should also be in good order and easily acceptable
m. As an alternative to this arrangement, fitting hollow one way discharge plug cocks or a system of interlocking valves would be acceptable.
n. Any system employed must prevent easy joining of oil and water circuits by accident.

52. Sketch the bilge pumping system on your last ship. What are bilge pipes made of and why? (Diesel Duck)
53. Draw a line diagram of a bilge pumping system for a container ship. (TCMS Sample, Diesel Duck)
    a. Indicate the position and the type of valves fitted to ensure satisfactory operation of the system
        1. The arrangement of the bilge and ballast pumping system shall be such to prevent the possibility of water passing from sea and from water ballast spaces into the cargo and machinery spaces, or from one compartment to another.
        2. Special provisions shall be made to prevent any deep tank having bilge and ballast connections being inadvertently run from the sea when containing cargo, or pumped out through a bilges pipe when containing water ballast.
        3. All bilge suction valves are of the screw down non-return type to prevent water from flowing back and flooding the bilges
    b. What arrangements are provided to ensure the integrity of the system should collision damage occur?
        1. Provisions shall be made to prevent the compartment served by any bilge suction pipe being flooded in the event of the pipe being severed or otherwise damaged by collision or grounding in any other compartment.
        2. For this purpose where the pipe is at any part situated nearer the side of the ship than one fifth the breath of the ship a non-return valve shall be fitted to the pipe in the compartment containing the open end.
        3. All the distribution boxes, cocks and valves in connection with the bilge pumping arrangements shall be position which is accessible at all times under ordinary circumstances.
        4. They shall be so arranged that in the event of flooding one of the bilge pumps may be operative on any compartment.
54. Describe with a simple line sketch a bilge system for a 7000 ton cargo ship. What is a bilge injection valve? What is the main difference between bilge and ballast? (Diesel Duck)
    a. The line diagram consist of a typical bilge suction arrangement where the bilge pump, ballast pump, general service pump, or the OWS can be used for pumping out any bilge.
    b. The distribution valve chest is situated in the engine room to enable any bilge to be pumped out by the watch keeping engineer.
    c. All bilge suction valves are of the screw down non return type to prevent water flowing back and flooding the bilges.
    d. The operated hand wheels are labeled by engraved brass plates as to which bilge the pipe runs into.
    e. A mud box is fitted on the bilge suction of each pump and open end of every bilge pipe in the bilges is enclosed a strainer box.
    f. A bilge pump has suctions from all bilge main and engine room bilge, with discharge to fire main, oily water separator and overboard.
    g. A ballast pump has suctions from sea, ballast main, engine room bilge direct and bilge main with discharge to overboard, the ballast main, the oily water separator and possibly the main sea water circulating system.
    h. A general service pump has suction from sea, ballast main, bilge main and engine room bilges, which discharges to the fire main, the ballast main, the ows, and overboard.
    i. In this way three pumps provide effective alternatives for all essential services in the event of breakdown of one or even two.
    j. The mains must be at least 65mm and the branches 30mm.
    k. The pumps should be of the self-priming type unless efficient priming devices are provided.
    l. The capacity of the pumps should give water speeding the main line of not less than 2m/s and the capacity should be about 65% of the displacement of the ship.
    m. Vessels should have at least four independent power pumps connected to the main line pump should have a direct suction to the space in which it is situated, such suction to be at least the same bore as the bilge line.
    n. Not more than two such suctions are required and in the machinery space such suctions should be arranged, one each side.
    o. Emergency bilge pumps are also used on ships in the case of emergency such as a compartment flooding due to, most likely, hull damage.
        1. It is a self-contained unit consisting of a centrifugal pump to deal with the water, reciprocating, rotary air pumps to rid the water suction of air to help priming of the centrifugal pump, and an electric motor to drive the pump.
        2. The drive shaft is vertical and the electric motor is above the pumps, the motor being enclosed in an air bell to protect it from being flooded when the compartment is full of water, thus the system continues to work when the unit is completely submerged.

        3. The electric supply is taken from the ships emergency electrical circuit and the unit can be operated by remote control.
    p. The bilge injection valve is one of the most important fitting in the machinery space.
        1. It is provided for use in the event of serious flooding in the machinery space. By closing in the main injection valve and opening up the bilge injection valve the largest pump (or pump) in the engine room are drawing directly from the lowest point in the space; this suction can remove large quality of water.
        2. The diameter of the BILGE INJECTION VALVE IS AT LEAST 2/3 OF THE DIAMETER OF THE MAIN SEA INLET.
        3. Valve spindle should be clear above the engine room deck plating so that examination and greasing, with cleaning of strum or strainer.
    q. Bilge pipes should not be led through oil tanks or double bottom tanks.
    r. Joints should be flanged, pipes well secured and protected against damage.
    s. The pipes should be independent to the bilge system only.
    t. Collision bulkhead should not be pierced below the margin line more than one pipe, such pipe to be fitted with a screw down valve operated from above the bulkhead deck.
    u. Valve chest being secured to the forward side of the collision bulkhead (divide peaks may have two pipes)
    v. Valve and cocks not forming part of a pipe system are not to be secured to watertight bulkhead.
    w. Pipes, cables, etc. passing through such bulkhead are to be provided with watertight fillings to retain the integrity of the bulkhead.

Auxiliary machinery

The constructional arrangement, operation and maintenance of steering engines and gears, refrigerating machinery, hydraulic and other auxiliary machinery, and such steam and internal combustion engines as are used for emergency and auxiliary machinery on board ship; deck machinery and cargo-handling machines.

55. What are economizers and heaters as per boiler exhausting? What are causes of moisture in them and how is moisture prevented? (Diesel Duck)
    a. The higher boiler pressures that are now becoming common have made the use of these heat recovery devices essential since the boiler is less efficient with temperatures and pressures this high
    b. Heaters, known as surface feed heaters, heat up air to be used for combustion using steam as the heating medium
        1. Fitted between the discharge side of the feed pump and the boiler
        2. Consists of cylindrical shell containing nests of tubes
        3. The feed water flows into the inlet branch of the water header, down through the nest of tubes, up through another nest and so on until it is discharged through the outlet branch of the heater
        4. Steam enters the top, passes around the outside of the tubes and out through the drain at the bottom
        5. It passes out as water since it has given up its latent heat to the feed water through the walls of the tubes
        6. Heating steam may be taken from the auxiliary exhaust line, or live steam may be bled off some part of the steam range
        7. Two heaters may be used in series, the first heated by exhaust steam and the second by live steam
    c. Economizers are devices intended to heat boiler feedwater (to 105C and higher) by means of the waste gases as they pass from the furnace to the stack
        1. By placing economizers and heaters in the path of the hot furnace gases, much of the heat is recovered
        2. Economizers usually consist of groups of seamless steel tubes so arranged that the hot furnace gases pass around the tubes which carry feedwater
        3. Tubes may be fitted with fins to provide greater heating area and circulate gases
        4. Are placed after the surface feed heaters in series
        5. The feed water enters the top of the economizer, passes through the tubes and headers and leaves at the bottom (which is the hottest region of the gases) to pass directly into the steam drum
56. How do you charge a CO_2 refrigeration system? How do you know when it is enough or too much? (Craig)
    a. CO2 refrigeration systems sometimes require charging due to leakage or maintenance or an initial charge of the system
    b. CO2 is supplied in steel bottles of various sizes, 22 to 40 lbs. in the liquefied state.
        1. Pressure is roughly 1000 psi
        2. The CO2 must be pure and free of water and air
        3. If the gas cannot be obtained dry, a CO2 dryer should be fitted to machine or the charging pipe
        4. Also, before charging, the bottles should be placed valve down for 24 hours prior to charging and the valve opened just slightly to drain any collected water
    c. It is a non-poisonous gas but great care must be taken when handling it due to its oxygen displacing characteristics and that it can cause severe frostbite when flashing off

d. Before charging, the compressor should be filled with oil to the recommended level, this will have to be done with a pressure pump if the system is pressurized and just requires a top-up
    1. To start the charge, suspend the bottle with valve upwards on the spring balance
    2. Connect by copper pipe to small screw down valve at the end of evaporator coil
    3. Note the weight of the bottle
    4. Open valves slowly on bottle and evaporator and the CO2 liquid will flash off and enter system as a gas
    5. See that the connecting joints are tight
e. After the CO2 has passed into the system, note weight again and the difference is the weight of CO2 that has passed into the machine
f. When bottles have had about 10 lbs. taken out, they may be warmed by pouring on hot water to assist in driving out further gas
g. The lower end of flask will remain cool so long as liquid CO2 remains but when the whole flask is heated, no more CO2 remains and the valve should be closed while bottle is still warm.
h. To get the utmost out of the bottle, the system should be pumped down to about 225 psi by running the compressor for a few minutes with a closed regulator valve.
i. If the system is fully charged, the condenser will indicate around 8C above the temperature of the seawater entering the condenser
j. An excessive charge is indicated by the gauge standing higher and an excessive condenser pressure
k. A low charge shows a lower difference between the seawater and the refrigerant in the condenser
    1. Leaks can be found with a soapy water spray test on suspect joints
    2. Another test for low gas is to close the regulator – if sufficient gas is present, the evaporator gauge should hardly fall from some 15 or more revs of the machine
    3. If the gauge falls immediately, it indicates shortness of CO2
    4. If the machine is short on gas, the refrigerating work will be but a fraction of its proper duty

57. Describe a CO2 refrigeration system. What are the advantages and disadvantages of CO2 as opposed to ammonia? (Diesel Duck x 2)
    a. The CO2 refrigeration system works on the vapor compression system and is only found on older vessels
    b. The pressure of the CO2 is controlled as it flows through the system in order to reach a desired vaporization and condensation temperature
    c. CO2 is an inert vapor, non-poisonous, odorless, and is non-corrosive.
    d. It has a very low natural boiling point (-78C) which means it must be run at very high pressures to bring it to temperatures where it will vaporize and condense at the normal temperature range of a refrigeration machine.
    e. A further disadvantage is that its critical temperature is about 31C, which falls into the range of seawater temperatures.
    f. At the critical temperature, it is impossible to liquefy the vapor, no matter what pressure so that the seawater cooled condenser is rendered useless and the system will fail to cool
    g. Vapor compression system consists of 4 major components:
        1. Compressor
            1. Driven by an electric motor
            2. Function is to raise the pressure of the vapor refrigerant, causing its saturation temperature to rise so that is it is higher than that of the cooling medium (normally seawater)
            3. Also promotes circulation of the refrigerant by pumping it around the system
            4. Started and stopped by the LP controller in response to the pressure in compressor suction.
            5. Also, there is a HP cutout with a hand reset to protect the compressor and system.
            6. One compressor will control a number of cold compartments through thermostatically controlled solenoids.
            7. When each room is cold enough, the solenoid will close off liquid refrigerant to that space.
            8. When all solenoids close, the compressor will stop due to the drop in pressure by the LP controller
            9. Subsequent rise of compartment temperature will cause the solenoids to be reopened by the room thermostats.
            10. This raises the pressure in the compressor suction, which will cause the LP controller to act to start compressor.
            11. Compresses CO2 to 70 bar and 93C
        2. Condenser
            1. Cooled by seawater
            2. Function is to liquefy the refrigerant and sub-cool it below the saturation temperature by circulating seawater or air.
            3. Latent heat from the evaporator is transferred here to the cooling medium
            4. Cools refrigerant vapor to roughly 30C, changes to liquid
        3. Regulator
            1. Referred to as expansion valve, each cold room is fitted with one, in addition to solenoid.

            2. Function is to regulate the flow of refrigerant from the HP side of the system to the LP side of the system
            3. The drop in pressure will cause the saturation temperature of the refrigerant to fall so that it will boil at the low temperature of the evaporator
            4. This valve is controlled thermostatically through a capillary tube connected to a temperature sensor (bulb) in the cold room.
            5. CO_2 pressure drops to 20 bar which results in temp around -18C
        4. Evaporator
            1. Function is to cool the air in the fridge space
            2. Cools by having the refrigerant entering the evaporator at a cooler temperature than that of the air in the space, which will cause the refrigerant to receive latent heat and evaporate
            3. Normally has a fan to circulate and distribute air around it
    h. System is completely closed circuit, same amount of refrigerant continuously passes through system
    i. Only requires recharge if leakage occurs
    j. Refrigerant is drawn as a vapor at low pressure from the evaporator into the compressor where it is compressed to a high pressure to form a superheated vapor.
    k. It then passes through the condenser to be cooled and condensed into a liquid at approximately sea water temperature, the heat being given up by the seawater surrounding the pipes of refrigerant and pumped overboard
    l. The high pressure liquid then passes along to the regulator which is just a valve slightly open to limit flow through it.
    m. As the liquid passes through the regulator, the pressure is much lower and some of the liquid flashes off into a vapor, absorbing the required amount of heat to do so from the remainder of the liquid and causing it to fall to a low temperature so that the refrigerant enters the evaporator at a lower temperature than the surroundings.
    n. The liquid/gas mixture passes through the coils of the evaporator where it receives more heat to evaporate it fully before being taken through the compressor to start the cycle again.
    o. This received heat in the evaporator causes the brine or cold room air to be cooled to a low temperature.
    p. Ammonia (NH_3) is a poisonous vapor and must have a compartment of its own that is sealed off in case of leakage
        1. Natural boiling is -39C so it can be run at much lower pressure than CO_2 and is a superior refrigerant thermodynamically
        2. CO_2 loses much efficiency with warm cooling water (over 30C)
        3. Water will absorb ammonia so water spray can be used for protection
        4. Ammonia is corrosive to copper so parts must be made with nickel steel and Monel.
        5. May taint food if it leaks
        6. Will form explosive mixture with air

58. Draw a line diagram of a Freon refrigeration cycle and indicate the operating pressures and temperatures. Explain how different temperatures are maintained for meat, vegetable and dairy products. Detail the position of automatic condition (temperature) sensing devices and explain how these operate to control the running of the machine. (Adam, TCMS Sample, 1982)
    a. The basic components of any refrigeration system working on the vapor compression system are the:
        1. Compressor
        2. Condenser
        3. Expansion valve
        4. Evaporator
    b. Freon was often used and was otherwise known as R12
        1. It is phased out for more environmentally friendly refrigerants but the principles are the same
    c. Compressor:
        1. The temperature at which a fluid boils or condenses is known as the saturation temperature and this varies with pressure
        2. The compressor in the refrigeration system raises the pressure of the vaporized refrigerant, causing its saturation temperature to rise so that it is higher than that of the sea water or air cooling the condenser
        3. The compressor also promotes circulation of the refrigerant
    d. Condenser:
        1. In the condenser, the refrigerant is liquefied and sub cooled to below the saturation temperature by the circulating seawater or air
        2. Latent heat, originally from the evaporator is transferred to the cooling medium
        3. The liquid refrigerant, still at the pressure produced by the compressor is passed onto the expansion valve
    e. Expansion valve:
        1. The expansion valve is the regulator that the refrigerant flows from the high pressure side to the low pressure side of the system

        2. The pressure drop causes the saturation temperature of the refrigerant to fall so that it will boil at the low temperature of the evaporator
        3. In fact, as the liquid passes through the expansion valve, the pressure drop causes the saturation temperature to fall below its actual temperature
        4. The result is that some of the liquid boils off at the expansion valve taking latent heat from the remainder and causing its temperature to drop
        5. The expansion valve throttles the liquid refrigerant and maintains the pressure difference between the condenser and evaporator while supplying refrigerant to the evaporator at the correct rate
        6. It is thermostatically controlled, based on the temperatures inside the cooled spaces
    f. Evaporator
        1. The refrigerant entering the evaporator at a temperature lower than the secondary coolant (air or brine) receives latent heat and evaporates
        2. Later this heat is given up in the condenser when the refrigerant is again liquefied
    g. Freon is a halogenated hydrocarbon derived from methane with the hydrogen being replaced by chlorine and fluoride
        1. Considered to be nontoxic except in high concentrations that may cause oxygen deficiency
        2. Gives off poisonous gases when in contact with flame but is not technically flammable
        3. Gas escaping under pressure will also cause skin damage on contact
        4. Odorless and non-irritant
        5. Working pressures and temperatures are moderate
        6. High critical temperature 112C well above working range
    h. Cycle:
        1. Compressor is started and stopped by the LP controller in response to the pressure in the compressor suction
        2. There is also a HP cut-out with reset which will shut off the compressor in event of high discharge pressure
        3. Compressor will supply a number of cold compartments through thermostatically controlled solenoids
        4. Thus as each room temperature is brought down, its solenoid will close off the liquid refrigerant to that space
        5. When all compartment solenoids are shut, the pressure drop in the compressor will start the compressor to be stopped via the LP controller
        6. Subsequent rise of temperature will cause the solenoids to open by room thermostats
        7. Pressure rise in the compressor suction acts through the LP controller to restart the compressor
        8. Each cold compartment has a thermostatic expansion valve, as the regulator through which refrigerant is passed
        9. On large system, a master solenoid may be fitted so that a compressor fault will cause the solenoid to close, preventing flooding of liquid refrigerant and possible compressor damage
        10. Regular defrosting of the evaporator is necessary.
            1. A timed switch de-energizes the solenoids and powers heater to the evaporator coils to melt off any built up ice

59. Describe a refrigeration system suitable for a ship carrying frozen cargoes. Give the approximate temperature for storage of: (Diesel Duck x 2) **See answer above**
    a. Meat/Fish (-5C to -7C)
    b. Dairy (1C)
    c. Vegetables (+3C)
60. Describe a power steering system and discuss the emergency procedures. (Craig, Diesel Duck)
    a. Electric hydraulic steering gear uses an electric motor to drive a hydraulic pump to power a cylinder attached to the tiller in order to move the rudder
    b. The hydraulic pump is a constant speed, variable delivery pump
    c. The delivery of oil is achieved by translating the movement of the steering wheel into the stroke movements of the pump by the inclusion of a telemotor system
    d. Hydraulic rams are fitted to the port and stbd side of the tiller, linked at their inboard ends by a crosshead and swivel block.
    e. The outboard ends of the rams work inside individual cylinders, which are connected by pipework to the pump
    f. The function of the pump is to draw oil from one cylinder and force it into the other cylinder, causing this rams to move and correspondingly, the tiller
    g. The pump may be a Hele-Shaw rotary variable delivery pump.
    h. This pump runs continuously in the same direction and the position of a moveable plate inside the pump controls the suction and discharge of the oil
    i. When the plate is in mid-position, no oil is drawn or discharged.
    j. When the plate is moved in one direction, oil is drawn from one cylinder and pumped to the other
    k. When the plate is moved in the opposite direction, oil is pumped in the opposite direction

61. Describe any type of steering gear you are familiar with and state clearly how the movements of the gear are made to comply with those of the steering wheel. What provisions are present for wear down? What happens when heavy sea strikes the rudder? How do you charge it showing a sketch with charging lines? What pressures do you expect (Andy, Diesel Duck x 2)
    a. The electric hydraulic steering gear uses an electric motor to drive a hydraulic pump for pumping and discharging hydraulic oil from one cylinder to the other depending upon the direction required.
    b. Movement of the rudder stock is achieved by the force of the hydraulic oil being exerted.
    c. These rams are of steel construction while the cylinders usually gunmetal.
    d. The hydraulic pipes in the system are heavy gauge copper, and the hydraulic fluid is a mineral oil.
    e. The hydraulic power is supplied by constant running rotary pumps.
    f. The delivery of the pumps to the rams is achieved by translating the rotary movement of the steering wheel into the "stroke" movements of the pumps by the inclusion of the telemotor system.
    g. The electric-hydraulic steering gear consist of a hydraulic rams situated on the port side of the tiller and another on the starboard side, linked at their outer ends to the tiller and by a crosshead and swivel block, the other ends of the rams working inside their own hydraulic cylinder, pipes connect these cylinders to a hydraulic pump.
    h. The function of the pump is to draw oil from one cylinder and pump it (at high pressure) into the other, thus causing one ram to move out and push the tiller over while the other moves back into its cylinder.
    i. The hydraulic pump is of the rotary displacement types driven by an electric motor.
    j. The pump is of special construction and may be a Hele-Shaw or Williams-Janney design.
        1. It runs continuously in the same direction and the position of a moveable plate inside the pump controls the suction and discharge of the oil.
        2. When the plate is moved in one direction from mid position no oil is drawn in or discharged.
        3. When the plate is moved in one direction from the mid position oil is drawn from one cylinder and discharged into the other.
        4. When the plate is moved in the opposite direction the suction and discharge of the oil is reversed in direction.
        5. The plate is actuated by a control rod which is attached at its outer end to the hunting gear.
    k. If a heavy sea strikes the rudder the shock is transmitter through the tiller to one of the cylinder and double spring loaded relief valves allow the tiller to give way slightly (80-190 bar) by bypassing a little of the oil into the other cylinder resulting displacement of the rudder, tiller and ram crosshead moves the pump control rod through the hunting gear and the tiller is automatically brought back to proper position.
    l. The following sketch shows simply to operation of the hunting gear.
        1. The telemotor moves the end of the floating rod A to A1 and the pump control is moved, therefore from B to B1.
        2. Pumping of the hydraulic oil causes movement of the rams and the end of rod C moves to C1, thus causing a pump control to be pulled back to the neutral position B.
    m. An emergency tiller is attached directly to the rudder stock for emergency steering, if the hydraulic system fails. Due to normal operation this hand wheel is designed by removing connecting pin which is attaches it to the control rod.
    n. The steering gear itself must be completely filler with oil and all air must be excluded. Thus the air release valves are opened on hydraulic cylinders and pumps also stop valves pump can be used to pump the oil around the system (while keeping the replenishing tank topped up)
    o. It can be put on stroke by the hand wheel and turned by a bar.
    p. The rams may be filled through the filling holes until all air has been displaced, before starting to pump the system through.
    q. When all the air has been purged from the system and the level in the relishing tank ceases to fall, the air released valves are closed.
    r. Finally the by-pass and stop valves are set for normal operation and the pump started.
    s. Using the hand control, the gear is then run from hard over to hard over slowly and the air release valves are open again to check.
    t. To allow for wear down in the crosshead arrangement a wear down rudder allowance of 19mm (3/4") is provided so as not to induce bending stresses on the ram.
62. Describe a telemotor system for steering gear, how would you ensure that the system is running properly. What would be the first thing you would do if the system failed at sea? (Lawson, Dave, Mike, Diesel Duck x 2)
    a. The telemotor, on many vessels, has become the standby steering mechanism, used only when the automatic steering fails.
    b. It comprises of:
        1. A transmitter on the bridge
        2. A receiver in the steering compartment, connected to the variable delivery pump through the hunting gear
        3. Transmitter and receiver are connected by solid drawn copper pipes full of liquid
        4. Charging unit
    c. Liquid displaced in the transmitter causes a corresponding displacement in the receiver end of the pump control

d. The transmitter consists of a cylinder with a pedestal base, which contains a piston operated by a rack and pinion from the steering wheel
    1. The casing of the transmitter is usually of gunmetal
    2. When the steering wheel moves, the fluid is pumped down through piping to the steering gear into the receiver and forces the cylinder to move
    3. The suction of fluid from the opposite cylinder enables this movement to take place
e. The make-up tank functions automatically through spring loaded relief and make-up valves
    1. Excess pressure in the telemotor system causes oil to be releases through the relief valve into the make-up tank
    2. Loss of oil is made up through a lightly loaded make up valve
    3. The two valves are connected to the cylinder through a normally open shut-off valve
    4. When the piston is in mid position, both sides of the system are connected and this can be considered neutral
    5. There is also a hand operated bypass valve to connect both sides of the system
    6. The tank must be kept topped up with a good quality mineral oil or glycol mixture as an emergency alternative
    7. Pressure gauges are connected to each main pipeline and air vent cocks are also fitted
f. The receiver in steering gear consists of two fixed rams with moving opposed cylinders
    1. Centering springs are fitted to bring the cylinders to mid position
    2. Movement of the telemotor receiver is limited by mechanical stops set at 35 degrees
    3. The receiver is connected to the hunting gear through a control spindle
    4. By switching the changeover pin, this receiver can be run locally in an emergency.
    5. The receiver cylinder is normally gunmetal and the rams are bronze or steel
g. Charging:
    1. Air cocks are situated at each receiver cylinder for use in charging the system
    2. Charging valves are located on the receiver and positioned in such a way that when charging is necessary, the circuit valves are opened and the charging valves are opened
    3. The charging tank is filled with clean oil and the hand operated pump moves oil through the pipes to the receiver
    4. The bypass valve should be opened to equalize charging pressure on both sides of cylinder (transmitter charging valves are still closed at this time)
    5. The receiver air cocks should be open until a steady stream of airless oil escapes and then closed to allow fluid to be passed through to the transmitter
    6. The bypass valve is left open and the charging valves to the transmitter are opened
    7. Once there is a steady stream of oil escaping from transmitter air cocks, they can be closed.
    8. Once there is a clear stream of oil exiting the return line into the charging tank in unison with the stroke of the hand pump, charging is complete.
    9. Valves can be set back to normal running.
    10. A spring loaded non-return valve is fitted to the return line to prevent gravity from causing air to be admitted into the system
h. Testing:
    1. Tested using the creep test which is carried out before the ship leaves port.
    2. Consists of putting steering wheel hard over in one direction and lashing the wheel to hold it in place.
    3. The position of the receiver crosshead connection is marked and the system is inspected to see that there are no leakages.
    4. After a reasonable amount of time (half hour or so), the position of the crosshead is checked to see if any slip or creep has occurred
    5. A similar procedure is carried out with the wheel locked over in the other direction.
    6. If there are no leakages and no slip from hard over port and starboard positions, it indicates the telemotor system is tight and in good condition.
i. If the system failed at sea:
    1. Common faults are leaky piston rings or glands so a spare set should be on hand
    2. If the telemotor fails the creep test (i.e. with the wheel lashed hard over, the rudder gradually moves to amidships), this is a result of leakage
    3. External leakage will often be at the receiver gland so this can be observed in the steering compartment
    4. Internal leakage will be at the transmitting cylinder and can be checked by closing the transmitter circuit valves and trying to move the wheel – it should not move.
    5. If leakage cannot be traced to the transmitter, examine the hand operated bypass valve and pipe joints as they represent the only other possibilities of leaks
    6. If leakage occurs under normal working, the system will still work due to the automatic bypass valve that opens the transmitter to the receiver at amidships position

7. The added capacity of the transmitter enables the gear to be put hard over even with 20% leakage past the rings in the transmitter
8. If, say, the wheel was stuck at hard over to port and the receiver cylinder was at amidships due to internal leakage in the transmitter, the hand bypass could be open temporarily to re-center the wheel and then the wheel could be moved port or starboard again
9. This valve operates like the automatic bypass valve except forces the transmitter and receiver connection to be equalized in any position, therefor should only be used in an emergency like described
10. If the telemotor failed completely, emergency steering must be utilized which usually involves hand steering in steering compartment or pope deck
11. Communications would be established with the bridge to steer vessel from the stern
12. These practices must be practiced regularly for familiarity and to meet safety regulations

63. Describe with the aid of sketches a hydraulic telemotor/receiver. How is air purged from the system? Common defects/test? What type of fluid is the system charged with? (Jackson, Adam, Diesel Duck x 2, 1982)
    a. The telemotor installation provides a hydraulic connection between the helmsman on the bridge and steering gear
    b. This is the most efficient method of transmitting and converting the revolving motion imparted to the steering wheel on the bridge to the required motion on the steering gear control
    c. The installation in its simplest form consists of:
        1. one transmitter placed on the bridge
        2. one receiving cylinder in the steering compartment
        3. two copper pipes connecting these two instruments, the whole system being charged with suitable fluid
    d. The action of the gear relies upon the fluid displaced in the transmitter bringing about a corresponding displacement of fluid in the receiving cylinder
    e. This causes the receiving cylinder to move in correspondence with the piston in the transmitter
    f. This piston is connected to the hunting gear, which is connected to the variable delivery pumps
    g. In the transmitter, the steering wheel by means of a rack and pinion, gives a reciprocating motion to the piston attached to the rack
    h. When in amidships, there is an open connection between top and bottom of cylinder through the bypass formed by two small holes drilled in the annular space surrounding the center of the cylinder
    i. The replenishing tank is formed by a circular outer casing around the head of the transmitting cylinder and is cast as one with the cylinder
    j. Between the replenishing tank and transmitter, there are self-contained relief and suction valves to control oil volume in circuit depending on temperature or leakage
    k. The suction valve is very lightly loaded, only enough to properly seat it
    l. The working fluid is a mineral oil of :
        1. low viscosity but not too low to reduce gland sealing
        2. low pour point
        3. protection against rusting
        4. non-sludge forming
        5. non-corrosive
        6. good lubrication qualities
        7. high flash point
        8. level is checked in gauge glass in make-up tank
    m. As an emergency alternative, a glycol mixture can be used

64. Describe a variable delivery pump used for a modern steering gear. These pumps can overheat if they are not pumping for a long period of time, why? And what measures are sometimes used to prevent this? (Paul, Diesel Duck x 2)
    a. Variable displacement pumps allow an infinitely variable delivery in either direction, with a constant speed electric drive
    b. An example of a variable delivery pump used for steering gear is the Hele-Shaw design:
        1. The Hele-Shaw pump is otherwise known as a radial cylinder pump
        2. It consists of a hollow bronze central casing that contains several radial cylinders (normally 7 or 9).
        3. The radial cylinder block rotates around a fixed steel constructed valve arrangement having two ports opposite to one another and in line with the bottom of the rotating cylinders.
            1. These ports form the incoming and outgoing oil passages and ports
        4. Hardened steel pistons extend outward from each cylinder and are pinned to bronze slippers that are free to slide circumferentially in grooves in a rotating floating ring.
            1. This floating ring has its own annular bearings that can be shifted off center from the pump shaft
            2. A push/pull guide rod which extends out of the pump casing controls the position of the floating ring

3. When the pump is turned over and the floating ring is forced off center, the plungers are given a reciprocating motion, causing the pump to function.
4. When the floating housing is in mid position, there is no pumping action.
5. By pushing the floating housing to the opposite side of center, the pumping action is reversed.

5. All the rotating elements are housed within a cast case which is provided with a drain for the leakage past the plungers and with suction and discharge connections
6. This pump gives from zero to max delivery in either direction, without stopping the pump – that is why it is a preferred pump

c. Another good example of a variable delivery pump is a swash plate type pump.
   1. The casing is constructed of fabricated high strength steel, to withstand high oil pressures during operation
   2. The interior parts are made with case hardened steel (i.e. pistons)
   3. This pump is run by an electric mode in a constant direction and speed
   4. It is fitted with a mechanical control rod that controls the angle of an internal swash plate
   5. The control rod is attached to the hunting gear, which is controlled by the telemotor receiver
   6. Depending on the angle of that swash plate, oil is pumped one direction or the other through the suction/discharge ports
   7. If the swash plate is moved so that the upper piston is moved inwards, the top port will become the discharge port since it has lower volume capacity and the incompressible oil is discharged through its port
   8. The lower piston has become the suction cylinder since it has more oil volume available and draws the oil in to fill that void under vacuum
   9. If the control rod was moved in the opposite direction, the exact opposite would occur with the lower cylinder becoming the discharge cylinder
   10. In this way, a variable amount of oil can be pumped to either steering cylinder, which will in turn move the tiller to the desired angle.
   11. This type of pump is used because it can move from zero delivery to full delivery in one direction and the other direction very fast, without having to stop the motor
   12. This type of pump is capable of 2500-4000 psi so the size of steering gear can be reduced

d. The provisions made for this pump heating up are:
   1. An auxiliary pump can be used to circulate the oil back to the replenishing tank, which will in turn cool the pump
   2. A cooler may be fitted in line with the oil circulation
   3. The wheelsman may be instructed to turn the wheel back and forth if alongside to circulate some oil
   4. A leak off port may be fitted to the pump to ensure there will always be some new cooler oil drawn into the casing

65. Sketch and describe a quadrant and tiller for a steering gear, showing how they are connected to a rudder post. What happens when a heavy sea strikes the rudder? What is the sealing arrangement for passing the rudder stock through the ship's hull? (Diesel Duck x 2)
   a. The steering engine or electric motor transmits its movement to the tiller, firmly keyed to the rudder stock in two steps, first by means of a worm on the engine crankshaft which engages with a worm wheel.
   b. The shaft of this worm wheel carries a pinion which meshes with a large quadrant, the center of which sets loosely over the head of the rudder stock above the tiller.
   c. Two heavy shock absorbing helical buffer springs connect the two side of the fixed tiller to the loose quadrant.
   d. When the quadrant is moved it pulls the tiller with it through one of the springs which takes the load in compression so if one of the springs break it will not pull the tiller to one side and impair steering.
   e. The function of the springs is to absorb the shock of heavy seas sticking the rudder and so prevent damage to the steering gear and the teeth on the driving pinion and quadrant.
   f. This spring action powers the movement of the rudder through the connection of the inboard side of the springs to the tiller
   g. Note that the quadrant is free to turn on the rudder stock
   h. An emergency hand steering gear may be fitted to drive a pinion engaging with a tooth quadrant extension secured to an arm on the tiller, the drive being from a hand wheel carries on a pedestal above the steering gear, through a worm gearing, friction clutch and vertical shaft down to the quadrant driving pinion.
   i. The shackle shown on the line of each wing of the loose quadrant is for coupling block and tackle gear to operate the rudder (and also the emergency hand wheel fitted).
   j. The block and tackle arrangement is worked through wire rope, guided by puller and led to the after winch.
   k. A screw-operated brake is fitted to enable the rudder stock to be locked while changing over from engine to emergency steering, or while repairs are being carried out
   l. The steering engine and driving pinion can be slid out of gear after the emergency gear has been coupled up.
   m. If one of the helical springs breaks a key can be placed in the key way of the quadrant for direct steering, through the quadrant, to the rudder stock.

66. With the aid of suitable sketches, discuss the function, importance, or operation of the following arrangements or devices fitted to steering gear: (TCMS Sample)
    a. Overhead oil tank
        1. Tank is fitted overhead so that head pressure helps in ensuring pumps always have full suction piping, also the return is above the liquid level and any air can be vented off as the oil settles into the tank
        2. Steering pumps have suction connections through non-return valves from the replenishing tank
        3. Losses of oil from the system are automatically made up from this reserve of oil
        4. A certain amount of leakage occurs in the pumps and is replenished with cooler oil to ensure they don't overheat
        5. Oil from this tank is also used when first charging the system or when purging any existing air
            1. Purging valves on the cylinders and pumps are opened, as well as bypass valves and the system is barred over and ensure all pipework is filled with oil and no air exists
            2. The system is said to be charged when the system is running and the level in this tank is no longer dropping
            3. Purging valves and bypass valves can now be closed and the system valves set for normal operation
    b. Relief valves
        1. Fitted to pipes connecting opposing rams so in the event of over pressure in one ram, they will deliver oil to the other ram.
        2. Intended to allow the rudder to give way when subjected to heavy seas or direct loading, thereby removing any abnormal stress on the gear
        3. Designed to lift with about 10% over pressure
        4. The movement of the hunting gear will correct the rudder movement back to the original location by putting the pump on stroke
    c. Hunting gear
        1. A simple arrangement of levers that has 3 connections:
            1. Hydraulic pump
            2. Telemotor
            3. Tiller
        2. If the telemotor link is moved to the right, the hunting lever will swivel about C as a fulcrum and the pump control rod will be pushed inwards (B to B1)
        3. The pump will then draw oil from the left cylinder and discharge it into the right, which moves the crosshead and tiller to the left
        4. As the crosshead moves, A now acts as the fulcrum for the hunting lever and the movement of C to the left will cause the other end, connected to the control rod to move to the left (B1 back to B)
        5. This brings the control plate in the pump back to its mid position, meaning the pump will cease to deliver oil and the gear will come to rest at this position
    d. End stoppers to rudder movement
        1. The mechanical outside stops prevent unlimited rudder movement in case of steering gear damage that caused the rudder to become disconnected from its normal hydraulic or electronic stops
        2. This is to help manage movement of the rudder and prevent further damage and possible contact with the propeller
        3. Telemotor limits are set to 35 degrees which gives the best steerage for hard over, any more is inefficient or ineffective
        4. Non-mechanical limits are normally set to 37 degrees to prevent the rudder from being forced against the outside stops
        5. Mechanical stops are set a few degrees more, say 39 degrees
67. Describe the construction and use of an evaporator. Describe all the fittings on its shell and their uses. (Diesel Duck x 2)
    a. The primary purpose of an evaporator for ships is to produce fresh water for use as drinking water, boiler feed and other services
    b. An evaporator is primarily a heat transfer apparatus, the heat heat is supplied to the coils by use of steam and is transmitted through the metal of the coils to the water, which is boiled giving off fresh vapor and leaving behind the salts and other matter
    c. A simple single-effect evaporator consists of a vertical cylindrical shell, the lower half is the vapor space and contains a baffle plate to throw off any water particles that may rise with the vapor
    d. One end of each copper coil is connected to a steam header that is supplied with steam from the auxiliary steam line or the exhaust range
    e. The other end is connected to an exhaust header with a drain at the bottom
    f. Some evaporators have an arrangement whereby all the exhaust steam and condensed water from the upper coils finally pass through the bottom coil to ensure that all the heating steam has been condensed and thereby given up all its latent heat before leaving by the drain as water
    g. A large hinged door is provided in way of the coils and also a hand hole near the bottom of the shell
    h. Seawater is pumped into the evaporator and the hot coils cause sea water to boil, the vapor given off passes through the vapor valve at the top

i. From there it is lead to either the condenser where it is condensed to make extra feed for the boilers or to a distiller where it is condensed as make up for the domestic fresh water tanks
j. In some cases, the vapor may be passed to the heating side of a feed heater where its latent heat as well as some of its sensible heat can be given up to the feed water
k. As the seawater boils and passes away as vapor, the salt and other solids are left behind which cause an increase in the density of the water in the evaporator
l. Therefore, to maintain a predetermined steady low density, the evaporator is run with a constant blow down through a brine ejector
m. Some of the solid matter deposits as scale on the heating coils and must be cleaned off at regular intervals
n. There are 4 major types of evaporator:
    1. Submerged type
    2. Flash Type
        1. Boiling produced by pressure reduction instead of temperature elevation
        2. Pressure is reduced with a vacuum pump or air ejector
    3. Vapor compression
    4. Basket type

70. Sketch and describe a metallic packing gland. (Diesel Duck)
71. Describe the construction and operation of a purifier for lubricating oil. (Diesel Duck)
    a. An oil purifier is an essential part of any system of forced lubrication.
        1. Its purpose is to purify the oil by the removal of impurities and so maintain the oil conditions that it can be used over and over again with perfect safety.
    b. Of the impurities normally found in marine lubricating oil (water, sludge, dirt, carbon, bits of metal, acid), all except the acid and soluble sludge can be removed by centrifugal purification
        1. Also water and oil when together tend to emulsify
        2. Water finds its way into storage tanks through leakage from sea, condensation.
        3. Dirt, sand and metallic dust are picked up from the engine parts and pipe connections through which it circulates, and rust from the tanks in which it is stored.
    c. The purifier, which is also a separator, depends for its action on centrifugal force.
        1. The force developed by the centrifuge in separating oil from water and sediment rests on the law of inertia
        2. Objects prefer to stay in motion and travel in a straight line once moving
        3. This tendency is translated into a force pulling outward on spinning objects
    d. The purifier contains a hollow bowl which is rotated at high speed on its axis
        1. The bowl in which the separation takes place carries a number of coned shaped metal discs, the disc having holes through which the oil can pass in an upward direction.
        2. When oil is drawn into the bowl and set in motion, the heaviest impurities are deposited on the wall of the vessel and the water, since it is denser than oil forms a layer between the solid impurities and the oil.
        3. A force many thousand times the force of gravity can be obtained by high speed rotation
        4. A cylindrical interface is formed between the oil and water
        5. The position of this interface is very important and is set by a dam ring called a gravity disc at the water outlet of the purifier
        6. Different oils can be adjusted for with various diameter rings
        7. As a general rule for efficiency, the largest diameter ring that does not break the seal should be used
        8. The centrifuge consists of an electric motor driven through a worm gear to a vertical shaft, atop which sits the bowl assembly
        9. An outer casing framework surrounds the bowl and carries the various feed and discharge connections
        10. A simple centrifuge can be a solid assembly that retains sludge and must be shut down for cleaning
        11. A self-cleaning purifier has an upper and lower bowl assembly that can split during operation in order to discharge built up sludge
        12. Dirty oil flows from the settling/storage tank or sump and enters the bowl at the top central area
        13. The oil is pumped downwards to the bottom of the bowl and then passes up through a stack of discs
        14. The stack can contain up to 150 discs and are separated by a 2-4 mm clearance
        15. This clearance is where the separation of impurities and water takes place
        16. A series of aligned holes are at the outward edge of the discs allow entry of the dirty oil
        17. The centrifugal action cause the lighter clean oil to flow inwards while the water and impurities flow outwards
        18. The water and impurities forma a sludge that moves outwards along the undersides of the discs to the periphery of the bowl

    19. Insoluble impurities remain at the edge of the bowl while water and soluble impurities flow upwards along the edge of the bowl and out of the water outlet
    20. The discs act as an extended settling surface area, the more area, the more purification is achieved
  e. The action of the purifier is a follows; the oil to be purified enters at the top and flows downwards to the lower part of the bowl.
    1. Due to the speed at which the bowl is made to revolve, about 7000 rpm, the centrifugal force imparted to the oil causes it to ascend through the holes in the disc.
    2. In the process any solid material is thrown outward to the periphery of the bowl, where it is retained in sediment.
    3. Water being heavier than the oil passes outward and upward along the outer edges of the disc and from there to the water discharge outlet.
    4. The oil having a lesser specific gravity than the water, passes upward between the disc and then to the oil discharge outlet.
    5. The construction of the purifier is such that that it will adjust itself automatically to varying proportion of oil and water, so that when no water is in the oil there is no discharge from the water outlet and vice versa.
  f. The same type of purifier can be used in the purification of fuel oils, but it may be necessary to change the gravity disc used in the bowl to suit the specific gravity of the oil.
    1. The gravity discs are stamped with the range of specific gravities.
  g. Some types of purifiers are self-cleaning. Manual cleaning may be preferred so that the solids can be examined and also because use may be intermittent and the extra expense not justified.
    1. While the oil is passing through the purifier the sliding bowl bottom is held up in position by the operating water beneath it.
    2. The sliding bottom seals the bowl by being pressed against the sealing ring in the rim of the cover.
    3. Solid from the oil are thrown outwards by centrifugal force and collect against the bowl periphery.
    4. At intervals dictated by either time or choice the oil feed is turned off and the bowl opened to discharge the solids.
    5. There are a number of discharge ports around the bowl.
    6. At the end of the discharge the bowl is closed and after the liquid seal has been established the oil feed is continued.
    7. During normal running the pressure exerted by the water under the sliding bottom is sufficient to keep it closed against the pressure from the liquid in the bowl.
    8. The operating water tank maintains a constant head of water to the passing through the operating valves.
    9. The paring discs, which acts like a pump opposing this head provided that the radius of the liquid remains constant.
    10. If the evaporating or leakage causes a slight water loss the reverse pumping effect of the paring disc is reduced and water from the operating tank and the quantity of water in the passing chamber back to the correct radius.
    11. The operating slide prevents loss of water from beneath the sliding bowl by closing the drain holes.
  h. With self-cleaning, there can be considerable continuous use before maintenance is required
    1. This cleaning is achieved by an ejection process that discharges built up sludge at regular intervals
    2. These intervals are timed to rid sludge before it interferes with separation process
    3. The oil feed is shut off and oil in the bowl is flushed out by water
    4. Operating water is then fed to a hydraulic system through a feed port to open spring loaded discharge valve
    5. This cause the bottom bowl to drop which opens a sludge port that allows centrifugal force to force out sludge
    6. When the times discharge period is over, operating water is diverted to close the bowl
    7. Water is also fed into the bowl to remake water seal required for interface for separation
    8. The oil pump is brought back online and process starts again

72. Sketch and describe a self-cleaning purifier. How would you convert a purifier into a clarifier? Enumerate the routine maintenance you will carry out to have trouble free operation. (TCMS Sample)
  a. Clarification is the removal of suspended solids from liquids
    1. Since there is not a significant amount of water in the oil, an interface is not required for separation
    2. This means that you must remove the gravity disc for clarification to take place
    3. The bowl operates at maximum separating efficiency since oil can use full bowl for separation
    4. Also discs do not need distribution holes
    5. Without these distribution holes, the sediment is subjected to higher centrifugal force and is thrown to the outside
    6. The clarifier removes any of the finer and slightly lighter particles and can be placed in series with a purifier (after the purifier)
    7. There is only an oil outlet – must be cleaned manually
  b. Maintenance required for such a purifier includes:
    1. Bow should be periodically stripped down and thoroughly cleaned as well as disc stack
    2. This is a precise machine that runs at high speeds so must be carefully balanced to safely operate – care must be taken when working with parts – some have left hand threads as well
    3. Worn seals must be replaced and coated with silicon grease if recommended

        4. Gearbox oil should be changed regularly
        5. Operating water system should be cleaned and strainer checked/cleaned
        6. The oil/fuel entry strainer should be cleaned regularly
        7. The bearings should be checked regularly

73. Sketch a multi flow type of shell and tube type of lubricating oil cooler indicating the direction of flow and coolant. Name the materials used for the various components (TCMS Sample)
    1. Tube coolers for engine jacket water are circulated with seawater while coolers for oil are often circulated with jacket water
    2. The cooling medium is in contact with the inside of the tubes and the end bells, also called water boxes
    3. Two pass is common in order to get more use out of the cooling medium as it passes through the cooler
        1. Cooling water enters at the bottom and exits at the top to prevent air locks
    4. The oil or jacket water is in contact with the outside of the tubes and the shell of the cooler
    5. Baffles are used to direct the flow of coolant through the cooler and prevent it from exiting before acting as cooling medium,
        1. These also support the tube stack
    6. To allow for thermal expansion, one end of the stack is fixed between the cover and casing, while the other is free to slide on the sealing ring joint
    7. The fixed end of the tube plate is sandwiched between the shell and the water box
    8. If the O-rings leak at the floating end, a tell- tale ring with holes in it will allow liquids to escape without mixing
    9. The tube plates are held rigidly at a predetermined distance apart by means of stays
    10. Tubes are expanded into both tube plates
    11. Ends of the tubes are carefully annealed to prevent the bad effects of cold working when being expanded
    12. Amount of cooling surface should be enough to keep oil in the engine at about 112F and seawater temp of 90F.
    13. Materials:
        1. Shell – cast iron or fabricated mild steel
            1. Not in contact with seawater so can be a ferrous metal
        2. Water Boxes – fabricated mild steel, their insides coated with rubber or anodes placed for protection
        3. Tubes – aluminum brass, aluminum bronze or 70/30 cupro nickel
            1. Ordinary brasses have been used with limited success
            2. Early tube failures have been caused by pollution and turbulence
        4. Tube plate – aluminum bronze or naval brass
        5. O-rings are made of synthetic rubber

    b. What major faults are likely to arise with this equipment
        1. A rise in the discharge temperature, if the jacket water temp is normal, denotes that the cooler tubes may be fouled and requires cleaning
        2. Air locking of fluid spaces
    c. How are these faults inhibited
        1. End bells are easily removed so that tubes can be periodically cleaned with brushes
        2. Oil side can be cleaned with solution
        3. Zinc anodes must be checked and replaced so that corrosion is limited to them and not to cooler materials
        4. Only the minimum seawater should be circulated to prevent corrosion and erosion problems
            1. This is normally controlled by properly setting the thermostatic control valves
        5. Inlet strainers must be kept clean and in good shape
            1. Damaged strainers will allow solids to block cooler tube passages

74. Describe how the engine room of a motor ship is ventilated. Give reasons for the ventilation of diesel engine rooms. What provision is made to prevent moisture from entering through the ventilation system and what would be the effects of too much moisture getting carried in the machinery spaces? (Diesel Duck)
    a. Ventilation can be defined as the movement of air from outside the ship to inside of the ship, or from the inside of the ship to the outside of the ship.
    b. Ventilation systems can be broken down into two parts air supply and exhaust.
    c. The air supply system consist of weather intake, centrifugal fans, and duct work through the engine room so positioned that the entire engine room is supplied with fresh air.
        1. In the supply air system air is drawn in through the air inlet vent by the centrifugal fans and pushed through the duct work to the engine room spaced.
        2. The supply fans are usually two speeds because less air flow may be required in the heating season.
        3. Each of the duct holds may be fitted with cut off shutters to cut air flow to any space it is not required.

4. The ventilation air intake parts are fitted with fire dampers to cut off are supply in case of fire and fans have remote shut offs outside the engine room for use in case of fires.
5. With the increase in generator capacity on board ships the fans are able to produce higher pressure of ventilation in the engine room of a ship is to supply the air necessary for the operation of the engines and possible boiler, also to remove contaminants and heat generated by the running machinery.
6. The air supply is used for cooling the spaces and machinery and to make the spaces somewhat comfortable for working.
7. With the introduction of heating and air conditioning the engine room can be very live able in hot and cold weather.

d. The exhaust system consists of a hood or canopy and exhaust or extraction fans, ductwork, and a weather opening.
   1. In the case of exhaust air they can be extracted from the engine room by pressure difference.
   2. The gases will rise through the engine room and escape through the funnel.

e. To reduce a large flow of moisture through the ventilation system, provisioned must be made.
   1. Most ships have filters installed in the system to absorb the moisture.
   2. The ductwork may be provided with drains and if a build-up of moisture is large enough it can be drained.
   3. In more modern ships an air dryer will be fitted in the system.
   4. The end of the ductwork openings are designed to not blow on electric motors or electric equipment.
   5. If there was too much moisture in the machinery space its biggest effect would-be on the electrical equipment.
      1. Moisture is a very good conductor of electricity, therefore an electric equipment exposed to moisture will most likely overheat causing a breakdown in insulation on the wiring forming a short of ground.
      2. This may cause fuses to blow or the electrical equipment to burn out.

f. Engine should also be vented because of gases escaping from the engines.
   1. These gases can be very harmful to humans.

75. Describe a reducing valve. Where this would be used? What else would be fitted on the low pressure side and why? (Mike, Diesel Duck)
   a. A reducing valve is used to reduce the supply pressure of steam or air to a suitable working level for the operation of auxiliary equipment.
   b. The valve shown consists of a valve body, valve, valve seat, valve spindle, adjusting nut, spring and diaphragm.
   c. The reducing valve steam or air on the inlet side of the valve to the lower side pressure on the outlet side of the valve.
   d. The adjusting nut is used to regulate spring compression and determine the pressure of the outlet side.
   e. The adjusting nut also acts against the spring diaphragm to lift the valve from its seat slightly and allowing a reduced amount of air and therefore lower air pressure to the outlet side of the valve.
   f. If the air pressure should increase on the lower side, air will act downward against the diaphragm and causer the valve to close slightly thus keeping the air pressure on the low side at it's working level.
   g. A gauge is fitted on the lower side of the reducing valve to monitor the pressure and will also aid in the adjusting the spring tension to attain the correct pressure setting.
   h. The gauge will help in determining that the valve is working properly.
   i. A relief valve is also placed on the low pressure side to relieve and high pressure should the valve malfunction thus preventing any damage to the auxiliary equipment.
   j. The valve body is usually of cast iron or steel.
   k. Valve, valve seat and valve spindle are steel or bronze.
   l. All materials will depend on the operating condition of the valve.
   m. Since the valve must be in equilibrium under the action of the forces which act upon it
      1. downward force=upward force
      2. p1xA = (p1-p2)xa+F
      3. if p1, A and a are constant we have:
      4. p2 varies directly as F
   n. Hence if the supply pressure is kept constant the discharge pressure can be reduced or increased at will by rotating the adjustment screw.

76. Sketch and describe the construction and operation of a windlass. What provision is made for a power failure? (Diesel Duck)
   a. A windlass is used to lift anchors or assist in way of the ship, and therefore its size and power depend upon the masses of the anchors and cable and full hauls which is governed by the size of the ship.
   b. It may be powered by a steam engine, hydraulic or electric motor.
   c. The basic design is that of a double purchase lifting machine consisting of a primary shaft, intermediate shaft and main half-shaft, with corresponding pinions and gear wheels as shown in the diagram.
   d. In the electrically driven windlass, the primary is driven by a worm a worm wheel through a worm shaft from the electric motor.
   e. The primary shaft carries a pinion which meshes with an intermediate shaft mesh with two main gearwheels one on each main half.
   f. Each main half shaft carries a cable lifter which has snug around its circumference of the size and pitch to suit the links of the cable.
   g. The cable lifters are not fixed on the shaft but are mounted freely to allow them to rotate independent of the shafts.

h. A screw operated steel hand brake is fitted around a brake drum on the outer edge of the rim of the cable-lifter controlling the speed of the cable when paying out and for locking it stationary when required.
i. The power for hoisting is transmitted through a clutch formed by jaws on the side of the main gear wheel may be fit a corresponding set of jaws on the side of the cable lifter.
j. The main gear wheel may be a sliding fit and keyed to its half shaft allows it to be moved actually into and out of gear alternatively.
k. The gear wheel may be fixed on the shaft and the cable lifter moved laterally to engage gear, a screw control rod attached to a cod piece riding in a groove in the boss of either the main gear wheel or the cable lifter operated the clutch.
l. Thus the two cable lifter is entirely independent the anchor may be fitted both at once and separately or one may be fitted while the other is being lift.
m. Each end of the intermediate shaft is extended through a dog clutch to carry a warping drum.
n. In the event of a power failure, the windlass can be operated by hand gear consisting of a lever and pawl to act as a ratchet on the teeth of the intermediate gear wheel.
o. In windlass cable lifter brakes must be able to control the running anchor and cable when the cable lifter is disconnected from the gearing during "letting go".
p. Average cable speed varied between 5 to 7 meters per minute during operation.
q. The windlass must be able to have a certain weight of cable at a specified speed.
r. This full load duty of the windlass varies but is common between 4 and 6 times the weight of one anchor, the speed of haul being at least 9 meters per min up to 15 meter per min.
s. The braking effort obtained at the cable lifter must be at least equal to 40 % of the breaking strength of the cable.

Power transmission

Construction details, alignment, lubrication, expansion, clearances and wear allowances of thrust blocks, shafting, bearings, stern tubes, propellers, nozzles, thrusters and ship side fittings.

77. A new propeller is to be fitted to an existing shaft. State how you would do this giving diameter and key sizes? When the propeller is fastened in position, how is it verified that it is fully in place? (Craig, Diesel Duck x 2)
    a. When fitting a new propeller to a tail shaft already in place, the tall shaft should be first checked for signs of wear and corrosion.
        1. The key should be removed from the shaft and the bottom of the keyway carefully examined for signs or fretting
            1. The key is then tested in the keyway of the new propeller.
            2. It must be good fit on the sides to prevent movement left or right when reversing the propeller
        2. The thread of the shaft is examined for corrosion and condition
            1. For a right hand propeller, the boss nut should have a left hand thread so that it will be self-locking when revolving
        3. The taper on the shaft is examined for corrosion or any signs of movement of the old propeller.
        4. Also the shaft at the end of the liner is examined for corrosion.
    b. The propeller boss and shaft are both fitted with a taper of roughly 1"/foot and this interference fit is where the necessary friction is – the key cannot be relied on to secure propeller against large torsional loads
        1. The new propeller is first smeared the taper with mechanical blue.
        2. The propeller is then slipped on over the taper and securing nut hardened up temporarily and then removed with propeller
        3. Any high spots will be noted by the taper being scraped clear and the mechanical blue showing up on the propeller boss.
        4. The high spots are scraped down again and the propeller is placed on the shaft taper.
        5. The process is continued until about 80% or more of the propeller has turned blue.
    c. The nut is then slacked back and the propeller is dropped back against the nut.
        1. A ball of soft lead wire is laid on the top of the shaft and the propeller is then hammered up until two marks on the boss and nut coincide.
        2. The nut is slackened back again and the propeller is also dropped back against the nut.
        3. The rectangular shape of the squished lead will indicate the size of the rubber ring needed.
        4. The rubber ring is sandwiched between the propeller and the end of the brass lined to ensure that no part of the steel shaft is in contact with the sea water.
    d. The nut is removed and the propeller is forced is taken right back in order to insert the key in the keyway.
        1. The propeller is forced upon the taper again until the marks coincide, the nut is removed again and feeler is inserted on the top of the keyway its whole length.
        2. Top of the key must not touch the boss.
    e. When this is checked the rubber ring is put in place, up against the lines.

        1. The propeller is put on the taper again and the nut hammered up with a ring spanner until the marks on the nut goes beyond the mark on the boss slightly.
        2. This is to ensure the propeller is hard in its place and seal is compressed
        3. A stopper plate is next bolted to a recess in the propeller nut.
            1. A pintle on the plate passes through the hole drilled into the propeller nut.
            2. This is a locking device to prevent the nut from backing off.
    f. The size of the key is governed by the size of the shaft.
        1. If the size of the shaft is say 300mm diameter, the key width size is equal to 1/5 diameter shaft so say 60mm
        2. The key depth is equal to 1/2 breath of keyway so say 30 mm
    g. The propeller nut and the end of the tail shaft should be protected in some way against the corrosion action of the seawater.
        1. The practice is to fit a hollow cone-shaped casting (filled with grease) over the nut and bolt and bolt it to the propeller boss.
        2. If no cone is fitted over the propeller nut it should be cemented over.

78. Describe how a spare blade is fitted to a built up propeller and how the pitch is found and adjusted. Include securing arrangement. (Jackson, Diesel Duck x 2)
    a. If a blade was lost or damaged on a built up propeller the following method can be used to fit a spare blade:
        1. With ship in dry dock, turn the propeller shaft until one of the remaining blades is in an upright or vertical position
        2. Then, with a straight edge fixed in place against the stern post, and at a convenient radius R, mark the blade at the leading edge A
        3. Shift the straight edge to the other side of the blade and mark the following edge B
        4. Now turn the shaft around until the surface of the boss to receive the spare blade is in position
        5. When the new blade is placed on the boss, turn round the flange until the leading and following edges coincide with the marks on the straight edge
        6. The new blade will then have the correct pitch angle and the studs may be tightened up
    b. To measure pitch:
        1. Pitch is meant by the advance of the screw of the propeller per revolution in say, a solid nut
        2. Fix up the plate in the wood block so that it is exactly parallel to the machined back of the boss
        3. Arrange that the poker is placed at a radial position of say 2/3 out from center of boss
        4. With blade in any position, push in the poker gauge until it makes contact with the blade surface then score a mark A at this position
        5. Arrange with the E/R staff that on a signal, the shaft will be turned exactly 1/12 of one revolution (by means of marks on the inside of the vessel say on main bearings
        6. At this point make another mark with the poker gauge – mark B
        7. The distance between marks A and B, measured in inches, is equal to the full pitch in feet at the radial position of the poker
79. Name three materials commonly used for construction of propellers. Compare and contrast these materials. (Diesel Duck)
    a. Material must be:
        1. To allow for thinner blade sections, the material for a propeller should possess properties of strength and toughness
        2. Should have the ability to develop a smooth surface polish
        3. Should also be resistant to sea water corrosion
        4. Resistant to cavitation erosion
        5. Should be capable of withstanding severe shock loading
        6. Should be suitable for casting into complex shape
        7. Material should be repairable
    b. For many years, nearly all large propellers were brass or manganese bronze
        1. This is a copper-zinc alloy that contains manganese, aluminum, iron, tin and sometimes nickel
        2. Has tensile strength of 40 to 50 MN/m2
    c. The high tensile brass has largely been superseded by aluminum bronzes
        1. They largely contain 8-10% aluminum
        2. 10-12% manganese
        3. 2-3% iron
        4. 2-5% nickel
        5. The balance is mainly copper
        6. Have higher tensile strength of about 65 MN/m2
        7. Lower specific gravity
        8. Often used on icebreakers

        9. Higher Brinell hardness
        10. Better corrosion resistance
    d. Nickel aluminum bronze
        1. Alloy has higher % of nickel
        2. Results in propeller with higher fatigue strength and wastage resistance
    e. Another material is stainless steel
        1. Contain around 24% chromium
        2. Are about as strong as aluminum bronze
        3. Susceptible to crevice corrosion and cracking in service

80. How is a liner fitted to a tail shaft? How is the thickness of the liner calculated? What is fitted between the liner and propeller hub and why? (Diesel Duck)
    a. Propeller shafts are brass lined from end to end to prevent galvanic action taking place between the brass liner and steel of the shaft
    b. The thickness is generally ¾" for a 12" shaft but may be 1" for a 24" shaft
    c. The liner provides a good bearing surface to run on the stern tube bearing
    d. Also the liner can be removed and replaced to avoid replacing a full steel shaft
    e. The liners are fitted in two styles:
        1. Shrunk on hot
        2. Forced on cold by hydraulic ram pressure
    f. Shrinking on:
        1. The shaft is supported by bolting up to one of the tunnel lengths, which leaves the whole length free to receive the liner
        2. The liner is then heated by gas burners and after sufficient expansion has taken place, the liner is drawn over the shaft by means of block and tackle
        3. When the liner cools down, the contraction resulting is sufficient to lock the liner to the shaft
        4. Before the liner is bored out about 1/500 less in diameter than the shaft
    g. Forced on cold:
        1. In this method, the liner is stepped to three diameters, the difference at each being 1/32"
        2. The forward and after diameters should be a bearing fit but the center length need not be so
        3. As in the shrinking on method, the liner is bored out a trifle less than the diameter of the shaft at each step
        4. The liner is then forced on over the end of the shaft by a hydraulic pressure of about 110 tons
        5. Note that the ram pressure only requires to be exerted for one of the stepped lengths, as the three fit simultaneously
    h. A rubber stop ring is fitted hard-up between the end of the shaft liner and the propeller boss
        1. The boss is recessed out to allow the rubber ring to be fitted
        2. The object of the rubber ring is to prevent the access of water to the metal of the shaft and thus prevent galvanic corrosion between the shaft steel and the brass liner, which would cause shaft corrosion

81. Describe how you would check a tail shaft for wear down. On a 12" (300mm) diameter shaft, how much wear down would you allow on a lignum vitae stern bush? What might happen with excessive wear down of the stern bush? (Diesel Duck x 2)
    a. Wear down is the amount a tail shaft bearing wears over a period of time
        1. It can occur due to:
            1. Vibration or whirl
            2. Poor workmanship
            3. Inferior materials
            4. Presence of sand/sediment in water
            5. Propeller damage
    b. Wear down of stern tube bearings can be measured in two manners;
        1. By inserting a small copper or wooden wedge between the shaft liner and outer end of bearing at the top
            1. There should be record of the previous measurement and the current reading should be subtracted from that to result in a wear down measurement
        2. By inserting a poker gauge (having the original markings) inserted through a hole near the end of the stern tube until it touches the shaft
        3. May be able to use feeler gauges as well between the stern tube and liner
        4. Can use a jack under the shaft and an dial indicator fitted on top of the shaft near stern bush to read off vertical clearance
    c. Because of the weight of the shaft, most of the wear will be on the bottom strips
        1. These staves are cut so that the wood grain is cut radially in the bearing for longer life, not required for the upper staves
    d. If the wear down was allowed to become excessive, the bending of the prop shaft would cause increasing tensile and compressive stresses as the shaft rotates and possible fracture due to fatigue
    e. The clearance should be examined every 3 years
    f. Maximum wear down on a 12" shaft would be 8mm (5/16") before the stern tube bearings would require replacement

- g. If the wear down is excessive, the stern bush will have to be withdrawn and refitted with wood and bored out at a shop
    1. After the new strips are installed, a circular wood gauge the same diameter as the shaft is pushed through to find any high spots

82. Describe a stern tube and propeller shaft. How are they fitted to a new ship? (Diesel Duck)
    - a. The purpose of the stern tube is to allow transit of the tail shaft while also keeping the aft end of the ship water tight
    - b. The stern tube is generally constructed of cast iron, the thickness varying from about 1 ½" to 2 ½"
    - c. The tube is larger in diameter at the forward end and slightly less at the stern post end for convenience in fitting in or taking out
    - d. For a sea water lubricated stern tube:
        1. The forward end is flanged and bolted to the after bulkhead
        2. A make-up ring of lead or wood (or rubber) being inserted between the two.
        3. The forward end is supplied with a packing gland or mechanical seal to keep water out of the tunnel
        4. The aft end is supported by the stern frame boss and secured to the stern post by a large steel nut
        5. Here, the tube is fitted with a bearing composed of lignum vitae which is a very hard wood fitted dovetail fashion into the after brash bush.
        6. Lignum vitae is self-lubricating in water
            1. The staves are fitted with end grain vertical beneath the shaft for better wear resistance
            2. Staves in the upper part are cut with the grain in the axial direction for economy
            3. The staves are shaped with V or U grooves between them at the surface to allow water access
                1. Grooves also accommodate debris
                2. Bearing length is equal to 4 times shaft diameter
                3. Newer bearing materials are based on phenolic resins
        7. The wood strips are held in place on the forward end by a collar on the bush or on the stern tube
            1. This keeps the staves from sliding forward
        8. The strips are held in place aft by a check ring that is secured by means of bolts to the flange of the stern bush
            1. This bush is a brass ring secured with set screws and sealed with white lead protects the outer screw thread from seawater
            2. This keeps the staves from sliding aft
        9. The bush is fitted to the stern tube by countersunk screws
    - e. Oil lubricated stern tube:
        1. Advantages:
            1. A full length bronze liner is not required
            2. Friction and wear down are low
            3. Corrosion is prevented
        2. Disadvantages:
            1. More expensive
            2. More complicated
            3. Outer seal is vulnerable to debris/ice
            4. Leakage causes environmental damage
        3. Instead of wood line bearing, the bearing material used is white metal
        4. Since there is exclusion of seawater, the bushing can be made of cast iron
        5. There is an external face type seal fitted to the outside of the stern tube to keep oil in and seawater out
            1. Pressure of oil under head pressure also aids in sealing
        6. The inboard end is sealed either by a packing gland or with another mechanical seal
        7. A minimum bearing length of 2 times shaft diameter will ensure bearing load does not exceed a high level
        8. The tube is fabricated and welded directly to the extension of the stern frame boss and to the aft peak bulkhead at the forward end
        9. The seals at each end in older units were lip seals riding on chrome steel liners
            1. Heat produced by the friction will result in hardening and loss of elasticity of the rubber
            2. Cooling on aft end is by contact with seawater
            3. Oil circulation is aided by convection that is arranged to maintain low temperature of seals at the inboard end
        10. Floating ring mechanical seals are an upgrade
    - f. A rubber stop ring is fitted hard-up between the end of the shaft liner and the propeller boss
    - g. The boss is recessed out to allow the rubber ring to be fitted
    - h. The object of the rubber ring is to prevent the access of water to the metal of the shaft and thus prevent galvanic corrosion between the shaft steel and the brass liner, which would cause shaft corrosion
83. Describe the construction of a tail shaft. What metals are used? What tests are used and the readings you would expect to find on the steel used in construction of a tail shaft. (Diesel Duck x 2)

a. The tail shaft is the aft most length of shafting that has the propeller attached to its end
b. Its purpose is to:
    1. Transmit the engine power to the propeller
    2. Support the propeller
    3. Transmit thrust from propeller to hull
    4. Withstand changing operating loads such as emergency stops
    5. Be free from vibration and be reliable throughout its operating range
c. Properties:
    1. High tensile strength
    2. High yield strength
    3. Good ductility
    4. Good impact strength
    5. High modulus of elasticity
    6. It requires toughness and fatigue resistance
    7. Be able to weld
    8. Economical
    9. It is 10% greater in strength than the tunnel shafting due to more varied stresses and the liability of sea water corrosion
d. Open hearth, basic oxygen or electric arc processes are used to produce shaft steel
e. It is forged from good quality mild ingot steel of 28 to 32 tons/psi tensile strength
f. Typical composition of carbon steels are:
    1. Carbon .2-.5%
    2. Manganese .4-.9%
    3. Phosphorous .05% Max
    4. Sulfur .05% Max
    5. Silicon .1-.45%
g. Alloys such as nickel, molybdenum, and vanadium can be added to improve strength and ductility and impact properties at low temps (desirable for ice breakers)
h. After forging, shafts are first normalized to improve grain structure and then annealed to achieve the desirable physical properties
i. The shaft is machined all over, the taper at the end taking the propeller boss is roughly .75"/foot to 1"/foot and has length of roughly 3 x shaft diameter
j. After machining, the shaft is stress relieved
k. Grain structure should be homogenous, fine grained ferrite and pearlite
l. The bearing surfaces must be smooth turned as well as the faces of flanged couplings
    1. Bolt holes must be carefully bored and reamed to give an accurate finish
    2. Torque is transmitted by the friction between flanges and also through the shanks of the bolts
m. The keyway is milled out and has semicircular ends to avoid stress concentration
n. The key prevents the propeller from turning on the taper
o. The propeller is drawn hard up onto the taper by the fine thread propeller nut.
p. A rubber ring is fitted between the hub and the end of the liner to prevent galvanic corrosion
q. The nut is further secured by a keeper plate
r. The shaft is connected at its forward end by tapered mild steel coupling bolts
s. To protect a shaft from corrosion, it has a gunmetal or bronze liner shrunk on
t. This liner may be in one or more lengths and is machined to have the diameter of the forward end slightly greater than the aft end
u. This diameter difference is to help fit into the stern tube
v. The following are the working stresses induce in a propeller shaft:
    1. Torsion – going ahead and astern, which varies with power developed by engine
    2. Compression – while going ahead
    3. Tensile – while going astern
    4. Bending and shearing – due to weight and overhang of propeller on end of shaft
    5. Tension at taper – due to tightening of prop nut
    6. Fatigue – due to the variation and combination of the above stresses
w. It should be noted that when bending occurs, the upper layers of the metal are put in tension and the lower layers in compression. These varying stress are created when the propeller spins in water.
x. For these stresses, the prop shaft is the greatest in diameter

84. Describe a modern method of aligning shafting on a ship. What method is used for boring out to fit a stern tube? (Diesel Duck)
    a. **Avoid this question due to length of required answer**

85. Describe how a large reciprocating engine is fitted in a ship. Sketch a hold down bolt and describe how the area under an engine is suitably strengthened. (Lawson, Dave, Diesel Duck)
    a. The bedplate is one of the most important parts of a marine engine.
    b. Bedplates are completely enclosed on the underside in order to form an oil sump
    c. They support the bearing for the crankshaft by cross girders
    d. The present practice is to construct bedplates of welded mild steel in order to prevent financial loss in the event of cast bedplate turning out to be deflective.
        1. Also allows lighter construction
        2. Smaller bedplates are still often cast iron due to good internal damping
    e. The two main types of bedplates are
        1. Trestle Type
            1. With the trestle type, bedplate stools are provided, being constructed of iron or steel casting or one built of plates and angles riveted by stepping up the double bottom tank top to accommodate and give a solid foundation for the bedplate.
            2. These two parallel stools run fore and aft and are raised
        2. Box type
            1. The box type enables the engine to be bolted directly to the double bottom tank tops, thus eliminating the necessity to build an elevated sealing, as with the trestle type bedplate, which must be very soundly constructed and very robust to obtain the desire degree of rigidity.
            2. Trouble with engine alignment is becoming more and more obsolete with the introduction of the box type bedplates provided however that the design allows access to the holding down bolts.
    f. The ship's hull is strengthened by :
        1. The engine bedplate is supported by the foundation plate that forms part of the inner bottom plating or tank top of the hull double bottom
        2. The hull structure under the engine is made very stiff, longitudinally by additional intercostals on each side of the center keel plate and transversely by making all floors solid
        3. Stiffness is also increased by making the depth of the double bottom to maximum possible dimension
        4. Localized stiffness under engines is tapered off gradually to the sides of the hull and fore and aft so that stress raisers are reduced to a minimum between the very rigid cellular structure under the engine and other parts of the hull
    g. Direct drive engines are jacked up using jacking bolts to accurately align the main bearing centering with the propeller shafting.
    h. Hold down bolts are then drilled and tapped in the tank top.
        1. Cast iron or steel chocks are then carefully machined and fitted between the tank tops and bedplate.
        2. Chocks must be located at each bolt and their total area must be sufficient to support the engine and chocks must be tight when the bolts are hardened down.
    i. An alternative to chocks would be a non-shrink epoxy resin chocking material cast into the space between the engine and tank top.
        1. This may not be as strong as cast iron, but by filling a larger area and by the intimate matching of surfaces left by casting it will give excellent load bearing and avoid the possibility of fritting which can occur with metal chocks.
    j. Mild steel bolts are then screwed into the tank top until the conical -face at the lower end on the plain part of the bolt seats on the tank top and forms a watertight joint.
    k. A grommet and nut are placed on the bolt under the tank top.... recommended torque, and then the upper nut is tightened.
    l. This procedure ensures a seal between the conical face of the steel and the tank top, thus preventing any liquid spillage into the double bottom tank which usually contained fuel or oil.
    m. Nuts must be hydraulically tested and chocks hammer tested at regular intervals and additionally tested after heavy weather or damage.
    n. These tests should be carried out as the engine operates as any weakness in the foundations will be more easily detected.
    o. Side and end thrust (transverse and longitudinal) is transmitted through brackets welded to the tank tops at the sides and ends of the bedplates.
    p. Vertical chocks or packing pieces are fitted and locked between each bracket and the engine.
    q. Side brackets are situated at the ends of each transverse member, and end thrust is taken in a similar manner.
    r. Although the main forces are transmitted at the bedplate further transverse struts to secure large engines to the ships structure are fitted at upper platform levels.
    s. The bearing halves are semi-circular this allows for removal of the bottom bearing half by rolling it around the crankshaft.
        1. The bearing halves or bushings are made of cast iron or cast steel, lined with white metal.
    t. The bedplate is constructed of vertical sections at each section throughout the length of the crankshaft, spaces being cut through this section to allow for oil flow.
    u. Inspection doors are placed on each side of the bedplate these doors being located between each section of the bedplate and held by bolts screwed into the bedplate.

v. The transverse vertical girders have their connector section which contains the main bearing saddle and tie bolt connection formed by a steel casting which is welded in
w. These transverse girders with main bearing saddlers are fitted between each throw of the crankshaft, as close as design allows and are secured by substantial butt welds to complete the rigid structure of the bedplate.
x. All welding in bedplates must meet a high standard and be carefully controlled.
    1. It must be stress relieved, shot blasted and tested.
    2. Plate edges must be correctly prepared and double butt welds used where possible.
y. Bed plate flanged is machined for landing on support chocks and for assembly of other parts.
z. Regular inspection of internal parts should be made, partially of the girders for fatigue and cracks.

86. Sketch and describe the construction and operation of a flexible coupling you are familiar with. (Jackson, Diesel Duck x 2)
    a. I believe this question relates more to a fluid coupling such as a Vulcan coupling, rather than a flexible rubber coupling but I will describe both:
        1. Fluid coupling:
            1. These are completely self-contained, apart from a cooling water supply, they require no external auxiliary pump or oil feed tank
            2. A scoop tube when lowered picks up oil from the rotating casing reservoir and supplied it to the vanes for coupling and power transmission
            3. Withdrawal of the scoop tube from the oil stops the flow of oil to the vanes, which then drains to the reservoir
            4. During power transmission, a flow of oil takes place continuously through the cooler and clutch
            5. Fluid couplings operate smoothly and effectively
            6. They use a fine mineral lubricating oil and have no contact and hence no wear between driving and driven members
            7. Torsional vibrations are dampened out to some extent by the clutch and transmitted speeds can be considerably less than engine speed if required by suitable adjustment of the scoop tube
            8. It is possible to have a dual entry scoop tube for reversible engines
        2. Flexible coupling:
            1. The flexible rubber coupling are used between engine and gearbox to damper the torque fluctuations, reduce the effect of shock loading on gears and engine.
            2. They also cater for misalignment, minimize vibration and reduce noise levels.
            3. Since oil will attach natural to rubber these coupling are usually made with reinforced synthetic rubber which is oil resistant.
            4. Before these coupling are installed all parts must be cleaned and free from grease and oil.
            5. The coupling disc is held in position by nut and bolts.
            6. A steel ring is fitted on the side opposite the contact side, when in position will ensure even torque on the coupling disc.
            7. Marks on the coupling will change form, if the coupling starts to wear and loose its strength.
            8. Another indication of wear maybe rubber in the form of dust particles around the coupling area.
            9. These couplings may be used for different machinery so the size and shape may vary for each unit.

87. Describe how the following engines are reversed: (Diesel Duck x 2)
    a. Triple expansion steam engine
        1. Reversing is achieved by use of a Stephenson's link motion type
        2. The link consists of two eccentrics, one for ahead and one for astern
        3. Each eccentric is fitted with a separate eccentric rod, connected at the top to two parallel quadrant bars by means of pins and brass bearing bushes.
        4. Movement of the reversing lever brings the quadrant bars over from the ahead position to the astern position so that the astern eccentric rod is now in line with the valve spindle.
        5. The ahead eccentric rod will now be idling and the valve will receive its motion from the astern eccentric rod.
        6. The engine should now be running in reverse.
        7. When running dead slow, the reversing gear can be thrown right over.
        8. At other speeds, the engine stop valve is closed before the gear is reversed and then gradually opened.
    b. Steam turbine
        1. Steam turbines have an astern turbine and when reversing is required, the ahead stop valve is closed and the astern stop valve is opened.
        2. This admits steam to the astern turbine to brake the ship's ahead speed.
        3. The power is roughly 70% of ahead turbine.
        4. A deflector plate is incorporated between the ahead and astern turbines.
    c. Directly reversible diesel engine

    1. Engine must be stopped to reverse.
    2. Engine is reversed by changing the position of the cams
    3. There are two cams for each valve
    4. The astern cam is brought in line with the valve rocking gear in order to run the engine in an opposite direction
  d. Geared diesel engine
    1. Reversing is completed through transmission gears which are normally operated by a hydraulically operated clutch.
    2. The pressure pump is normally operated by the main shaft that turns the main gear wheel.
    3. When fluid is pumped, the pressure engages the clutch discs together causing friction on their surface and thus causing the shaft to turn.
    4. There is an ahead and astern clutch.
    5. The astern clutch causes the idler gear and reverse gear to turn by friction.
  e. Electric propulsion motor
    1. AC motor is reversed by reversing two of the three power leads
    2. DC motor is reversed by swapping the field leads or the armature leads.
  f. Steam steering
    1. Steering engine slide valves are of piston type and have no lap or lead.
    2. This means that steam is carried full stroke and the engine can start from any position of the crank.
    3. The piston valves are hollow and carry steam over ends or in the centre according to the position of the control valve.
    4. With the control valve in one position exhaust will take place at say the bottom of the cylinder and steam will be admitted to the top.
    5. With the control valve in the other position exhaust will take place from the top of the cylinder and steam will be admitted at the bottom, the piston will move in the opposite direction.

88. Discuss the merits and demerits of using roller bearings for the main propulsion shafting. Why are roller bearings seldom used with the propeller shaft itself? Why are fitted bolts used in the couplings connecting the lengths of propulsion shafting together? (TCMS Sample)
  a. Merits:
    1. Friction is reduced due to less surface contact than journals
    2. Friction is not speed dependent like journals – it is low at all speeds
    3. Require little lubrication – grease fitting on unsealed bearings
    4. Suitable for slow ships and steam turbine ships
    5. They are split housings so they are easy to mount/dismount
    6. Less maintenance
    7. More robust against contaminants
    8. May have some self-aligning capabilities
    9. Main advantage is that a greater range of bearing loads are possible for a given diameter or unit area covered
  b. Demerits:
    1. More expensive than journal bearings
    2. More machining required because no clearance is allowed
    3. Larger diameter takes up more space
    4. Once overloaded, they are rapidly destroyed
  c. Roller bearings are seldom used with propeller shafting because:
    1. Location in stern tube, there are space constraints
    2. Lubrication is available for plain journal bearings, water or oil
    3. There are corrosion concerns since rollers are built with steel that can corrode
    4. Journals are adaptable for thrust with addition of tilting pads
    5. Also the cost is a concern
    6. Since they are self-aligning, there may be too much play for the propeller shaft
      1. The after most tunnel bearing has a top and bottom bearing shell because it must counteract the propeller mass and take a vertical upward thrust at the forward end of the tail shaft
      2. If ball or roller bearings were used the top would wear very quickly
    7. When stationary, roller bearings have a tendency to be damaged (brinelled) due to small contact surface supporting weight
  d. Fitted bolts are used in couplings because they help avoid coupling slippage
    1. They can transmit high torque in case the flange friction is lost
    2. They allow a axial friction fit and can be spread around circumference of flange to spread out torsion
    3. If the bolts were loose fitting, they could wear due to fatigue and possibly shear off
    4. Fitted bolts allow the flange to be fitted so that it is literally one piece and fretting between the surfaces is near impossible

5. A tapered bolt allows good fit and is able to be tightened without the stretch causing clearance

89. Describe a single collar thrust block. How would it be fastened to the ship hull? How would it compare with a multi-collar thrust block? What care and attention does it require and how is clearance measured? (Diesel Duck)
    a. The thrust shaft is connected to the main engine crank shaft.
    b. In the case of a direct drive reciprocating engine, to the main gear wheel shaft.
    c. In geared installation; it functions as well as transmitting the engine torque also to the next shaft, is to transfer the thrust of the propeller, to the thrust block, which being securely fitted to the hull of the ship.
    d. The shaft is comparatively short with a coupling at each end a thrust collar in the middle of its length and a flange at each side of the thrust collar.
    e. The journals run in bearings housed in the thrust block which is secured.
    f. Each side of the collar bears upon a number of kidney shaped white metal faced pads supported in the thrust block
    g. Those on the forward face of the collar being to take the astern thrust.
    h. The back of each kidney piece has a hump or step to allow the pads to pivot and the slightly so that the lubricating oil, picked up by the collar from the bottom of the block can squeeze its way as a wedge shape film between the pad and collar surface and be dragged over the whole surface.
    i. Thus there is always a film of oil maintained between the faces and there is consequently no metallic contact.
    j. Thrust pressures in the region of 24 bar can therefore be carried without danger of overheating due to friction.
    k. Particular attention is giving to the strengthening of the structure of the double bottom heavy loads be supported and vibration minimized, but the thrust from the thrust block is to be transmitted to ship's hull.
    l. All structure below the boiler and engine rooms is increased in thickness, additional longitudinal girders are incorporated so that they are pitched closer together, all girders have double angles and all parts are bearing fit.
    m. A tank top plate of extra thickness (40mm or more) runs continuously from under the engine bedplate to under the thrust block seating, the forward edge of the thrust block base either contacts the engine bedplate or chocks are fitted to have the same effect of spreading thrust load over a greater area of the ship's hull.
    n. Chocks are also fitted at the after edge of the thrust block.
    o. Most medium diesels have the thrust block as an appendix to or integral with the engine.
    p. When the engines are going ahead the thrust force is taken up by the surface of collars.
    q. This reduces the length of the block and it will be obvious that this is not a drawback as the engines only need to run astern for short period.
    r. The thrust block is secured to the hull of the ship by means of a pedestal made up of plates and angle iron, the hull being strengthened at this part so to transfer the thrust and distribute it over the hull.
    s. The shoes are usually held in position by large adjusting screws each shoe having separate jam nuts to permit the load to be distributed evenly over the various collars.
    t. The faces of the shoes are usually filled with white metal which permits about 70 psi of effective surface when the engine is running at full speed ahead.
    u. On many ships the shoes are water cooled while on others they are contained in an oil bath.
    v. The modern Mitchell thrust block only one collar, the collar having kidney pieces or rolling fitted, and the pressure that can be carried may be as high as 500psi this style of thrust is fitted in all modern ships having either turbine, reciprocating or diesel machinery, as the friction is greatly reduced and the size and weight of the thrust block is greatly reduced.
    w. Base and covers are made of cast iron, while the bearing at each end are made of gunmetal.
    x. Lubrication carried out by means of an oil scraper, fitted in the collar which intercepts the oil brought up by the rotating collar from the oil bath below, so forming a cascade of oil over the thrust pads.
    y. The end bearings are self-lubricated and oil deflecting rings are fitted at each end to prevent oil escaping.

Prevention

Precautions against fire or explosions due to oil or gas; flash point; explosive properties of gas or vapour given off by fuel or lubricating oils when mixed with a quantity of air; the danger of leakage from oil tanks, pipes, gas producers and vaporizers, particularly in bilges and other unventilated spaces; vaporizers, particularly in bilges and other unventilated spaces; the action of wire-gauze diaphragms and the places where such devices should be fitted.

90. What is viscosity? What is flash point (open/closed) and fire point? Briefly describe the apparatus used to find closed flash point? (Jackson, Mike, Diesel Duck x 2, 1982)
    a. Viscosity is defined as the resistance of fluids to change shape or flow
        1. This resistance is due to the internal molecular friction of molecules, causing drag
        2. In fuel, viscosity is important since it must be low enough to flow and ensure correct atomization at the injector.

        3. Also important for penetration into the combustion chamber.
        4. Viscosity is decreased as temperature increases
        5. Must be sufficiently low to flow freely at lowest temperatures but high enough to lubricate the injection system and prevent leakage
        6. Generally expressed in seconds – the time required for a known quantity of oil to flow through a known size orifice
    b. 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)
        5. Common flash points are:
            1. Gasoline: -17C
            2. Kerosene: 22-65C, normally around 38C
            3. Diesel: 95C
            4. Heavy fuel: 100C
            5. Lube oil: 230C
    c. Firing point is the temperature at which volatile vapors given off from a heated oil sample are ignitable by flame application and will burn continuously
        1. Firing point can be anywhere up to 40C higher than the closed flashpoint temp for most fuel oils
    d. Cetane number is an indication of the ignition qualities of a fuel
        1. The higher the cetane number, the higher the ignition quality of fuel
        2. The time interval between injection and firing must not be too long
        3. If it is extended, this causes fuel knock and or explosion from unburned fuel
            1. Also causes loss of power and high exhaust temperatures
    e. Specific gravity is defined as the ratio of the density of a fuel to the density of an equal quantity of water at the same temperature
    f. 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

91. Wire gauze is sometimes fitted over ventilators and pipe ends. How, why and where is gauze fitted to ventilators? (Adam, Diesel Duck x 3)
    a. Gauze wire screens are fitted over ventilation pipes various ways.
    b. In some instances a single screen is used while in other instances a double screen is used.
    c. A flange is welded to the vent pipe and several holes are drilled into the flange.
    d. The gauze wire is fitted to the outside of the flange and a second flange is bolted to the first holding the gauze wire between the two flanges.
    e. In a double screen installation the procedure is the same except a second wire screen and a third flange is fitted.
    f. The gauze wire is fit over the vent pipe ends to protect potable water tanks from dirt and insects.
    g. In tanks containing flammable liquid the gauze protects it from dirt and sparks.
    h. Sludge and slop tanks are required to have these gauze screen fitted to them as flame protection.
    i. If an open flame enters the vent pipe the gauze wire would help dissipate the flame.
    j. The screen should be bronze, brass, or nickel copper alloy and should be installed so that cannot easily be removed.
    k. It has to be ensured that the screens are never painted since that would negate their fire stopping properties

92. What is spontaneous combustion? What causes it and how can you prevent it? Where is it likely to be found? (Andy, Jackson, Diesel Duck)

a. Spontaneous combustion
    1. The self-ignition of a material (solid, gas or liquid) without being ignited by some outside source like sparks or flame
    2. Gases are given off by the substance during slow oxidation that gradually increase in temperature until kindling temperature is reached and the gases catch fire or explode
    3. Ignition can also occur through the chemical interaction of two or more substances, one of which is often air or water.
    4. Often caused by damp cargo such as coal, hemp, copra, grain, etc.
    5. Can also occur in oily rag bins
    6. Centre of these material piles have little ventilation to allow for cooling or dissipating effect
    7. Normally, these fires will only smolder due to lack of oxygen, until uncovered
    8. Therefore, great care must be taken when such a fire is discovered to prevent air from getting at it
    9. Examples of chemical reactions:
        1. Sodium and potassium react with water.
        2. Magnesium, titanium, calcium, and zirconium oxidize rapidly in the presence of air.
        3. A Class D extinguisher must be used for metal fires
b. Prevention for spontaneous combustion are:
    1. Careful storage of materials is an ever present fact in the prevention of fire
    2. Avoid taking on damp cargo if possible
    3. Must be good ventilation in cargo holds and engine room spaces
    4. Store oily rags in covered metal container and regularly empty it
    5. Never put flammable material near sources of heat, which could accelerate combustion
    6. Keep tank tops clean and bilges dry
    7. Chemicals that may oxidize should be stored in suitable containers indicating their fire risks

Coal fuel

Spontaneous combustion of coal; explosive properties of gas given off by coal dust creating explosive material.

Fire detection

Methods of dealing with fire; action and maintenance of mechanical and chemical fire extinguishers and other firefighting appliances; respirators and safety lamps; smoke and heat detectors; sprinkler systems, wet and dry valves; permanently-fixed gas-smothering systems and methods of activating; dangers of smothering gas to life.

93. Fire protection, detection, and suppression including automatic sprinkler and fire extinguishing apparatus on a passenger vessel. (Craig, Diesel Duck x 2)
94. Describe a type of automatic sprinkler system that would be used on a vessel and its operation. (Lawson, Dave)
    a. Accommodation and service spaces of passenger vessels are protected against fire by an automatic sprinkler fire alarm/detection system
    b. Function is to minimize both fire and water damage
    c. Sprinkler system comes into immediate operation on the outbreak of a fire and also alarms to warn the ship's crew that a fire has broken out in a given section of the ship
    d. The system includes a network of piping to carry water to a number of sprinkler heads that are fixed to the ceiling of protected rooms.
    e. Sprinklers are placed so that every corner is protected of the water spray
        1. Grouped in sections of not more than 150 heads
        2. Each section has an alarm system
        3. Must supply 5L/minute per m2 space protected
    f. Pipes are coupled to a water supply by suitable control valves
        1. These pipes are galvanized steel for corrosion protection
    g. The heads are fitted with a glass valve that is seated upon a flexible metal diaphragm and is held in position by a central strut consisting of a barrel shaped bulb fitted into the end piece
        1. The diaphragm is always in a state of tension and exerts a continuous pressure against the glass valve, keeping it seals from leakage
        2. A fire in one section would cause a rise in temperature, causing a quartzoid bulb in a sprinkler head to break
        3. The bulbs are manufactured with a small gas space inside and when heated, this pressurizes the bulb until it breaks
        4. Could also be fitted with a fusible link instead of bulb that functions the same way
            1. Heat causes the metal link to melt away, opening the head

    5. There are three colors to identify heads, depending on location and normal temperature found there:
        1. Red = 68C
        2. Yellow = 79C
        3. Green = 93C
- h. The system is kept ready for use by being always pressurized with freshwater from a pressure tank that is half full of water and half full of compressed air
- i. This will supply the sprinklers for a limited time
- j. Pressure to the highest sprinkler head should be at least 4.8 bar
- k. In the event of a real fire and the pressure in the sprinkler press tank falls below a predetermined setting, a pressure relay will then signal a seawater pump to start supplying water pressure to the system
- l. This would then start spraying the area with pressurized freshwater in a 1/2" stream that hits a deflector and a drenching spray covers a wide area
- m. Water only passes through those heads that are opened by heat
    1. The non-return valve for that section opens and allows bleeds off some water pressure to the alarm circuit which operates a pressure switch
- n. This gives an alarm on the control panel normally situated on the bridge
    1. Panel will show the section where the sprinkler head is activated, which should cause someone to investigate
    2. If it is a genuine alarm, the fire alarm will be sounded
    3. If it is a false alarm, the manual stop valve for this section, which is locked open, can be shut
    4. The key for this stop valve is normally behind a break glass panel in the vicinity if the valve
- o. A test circuit is fitted so that the pressure switch can be isolated and by draining can cause the pump to start
    1. The pump test valve is opened to give water flow
- p. Pump must be connected to main and auxiliary power supplies and there must be connection to fire main by non-return valve in case the sprinkler pump fails
- q. This system can be connected to a shore supply of water for dry dock
- r. Advantages:
    1. Automatic and quick operation
    2. Firefighting medium is cheap and plentiful
    3. System is easily tested
- s. Disadvantages:
    1. Cause a lot of damage when used
    2. Danger of free surface effect if a lot of water is used high up on accommodation decks
    3. System has to be flushed with freshwater after use
    4. A good eye has to be kept on pressure tank

95. Sketch and describe a dry sprinkler system. How is air pressure maintained? Describe the procedure carried out to reset the dry valve once tripped. (Jackson, Diesel Duck x 2)
    - a. Some vessels that trade in low temperature areas, have dry pipes installed to prevent freezing damage to the system
    - b. The dry pipe extends upwards from the section valve (dry valve) that also acts as the link between the sprinkler system water pressure and the dry pipe that is pressurized with air
    - c. Water pressure is contained by the water clapper that is held on its seat by the center valve
    - d. The space above the center valve is filled to the level with water and the pipe above that is filled pressurized air
    - e. The center valve is made watertight by a joint and the intermediate space is dry
    - f. When operation of a sprinkler head releases the pressure in the dry pipe, the center valve is pushed up by the force of water under the clapper
    - g. The clapper lifts and rotates on the yoke, being swung to one side by the effect of water flow on the skirt
    - h. The water floods up through the dry pipe causing the center valve to lock open and in filling the intermediate chamber, pressurizes and operates the alarm
    - i. Pressure gauges for air and water are required
    - j. The dry valve opens when the air pressure drops to 1/6th that of the water pressure
    - k. The cover has to be removed to reset the valve
    - l. Differential dry pipe valves use the principal of a lower air pressure on the top of the clapper holding back a higher water pressure below the valve.
    - m. The way this is accomplished in many valves is to build the valve with a large clapper that covers two seats.
    - n. The inner ring is the water seat in the middle of the valve; the outer seat is for the intermediate chamber that surrounds the water inlet.
    - o. The surface area that the air compresses may be five times the area of the water inlet.
    - p. In this way, 1 psi of air pressure will counteract 5 psi of water pressure. This is typically referred to as the differential.
    - q. Then, additional air pressure, usually 20 psi, is placed in the dry pipe valve.

- r. In such a valve, if the water pressure is 60 psi, the air pressure needed to equalize this force is 12 psi.
- s. Adding 20 psi of air pressure, 32 psi of air pressure is preventing the 60 psi of water pressure from tripping the valve.
- t. When a sprinkler head opens, the air pressure decreases.
- u. As the pressure decreases to below 12 psi, the force of the water pressure will overcome the air pressure, opening and latching the clapper in the open position thereby tripping the valve.
- v. To reset:
    1. Close the main control valve.
    2. Close the air supply valve(s).
    3. Open the system main drain, which is usually a 2-in. valve, the priming water level valve, condensate drain valve and the inspectors test connection.
    4. Drain each system auxiliary drain using the 5-gallon bucket. Draining the system may take several minutes, and water will continue to drain to low points even after the valve is reset.
    5. After the system has drained, close the auxiliary drain valves. Leave the inspectors test and main drain valves open.
    6. After you are sure there is no pressure on the system and the system is drained, remove the faceplate nuts, cover and gasket.
    7. Never open the faceplate of a pressurized dry pipe valve.
    8. Ensure the clapper latch system has engaged and the clapper has not fully closed onto the valve seat.
    9. Some models have the latch on the faceplate and must be verified as you remove the faceplate.

96. Describe a CO2 gas smothering system, including piping, storage, alarms and operation. What procedures and precautions should be taken when releasing the gas? How are the bottles tested for charge level? (Andy, Paul)
    - a. CO2 is colorless, odorless and heavier than air
    - b. It fights fire in the following three ways:
        1. Displaces the atmosphere
        2. Lowering the oxygen level
        3. Smothering the fire
    - c. Gas is normally stored in 50 pound bottles at a pressure of around 50 bar (750 psi)
    - d. 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
    - e. 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
    - f. Can be automatically set off by temperature sensors
    - g. The lever for releasing the CO2 is then operated, which in turn operates the starting bottles
    - h. 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
    - i. 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
    - j. The CO2 then discharges to the machinery space through multi-jet nozzles designed to discharge large volumes of gas at a fast rate
    - k. 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
    - l. 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
    - m. 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
    - n. 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. CO_2 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
- o. Advantages:
    1. Quick operation
    2. Rapid filling of space with CO_2
    3. No power required to use system
    4. Non-conductor of electricity
    5. Does no damage, clean
    6. Relatively inexpensive
- p. 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 reentering space

97. Sketch and describe a soda acid and portable foam fire extinguisher. What types of fires are both used for? How does the action of one differ from the other? How are they inspected, cared for and recharged? (Diesel Duck x 3)
- a. Soda acid extinguisher
    1. Riveted mild steel, lead coated internally and externally, is used for the body of the extinguisher
        1. Shell is about 2 mm thick and 180mm diameter and 530 mm high
        2. Shell ends are dished and welded or riveted to the wrapper plate
        3. Must be capable of withstanding pressures of 14 bar due to blockage
        4. Body is tested hydraulically to 25 bar approx.
        5. Retested to 21 bar every 4 years
    2. A screwed brass neck ring is riveted to the top dome of the mild steel body
    3. The brass head assembly, which incorporates plunger and acid bottle carrying cage, is screwed into this brass ring
    4. The head assembly joint in either acid resisting rubber or greased leather
    5. The nozzle is made of brass and the delivery tube with loose gauze filter is generally copper
    6. To ensure that the solution does not leak out of the nozzle due to an increase of air pressure (temperature increase), a non-return vent valve is normally incorporated into the head assembly
    7. A 9L sodium bicarbonate alkaline solution fills the body to the limit of the level indicator and the glass bottle in the carrying cage contains sulfuric acid
    8. Device must be held upright to use
    9. When the plunger is pressed, the acid bottle is shattered and the acid is released
    10. The sulfuric acid will then react with the surface of the sodium bicarbonate solution and the result of this chemical reaction is CO_2
    11. The CO_2 builds pressure and the solution is driven out of the extinguisher through the dip tube and nozzle
    12. The length of jet is approx. 9m for about 1.5 minutes
    13. Working pressure is about 2.7 to 3 bar
    14. Soda acid extinguishers should not be used for fighting oil fires since the principal substance discharged is water
    15. Should be recharged yearly:
        1. The cap is unscrewed and contents emptied
        2. The non-return vent valve is checked for blockage
        3. Internal pipe is checked for blockages
        4. Refilled with fresh sodium bicarbonate and acid
- b. Foam extinguisher
    1. May be chemical or mechanical:
    2. Chemical:
        1. Outer casing similar in construction to soda acid extinguisher
        2. Has a long container of polythene suspended from the neck ring and filled with aluminum sulfate solution
        3. Outer container is filled to marked level with sodium bicarbonate solution
        4. A lead disc sits on top of the inner container and acts as a stopper
        5. By inverting the extinguisher and shaking it, the disc is dislodged and the two solutions mix and react

6. The chemicals react in much the same way as the soda-acid extinguisher but slower, giving time for bubbles to form
7. Foam making substances added to the sodium bicarbonate solution determine nature of foam
8. Usually of 8:1 or 12:1 expansion
9. Because extinguisher is inverted for use, no internal pipe is fitted
10. When recharged, cap seal should be checked and pressure relief holes in rim checked
11. May be slow in cold condition and unreliable if chemical has deteriorated due to heat

3. Mechanical:
    1. The body is made of welded steel, zinc coated with a solid brass ring silver soldered to it
    2. The removable head assembly that incorporates the plunger, is made from a solid brass pressing
    3. When the head assembly is screwed into the neck ring, it presses down on a thick rubber washer and flange on the charge container providing a seal and securing the charge container in place
    4. A nozzle made of aluminum alloy with fin protected air holes is connected to a reinforced hose one meter in length
    5. The hose is coupled to a brass elbow coupling that is soldered to the stainless steel dip tube
    6. To prevent accidental discharge, a swivel safety guard is provided that also holds the spring loaded plunger valve open
    7. This vents the extinguisher thus preventing dribbling from the nozzle
    8. When the plunger is depressed, it pierces the tin/copper seal, releasing CO2 which is sealed in a capsule at 53 bar
    9. This ruptures the plastic bag containing foam solution and forces it to mix rapidly with water
    10. The foam solution is then driven up the dip tube through a hose to a nozzle
    11. The nozzle aerates the solution to produce a good quality firefighting foam
    12. 9L solution produces approx. 72 L foam
    13. Jet length of approx. 7m for around 50 seconds
    14. Body is tested to 25 bar
    15. Can be rapidly reloaded by filling with water and dropping new charge in and replacing head assembly

98. Give a detailed list of all the firefighting equipment in the engine room and boiler room of a modern oil burning vessel. How is this equipment tested? Make a diagrammatic sketch of the engine and boiler rooms showing the position of the equipment. (Diesel Duck)
    a. The emergency fire pump is often fitted at the forward end of the ship, low down to the waterline so that it is always primed and ready for use
    b. The fire pump has its own suction and its motor is driven by the emergency switchboard
    c. The pump can be started locally, from emergency switchboard or from the bridge
99. Describe engine room fire precautions and firefighting equipment fitted on an oil burning vessel? How is it used to fight a bilge fire. (Mike, Diesel Duck x 2)
    a. In an engine room?
        1. For a small fire in machinery space, you could use a foam or dry powder fire extinguisher as this is a Class B fire
        2. These extinguishers would have a smothering effect on the fire
    b. On tank top
        1. Same as above
    c. In accommodation
        1. You would use a water extinguisher on this type of fire as it is Class A
        2. The water would have a cooling effect on the heat source
    d. An electrical fire
    e. Galley oil fryer
        1. If you don't know if electrical supply has been isolated, best to use CO2 extinguisher
        2. This would have a smothering effect on fire
    f. For fire prevention, all these devices should be kept in good working order:
        1. Emergency pump and fan stops, collapsible bridge oil valves, water tight doors etc. should be in good working order.
        2. All fire detection devices should be tested regularly and all faults rectified.
        3. All engine room personal should be fully conversant with the recognized procedure for dealing with a fire aboard ship and should know its where about and methods of operating all firefighting equipment.
        4. Non return valves and safety relief valves are fitted throughout the engine room.
            1. There are relief valves on cylinders, boilers, and crankcases.
            2. There are relief valves on air receivers and relief disc on crankcases.
            3. There should be non-return valves in fuel oil lines.
        5. Oil mist detectors are fitted to IC engines.
    g. In every ship class I (i.e. a passenger ship engaged on voyages and of which are long international voyages) there shall be provided;

1. Fixed fire extinguishing installation operated from outside of the space and capable of giving a depth of foam of at least 150mm in not more than four minute over the largest single area over which oil fuel liable to spread.
    1. Such installation shall include mobile sprayers ready for immediate use in the firing area of the boiler and in the vicinity of the oil fuel unit.
    2. A pressure water spray system of fire smothering gas installation can be used as an alternative.
2. A 136 liter foam fire extinguisher (or 45kg CO_2) capable of delivering foam to any part of the compartment.
3. Two portable fire extinguishers suitable for extinguishing oil fires
4. A receptacle container at least 0.3 m^3 of sand and a scoop
5. Two fire hydrants one port and one stbd with hose and nozzles (spray nozzles must also be provided)
6. There should be an international shore connection provided to enable water to be supplied from another ship or from shore to the fire main and fixed provision shall be made to enable such a connection to be used on the port and starboard side of the ship
7. Every ship of class I of 4000 tonnes or over shall be provided with at least three fire pumps.
    1. The arrangement of sea connections, pumps, and the source of power of operating them shall be such as will ensure that a fire in any compartment will not put all the fire pumps out of action
8. Every class I ship shall be provided with are least two firemen's outfits each consisting of:
    1. A safety lamp, a fireman axe, breathing apparatus or smoke helmet or smoke mask.
    2. The outfits shall be kept in widely separated places.
9. Emergency controls for shutting off fans, oil fuel pump, purifiers and for closing suction from oil tanks.
10. Also there should be emergency shut off valves for generator and boilers.
    1. These should be arranged so that they can be operated from a readily accessible position, which is not likely to be cut off by fire in the engine room or boiler room.
11. Wire gauze must be also fitted to vents of all oil fuel tanks.
12. Every ship of class I shall be provided with water pipes and hydrants. The diameter of the water pipes shall be sufficient to enable an adequate supply of water to be provided for the simultaneous supply of at least two fire hoses and for the projection thereby of two powerful jets of water.
13. The number and position of the hydrants shall be such that at least two such jets may be directed into any part of the ship by means of two fire hoses each not exceeding 18 m in length, each jet being supplied from separate hydrant.
14. Portable fire extinguishers shall have a capacity of not more than 13.5 liters and not less than 9 liters.
15. CO_2 extinguishers shall have a capacity of not less than 3.2 kg.
16. Dry powder extinguisher shall have a capacity of not less than 4.6 kg.

100. Give the main causes of fire on ships using liquid fuel. What are the general precautions to be taken against fire hazards? At the outset of fire, what should be done to prevent the fire spreading? (1982)
    a. The main causes of fire aboard ships are:
        1. High pressure fuel leaks onto hot exhaust piping
            1. Can be prevented by placing protective sheathing on high pressure pipes and exhausts
        2. Fuel and oil leaks
            1. Fuel filter covers not correctly torqued
            2. Leakages of fuel at boiler burners, causing accumulation of gas
            3. Fuel pump glands
            4. Through bulkhead fittings or pipe fittings
            5. Engine crankcases leaking oil
            6. Tanks overflowing or drains not closing properly
        3. Electrical fires
            1. Can be prevented by testing and regular maintenance of equipment
            2. Regular testing of overload devices
            3. Checking that insulation is in good condition
            4. Checking connections are made properly
        4. Explosive gas may be ignited by:
            1. Bad insulation
            2. Short circuits
            3. Localized heating such as hot bearings
            4. Overloads
            5. Incorrect fittings such as a light fitting that is not explosion proof
    b. Cleanliness is the best prevention against fire
        1. No oily waste should be allowed to accumulate and should be put into metal containers having close fitting lids

        1. Containers should be emptied every day to prevent spontaneous combustion
    2. No oil leakage should be tolerated
    3. Tank tops and bilges should be hosed down often
    4. Tank tops and bilges should be painted white and illuminated if possible to see leaks quickly
    5. Naked lights should not be used near oil vapors
    6. Electric wire should be in armored cable to prevent chafing damage
    7. Crankcase mist detectors should be monitored closely
    8. Oil paints should be stored in air tight containers away from sources of heat
    9. Boxes of sand should be kept close as firefighting agent
    10. Cofferdams should be placed between fuel tanks and other spaces if possible
    11. Gauze wire should be fitted to ventilation pipes of oil tanks
c. In the event of a fire I would:
    1. Pull fire alarm
    2. Notify bridge of extent of fire
    3. If small fire, try to extinguish with portable Class B extinguisher
    4. Close all ventilators and flaps to cut oxygen sources
    5. Close water tight doors in vicinity
    6. All close by oil tanks should be isolated
    7. Shut off pumps or machinery nearby
    8. Start fire pump
    9. Foam making equipment should be used to contain fire, water jet may spread fire
    10. Boundary cool with water
    11. Try to contain fire with sand or other media
    12. If the situation becomes hopeless, evacuate space and seal off to use fixed system

Safe working practices

Mechanical safety in overhauling workshops, protective equipment, lifting-tackle safety and tests, precautions and tests when entering tanks; first aid related to injuries that may be expected in machinery spaces, use of first aid equipment and methods of obtaining second aid.

101. Enumerate the safe practices to be adhered to when personnel are: (TCMS Sample)
    a. Dismantling machinery during rough weather conditions
        1. If possible, working on machinery during rough weather should be avoided.
        2. If unavoidable, some precautions should be taken to ensure personnel are not hurt
        3. Hot surfaces nearby should be covered with insulating material to avoid contact burns
        4. Extra care must be taken with lifting due to swinging action, heavy parts should be well secured and nobody should work under or too close to the load
        5. Ensure oil spills or anything slippery is quickly cleaned up since falling is more likely in rough weather
        6. The machinery should be shut down and locked out to work on it unless emergency conditions exist
            1. Turning gear should be engaged if possible and then locked out
        7. Staging should be erected and lashed down
    b. Replacing jointing or overhauling valves in steam lines
        1. Steam lines are naturally extremely hot and also under pressure so should not be worked on or even near when live
        2. Personnel have been badly burned and killed aboard vessels due to steam leaks and water hammer
        3. If emergencies require it, personnel working near live steam lines must be fully protected with thermally protective clothing and face shield
        4. To work on valves or gaskets, the line must be isolated and locked out so that no one opens steam to that line while personnel are working on it
        5. It should also be left as long as possible to cool the pipework down
        6. When admitting steam to the line after repair, it should be slowly warmed through with drains open to rid any condensate and reduce any chance of water hammer that could cause a rupture and injure or kill personnel
    c. Working in double bottom tanks
        1. Dangers:
            1. Fuel tanks may be deficient of oxygen due to hydrocarbons – vent pipes must be clear
            2. Also rusting extracts oxygen from the air

3. Paint fumes may displace oxygen without proper ventilation
4. Potentially toxic or explosive gases may be found in:
    1. Permanent ballast tanks may have hydrogen present if cathodically protected
    2. Cargo tanks may give off carbon monoxide, sulfur dioxide, nitrate oxide, nitrogen dioxide
    3. Methane may be present in freshwater tanks due to microorganisms
    4. Hydrogen sulfide is toxic and produced by bacteria in water

2. An entry permit must be obtained from a responsible officer
3. The space must be well ventilated and oxygen levels tested by a calibrated meter
    1. Normal oxygen levels are 21%
    2. Low oxygen levels can cause unconsciousness and fatal injuries
4. Safety gear such as self-contained breathing apparatus, rescue lines, hoisting gear and first aid kit must be at hand
5. Someone must be on standby at the entrance who is in communication with the people in the space and must be able to raise an alarm in the event of difficulties

d. Lifting heavy loads manually, and with lifting tackle
1. Heavy loads should, whenever possible be lifted with mechanical assistance such as chain falls or electric hoists
2. The lifting eyes and tackle must be certified and inspected prior to use
    1. The eye bolts must be fully threaded in
    2. Wires or slings must not be frayed
3. When manually lifting, ensure you get help if necessary to even out the weight distribution between multiple people
4. The back should be kept straight as the object is lifted to avoid injury
5. Lifting tackle must be catalogued and checked regularly by certified personnel
6. Only personnel familiar with their operation should use it and training should be provided for those unfamiliar
7. Personnel should never stand under a load or be near a load that may swing and hurt them

Cold weather practices

Special arrangements for operation in waters with ice; lay out and operation of ice-related shipboard systems, cold weather lay-up.

Control systems

Automation and instrumentation in block diagrams, periodically unattended machinery spaces, techniques and work practices, control, remote-control stations, system monitoring.

102. Describe any type of governor suitable for propulsion engines. Show how you are familiar with its construction and operation. (Diesel Duck x 3)

a. The electric governor, which is operated without a flyweight has proportional and reset action with the added advantage of load sensing.
b. With the governor, a small permanent magnet alternator is used to obtain a speed signal from the engine.
c. The advantage of using permanent magnet is that there will be no slip rings or bushing to wear.
d. The alternator generates voltage that determines the speed signal.
e. This signals converted into DC voltage by a rectifier.
f. This DC voltage is proportional to engine speed.
g. The DC voltage is then sent to the amplifier and controller which also require a reference DC voltage of opposite polarity from the speed setting unit. (This voltage is represented of the diesel operating speed desired)
h. These two voltages are connected to the input of an electric amplifier.
i. If the voltages are the same, the amplifier is equal and opposite, they cancel and there is no change in amplifier voltage output.
j. If the voltage is different, the amplifier sends a signal through the controller to the electrohydraulic converter which via a servo -motor will change the fuel rack to lower or increase speed as required.
k. In order that the system is isochronous, the amplifier controller has internal feedback.
l. The load sensing unit is included in the governor to correct the fuel supply to the prime mover before a speed change occurs.
m. 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.
n. The example of the electric governor the electric output of the main generator would be tapped and it any load alternation took place on the main generator this would be synchronized 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.

103. Describe an electrical bridge-engine room telegraph. How does the "wrong way" alarm operate? (TCMS Sample)

a. An example of an electric telegraph is the Chadburn Synchrostep
    1. This device is inherently telemetering rather than a control system as such
    2. These instruments are robust, watertight, contain night illumination, alarms and can run on DC or AC
    3. When the telegraph is operated, it will alarm continuously until answered
    4. In the event of current failure, an alarm can also be given
    5. A recorder system can give out a print out of telegraph orders so that it won't have to be manually recorded
b. The transmitter consists of a face plate commutator and brush carrier
c. The brush carrier is connected to the operating handle and indicating pointer or pointers (top and side)
d. Moving the operating handle rotates the brush carrier and this causes alteration in polarity in the windings of the receiver
e. A permanent magnet rotor (wound rotor for AC) will immediately take up a new position that corresponds exactly to the transmitter request, this rotor carries an indicating pointer
f. Three positions are shown in the diagram with 15 degrees between each position but generally there are 12 positions of 15 degree intervals (180 degrees total)
g. The drawing shows the system in equilibrium with equal DC currents in line B and C and zero current in line A
h. The receiver rotor is locked by equal and opposite torques from the attractions on unlike pole faces
i. Assume the transmitter to be moved 30 degrees clockwise
j. Current flows to the receiver from line C, subdivides at point X and equal currents return through lines A and B of magnitude I/2
k. This creates a strong N pole at fixed magnet X and two weak S poles at the other two fixed magnets
l. The receiver indicator will therefore turn to the corresponding position of 30 degrees clockwise
m. Wrong way alarm:
    1. For clockwise (say ahead) rotation of the transmitter, line A will be carrying return current.
    2. If the engine driven speed tachogenerator is rotating in the same direction, its output can be arranged to be in the same sense as line A
    3. A summed signal (additive) will maintain a wrong way alarm in the isolated condition
    4. Incorrect rotation of the engine will create signals in opposition, which causes the alarm to be activated
    5. The same applies for counter clockwise (say astern) rotation of the transmitter when line A will be carrying supply current.

104. Describe the following control systems and state the advantages and disadvantages of each: (Diesel Duck)

a. Pneumatic
    1. A pneumatic control system is one that uses air to control the operation of a system such as a winch, governor, steering, etc.
    2. Compressed air is piped to the system either directly or through a reducing station and is used to operate the system
    3. Advantages:
        1. Air is readily available aboard ships
        2. Relatively cheap to utilize
        3. No messy liquids in event of a leak
        4. Leaks are readily detectable by noise
        5. Can be used at low temperatures if properly maintained (drained at low points, driers working, etc.)
        6. It will not damage cargo in event of leak if used to operate hatches, ramps, belts, etc.
        7. Pressure can be easily regulated
        8. Fairly reliable
    4. Disadvantages:
        1. Subject to moisture from condensation which may cause corrosion or freezing damage
        2. Air must very clean – free of oil, fuel, salt and moisture
        3. If a leak develops in a noisy or remote area, it would be hard to detect
        4. A leak will cause increased running time on compressors
b. Hydraulic
    1. A hydraulic control system used fluid power to run an operating system
    2. Since fluid is virtually incompressible, it can be pumped to move pistons and to rotate motors very precisely and powerfully
    3. Normally a low viscosity mineral oil is used since it is non-freezing, non-corrosive and has good lubricating/wear properties
    4. Advantages:
        1. Provides high torque for systems that need to be started at high speed or high pressure
        2. Pressure can be regulated fairly easily
        3. Leaks can be easily detected
    5. Disadvantages
        1. Fairly expensive due to high strength components

        2. Expensive to maintain with oil
        3. Leaks are messy and dangerous because oil is a pollutant and also slippery
        4. If a line bursts, the high pressure may be dangerous to personnel
        5. Expensive to run lines a long distance so more than one unit may be needed

c. Electrical
    1. An electrical control system utilizes electrical power to operate a system
    2. Advantages:
        1. Easy to run wiring long distances
        2. No leaks of air or fluid to worry about
        3. No dangers of freezing
        4. Cheaper to install compared to hydraulics
        5. Cheaper to run since ship's generator will be running anyway
        6. More precise control
        7. High power can be obtained
    3. Disadvantages:
        1. Moisture in marine environment can cause shorts or grounds, disabling the system and possibly injuring or killing personnel
        2. Potential for interference from other electrical sources may cause problems
        3. May be harder to troubleshoot since problems are not often as simple as air or hydraulic

Pollution prevention

Devices to prevent pollution from oil, sewage, air; regulations to be observed regarding pollution.

105. Sketch an automatically operated modern oily water separator. (TCMS Sample)

a. Describe how it works
    1. By international agreement under the MARPOL convention, most commercial vessels need to be fitted with an oily water separator to remove oil contaminants before bilge water is pumped overboard.
    2. The amount of oil (ppm) differs by region but in Canadian waters, discharge is mostly 15ppm except in the Great Lakes and St. Lawrence where it is 5ppm. Discharge in the Arctic is 0 PPM.
    3. The force of gravity due to water and oil having densities contributes to oil separation as does:
        1. Heating coils
            1. With added heat, the viscosity and density of the oil is reduced and helps it to rise
        2. Baffles and weirs
        3. Filters
    4. The complete unit if filled with clean water and the oily water is pumped into the first stage coarse separating compartment
    5. Here, oil having a lower density than water will rise to the surface with heating coils aiding in this process
    6. This upper area is known as the collection space
    7. A sensor will sense the level of oil and it will be dumped when it reaches a certain level to a dirty oil tank
    8. Remaining oily water will move down to the fine separation compartment and move slowly between catch plates
    9. More oil will separate on the underside of these plates and move outwards until free to rise up to the collection space
    10. Almost oil free water then passes onto the 2nd stage of the unit
    11. Here, two coalescing filters are situated with the first removing any physical impurities and promotes some filtration
    12. The second filter elements achieve final filtration
    13. Clean water then leaves the second stage on to a clean water holding tank via a 15ppm monitor with audible and visual alarms overboard
    14. Automatic operation:
        1. This separator uses concentric cylindrical oil coalescing cartridges through which the oily water is drawn by a positive displacement pump
        2. The coalesced oil rises to the top of the separator where its accumulation is detected by an oil-water interface probe
        3. When in normal mode, a controller is constantly monitoring the oil water interface level and the overboard discharge for oil content
        4. In the event of the effluent exceeding set limit, the process is stopped and the alarm given

5. When the oil water interface reaches its lower level, the controller changes the operation to one of cleaning by back flushing and oil discharge
6. The oil water interface will then rise to the higher level when reversion to normal mode takes place
7. By using an OWS in suction mode rather than delivery mode, disintegration of the oily water mixture prior to separation is achieved, thus improving separation efficiency

b. What routine care and attention is required in order to maintain satisfactory performance?
    1. Unit must be primed with clean water after each use and left in that condition
    2. Coalescing beads must be cleaned or renewed regularly
    3. Probes must be cleaned
    4. Strainers must be kept clean
    5. Coalescing filters must be changed when clogged
    6. Oil in secondary stage may have to be manually drained

Maintenance

Routine maintenance, prevention of damage to machinery, preventive maintenance, corrective maintenance, planned maintenance, record keeping relating to maintenance, deployment of human resources for effective maintenance and repair.

Lifesaving appliances

Operation and maintenance of lifesaving appliance; launching and retrieval machinery.

Damage Control

Methods of damage control, with specific reference to action to be taken in the event of flooding of seawater into the machinery spaces.

Electrical safety

Safe operation and maintenance of electrical and control equipment, precautions to be observed to prevent injury to personnel and machine, methods of cleaning and drying of equipment, particularly equipment flooded by seawater

Non-destructive testing

An awareness of non-destructive testing, to include: magna flux, dye penetrants, ultra sonics, nuclear, vibration analysis, spectronic oil analysis for wear indication, z-ray, and thermographs.