058-01 - APPLIED MARINE ENGINEERING

FRIDAY, 24 February 2023

1400-1600 hrs

APPLIED MARINE ENGINEERING

Attempt ALL questions
Marks for each part question are shown in brackets

1. With reference to austenitic stainless steels:

   (a) list the THREE main constituents with approximate percentage composition; (3)

   (b) state the main difference between grades 304 & 316 and how this is achieved; (3)

   (c) list TWO typical applications for EACH grade stated in part (b) that would be found on a modern vessel. (4)

2. With reference to carbon fibre:

   (a) describe how the base raw material is turned into a useable carbon fibre; (2)

   (b) describe how the fibres produced in part (a) are turned into a usable product; (2)

   (c) explain how its internal structure gives it its unique strength properties; (2)

   (d) list FOUR properties of carbon fibre that make it desirable for marine fabrication. (4)

3. (a) Describe how a Brinell hardness test is carried out. (3)

   (b) With reference to a ball race bearing, explain EACH of the following terms:

      (i) brinelling; (2)

      (ii) false brinelling. (2)

   (c) Explain how false brinelling can be reduced in practice. (3)

4. With reference to joining a steel hull to an aluminium superstructure:

   (a) explain, with the aid of a sketch, the process of *explosion welding*; (6)

   (b) explain why this joint is superior to an insulated bolt joint. (4)

5. With reference to marine corrosion:

   (a) list EIGHT factors that influence the rate of corrosion for an unprotected metal surface; (4)

   (b) explain the process of galvanic corrosion; (4)

   (c) state TWO major factors influencing the severity of galvanic corrosion. (2)

6. With reference to glass reinforced plastic (GRP) hulls:

(a) state THREE causes for EACH of the following defects to occur:

(i) de-lamination; (3)

(ii) osmotic blisters; (3)

(iii) stress cracking; (3)

(b) state the part of the underwater section of the hull on which osmotic blisters most commonly occur. (1)

7. (a) Describe, with the aid of a sketch, how a Bourdon Tube can be utilised to measure temperature. (8)

(b) State a typical application and location for this type of device. (2)

8. (a) Describe with the aid of a sketch, how Bi-metallic strips are utilised to measure temperature. (8)

(b) State a typical application for this type of device and its main shortcoming. (2)

9. With reference to engine governors, explain EACH of the following terms:

(a) sensitivity; (2)

(b) hunting; (2)

(c) speed droop; (2)

(d) stability; (2)

(e) isochronous governing. (2)

10. (a) State the reasons for fitting a pneumatic process valve with EACH of the following:

(i) a volume booster; (2)

(ii) a feedback positioner. (2)

(b) State, with reasons, the type of actuator fitted to the process valves for EACH of the following systems:

(i) a fuel supply system in which the valve must not move on loss of power to the control system; (3)

(ii) a lubrication oil cooling system in which the valve diverts the oil through a cooler. (3)

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1. With reference to austenitic stainless steels:

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(b) state the main difference between grades 304 & 316 and how this is achieved; (3)

(c) list TWO typical applications for EACH grade stated in part (b) that would be found on a modern vessel. (4)

The three main constituents of austenitic stainless steel are:

1. Iron: As the base metal, iron makes up the majority of the composition, typically ranging from 60% to 70%.
2. Chromium: This is the key element that gives austenitic stainless steel its corrosion resistance. It usually constitutes between 18% and 20% of the composition.
3. Nickel: This element contributes to the austenitic structure and enhances properties like ductility, toughness, and strength at low temperatures. The nickel content in austenitic stainless steel typically ranges from 8% to 10%.

While these three elements form the core of austenitic stainless steel, other elements can be added in smaller amounts to further enhance specific properties. These include:

- Carbon: Increases strength and hardness but decreases ductility and toughness.

- Manganese: Improves strength, workability, and hardenability.
- Nitrogen: Provides additional strength and enhances corrosion resistance.
- Molybdenum: Increases high-temperature strength and resistance to certain types of corrosion.

b) Both 304 and 316 are popular grades of austenitic stainless steel, but they do have some key differences:

Molybdenum content:

- 304: Does not contain molybdenum.
- 316: Contains 2-3% molybdenum, which significantly improves its corrosion resistance, especially in chloride-rich environments like saltwater.

Corrosion resistance:

- 304: Offers good corrosion resistance to mild environments, food acids, and freshwater.
- 316: Offers superior corrosion resistance to chlorides, acids, and saltwater, making it ideal for marine applications, chemical processing, and food processing equipment exposed to harsh cleaning solutions.

Applications:

- 304: Widely used in kitchen equipment, architectural trim, automotive parts, and other general applications where good corrosion resistance is needed but saltwater exposure is minimal.
- 316: Widely used in marine hardware, chemical processing equipment, medical implants, high-temperature applications, and food processing equipment requiring extra corrosion resistance.

Cost:

- 304: Less expensive due to the absence of molybdenum.
- 316: More expensive due to the addition of molybdenum.

Other differences:

- Formability: Both are highly formable and weldable, but 304 may be slightly easier to work with.
- Strength: 316 may have slightly higher strength due to the molybdenum content.

Here's a table summarizing the key differences:

Feature	304	316
Molybdenum content	No	2-3%
Corrosion resistance	Good	Superior, especially to chlorides and salt
Applications	Kitchen equipment, architecture, automotive	Marine, chemical processing, medical, food processing with harsh cleaning
Cost	Less expensive	More expensive
Formability	Highly formable	Highly formable
Strength	Good	Slightly higher

Application 1: Food processing equipment (tanks, pipes, utensils)

- Possible grades: Austenitic stainless steels like AISI 304 (18/8) or 316 (18/10 Mo).
- Key features:
    - Corrosion resistance: Resists corrosion from food acids, cleaning chemicals, and saltwater.
    - Formability and weldability: Easy to shape and weld for complex equipment designs.
    - Hygiene: Smooth, non-porous surface prevents bacteria growth and is easy to clean.
    - Austenitic: Non-magnetic and has good low-temperature toughness.

Application 2: Chemical piping and tanks

- Possible grades: Depending on the specific chemicals, AISI 316L (16/10 Mo low carbon), 904L, or super austenitic grades like 254SMO.
- Key features:
  - High corrosion resistance: Resists strong acids, alkalis, and oxidizing environments.
  - Pitting resistance: Resists localized corrosion from chlorides and other aggressive ions.
  - Crevice corrosion resistance: Resists corrosion in tight spaces like under gaskets.
  - High strength and durability: Handles pressure and temperature extremes.

Application 3: Marine hardware (fasteners, fittings, shafts)

- Possible grades: AISI 316L (16/10 Mo low carbon), 17-4 PH, or duplex stainless steels like 2205.
- Key features:
  - Excellent saltwater corrosion resistance: Resists pitting and crevice corrosion from seawater.
  - High strength and toughness: Withstands mechanical loads and stresses.
  - Good machinability and weldability: Easy to fabricate and join for complex hardware.
  - 17-4 PH and duplex grades: Offer higher strength and hardness for demanding applications.

Application 4: Medical implants (surgical instruments, prosthetics)

- Possible grades: AISI 316LVM (16/10 Mo very low carbon) or 316L with electropolishing.
- Key features:
  - Biocompatibility: Non-toxic and does not reject human tissue.
  - High corrosion resistance: Resists body fluids and sterilization chemicals.
  - High strength and fatigue resistance: Withstands repeated stresses without breaking.
  - Smooth surface finish: Minimizes risk of infection and tissue irritation.

Application 5: Cryogenic tanks and vessels (storing extremely cold liquids)

- Possible grades: AISI 304L (18/8 low carbon) or 904L.
- Key features:
  - Excellent low-temperature toughness: Maintains strength and ductility at very cold temperatures.
  - Good weldability: Can be welded reliably for strong and leak-proof tanks.
  - Corrosion resistance: Resists contamination from cryogenic liquids and cleaning chemicals.
  - 304L: Offers a good balance of properties and affordability.
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2. With reference to carbon fibre:

(a) describe how the base raw material is turned into a useable carbon fibre; (2)

(b) describe how the fibres produced in part (a) are turned into a usable product; (2)

(c) explain how its internal structure gives it its unique strength properties; (2)

(d) list FOUR properties of carbon fibre that make it desirable for marine fabrication. (4)

Part (a): Describing how the base raw material is turned into a usable carbon fiber

1. Precursor selection: The first step is to choose the right precursor material, which is typically PAN (polyacrylonitrile). PAN is a synthetic polymer that can be converted into carbon fiber through a high-temperature process.
2. Oxidation: The PAN precursor is then oxidized in air at temperatures between 200°C and 400°C. This process removes some of the hydrogen and nitrogen atoms from the PAN chains, making them more rigid and stable.
3. Carbonization: The oxidized PAN is then carbonized in an inert atmosphere at temperatures between 1000°C and 2000°C. This process drives off the remaining non-carbon atoms, leaving behind a highly ordered structure of carbon atoms.
4. Surface treatment: The carbon fibers are then treated with a sizing agent to improve their adhesion to resin and other materials.

Part (b): Describing how the fibers produced in part (a) are turned into a usable product

1. Layup: The carbon fibers are arranged in a mold or on a mandrel in the desired shape of the final product. This process is called layup.
2. Resin infusion or impregnation: Resin is then infused or impregnated into the fibers. This can be done through vacuum bagging, autoclave curing, or other techniques.
3. Curing: The resin is then cured, typically under heat and pressure. This process converts the resin from a liquid to a solid, binding the fibers together and forming the final composite product.
4. Finishing: The cured product may then be machined, painted, or coated to meet the specific requirements of the application.

Part (c): Explaining how the internal structure of carbon fiber gives it its unique strength properties

The unique strength of carbon fiber comes from its highly ordered internal structure. Each carbon fiber is made up of millions of carbon atoms arranged in a hexagonal lattice. This strong and stiff arrangement of atoms gives carbon fibers a very high tensile strength (strength under pulling forces) and a high modulus of elasticity (resistance to deformation).

In addition to its strong internal structure, carbon fiber is also very lightweight. This combination of high strength and low weight makes carbon fiber an ideal material for many marine applications, where weight savings and high performance are essential.

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3. (a) Describe how a Brinell hardness test is carried out. (3)

(b) With reference to a ball race bearing, explain EACH of the following terms:

(i) brinelling; (2)

(ii) false brinelling. (2)

(c) Explain how false brinelling can be reduced in practice. (3)

The Brinell hardness test determines the indentation hardness of a material by measuring the permanent impression left by a hardened steel ball pressed into its surface. Here's how it's carried out:

1. Preparation: The test surface is prepared by polishing and cleaning to ensure accurate testing.
2. Test Equipment: A Brinell hardness tester consists of a press capable of applying a specific load, a hardened steel ball (typically 10mm diameter), and a measuring microscope.
3. Load Application: The chosen load (based on material and test standard) is applied to the ball in contact with the test surface for a specific dwell time (typically 10-30 seconds).
4. Indentation Measurement: The diameter of the indentation left on the surface is measured using a microscope.
5. Hardness Calculation: Using the measured diameter, load, and ball diameter, the Brinell Hardness Number (HB) is calculated using a specific formula. Higher HB values indicate higher hardness.

(b) Ball Race Bearing Terms:

(i) Brinelling:

Brinelling is a type of permanent indentation damage on the raceway (tracks) of a ball bearing caused by excessive static or shock loads. These indentations resemble the size and shape of the rolling elements (balls) and can lead to:

- Increased noise and vibration: Uneven rolling due to indentations creates noise and vibration during bearing operation.
- Reduced load capacity: Indentations weaken the raceway, lowering the bearing's ability to handle loads without failure.
- Premature bearing failure: Repeated stress on the indented areas can lead to cracks and eventual bearing failure.

(ii) False Brinelling:

False brinelling, also known as fretting fatigue, is another type of surface damage that resembles brinelling but arises from different causes. It occurs due to:

- Microscopic vibrations: Slight movement or vibration between stationary rolling elements and the raceway creates wear and micro-cracks.
- Loss of lubrication: Inadequate lubrication allows direct metal-to-metal contact, accelerating wear and fatigue.
- Corrosive environments: Corrosive elements can break down lubricants and promote surface damage.

False brinelling appears as shallow, matte-textured lines or areas along the raceway and can also lead to noise, vibration, and reduced bearing lifespan.

(c) Reducing False Brinelling:

Several practices can reduce the risk of false brinelling in ball race bearings:

- Properly sized and selected bearings: Choosing bearings with adequate load capacity and appropriate materials for the expected loads and environment is crucial.
- Maintaining lubrication: Regular lubrication with the correct type and quantity of grease or oil minimizes metal-to-metal contact and protects against corrosion.
- Vibration control: Minimizing sources of vibration through proper component design, mounting, and alignment reduces stress on the bearing.
- Surface coating: Applying protective coatings to the raceway and rolling elements can enhance wear resistance and reduce micro-cracking.
- Monitoring and inspection: Regularly monitoring bearing noise, vibration, and temperature helps identify potential false brinelling before significant damage occurs, allowing for preventative maintenance.

By implementing these strategies, the risk of false brinelling can be effectively mitigated, ensuring optimal performance and lifespan for ball race bearings.

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5. With reference to marine corrosion:

(a) list EIGHT factors that influence the rate of corrosion for an unprotected metal surface; (4)

(b) explain the process of galvanic corrosion; (4)

(c) state TWO major factors influencing the severity of galvanic corrosion. (2)

(a) Eight Factors Influencing Corrosion Rate:

1. Salinity: Higher salinity in seawater leads to increased conductivity and promotes faster ionic movement, accelerating corrosion.
2. Temperature: Warmer water generally increases corrosion rates due to higher ionic mobility and chemical reaction kinetics.
3. Dissolved Oxygen: Oxygen acts as a cathodic reactant in the corrosion process, and higher dissolved oxygen levels in seawater intensify corrosion.

4. pH Level: Acidic (lower pH) environments accelerate corrosion, while alkaline (higher pH) environments can offer some protection.
5. Biological Activity: Marine organisms like barnacles and bacteria can create micro-environments that promote localized corrosion.
6. Water Flow Rate: Higher water flow can remove corrosion products and expose fresh metal to the corrosive environment, increasing the rate.
7. Metal Properties: Different metals have varying corrosion resistance based on their inherent properties and electrochemical potentials.
8. Stress and Surface Condition: Stresses and rough surfaces can act as initiation points for corrosion and accelerate the process.

(b) Galvanic Corrosion Explained:

Galvanic corrosion occurs when two dissimilar metals are in electrical contact and immersed in a conductive electrolyte, like seawater. Here's the process:

1. Potential Difference: The metals have different electrochemical potentials, creating a voltage difference between them.
2. Anode & Cathode Formation: The more active metal (lower potential) becomes the anode, where metal atoms ionize and release electrons.
3. Electron Flow: The released electrons flow through the conducting path (seawater) to the less active metal (higher potential), the cathode.
4. Cathodic Reaction: Electrons react with oxygen and water at the cathode, forming hydroxyl ions.
5. Metal Ion Movement: The metal ions from the anode migrate through the electrolyte towards the cathode.
6. Corrosion & Precipitation: At the cathode, the metal ions combine with hydroxyl ions to form insoluble metal hydroxides, which appear as corrosion products.

This cycle continues, with the anode corroding faster than it would alone, while the cathode is protected.

(c) Two Major Factors Influencing Severity of Galvanic Corrosion:

1. Potential Difference: The greater the difference in electrochemical potential between the two metals, the faster and more severe the galvanic corrosion.
2. Conductivity of the Electrolyte: Increased conductivity of the electrolyte (e.g., saltier seawater) facilitates higher electron flow and intensifies the corrosion process.

Understanding these factors and processes is crucial for mitigating marine corrosion. Using materials with similar potentials, applying protective coatings, and employing cathodic protection are some approaches used to combat this damaging phenomenon in marine environments.

Feb 2023

6. With reference to glass reinforced plastic (GRP) hulls:

(a) state THREE causes for EACH of the following defects to occur:

(i) de-lamination; (3)

(ii) osmotic blisters; (3)

(iii) stress cracking; (3)

(b) state the part of the underwater section of the hull on which osmotic blisters most commonly occur. (1)

(a) Causes of Defects:

(i) De-lamination:

1. Improper resin mixing: Incorrect resin-to-hardener ratio can lead to incomplete curing, weakening the bond between layers.
2. Insufficient resin application: Not enough resin between layers can create air pockets and weak bonds.
3. Contamination: Dirt, grease, or moisture trapped between layers can prevent proper adhesion.
4. Uneven pressure during layup: Inconsistent pressure can lead to voids and weak areas.
5. Excessive sanding: Removing too much material can thin layers and reduce overall strength.

(ii) Osmotic Blisters:

1. Water permeation: Diffusion of water molecules through the GRP laminate.
2. Presence of salts: Dissolved salts in the water attract more water, creating osmotic pressure.
3. Imperfect laminate: Micro-cracks, voids, or poor adhesion points allow water ingress.
4. Lack of protective barrier: Inadequate gelcoat or anti-osmosis coating allows water contact.
5. Temperature cycling: Expansion and contraction due to temperature changes can stress the laminate, exacerbating existing weaknesses.

(iii) Stress Cracking:

1. Mechanical overload: Excessive loads exceeding the design limits of the hull.
2. Impact damage: Punctures, dents, or other forceful impacts can initiate cracks.
3. Poor design: Stress concentrations due to sharp corners, inadequate reinforcement, or improper load distribution.
4. Fatigue: Repeated loading and unloading cycles can weaken the material and lead to crack propagation.
5. Environmental factors: UV exposure, chemical attack, or temperature extremes can degrade the mechanical properties of GRP.

(b) Osmotic Blister Location:

Osmotic blisters most commonly occur on the underwater sections of the hull exposed to prolonged water contact. This includes the keel, bilge areas, garboards, and lower portions of the transom. These areas experience constant immersion and higher salt concentrations, making them more susceptible to water permeation and osmotic pressure buildup.

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7. (a) Describe, with the aid of a sketch, how a Bourdon Tube can be utilised to measure temperature. (8)

(b) State a typical application and location for this type of device. (2)

(a) Measuring Temperature with a Bourdon Tube:

Imagine a classic Bourdon tube, typically used for pressure measurement, but with a twist. In this case, the tube is filled with a temperature-sensitive liquid instead of gas. Let's delve into its operation with the help of a sketch:

Sketch:

1. Bourdon Tube: The curved metal tube remains central to the device.
2. Temperature-Sensitive Liquid: The interior of the tube is filled with a liquid whose volume expands or contracts significantly with temperature changes.
3. Temperature Change: As the surrounding temperature rises or falls, the liquid inside the tube expands or contracts accordingly.
4. Tube Deformation: This expansion or contraction alters the curvature of the Bourdon tube due to the liquid volume pushing against the tube walls.
5. Linkage Mechanism: A linkage mechanism connects the free end of the tube to a pointer or dial indicator.
6. Temperature Reading: As the tube bends, the linkage translates the movement to the indicator, displaying the corresponding temperature on a calibrated scale.

Key Points:

- The choice of liquid inside the tube is crucial, typically featuring high thermal expansion coefficients for greater sensitivity.
- This type of thermometer is well-suited for harsh environments due to its robust construction and lack of fragile components.

(b) Typical Application and Location:

One typical application for a Bourdon tube temperature gauge is in industrial settings, mounted directly on:

- Pipelines: Monitoring the temperature of fluids flowing through pipes in various processes, like cooling water systems or oil pipelines.
- Tanks and Vessels: Measuring the temperature of liquids stored in tanks or vessels, such as chemical reactors or boilers.
- Machinery: Monitoring the operating temperature of critical components in engines, compressors, or other machinery.

Remember, while Bourdon tube temperature gauges offer reliability and versatility, their accuracy limitations compared to electronic counterparts might need consideration depending on the specific application.

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8. (a) Describe with the aid of a sketch, how Bi-metallic strips are utilised to measure temperature. (8)

(b) State a typical application for this type of device and its main shortcoming. (2)

1. Bi-metallic Strip Thermometer: Bending with the Heat

(a) Design and Operation:

Imagine a simple yet ingenious device: two thin strips of different metals bonded together lengthwise. This is the essence of a bi-metallic strip thermometer. Let's explore its design and operation with the help of a sketch:

Sketch:

- Two Dissimilar Metals: The strip consists of two metals with significantly different coefficients of thermal expansion. Typically, one metal expands much more than the other when heated.
- Bonded Together: Both strips are firmly joined along their entire length, creating a composite strip.
- Temperature Change: When heated, the metal with the higher expansion coefficient (denoted "High Expansion" in the sketch) expands more rapidly than the other, causing the composite strip to bend in the direction of the less expansive metal.
- Temperature Measurement: The degree of bending is directly proportional to the temperature change. A calibrated scale or pointer attached to the strip translates this bending into a temperature reading.

Key Points:

- The larger the difference in expansion coefficients, the more sensitive the strip is to temperature changes.

- Bi-metallic strips are simple, rugged, and relatively inexpensive, making them suitable for various applications.

(b) Applications and Shortcomings:

One typical application of bi-metallic strips is in bimetallic thermostats. These devices use the strip's bending to control electrical circuits based on temperature. For example, in an oven thermostat, the bending strip triggers a switch to shut off heating when the desired temperature is reached.

However, bi-metallic strips have a main shortcoming: limited accuracy. Due to factors like hysteresis (lag in response to temperature changes) and material fatigue over time, their readings can drift and become less precise. This makes them unsuitable for applications requiring high-precision temperature measurements.

Despite their limitations, bi-metallic strips remain valuable tools for temperature control and monitoring in various situations due to their simplicity, ease of use, and cost-effectiveness.

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9. With reference to engine governors, explain EACH of the following terms:

(a) sensitivity; (2)

(b) hunting; (2)

(c) speed droop; (2)

(d) stability; (2)

(e) isochronous governing. (2)

(a) Sensitivity:

Sensitivity in an engine governor refers to the responsiveness of the governor to changes in engine speed. A highly sensitive governor reacts quickly to even small speed variations, adjusting fuel delivery promptly to maintain speed stability. However, excessive sensitivity can lead to hunting, so achieving the optimal balance is crucial.

(b) Hunting:

Hunting describes an undesirable oscillation in engine speed caused by an overly sensitive governor. The governor overreacts to minor speed deviations, leading to adjustments in fuel supply that overshoot the correction needed. This creates a feedback loop where corrections become too large, causing speed to swing back and forth around the desired value.

(c) Speed Droop:

Speed droop is a fundamental characteristic of most engine governors. It defines the relationship between engine speed and load: as the load on the engine increases, the governor allows the engine speed to decrease slightly. This intentional "droop" ensures stable load sharing between multiple engines operating in parallel on a common bus. Without droop, load changes would cause large speed variations and unstable operation.

(d) Stability:

Stability in an engine governor refers to the system's ability to maintain the desired engine speed despite external disturbances or load changes. A stable governor minimizes speed fluctuations and quickly returns to the setpoint after any transient event. Various factors, including governor sensitivity, droop settings, and control algorithms, contribute to achieving stable governor performance.

(e) Isochronous Governing:

Isochronous governing, also known as constant-speed governing, aims to maintain engine speed exactly at the setpoint regardless of load variations. Unlike governors with droop, an isochronous governor completely compensates for load changes by adjusting fuel delivery to keep the speed constant. This is desirable for applications requiring precise and constant speed, such as generators supplying critical equipment. However, isochronous governors may require more complex control algorithms and can be less tolerant of disturbances compared to droop governors.

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10. (a) State the reasons for fitting a pneumatic process valve with EACH of the following:

(i) a volume booster; (2)

(ii) a feedback positioner. (2)

(b) State, with reasons, the type of actuator fitted to the process valves for EACH of the following systems:

(i) a fuel supply system in which the valve must not move on loss of power to the control system; (3)

(ii) a lubrication oil cooling system in which the valve diverts the oil through a cooler. (3)

Pneumatic Process Valve Accessories:

(a) Reasons for Fittings:

(i) Volume Booster:

- Increases air flow rate: A volume booster amplifies the low-flow pneumatic control signal from the controller to provide a high-flow output to the actuator. This is necessary when the actuator has a large volume or requires significant force to operate, which a standard control signal might not be able to provide effectively.

- Faster valve response: By increasing the air flow rate, the booster speeds up the actuator's response to control signals, leading to faster process adjustments and improved system dynamics.

(ii) Feedback Positioner:

- Improves accuracy and stability: A positioner measures the actual valve position and compares it to the desired position from the controller. Any deviation triggers the positioner to adjust the air pressure to the actuator, ensuring the valve reaches the exact desired position even if external forces or friction affect it. This significantly improves control accuracy and reduces steady-state errors.
- Overcomes friction and disturbances: Positioners compensate for frictional forces in the valve mechanism and external disturbances affecting the valve movement, ensuring the valve responds faithfully to the control signal despite these challenges.

(b) Actuator Types and Reasons:

(i) Fuel Supply System (Fail-Safe Operation):

- Spring-to-Close Actuator: Ideally, this actuator would close the valve (stopping fuel flow) when air pressure fails due to a control system outage. This provides a fail-safe mechanism to prevent uncontrolled fuel release, ensuring safety and system integrity.

(ii) Lubrication Oil Cooling System (Diversion Valve):

- Double-Acting Actuator: This actuator uses air pressure in both directions (open and close). In case of air pressure loss, the valve would stay in its last position, maintaining the current oil flow path (either through the cooler or bypass, depending on the valve state before failure). This avoids uncontrolled changes in oil flow that could affect lubrication and engine health.

Additional Notes:

- The specific choice of actuator and accessories depends on various factors like process requirements, safety considerations, and control performance objectives.
- Some applications might require specific valve designs or fail-safe features beyond the basic categories mentioned here.